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Evaluation Model of a Supply Chain's Sustainability Performance and Risk Assessment Model towards a Redesign Process - Case Study at Kuehne + Nagel Luxembourg.

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Nolle in causa est, non posse praetenditur (Seneca A.L. 4BC – AD65[1])

[1] (Burgen, 1996)

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Résumé

La présente thèse succède à une étude réalisée en Master chez Kuehne + Nagel Luxembourg Sàrl, intitulée « Carbon Intelligence : Validation of the Internal Carbon Calculator, GTCC ». Dans la continuité, le développement durable reste le cadre général pour cette thèse de doctorat, intitulée « **Modèle d'évaluation d'une chaîne logistique durable et modèle d'évaluation des risques en vue d'un processus de reconception** ». Cette thèse, effectuée au sein de la société Kuehne + Nagel, est financée par le Fonds National de la Recherche (FNR) à Luxembourg et est structurée en quatre parties, dont deux principales de contributions, encadrées par un chapitre d'introduction et un de conclusion. Le travail présenté dans cette thèse a pour ambition de fournir aux décideurs et responsables des chaînes logistiques, des outils et modèles permettant d'analyser les risques liés à la non-atteinte des objectifs de durabilité. Il repose sur un certain nombre de choix conceptuels et méthodologiques qui sont présentés à chaque étape, à savoir le développement et l'évaluation des indicateurs de durabilité et ainsi que l'identification et la quantification des risques liés à la situation existante, l'ensemble menant à une reconception de la chaîne logistique actuelle.

Le premier chapitre qui sert d'introduction, présente les activités de l'entreprise Kuehne + Nagel, introduit la démarche de recherche mise en place et pose le contexte industriel, la problématique de recherche et la démarche de résolution.

Actuellement[2], Kuehne + Nagel Luxembourg Sàrl emploie 587 personnes et est localisé sur 7 sites différents. L'opportunité du siège au Luxembourg, au cœur de l'Europe de l'Ouest, est incontestable d'un point de vue géographique. Kuehne + Nagel fournit des solutions logistiques de bout en bout, qui comprennent le fret maritime, routier et aérien, ainsi que la logistique contractuelle, les services internationaux de colis et la distribution.

La démarche de recherche distingue trois méthodologies différentes mises en place afin de réaliser les revues littératures intégratives, méthodologiques et théoriques. Tandis que la revue littérature intégrative est exécutée pour rassembler les domaines de recherche de manière à formuler un agenda de recherche, la revue littérature méthodologique est mise en place pour examiner les différentes approches existantes. La revue de la littérature théorique est réalisée pour développer les hypothèses qui doivent être testées. La méthodologie de recherche appliquée dans le présent travail peut être illustrée par la Figure 1 ci-dessous.

[2] Date du 1er septembre 2015

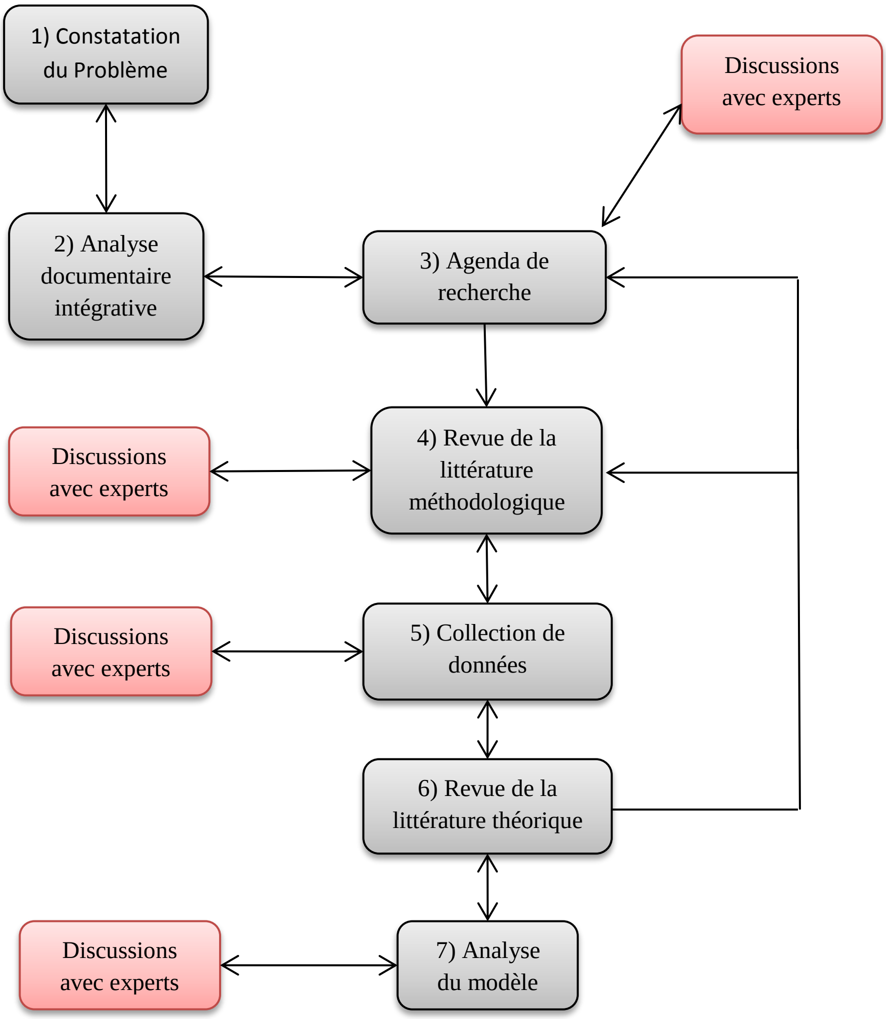

Figure 1 – Méthodologie de recherche

Les études portent avant tout sur le domaine de recherche de la durabilité. Dans une deuxième étape, ce sujet est fusionné avec le domaine de la logistique, puisque cette thèse traite les questions portant sur la logistique durable. Dans un troisième temps, le champ de recherche de la conception est pris en considération, étant donné que notre recherche se base sur l'évaluation et la quantification des risques précédant la phase de reconception d'une chaîne logistique existante. La phase de reconception de la chaîne logistique sera exclue du présent travail, tandis qu'elle servira de base pour l'étude concernant l'évaluation des risques. L'objectif majeur de recherche de la présente thèse consiste dans le développement d'un modèle d'évaluation du degré de durabilité d'une chaîne logistique et dans le développement d'un modèle d'identification et de quantification des risques éventuels. Ces risques peuvent soit déboucher sur une reconception de la chaîne logistique en question, soit être la conséquence d'une telle reconception. D'après Hodkinson et al. (2001), notre étude porte sur les sciences pragmatiques, dans lesquelles la pertinence pratique ainsi que la rigueur théorique et méthodologique sont élevées.

De nos jours, les concepts verts ainsi que la responsabilité sociale organisationnelle sont omniprésents. Ceci peut être observé avant tout dans les activités quotidiennes des entreprises des pays développés, où le concept du développement durable est devenu une préoccupation majeure. Ces nouvelles problématiques ont résulté dans des régulations plus strictes concernant notamment les impacts environnementaux sur les processus de production et les processus de manipulation des matières en fin de vie des produits (Houe & Grabot, 2009). Auparavant, l'intention des entreprises d'améliorer en continu leur compétitivité industrielle était limitée à la minimisation des coûts et à l'assurance d'un certain niveau de qualité exigé par les clients (Raith, 2013). Aujourd'hui, à côté de la dimension économique, deux nouveaux aspects doivent être pris en considération, à savoir, l'aspect écologique et l'aspect sociétal (Lehmacher, 2013). Cependant, les gestionnaires n'ont qu'une visibilité réduite des conséquences liées aux performances écologiques et sociétales. Cette visibilité réduite est souvent due à un manque de compréhension du concept de durabilité. Effectivement, eninterne chez Kuehne + Nagel, il a été révélé que la plupart des gestionnaires estiment la durabilité comme un mot clé utilisé dans le secteur du marketing, qui n'est mesurable qu'en termes théoriques, mais non praticable en réalité. De ces observations découlent donc la question de recherche « **Comment évaluer la performance générale de durabilité d'une chaîne logistique existante ?**». La performance générale de durabilité doit être comprise comme étant l'interaction des piliers économique, écologique et sociétale, tel que défini par Elkington (1997).

Le deuxième chapitre débute par une revue de littérature intégrative, à travers laquelle le concept de durabilité est défini. Cette recherche a permis de montrer que le concept de durabilité est plus complexe que celui présenté par Brundtland (1987) ou Elkington (1997). Néanmoins, les définitions fournies par ces deux auteurs servent de base pour notre définition dudit concept. En effet, nous considérons que ce concept est divisé en trois piliers distincts, définis par Elkington (1997), à savoir [1] économique, [2] écologique, et [3] sociétal ; mais contrairement à une grande partie des auteurs qui négligent ce dernier pilier « sociétal », nous l'approfondissons en considérant qu'il est divisé en deux sous-piliers : « Environnement de travail (Travail)» et « Questions éthiques (Ethiques)». Nous définissons donc la durabilité comme étant **« l'interaction des trois piliers économique, écologique et sociétal – où sociétal doit être compris comme étant la composition de l'environnement de travail et des questions éthiques inhérentes – afin de satisfaire les besoins d'aujourd'hui et de demain, sachant que ces besoins vont s'intensifier au cours du temps».** Cette définition inclut donc le facteur « temps », souligné par Brundtland (1897) et est illustrée en Figure 2 ci-dessous.

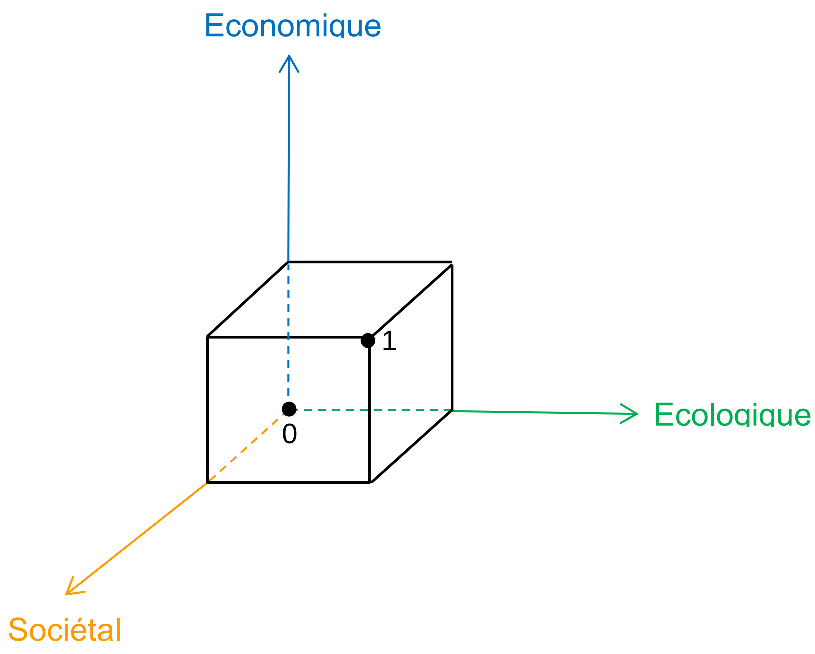

Figure 2 - Définition: Durabilité

Dans la deuxieme partie du chapitre 2, la revue littérature a été complétée par une étude menée en interne chez Kuehne + Nagel et par des avis d'experts au moyen d'entretiens directifs et semi-directifs. De plus, des questionnaires à choix multiples ont été effectués. Les deux premières parties du deuxième chapitre servent de base pour identifier le modèle d'évaluation du degré de durabilité d'une chaîne logistique existante et les indicateurs inhérents. Effectivement, la revue littérature complétée résulte en un tableau de bord qui est présenté en troisieme partie et qui consiste en treize indicateurs. Ces derniers peuvent être classés selon les 3 piliers de durabilité, à savoir économique, écologique et sociétal. Le fait que la capacité humaine de traitement des informations est limitée (Simon, 1959) nous amène naturellement à nous concentrer sur un nombre restreint d'indicateurs, présentés en Figure 3.

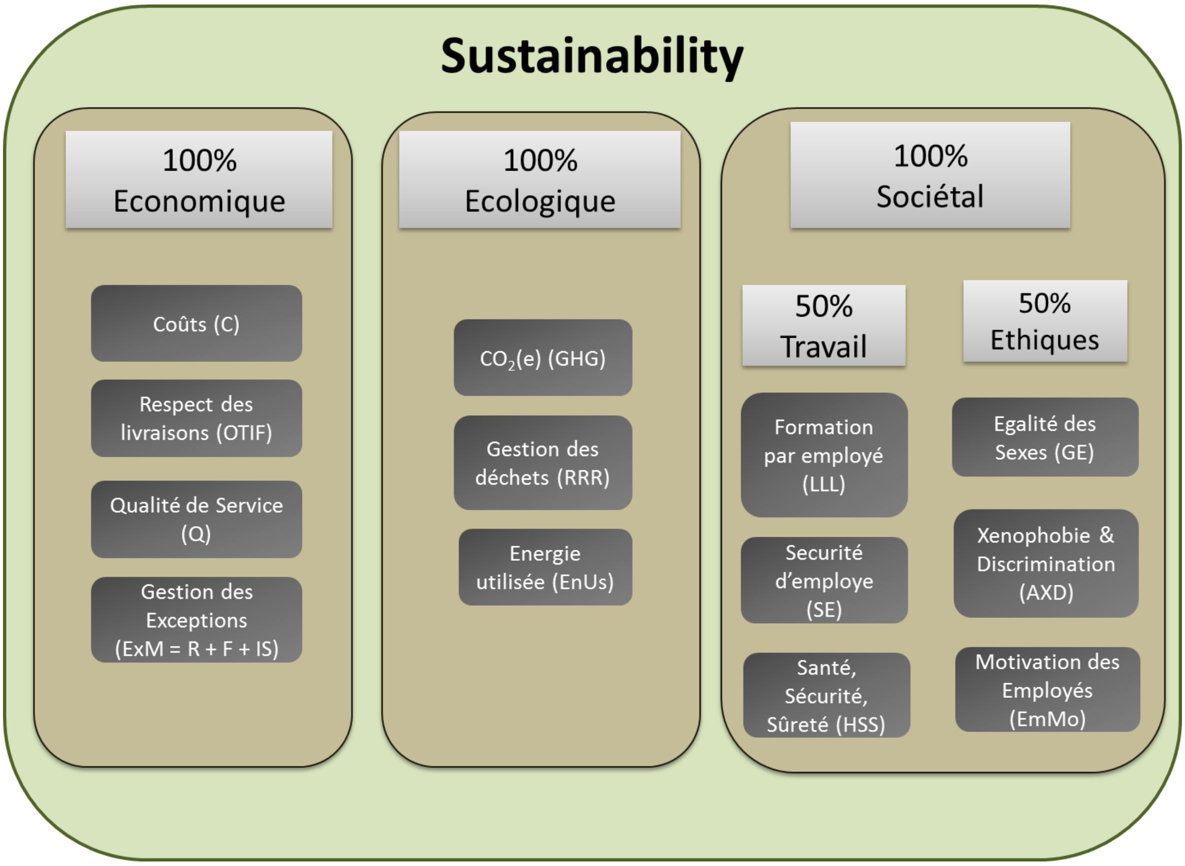

Figure 3 - Tableau de Bord: Indicateurs

La quatrième partie du chapitre 2 reprend une sélection des méthodologies existantes afin d'évaluer la performance d'une chaîne logistique. Les méthodologies sont présentées selon un point de vue managérial, puis, à un niveau plus fin, qui est le niveau de modélisation. A chaque niveau, un tableau de synthèse présente les avantages et inconvénients cernés lors de l'analyse des méthodologies retenues.

Afin de mettre en place une étude de cas, présentée dans la dernière partie du chapitre 2, des données ont été recueillies en interne chez Kuehne + Nagel. Cette étude de cas valide la faisabilité du modèle théorique développé. Notre proposition d'approche pour la durabilité n'étant pas encore appliquée, toutes les données ne sont pas enregistrées dans un historique dans l'entreprise. L'étude de cas mentionnée ci-dessus clôt le deuxième chapitre. Pour des raisons de confidentialité et de simplicité, toutes les données ont été normalisées avant d'être utilisées dans le modèle d'évaluation du degré de durabilité mis en place. Cette normalisation a, de plus, l'avantage que les différents indicateurs ne disposent plus d'unités permettant ainsi d'être reliés. En outre, la comparabilité entre les différentes chaînes logistiques, qui servent un même domaine, peut être garantie. La chaîne logistique servant d'exemple dans notre étude de cas est celle d'un client opérant dans le domaine industriel. Comme cette chaîne logistique a été conçue et gérée par Kuehne + Nagel de 2010 à 2013, toutes les données consolidées durant cette période sont existantes au sein de la succursale luxembourgeoise de l'entreprise. La chaîne logistique dudit client a été analysée du point de vue de Kuehne + Nagel, ce qui induit que la chaîne n'est pas considérée en entier, mais seulement à partir du moment où Kuehne + Nagel prend la responsabilité de celle-ci jusqu'au moment où l'entreprise cède cette responsabilité.

Il est impératif que, dans une deuxième étape, les indicateurs du tableau soient pondérés conformément au domaine servi par la chaîne logistique en question. Ceci est dû au fait que l'importance des indicateurs diffère selon le secteur d'activités considéré. La pondération des indicateurs ($\varkappa$) est calculée à travers la méthode de hiérarchie multicritère *(Analytical Hierarchy Process, AHP)*. Le calcul de la moyenne agrégée des différents indicateurs par pilier nous renvoie le degré de durabilité tridimensionnel. La prochaine étape de notre modèle consiste en l'identification des ensembles flous et des règles floues. En effet, nous suggérons que, d'un point de vue des décideurs et gestionnaires industriels, l'interprétation des résultats est plus simple si l'on traduit les valeurs numériques en termes linguistiques. Les résultats obtenus à travers l'étude de cas montrent que le degré de durabilité de la chaîne logistique du client était « moyen, proche de bien » en 2010, et « bien » dans les trois années suivantes. Le modèle d'évaluation du degré de durabilité d'une chaîne logistique existante est représenté en Figure 4.

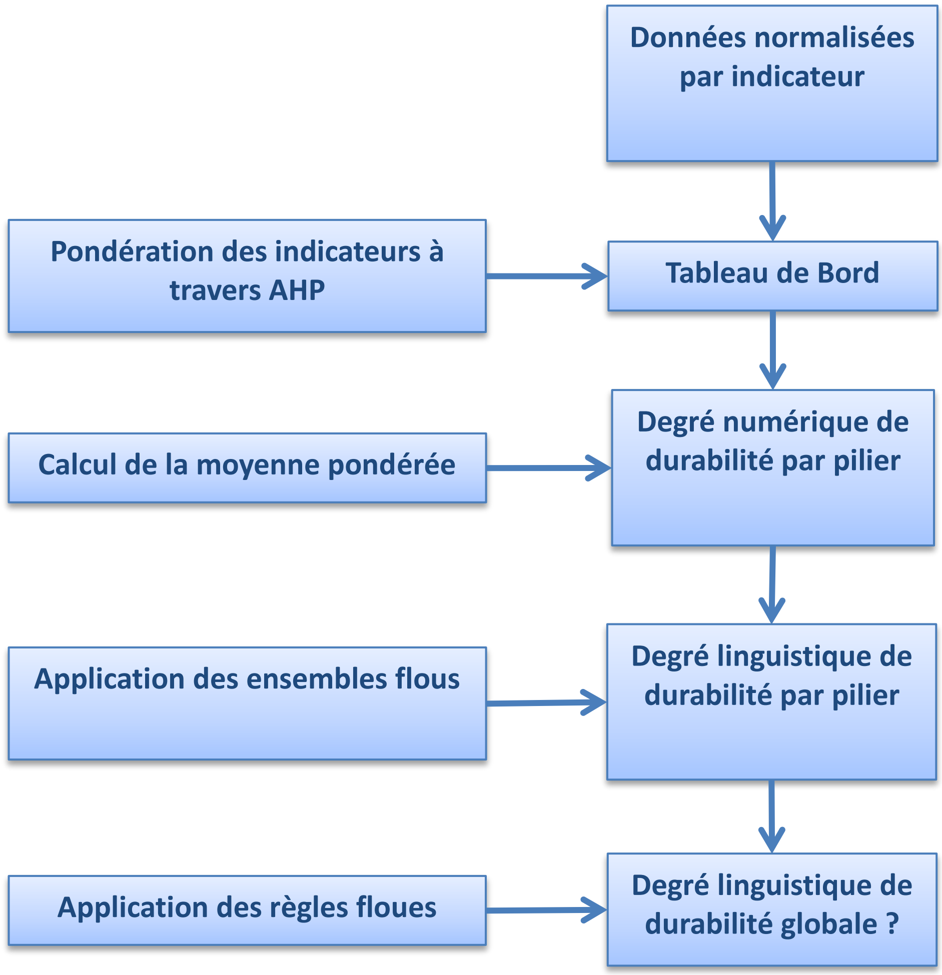

Figure 4 – Modèle d'évaluation

Afin d'obtenir une vision globale de l'état actuel de sa chaîne logistique considérée, le prestataire logistique l'évalue selon les enjeux en question. Cette vision globale est indispensable pour les décideurs afin de gérer les procédures futures. Il convient cependant de noter que toute modification des processus inhérents à une chaîne logistique comporte des risques, dont les gestionnaires doivent décider s'ils doivent être atténués ou évités. Par conséquence, la mise en place d'une reconception d'une chaîne logistique exige une analyse *ex-ante* des risques éventuels. Il n'est, néanmoins, pas possible d'analyser et de gérer tout risque éventuel inhérent à une chaîne logistique puisque, selon le niveau de précision, le nombre de risques éventuels peut être considérable. Dans le deuxième chapitre, le degré de durabilité de la chaîne logistique du client a été évalué. Pour que ce niveau de durabilité puisse être amélioré, la chaîne logistique doit être reconçue. L'intérêt majeur de ce processus de reconception consiste en la toute première étape, qui considère la gestion des risques précèdant la phase de reconception, comme expliqué auparavant. La question majeure de recherche qui en découle est donc « **Comment évaluer les risques précédents un processus de reconception en matières de durabilité?»**

Le troisième chapitre débute par une revue littérature intégrative, à travers laquelle la notion de conception est définie comme étant « **un processus de réflexion, où, dans une première étape, un besoin doit être identifié. Ce besoin doit être traduit dans un tableau de bord et ses formules associées, en vue d'en améliorer l'état actuel. Les connaissances techniques et scientifiques des concepteurs sont exigées puisque ces derniers doivent résoudre des contraintes et limitations potentielles »**. Ce processus de conception peut être illustré comme suit :

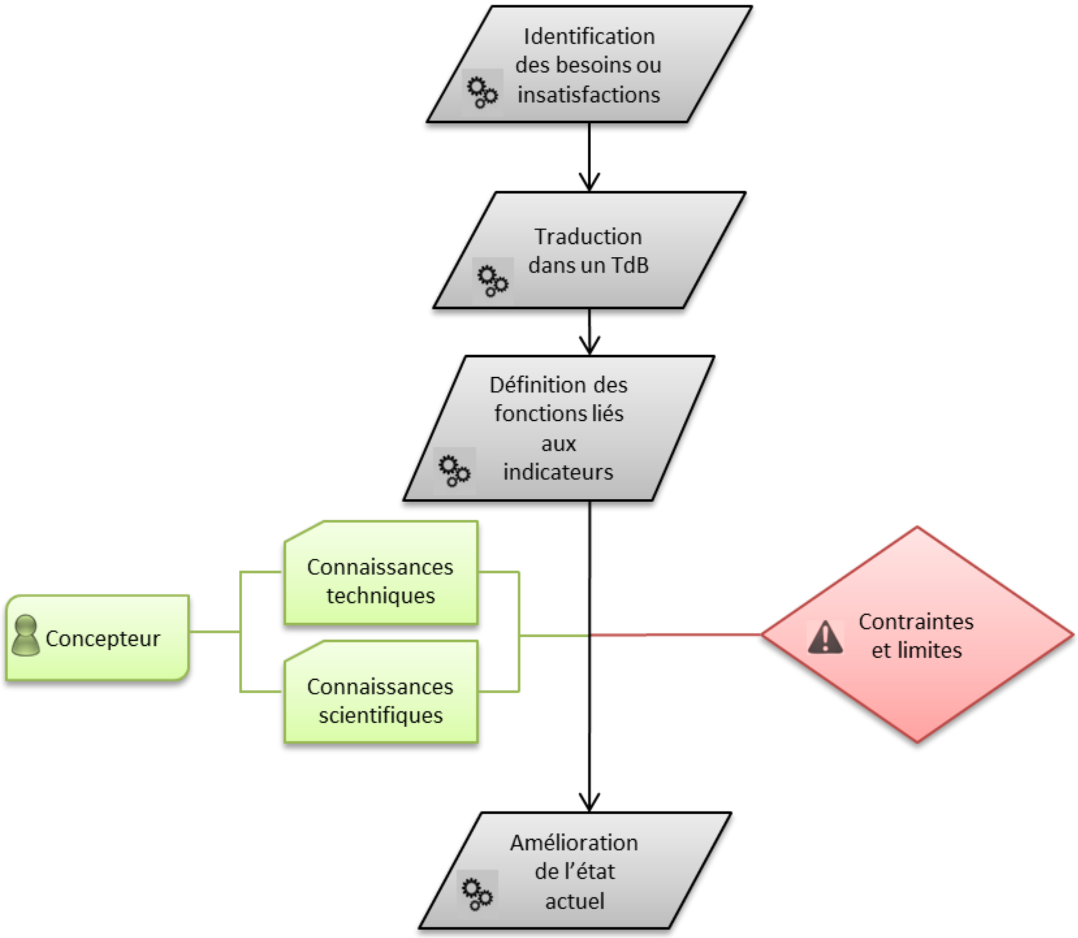

Figure 5 - Processus de Conception

Ladite revue littérature est ensuite complétée par une analyse menée en interne chez Kuehne + Nagel. Cette analyse identifie les quinze raisons principales débouchant sur une reconception de la chaîne logistique en question. Après une brève présentation d'une sélection des méthodologies quantitatives, qualitatives et hybrides de gestion des risques en section 3.3, concluant par des tableaux de synthèse qui soulignent les principaux avantages et inconvénients des méthodologies en question, un modèle de quantification des risques est présenté. Dans la présente thèse, le champ d'application de la gestion des risques contient l'identification, l'analyse et l'évaluation des risques, négligeant leurs atténuations. Ceci explique le choix des méthodologies analysées en partie 3.3. Les données collectées à travers le modèle d'évaluation du degré de durabilité de la chaîne logistique en question sont aussi utilisées par le modèle théorique d'évaluation des risques, présenté en Figure 6 ci-dessous.

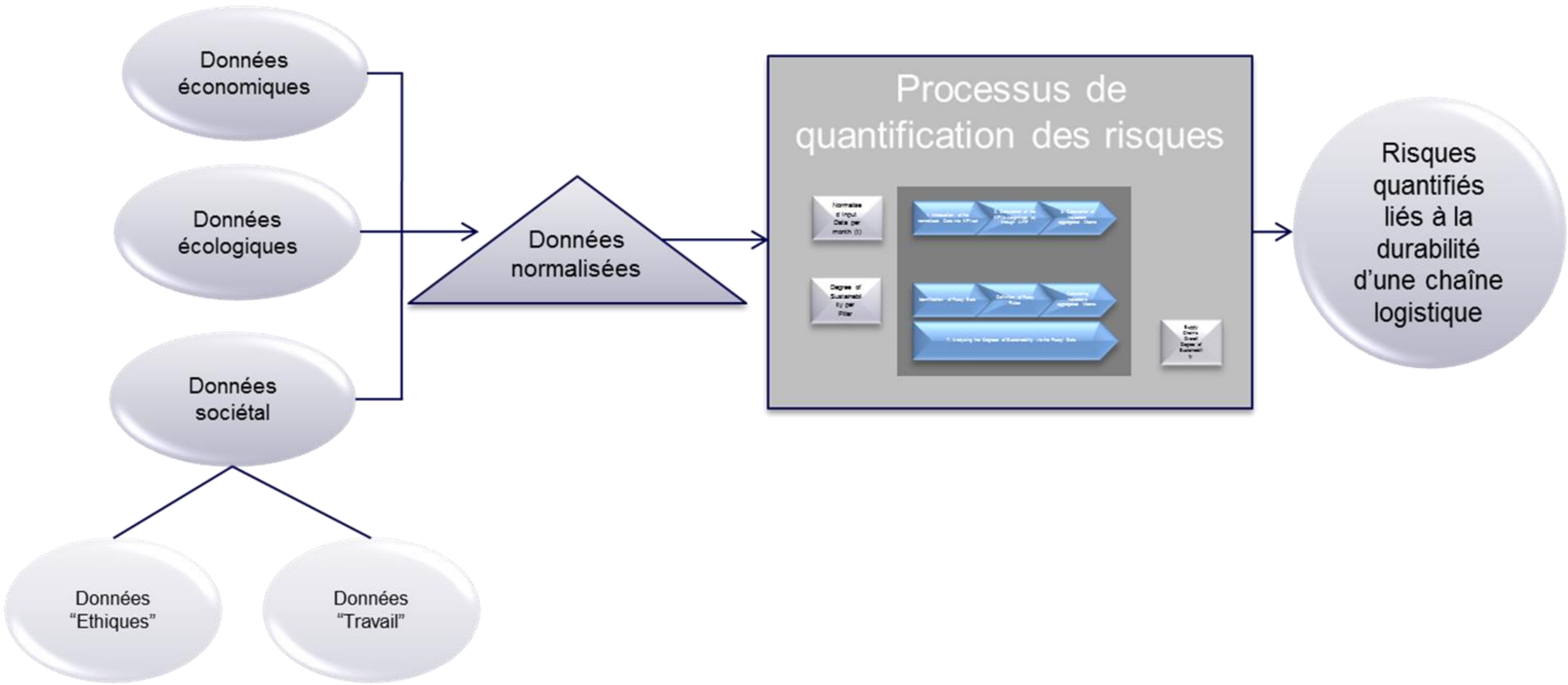

Figure 6 - Modèle de quantification des risques liés à la durabilité

Les données sont normalisées avant d'être introduites dans le processus de gestion des risques, résultant dans des risques quantifiés, tel que présenté en Figure 7.

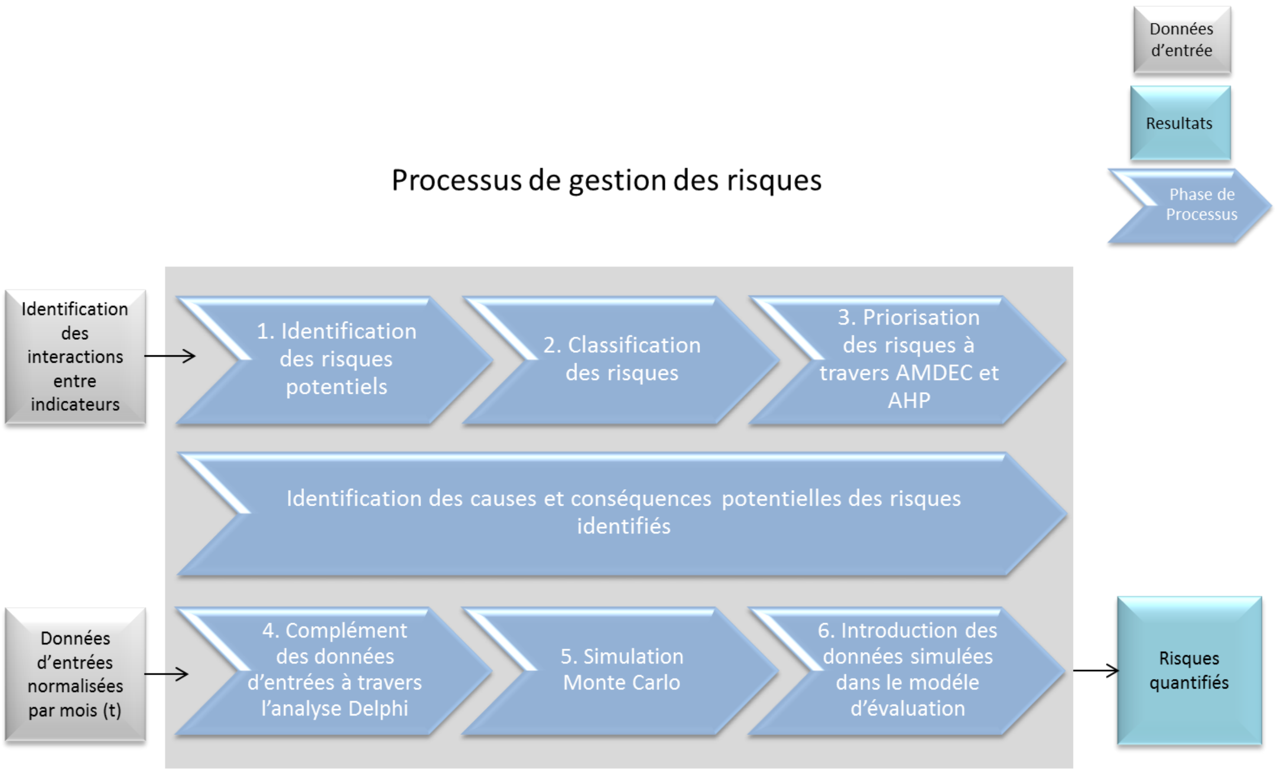

Figure 7 - Processus de gestion des risques

La procédure d'identification des interactions entre indicateurs a été soutenue par des réunions individuelles et des réunions en groupe avec les 14 experts internes. Les interactions identifiées ont servi de base dans la procédure d'identification des risques potentiels. Cette dernière a été réalisée à travers des réunions en groupe, durant lesquelles la méthodologie *« What If »* a été fusionnée avec la méthodologie d'études de danger et d'exploitabilité (*« Hazard and Operability », HAZOP).* Comme illustré en Figure 7, la deuxième phase du processus de gestion des risques considère la classification des risques identifiés. En effet, deux classes ont été distinguées, à savoir les risques internes à la chaîne logistique en question, et les risques externes à celle-ci. Ces deux classes présentent quatre, respectivement cinq sous-classes, tel qu' illustré en Figure 8 ci-dessous.

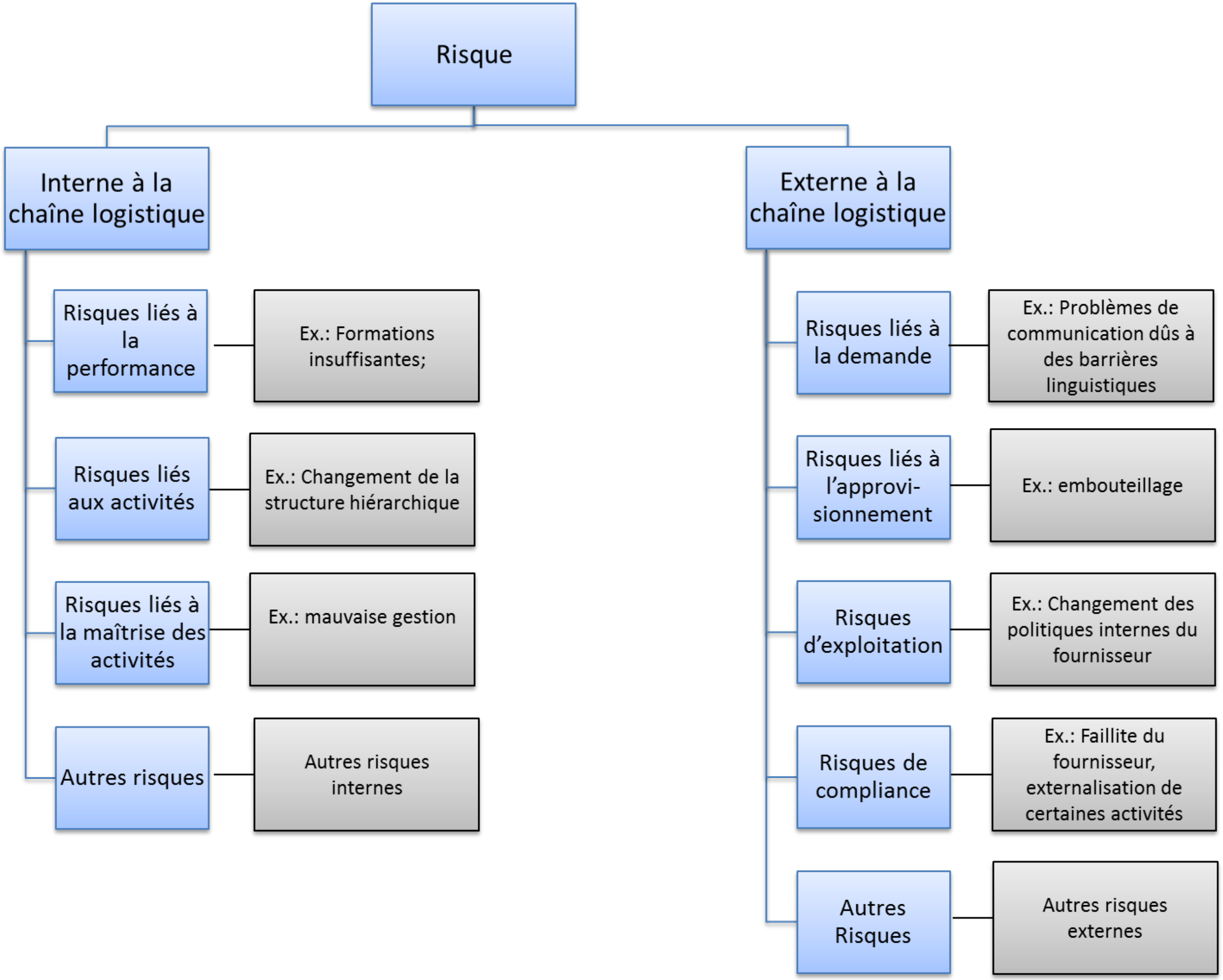

Figure 8 - Classification des risques

La troisième phase de notre modèle consiste en la priorisation des risques potentiels. Nous avons calculé cette priorisation à travers l'association de la méthode d'Analyse des Modes de Défaillances, de leurs Effets et de leur Criticité (AMDEC ; *Failure Mode and Effect Analysis, FMEA)* et de la pondération des indicateurs ($\varkappa_{KPI}$). En d'autres termes, le calcul se fait en fonction de la sévérité, de l'occurrence et de la détectabilité de l'indicateur en question, multiplié par le poids dudit indicateur. Ce dernier a été défini lors du calcul d'évaluation du degré global de durabilité d'une chaîne logistique existante. Le résultat provenant de la hiérarchisation est que **le risque d'une détérioration de la performance écologique de la chaîne logistique en question doit être considéré en priorité.** En d'autres termes, le risque à analyser en premier est celui de ne pas atteindre le degré de durabilité écologique qui a été atteint en 2013, toutes choses égales par ailleurs. Ce risque peut, d'après la Figure 8, clairement être classifié comme étant un risque interne à la chaîne logistique, lié à la performance. Les trois premières phases du modèle de quantification, à savoir l'identification, la classification et la priorisation des risques potentiels, aident à identifier les causes et conséquences potentielles résultant de l'amélioration de la performance d'un indicateur spécifique.

Il faut noter que les données d'entrées du présent modèle théorique de gestion de risques sont les mêmes que celles du modèle d'évaluation du degré de durabilité présenté au deuxième chapitre. Cependant, les données doivent être complétées afin de pouvoir quantifier les risques identifiés. En effet, les magnitudes des risques doivent être estimées par les experts à travers la méthode Delphi modifiée. Les données historiques actuellement disponibles étant insuffisantes pour la mise en place du modèle de gestion de risque, nous les avons complétées à travers un questionnaire Delphi, rempli en trois répétitions par un groupe restreint d'experts. De façon générale, la méthode Delphi exige l'anonymat des personnes participant aux questionnaires. Cet anonymat n'a pas pu être garanti lors de l'étude de cas mise en place dans la présente thèse et a donc dû être établi artificiellement. Les données complétées servent de base pour simuler un grand échantillon de taille n = 10 000 à travers la méthode Monte Carlo.

Communément, les chercheurs utilisent la méthode Monte Carlo en appliquant le théorème central limite ainsi que la loi des grands nombres. Néanmoins, nous avons utilisé la méthode Monte Carlo en négligeant le théorème centrale limite. Des discussions avec des experts internes et externes ont révélé que la distribution triangulaire donne des résultats plus réalistes que la distribution normale centrée réduite. Pour cette raison, si la distribution des données réelles peut être identifiée, cette dernière est prise en considération lors de la simulation Monte Carlo. Dans le cas contraire, les calculs se basent sur la distribution triangulaire. Or, dans notre étude de cas, nous avons effectué la simulation Monte Carlo deux fois à 10 000 répétitions. Tandis que nous avons accepté la loi des grands nombre dans la première simulation, nous l'avons négligée dans la deuxième. En d'autres termes, alors que nous avons négligé les interactions entre les différents indicateurs, nous les avons prises en considération lors de la deuxième exécution des calculs, tel que présentée en

Figure 9.

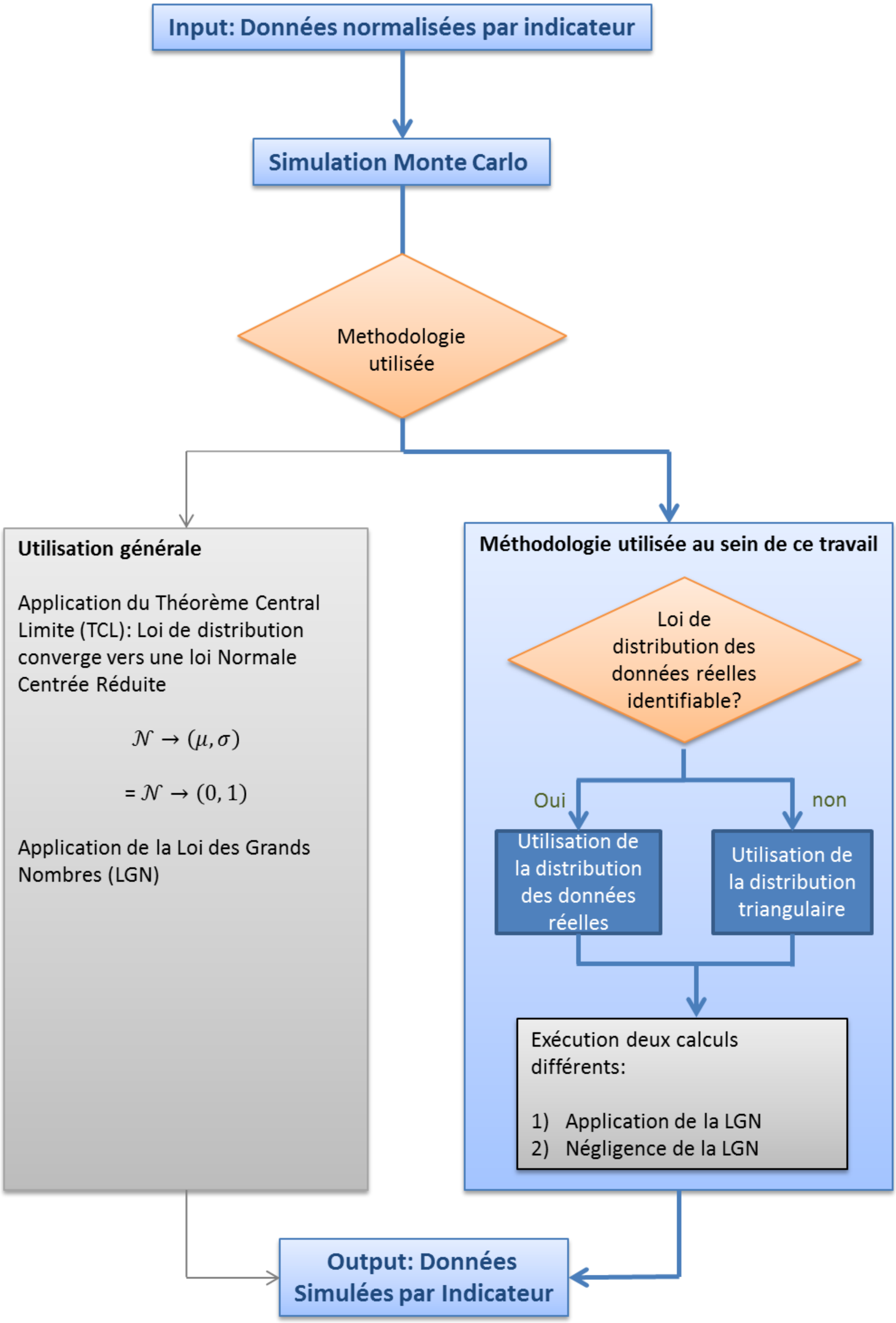

Figure 9 - Application de la méthode Monte Carlo

Après avoir effectué les 10'000 répétitions de simulations utilisant la méthode Monte Carlo, nous avons introduit les variables simulées dans le modèle d'évaluation du degré de durabilité qui a été présenté au deuxième chapitre. En effet, pour pouvoir quantifier le risque de détérioration de la performance écologique de la chaîne logistique, il faut traiter les variables simulées par le modèle d'évaluation résultant en 10'000 degrés de durabilité écologique simulés, à travers lesquels les fréquences peuvent être calculées.

Les fréquences calculées à travers notre étude de cas sont représentées graphiquement. Il devient évident que, même si l'on a négligé le théorème central limite lors des calculs de simulation, les valeurs théoriques simulées à travers la méthode Monte Carlo tendent vers une loi normale centrée réduite, comme le démontre l'allure de la courbe de la Figure 10 ci-dessous.

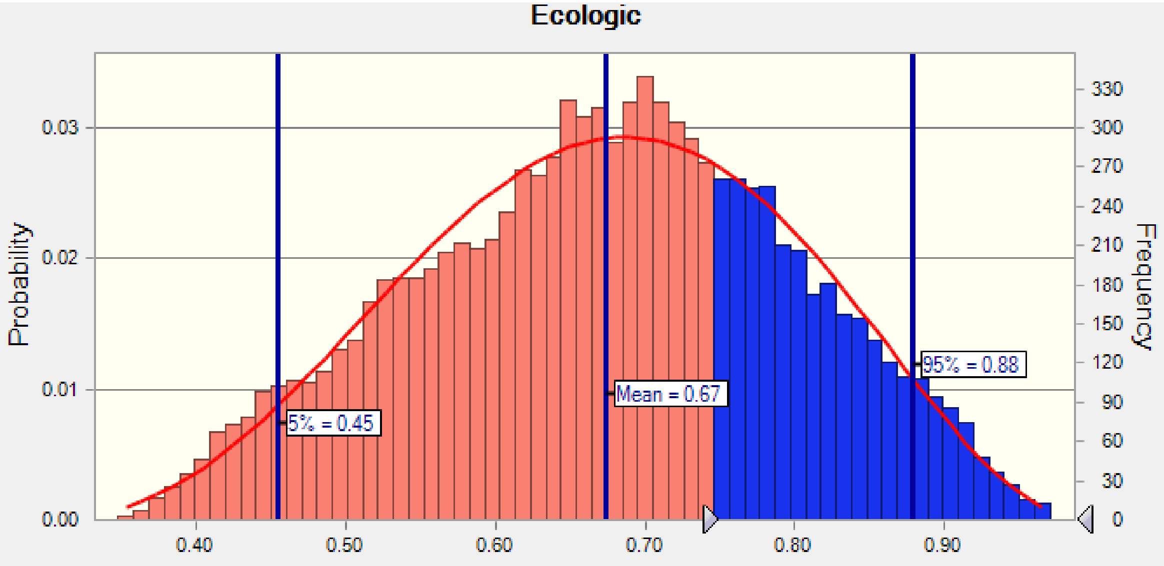

Figure 10 - Fréquences calculées

Les données de sortie du modèle de gestion de risques consistent donc en la quantification des risques en question. Dans notre étude de cas, le risque analysé est celui de ne plus atteindre le seuil de performance écologique de 0.75, qui a été réalisé en 2013. L'analyse des fréquences de ces performances écologiques a montré que ce risque est de 71.28 % si l'on prend en considération la loi des grands nombres. En négligeant cette loi, le risque en question est de 71.17%.

Les managers seront amenés dans une phase ultérieure à notre modèle, à diminuer ce risque par le biais de méthodologies de mitigation. Comme cette thèse avait pour but de mettre en place un modèle de quantification des risques, leurs mitigations n'ont pas été traitées. La gestion des risques doit être considérée comme un processus continu (Dittmann, 2014). L'étape subséquente de notre modèle consiste donc à envisager une stratégie à mettre en place concernant les risques considérés, i.e. : le niveau de risque qui est acceptable et les stratégies de mitigation et d'évitement des risques si le niveau de risque est considéré comme étant trop élevé. En d'autres termes, le présent modèle doit être élargi par un processus de mitigation de risques.

Le quatrième chapitre fournit des conclusions concernant les études du degré de durabilité de la chaîne logistique et l'analyse des risques éventuels associés.

Nos contributions majeures consistent en la mise en place de la base nécessaire pour implémenter le concept de durabilité dans les activités et opérations quotidiennes d'un prestataire logistique à travers deux modèles différents. Ces deux modèles peuvent être appliqués, quelle que soit la chaîne logistique en question et quel que soit son domaine servi. Ces modèles peuvent être utilisés en tant que modèle-type, n'ayant besoin que de légères modifications afin d'être applicables sur un autre risque. Or, le niveau de détail fourni par le modèle dépend des données utilisées et peut donc être changé selon les besoins. Néanmoins, les modèles présentent aussi des limitations. Ainsi, la normalisation requise pour pouvoir garantir la comparabilité entre les degrés de durabilité des différentes chaînes logistiques, exige que les gestionnaires définissent une valeur maximale identique pour toute chaîne logistique associée à un même domaine par indicateur. Ceci présuppose que ces valeurs maximales soient assez élevées pour qu'elles puissent être utilisées pour toute chaîne logistique d'un même domaine. En même temps, il faut que les gestionnaires n'exagèrent pas en définissant ces valeurs maximales. En effet, plus elles sont élevées, plus la valeur numérique du degré de durabilité tendra vers zéro. De plus, le modèle implique des indicateurs subjectifs. Afin de rendre les données concernant ces ? (indicateurs ?) aussi réalistes que possible, il faut exploiter un grand nombre d'avis des experts. Le problème réside dans le fait que tous ces experts doivent avoir une compréhension profonde de la chaîne logistique en question.

Les modèles développés servent de base pour implémenter le concept de durabilité aux activités quotidiennes, mais ne doit pas être considéré comme un modèle de gestion de risques fini. Les modèles d'évaluation du degré de durabilité et de quantification de risques développés à travers cette thèse doivent, dans une prochaine étape, être élargis par un processus d'identification et d'implémentation de stratégies d'atténuation des risques. Les hypothèses qui en résultent doivent ensuite être intégrées dans les calculs de quantification des risques avant que la reconception de la chaîne logistique puisse être effectuée. Dans la logique de l'amélioration continue, le processus de gestion des risques ne se termine pas par la reconception de la chaîne logistique en question, mais constitue une boucle fermée en reprenant la première phase du processus, à savoir celle de l'évaluation de la chaîne logistique en question, tel que démontré en Figure 11 ci-dessous.

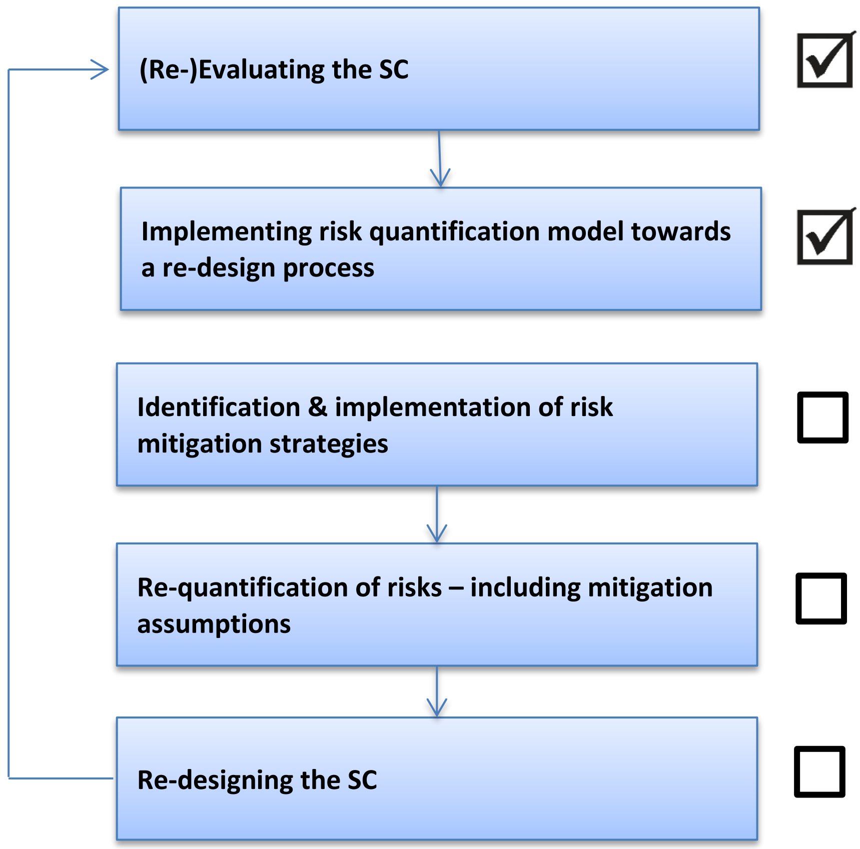

Figure 11 - Processus de Gestion des Risques

Les perspectives du présent travail sont aussi bien académiques qu'industrielles. D'un point de vue académique, il faut que de plus amples analyses soient effectuées pour que les interactions des indicateurs ainsi que les magnitudes des risques puissent être prouvées scientifiquement. Le modèle d'atténuation des risques susmentionné doit être développé aussi bien à travers des activités de recherche que par des activités industrielles. Dès que le modèle de gestion de risques est finalisé, il est indispensable qu'un cahier des charges soit élaboré. Or, ce cahier de charge doit servir de modèle-type, ne requérant que de légères modification afin d'être utilisable pour n'importe quelle chaîne logistique. D'un point de vue industriel, il serait intéressant de mettre en place un Benchmark (analyse comparative) de manière à ce que les leaders du marché en question soient publiés.

Cette recherche, financée par le Fonds National de la Recherche (FNR) Luxembourg, a conduit aux articles de conférences et posters listés ci-dessous :

- Deniaud I., Winter A., Caillaud E. 2012. Fuzzy Evaluation Model of a Sustainable Supply Chain. Case Study at Kuehne + Nagel. IEEE Conference on Logistics and Operation Management, Le Havre, France
- Winter A., Deniaud I., Caillaud E., Aggoune R. 2013. Modèle d'évaluation d'une chaîne logistique durable : Etude de cas chez Kuehne + Nagel. CONFERE 2012, Venise, Italie
- Winter A., Deniaud I., Caillaud E. 2013. Méthodes et modèle d'évaluation d'une chaîne logistique durable. Calcul des émissions de CO2 chez Kuehne + Nagel. CIGI 2013, La Rochelle, France
- Winter A., Deniaud I., Caillaud E., Gey M., Uribe E. 2013. Evaluation and Conception Model of a Green Supply Chain's Performance: Case Study at Kuehne + Nagel Luxembourg. Journée Poster. Strasbourg, France.
- Winter A., Deniaud I., Caillaud E. 2014. Risk Assessment of a Sustainable Supply Chain. Case Study at Kuehne + Nagel Luxembourg. GOL 2014. Rabat, Morocco.
- Winter A., Deniaud I., Caillaud E., Aggoune-Mtalaa, W. 2014. Towards the definition of sustainable supply chain. GSC 2014. Arras, France

Contents

List of Figures

List of Tables

List of Acronyms

3PL	Third Party Logistics
4PL	Fourth Party Logistics
AD	Anderson-Darling
AHP	Analytical Hierarchy Process
ALE	Annualised Loss Expectancy
ANOVA	Analysis of Variance
AXD	Actions taken against Xenophobia and Discrimination
B2B	Business - to - Business
BCM	Business Continuity Management
BOM	Bill - Of - Materials
BSC	Balanced Score Card
BTM	Bow-Tie Model
C	Costs
CBA	Cost Benefit Analysis
CI	Consistency Index
CLT	Central Limit Theorem
CO_2e	CO_2 equivalent
COG	Centre Of Gravity
CSR	Corporate Social Responsibility
DDHC	Déclaration des Droits de l'Homme et du Citoyen
De	Detection
DEA	Data Envelopment Analysis
DifSalary	Difference between Salaries
DRM	Design Research Methodology
DT	Decision Tree
DTL	Drivers' Training Level
EmMo	actions taken to increase Employees' Motivation
EMS	Environmental Management System
EMT	Ecological Modernisation Theory
EnUs	Energy Used
EOL	End-Of-Life
EPI	Environmental Performance Index
ERM	Enterprise Risk Management
ESI	Environmental Sustainability Index
ET	Event Tree
ETA	Event Tree Analysis
Ethics	Ethical Issues
ETO	Engineer - To - Order
ETS	European Trading Scheme
ExM	Exception Management
F	Flexibility
FeQuo	Femal Quota

FLA	Fair Labor Association
FMCG	Fast Moving Consumer Goods
FMEA	Failure Mode and Effect Analysis
FNR	Fonds National de la Recherche
FT	Fault Tree
FTA	Fault Tree Analysis
FTE	Full Time Equivalent
GE	Gender Equality
GFT	General Failure Types
GHG	Greenhouse Gas
GRI	Global Reporting Initiative
GSC	Green Supply Chain
GSCM	Green Supply Chain Management
HAZOP	HAZard and Operability
HFE	Human Failure Events
HRA	Human Reliability Analysis
HSS	Health, Security, and Safety
IPR	Intellectual Property Rights
IS	Issues Solving
KPI	Key Performance Indicator
KSF	Key Success Factor
LLL	Trainings per Employee *(Long Life Learning)*
LLN	Law of Large Numbers
LSP	Logistics Service Provider
MAUT	Multi-Attribute Utility Theory
MCDM	Multi Criteria Decision Making
MCS	Monte Carlo Simulation
MIP	Mixed Integer Programming
MTO	Make - To - Order
MTS	Make - To - Stock
NGO	Non - Government Organisation
NSCE	Network and Supply Chain Engineering
Oc	Occurrence
OTIF	On Time in Full delivery
PDF	Probability Density Function
PN	Petri Nets
PPP	Public Private Partnership
QADS	Quantitative Assessment of Domino Scenarios
QSHE	Quality, Security, Health, Environment
R	Responsiveness
RA	Risk Assessment
RBA	Risk Benefit Analysis
RPN	Risk Priority Number
RRR	Waste Management *(Reduce, Reuse, Recycle)*
RSME	Root Mean Squared Error
S	Sustainability

SC	Supply Chain
SCM	Supply Chain Management
SCOR	Supply Chain Operations Reference
SCR	Supply Chain Risk
SCRA	Supply Chain Risk Assessment
SCRLC	Supply Chain Risk Leadership Council
SCRM	Supply Chain Risk Management
SE	Security of Employment
Se	Severity
SLA	Service Level Agreement
SRA	Supplier Risk Assessment
SubGE	Subjective opinion about Gender Equality
SuSC	Sustainable Supply Chain
SuSCM	Sustainable Supply Chain Management
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TEQM	Total Environmental Quality Management
THERP	Technique for the Human Error Rate Prediction
TIGCI	Transparency International's Global Corruption Index
TKM	Ton - KiloMeters
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solutions
TQM	Total Quality Management
TripleRM	Risk, Resilience and Resource Management
Work	Working Environment
μ	Mean
σ	Standard Deviation

Introduction

1.1 BACKGROUND

In 2012, the PhD Candidate finished her master studies in “Management des Projets et Organisations, specialisation Qualité”, where her main field of study was quality management. The last semester consisted of an internship within Kuehne + Nagel Sàrl Luxembourg in which she performed her master thesis about “**Carbon Intelligence: Validation of the Internal Carbon Calculator named GTCC**”. It was hence a corollary that this PhD Thesis, founded by the Fonds National de la Recherche (FNR) succeeded the master internship within Kuehne + Nagel Sàrl Luxembourg.

1.1.1 Kuehne + Nagel

To date, Kuehne + Nagel’s main shareholder is the “Kuehne Holding AG”, which is owned a 100 % by Klaus – Michael Kühne. This holding owns 55.75% of the Kuehne + Nagel Group. At the age of 79, Klaus – Michael Kühne is still the company’s majority shareholder and he is still member of the Board of Directors. The Kuehne + Nagel group employs over 63’000 logistics specialists in about 1’000 locations, which are based in more than 100 countries. In 2015, according to the annual report, the annual turnover amounted to 20’283 million Swiss Francs[3]. The Kuehne + Nagel Group is the worldwide leader of air and sea transportations. In addition to this, the company is in the top ten of road and rail transportations as well as in Contract Logistics and Integrated Logistics. The internal politics of Kuehne + Nagel are based on Quality, Safety, Health Environment, and Security. According to its internal documentation, Kuehne + Nagel stands for quality, including the excellence of solution development, pricing, implementation and operation of new businesses. The fact that Kuehne + Nagel is certified by various standards; whereat the most popular are ISO 9001, ISO 14001 and the reference system OHSAS 18001 may be seen as a proof for its awareness of the importance of high quality.

Kuehne + Nagel opened its affiliated company in Luxembourg in 1970. Today, Kuehne + Nagel Sàrl consists of 587 members as its workforce[4]. The Luxembourgish subsidiary is present at 7 different locations in Luxembourg. Since Luxembourg is geographically positioned in the heart of Western Europe, it allows for faster and more efficient distribution to all main European economical intersections. Kuehne + Nagel Luxembourg provides tailored end-to-end logistics solutions, including sea freight, airfreight, contract logistics, parcel services and European overland distribution. The Luxembourgish branch’s headquarter is based in Contern, which is close to the Luxembourg Airport. Kuehne + Nagel Luxemburgish subsidiary’s total warehousing space measures 53’000m2 including Pharma Facilities. This area will be enlarged by the construction of a new building, whose construction began in April 2016. The total warehouse capacity of this new building will amount 46.000 m². Kuehne + Nagel Luxembourg is in accordance with the Kuehne + Nagel International policies, also based on continuous development and thus, on the Wheel of Deming (Hillmer & Karney, 1997).

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[3] I.e. about 23’514 million Euros *(1 Euro ≈ 1.2 Swiss Francs)*

[4] On the date of September 1st, 2015.

The PhD Candidate is affiliated to the Luxembourg's Branch's Network and Supply Chain Engineering (NSCE). The NSCE's team is in fact divided, being allocated in Luxembourg and in India. The department is hence not to be seen as a breakdown of another department but is to be seen as a supporting department for every other working unit. An important task of this department is the definition of bottlenecks in customer's supply chains (SCs). As shown on Figure 12, the NSCE identifies the optimal number, location and size of warehouses, optimises transportation, facilities and service trade-offs, determines the optimal assignment of customer to warehouse as well as the optimal allocation of products to warehouse and analyses the customers' cross-docking activities. Furthermore, it evaluates cross – dock or multi – drop trip opportunities, which enables customers to set up the best possible network configuration and to use their resources in the most efficient way. The objective of the NSCE department is to connect all links of the SC and to manage these by a global structured organisation. Equally important are the tasks like providing transparency and flexibility, controlling customer's SC(s) or defining networks which combine key information such as costs, service and quality levels,… The type of tasks executed by the NSCE shows that Kuehne + Nagel serves mainly Business-to-Business (B2B) customers.

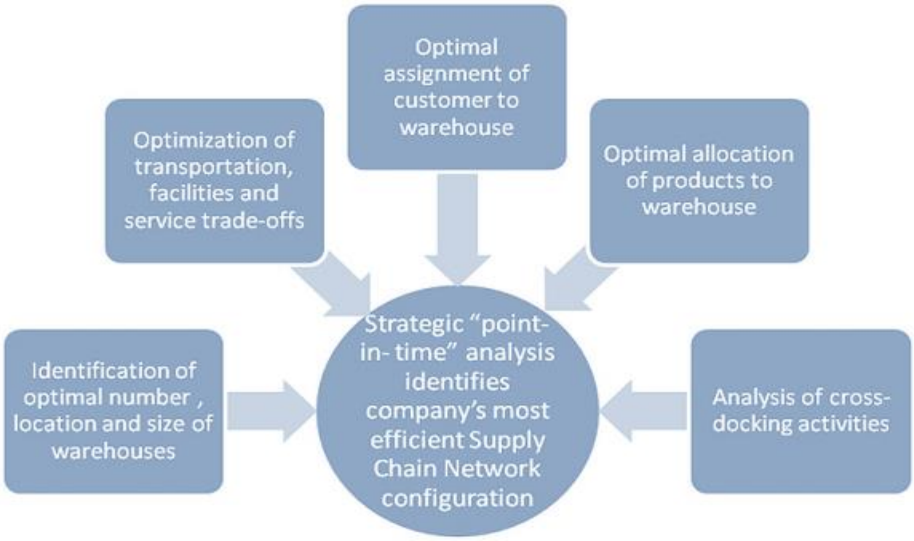

Figure 12 – Network and Supply Chain Engineering: Products and Deliverables

The NSCE is a corporate department and is therefore not subordinated to a specific office, but is involved in every single branch of the entire company. It has not only experience in SC simulations and calculations but it has also a certain experience in simulations and calculations concerning the "green visions and concepts" within SCs. The Corporate NSCE works in cross-functional teams: it operates in close cooperation with operational experts for the purpose of responding to customer's requests. Hence, it is evident that this department is involved into the Carbon Intelligence Project, which has been described in detail in the PhD Candidate's master thesis. The methodology used by the NSCE department is shown on Figure 2. It is almost the same for every product provided by the NSCE department.

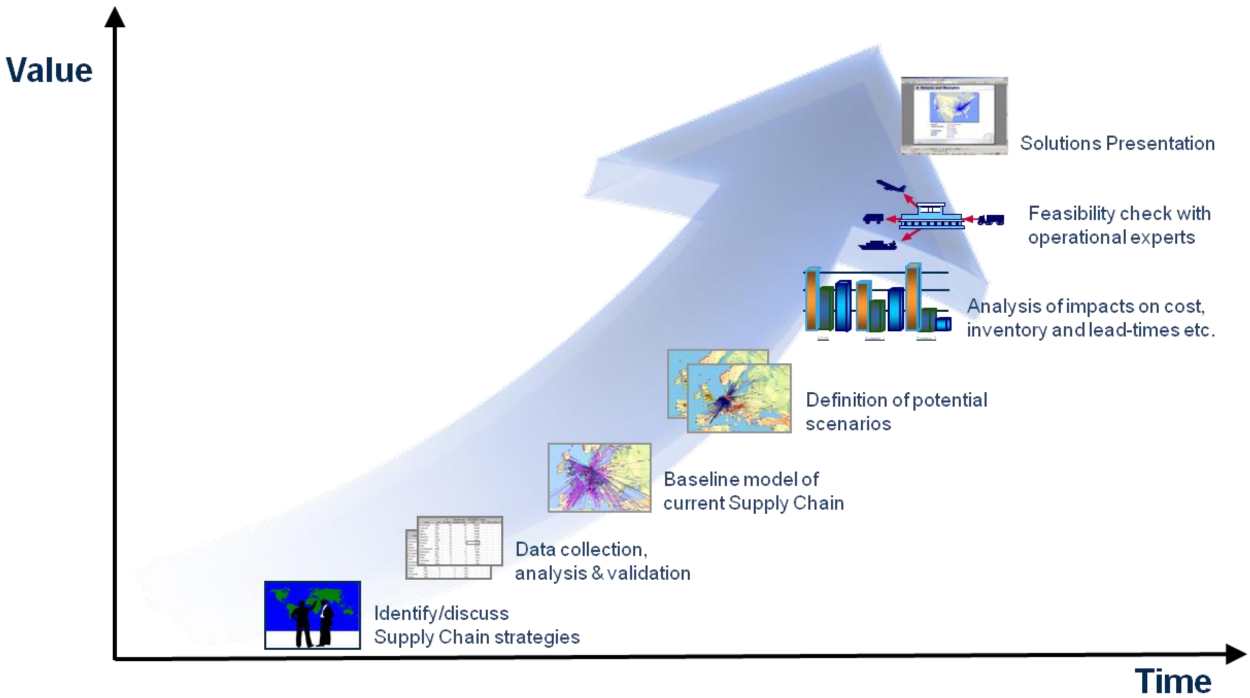

Figure 13 – Network Engineering: Methodology

In every project the very first step is its definition as well as the identification of the SC strategies. In this phase, potential boundaries are neglected, as the development of creativity is the most important part of this task. In a second phase, the required data is collected in order to elaborate the analysis and the validation of the aforesaid project. Afterwards, a so called "Baseline Model" will be developed in order to compare the customer's "As-Is" state of affairs with the situation as it should be. Using this Baseline Model, the different potential scenarios can be drawn and the latter are, in a following step, analysed considering the impacts on costs, inventories, and lead-times as well as on each other issue defined by the customer. The feasibility is checked by experts afterwards, so that realistic solutions can be guaranteed: up until that specific stage, the feasibility was not considered in order to foster creativity. Nevertheless, the feasibility needs to be seen as one of the most important issues, which can hence not be neglected. Those different alternatives will be presented to the customer. The customer then decides if the project will be implemented or not.

In an academic point of view, it is interesting to notice that the 'Kühne Logistics University' *(KLU)* is an independent, research-oriented and state-accredited private university, which is sponsored by the "Klaus – Michael Kuehne Foundation". The KLU, located in the dockland area of Hamburg in Germany, offers Masters in Management and Global Logistics as well as a PhD program in logistics, marketing and leadership[5]. The cooperation with the KLU has provided some interesting insights to the topic of sustainability but yielded that, within this academic entity, no thesis has been performed in the matters of sustainable SC's.

1.1.2 Industrial Issues and Research Objectives

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

[5] For more information, cf.: http://www.the-klu.org

stakeholders as well as its performance in terms of integrating its decision processes and its communication and information systems. The performance of a company is therefore highly dependent of its capacity to improve its internal processes (Lehmacher, 2013; Ravizza, 2012). Furthermore, customers' growing awareness of green and sustainable matters and new national and international regulations force enterprises to rethink their whole system (Wittenbrink, 2015).

Nowadays, the green concepts as well as the Corporate Social Responsibility (CSR) are ubiquitous. This may be effectively observed in daily businesses, where sustainable development became a major concern in the developed countries. Those new issues resulted in stricter regulations which mostly concern the impact of a product's manufacturing process, its use, and end of life handling (Houe & Grabot, 2009). Formerly, a company's ambition of improving its industrial competitiveness was mainly focused on minimising costs and on ensuring a certain service quality required by the customers (Raith, 2013). Today, besides the economical dimension, two new aspects need to be taken into account; i.e.: the ecological and the societal matters (Lehmacher, 2013). A company needs therefore to include the evaluation and the improvement of its economical, its ecological, and its societal issues into its performance evaluation models.

Actually, most of Kuehne + Nagel's customers require detailed information concerning their produced Greenhouse Gas (GHG) emissions, as they want to improve their SCs in a way that causes less impact on the environment. It is striking that most customers are not aware of the complexity of such calculations. The emissions produced during the transportation of goods do not only depend on the transport mode, but also on the distance covered. The latter may be calculated either as a beeline, or in a more realistic manner via several distance calculation tools. For the details of this calculation, we refer to the PhD Candidate's master thesis (Winter, 2012).

Many companies have only low visibility concerning the consequences of their ecological or societal performances, in contrast to their economical demeanours. The evaluation of added values, or the consequences of a more sustainable way of acting, is a highly sensitive issue due to the fact that enterprises need to newly develop their performance measurement systems. In a business point of view, the CO_2 calculation seems being the most tangible part related to the whole sustainability concept. The NSCE found out that most customers are interested in improving their SCs in the sense of sustainability, but they only ask for CO_2 calculations because this seems being the most tangible part of the whole concept. In addition, most of them have no idea of how these kind of calculations could be executed. In addition, they are unaware of the feasibility of **evaluating a SC's degree of sustainability**, as they cannot imagine what the sustainability approach entails more than CO_2 emissions. Today's approaches are mostly based on reverse logistics or on the green purposes while the sustainability matters are much more complex (Nikolaidis, 2013; Schmid & Spengler, 2009). In most business peoples' point of view, the evaluation of the degree of sustainability is only possible in theory since it is considered being too complex to be implemented on real cases. Some Kuehne + Nagel internal models consider the evaluation of the economic sphere, while others incorporate the evaluation of the company as a whole. This, however, cannot help the customer in evaluating his specific SC. Consequently the first research question of this work is:

- **Question [1]**: **How to evaluate the overall sustainability performance of a Supply Chain?**

Here, the overall performance is to be understood as the interaction of the sustainability concept's inherent pillars as defined by Elkington (1997). The immense number of authors interested in this subject matter has defined sustainability in many different ways. It is of major importance to have a common understanding of this topic. Therefore, the sub-question arising is:

- Question [1.1]: **How do we define sustainability?**

The evaluation model and its inherent method need to be elaborated in a general point of view. The considered model needs hence to be relevant for every SC, regardless of the area it operates. In addition, since the SC is never executed by only one stakeholder the different indicators used within this model need to be both, inter- and intra-organisational, and the evaluation methods need to be conclusive with the specifications of every SC in any domain whatsoever. Accordingly, the further resulting sub-question is:

- Question [1.2.]: **How to characterise a Sustainable Supply Chain (SuSC)?**

When common understanding of a SuSC's characteristics is guaranteed, it is important to know:

- Question [1.3.]: **Why do companies need to evaluate their Supply Chains (SC)?**
- Question [1.4.]: **How to evaluate a SC**?

The empirical model needs calculate the degree of sustainability by taking into account the three matters of sustainability (Elkington, 1997) as shown in Figure 14, by calculating:

$$Sustainability = f(Economic; Ecologic; Societal)$$

Figure 14 – Sustainability as defined by Elkington (1997)

The final result, being the global degree of sustainability of a certain SC, needs to align with the three sustainability performances.

Since most companies act according to the continuous improvement concept, the evaluation needs to be followed by an amelioration of the considered SC, i.e. a re-design of the latter. The re-design topic presents many challenges and interesting research questions, which will partially be discussed within this work. However, a risk assessment analysis needs to be performed *ex-post.*

The second question arising and to be answered is therefore:

- **Question [2]: What is meant by ‘redesigning’ a SC?**

To answer this question, we first need to agree on the following sub-questions:

- Question [2.1.]: **How to define ‘design’?**
- Question [2.2.]: **What is meant by design in a logistics perspective?**

As the (re)design of a SC goes hand in hand with taking a wide range of decisions, it is of major importance to have a clear picture of the possible risks and uncertainties resulting from the retained options regarding the eventual changes. We therefore tend to respond to the question:

- **Question [3]: How to evaluate eventual risks in the matter of sustainability, preceding a re-design process of a Supply Chain?**

To guarantee shared perception of what is meant by risk, the doubts to be cleared are:

- Question [3.1]: **How do we define risks?**

The results provided via the aforementioned evaluation model will lead us to further sub-questions, namely:

- Question [3.1.]: **How to identify potential risks?**
- Question [3.2.]: **How to evaluate potential risks?**

The empirical model needs to quantify the identified potential risks, so that managers may take adequate decisions to have the continuing ability of satisfying customers' requirements. The final results need hence to be analysed in accordance with the sustainability concept.

1.1.3 Research Methodology and Thesis Structure

Research fields

In order to answer the previously mentioned research questions, the major research field to be explored in this thesis consists of sustainability. In a second stage, this topic will be merged with the logistics domain, as this work will treat the sustainable logistics issues. In a third step, we will introduce the design field, whereby we restrict our research to the risk assessments preceding the redesign of an existing supply chain. The redesign phase of the supply chain will be out of scope of this work, although it serves as base for the risk assessment study. The different research fields considered are illustrated on Figure 15.

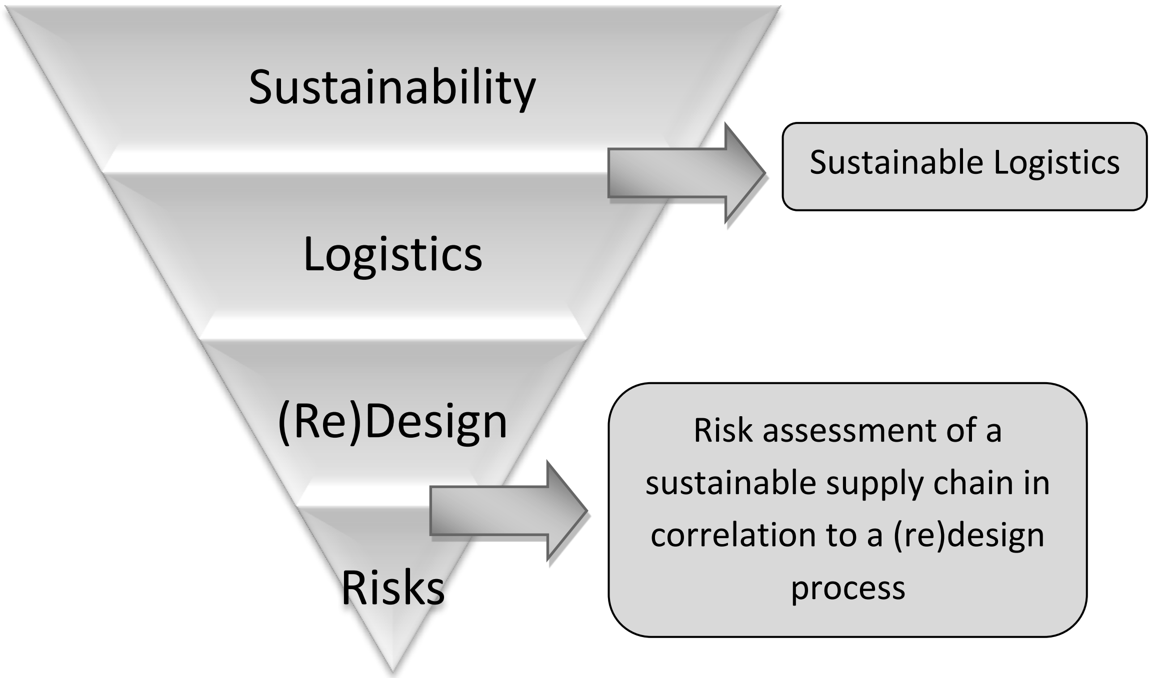

Figure 15 – Research Fields

Common understandings are crucial for the deep understanding of this work. The main keywords, namely [1] Logistics, [2] Supply Chain, and [3] Supply Chain Management will therefore be defined hereafter.

- **Logistics**

The keyword '*Logistics*' has more different origins. (Burr & Wagenhofer, 2012) explained that this keyword is twofold: on the one hand, etymologically, it comes from the Greek word "Logos", which can be translated by "explanation" or "description". On the other hand, they referred to logistics as the military replenishment which is generally accepted being one origin of the keyword "*Logistics*". Today, 'Logistics' and 'Supply Chain' are often considered being synonymous while professionals clearly distinguish between those two key words. Slats et al. (1995) stated that *"Logistics activities within an enterprise can be divided into (1) feed-forward flow of goods, including transportation, material handling and transformation […], (2) feed-back flow of information, including information exchange regarding orders, deliveries, transportation, etc., and (3) management and control, including purchasing, marketing, forecasting, inventory management, planning, sales and after-sales"*. Coronado Mondragon et al. (2012) defined logistics being *"a major economic activity comprising the process of planning, implementing and controlling the efficient, effective flow and storage of goods, services and related information from point of consumption for the purpose of conforming to customer requirements*." However, we define Logistics as follows:

Logistics can be understood as the fact of providing [i] the right thing, [ii] at the right time, [iii] in the right quantity and [iv] quality, [v] to the right place.

– **Supply Chain**

A Supply Chain (SC) can be defined as *"[…] the network of organisations that are linked through upstream and downstream linkages, in the different processes and activities that produce value in form of products and services in the hands of the ultimate customer"* (Martin Christopher, 1998). In other words, while the company's internal SC considers the flows of material, information and funds within the firm, the SC which is external to a specific enterprise considers those same flows between the different implied parties. The material flows can be graphically depicted as shown on Figure 16. In this figure, it becomes obvious that a SC depends on many different parties. According to (Bossel & International Institute for Sustainable Development, 1999), complex real systems *"[…]depend on other systems that depend on yet another set of systems, and so on."* In this logic, a SC can be regarded as a complex system since the SC itself depends on several sub-systems, namely, the different inherent companies as well as the different companies' supply chain management (SCM).

The very first process to be completed is the order of raw materials. The raw materials need to be extracted, and thus, the first **internal material flow** consists in the raw materials which are transported internally from the extraction point to an internal storage point. The first **external material flow** is realised between the raw materials extraction and the factory using those sources. The factories' outputs are semi-finished products, which need to be transported to a warehouse before being shipped to another factory. As one can see on Figure 16, there may be several factories and warehouses before the end product is conveyed to the wholesaler, and from there to a retailer. While the (end-) customer receives the needed finished product, this chain link is not to be considered as the end of a closed loop supply chain. In fact, the customer's waste, and thus the used products as well as their packaging are mostly separated. One part of this waste is then declared as garbage being disposed of, while another part will be recycled or remanufactured and will re-enter the supply chain as 'recycled (raw) material' or as 'remanufactured (raw) material' respectively, and will be reused according to the so-called 'Reduce, Reuse, Recycle' (RRR) concept. In fact, this concept claims that waste needs to be [1] reduced to a minimum, [2] reused and [3] recycled to a maximum (Büyüközkan & Çifçi, 2012). In their work, (Zwolinski, Lopez-Ontiveros, & Brissaud, 2006) have proposed a pro-active method intended to innovate in environment which is limited due to constraints relating to the expected properties of products to be remanufactured. They admit that a remanufacturing process is mainly implemented because of economic aspects.

As stated before, professionals often distinguish between logistics and supply chain. **In fact, while logistics is seen as the fact of providing the right product at the right time, in the right quantity and in the right quality to the right place, the supply chain considers the processes required to achieve the logistics' aims.**

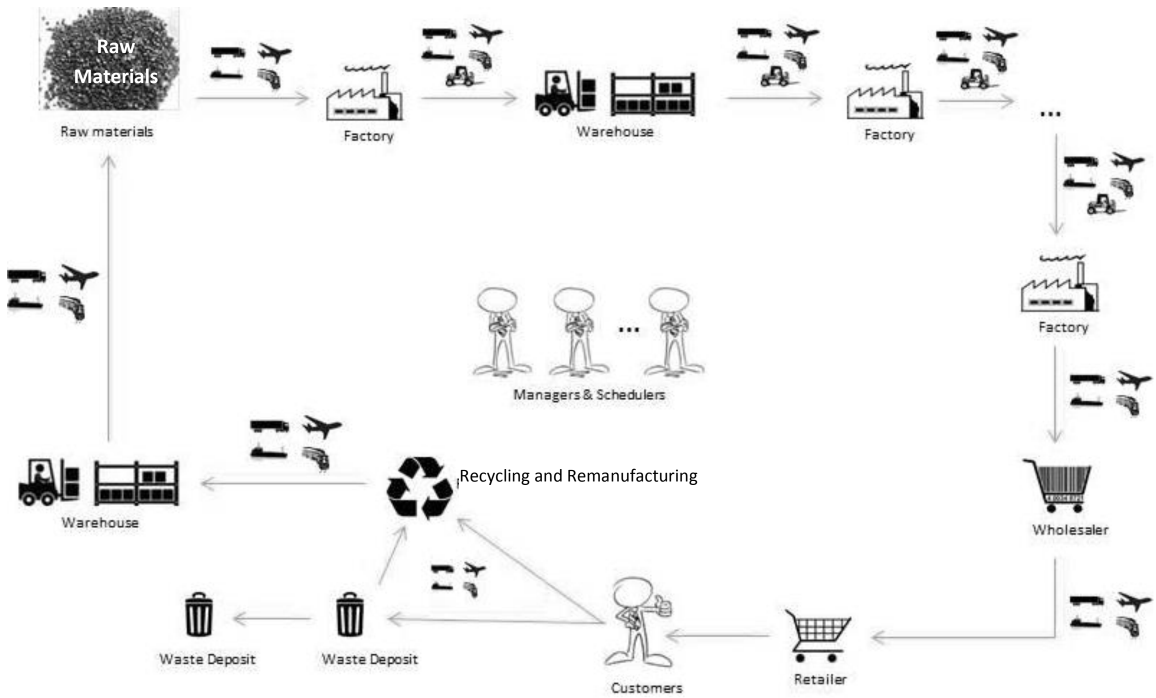

Figure 16 – Material Flows of a Supply Chain

A summary of the most important definitions found in the literature is provided in Table 1.

	Definition: Supply Chain
(BusinessDictionary.com, n.d.)	*"Entire network of entities, directly or indirectly interlinked and interdependent in serving the same consumer or customer. It comprises of vendors that supply raw material, producers who convert the material into products, warehouses that store, distribution centers that deliver to the retailers, and retailers who bring the product to the ultimate user. Supply chains underlie value-chains because, without them, no producer has the ability to give customers what they want, when and where they want, at the price they want."*
(Chopra & Meindl, 2007)	*"A supply chain consists of all stages involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers them-selves"*
(Ganeshan & Harrison, 1995)	*"A supply chain is a network of facilities and distribution options that performs the function of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers."*
(Lambert, Stock, & Ellram, 1998)	*"A supply chain is the alignment of firms that bring products of services to market."*
(Seuring & Müller, 2008)	***"The supply chain encompasses all activities associated with the flow and transformation of goods from raw materials stage (extraction), through to the end user, as well as the associated information flows. Material and information flow both up and down the supply chain."***

Table 1 – Definitions: Supply Chain

While all the above mentioned explanations are of high interest, we consider the definition given by Seuring and Müller (2008) being the most relevant for the necessities in this work:

"The supply chain encompasses all activities associated with the flow and transformation of goods from raw materials stage (extraction), through to the end user, as well as the associated information flows. Material and information flow both up and down the supply chain."

- **Supply Chain Management**

The Supply Chain Management (SCM) concept exists since the early 1980's (Ahi and Searcy, 2013). Nevertheless, several authors have defined it in many different ways. Most authors refer to SCM as a management or organisation of the different activities needed to achieve the goals set by logistics, including the different internal and external flows (Ahi and Searcy, 2013). Others explain that SCM is needed to achieve a sustainable competitive advantage (Seuring and Müller, 2008). (Mentzer et al., 2001; Rha, 2010a) state that it connects the different elements beginning at the manufacturing process and ending with the delivery to the end users, including all participating companies' contributions in the SC. In addition, they claim that the SCM includes the systemic on the strategic level of the traditional business functions, so that an improved long-term performance of the individual companies and of the SC itself may be achieved. On the other hand, (Hassini, Surti, & Searcy, 2012) define SCM being *"the control of the supply chain operations, resources, information and funds in order to maximise the supply chain profitability or surplus – the difference between the revenue generated from a customer's order and all the costs incurred by the supply chain while satisfying that customer's order",* while Zhang (2001) lays the accent on the fact that SCM needs to be seen as an assemblage of approaches used to efficiently integrate the different involved stakeholders so that commodities are produced and distributed in a manner that decreases system wide costs at a minimum and meets the customers' service level expectations.

"Firms that possess logistics know-how in coordinating economic resources may have opportunities to provide advice. Such logistics coordinators, also called third-party logistics (3PL) providers, have been gaining attention" (Tezuka, 2011). Thus, a Third-Party Logistics (3PL) provider handles all physical distribution and logistics, i.e. warehousing, clearing, freight forwarding, packaging, material inbound and outbound, safety, contacting carriers and so on. It consists hence of executing tasks at real time to achieve present goals. Fourth-Party Logistics (4PL), on the other hand, are involved in customer support, supply chain planning, analytic reporting, allocating customer services (such as IT solutions) etc. In more general terms, the 4PL considers the management of customers' SCs resulting in less field work than 3PL solutions. Opposed to 3PL logistics service providers (LSP), 4PL LSP is in charge of planning the attainment of future aims. To do so, past information and execution assessments are used to improve the considered SC. Both, 3PL and 4PL service providers handle their customers' outsourced business, but depending on the service level agreements (SLA), the provided services may vary between 3PL and 4PL. For more detailed explanations considering the different supply chain networks, we refer to ((Chopra, 2003)). It becomes apparent that companies, in order to provide the aforementioned 3PL or 4PL services, need appropriate methods and tools, and hence decision support systems, so that managers may take their decisions in the shortest possible time and under optimum conditions.

A summary of the most relevant definitions found in literature is given in Table 2.

	Definition: Supply Chain Management
(Ahi & Searcy, 2013)	"Many avenues of research have been pursued under the umbrella of SCM. Since the introduction of the concept in the early 1980s, SCM has been used to describe the planning and control of materials, information flows, and the logistics activities internally within a company and also externally between companies."
(Hassini et al., 2012)	*"the control of the supply chain operations, resources, information and funds in order to maximise the supply chain profitability or surplus – the difference between the revenue generated from a customer's order and all the costs incurred by the supply chain while satisfying that customer's order."*
(Mentzer et al., 2001)	*"Supply chain management is defined as the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole."*
Rha (2010)	"SCM stands for the chain connecting each element of the manufacturing and supply process from raw materials through to the end users, and handling integration of all participating firms' contribution in the supply chain."
(Seuring & Müller, 2008)	"Supply chain management (SCM) is the integration of these activities through improved supply chain relationships to achieve a sustainable competitive advantage."
(Y. Zhang, 2001))	*"Supply chain management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requirements."*

Table 2 – Definitions: Supply Chain Management

Obviously, the definition given by Hassini et al. (2012) is highly finance based, while the one given by Zhang (2001) has only a financial connotation. As each company has its' own finance department, this financial compound is considered being interesting but not sufficient for this work. However, the other definitions provided are accepted being appropriate and will therefore serve as base for our definition.

Hence, we define **SCM** as:

> **Supply Chain Management can be seen as the internal and external organisation of the different logistics activities in order to take pertinent decisions to achieve the final aims of supply chains.**

Research Methodology

As common understanding has been assured through the definition of the most important keywords, it needs to be elicited how this research has been conducted. The configuration of this thesis is segmented into 4 chapters, which will be explained more in detail in section 1.1.4

Since sustainability is defined being the intersection of the economical, the ecological and the societal pillar, the methodology used to generate this research is based on the industrial engineering approach, the economical purposes and on the humanities and social sciences. While theoretical research requires profound literature investigation, empirical research in business and management studies requests extensive interaction with experts. The main objectives of this work may be deduced from its title "*Evaluation Model of a Supply Chain's Sustainability Performance and Risk Assessment Model towards a Re-design Process*". Consequently, the aforementioned objectives are twofold: [1] providing a model which helps to evaluate a given SC's degree of sustainability, and [2] purveying a model to identify and quantify eventual risks, while taking into account the above-named cruces. In accordance with the two research objectives a research methodology including literature review and empirical research, has been designed. In their work, (Hodgkinson, Herriot, & Anderson, 2001) described the academic-practitioner divide, explaining the different types of sciences, based on their included theoretical and methodological rigour, and on the practical relevance, as shown in Figure 17. Effectively, this work's aim is not only to provide a valid theoretical model that meets the academic exigence, but it simultaneously needs to be practicable in the business environment. In other words, it is imperative to meet both theoretical and methodological rigour as well as applied relevance. For this reason, the research methodology is divided into two principal research phases: The Research Phase I refers to the first objective and concerns the evaluation of an existing SC's degree of sustainability, while the Research Phase II is related to the second goal, comprising a risk quantification study which usually precedes the re-design phase required by the continuous improvement concept. We therefore consider this work being integrated in quadrant 2 shown in Figure 17: 'Pragmatic Science', where theoretical and methodological rigours as well as the practical relevance are of high importance.

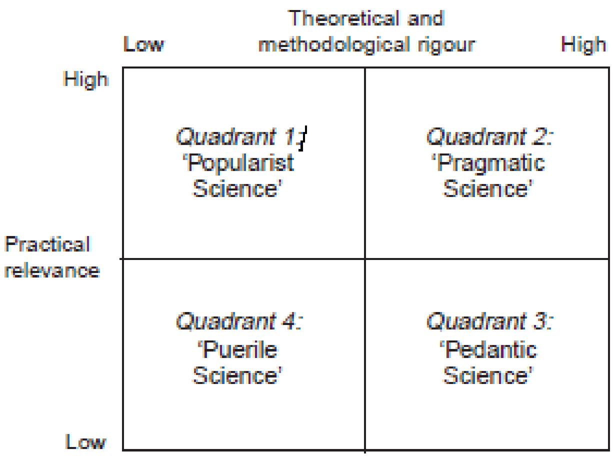

Figure 17 – Typology of research in industrial, work and organizational psychology by Hodgkinson et al. (2001)

To acquire multidimensional insights in the topics, and to guarantee valid and reliable research results, we developed a research framework pursuing a pragmatic research perspective as well as a methodological triangulation to gather the data required. Research Phase I as well as Research Phase II include both, a qualitative and a quantitative part, whereas we will give more weight to the quantitative one. The qualitative part will mostly be based on a literature review. The purpose of the familiarisation through literature review is to embed the different approaches, i.e.: industrial engineering, economics, humanities, and social sciences into the models to be proposed. We agree with (Mentzer & Kahn, 1995) stating *"The literature review and observation are two forms of logical induction that promote substantive justification. […] Substantive justification should provide the foundation and rationale of how the subject to be studied will make a significant and important contribution to its discipline – in other words, to justify the value of the research within its substantive area"*. Hence, in an academic perception, the literature review may be seen as the leitmotiv of the whole work. Furthermore, as the models to be proposed in this work are supposed to be as realistic as possible, and given the fact that the logistics environment is rather complex, the literature review helps to get insights on how to simplify things without getting simplistic. Effectively, there are three types of literature review (Mentzer & Kahn, 1995), which will all be implemented in the execution of this study:

- **Integrative literature review** is executed in order to pull together research areas so that a research agenda may be formulated. This usually results in a set of future research suggestions.
- **Methodological literature review** is done to examine several approaches for undertaking research. The advantages and drawbacks of various methodologies are compared and conclusions are drawn.
- **Theoretical literature review** is carried out to develop assumptions which need to be tested.

Since the selection of an appropriate research methodology is of major importance for every study, (Yin, 2003) proposed a research classification system , differentiating five basic questions, namely [1] *"who?"*, [2] *"what?"*, [3] *"where?"*, [4] *"why?"*, and [5] *"how?"*. Besides one sub-question, all of the previously defined research questions[6] can be classified being "how?" questions, which, according to Yin (2003), tend to be inherently explanatory. The use

[6] The research questions have been defined as from page 5 of this work.

of research methodologies which are able to deal with links that can be traced over time such as case studies is therefore justified. Consequently, both research phases will be completed by a case study. Effectively, a close eye on a practical real-life instance may help to obtain a precise overview of the actual interaction of variables or events ((Su & Lu, 2003). In addition, they argue that a case study may be used to establish valid and reliable evidence.

The process of setting up this study can be defined in seven main steps as demonstrated on Figure 7. Those steps are [1] Problem Ascertainment, [2] Integrative Literature Review, [3] Defining the Research Agenda, [4] Methodological Literature Review, [5] Data Collection, [6] Theoretical Literature Review, and [7] Model Analysis. Obviously, backward steps are possible at every stage of this process. Effectively, due to several reasons, the researcher's own mental concept of how to solve the considered research problem changes over time. Beyond others, those reasons are:

- **Literature review**
  - Figuring out that a given methodology cannot be used;
  - Finding a methodology the researcher did not know before;

- **Discussions with Experts**
  - Figuring out that the Data are not available;
  - Noticing that the methodology retained cannot be used in this specific case;
  - Experts are not convinced of the methodology's feasibility in everyday business

- **Self-criticism**
  - The researcher is not convinced of the model and queries the previously accepted methodologies and definitions

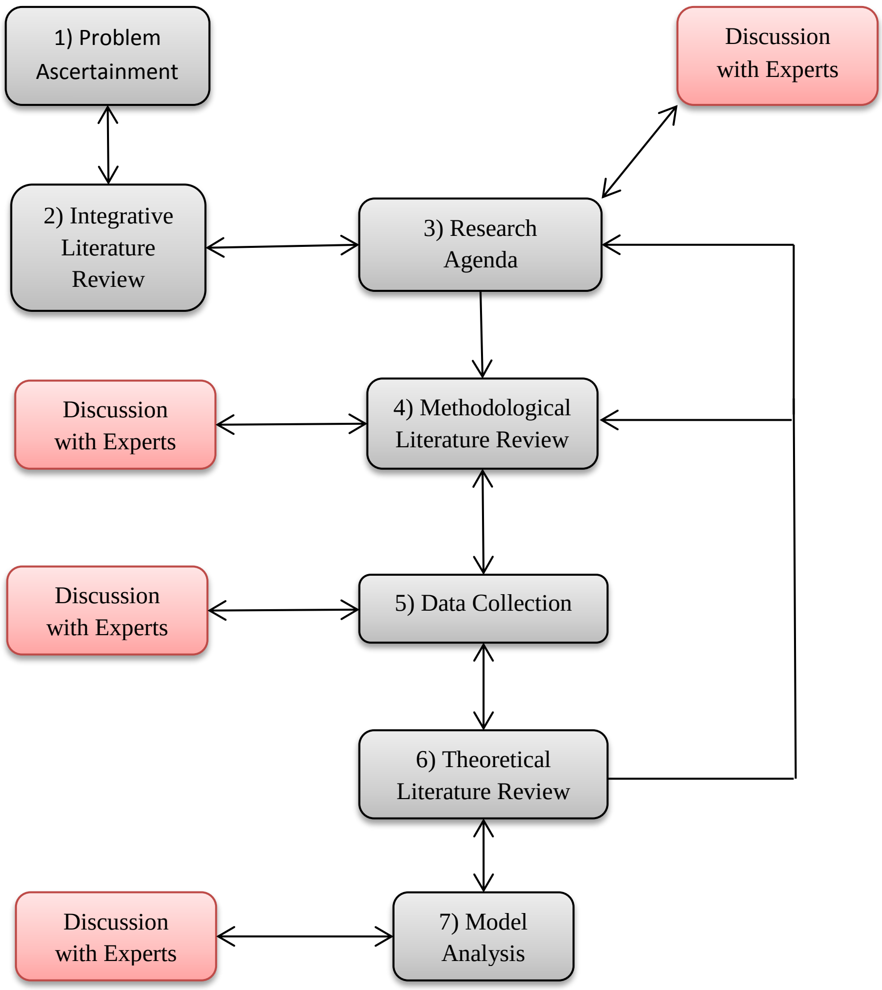

Figure 18 – Process of Thesis Elaboration

Case Studies

The data acquisition will mostly be conducted via the scan of internal available data. Some data, however, need to be estimated by experts. In fact, the case studies which are supposed to prove the models' usability in daily businesses, considers the timeframe from 2010 to 2013. On the one hand, during this period of time, Kuehne + Nagel did not consider sustainability as it will be defined in this work. Consequentially, some data have not been tracked during this period. In addition, since some data cannot be measured as such, it is clear from the outset that those data also need hence to be evaluated by experts. For this purpose, surveys based on linguistic variables, as well as a survey based on the Delphi Method[7] will be generated.

The greatest concern is to elaborate the models, i.e.: the evaluation model and the risk assessment model, in a way that they may be employed for each and every SC no matter its economic sector. To remedy this problem, the models will be based on an Analytical Hierarchy

[7] The Delphi Method will be explained in Detail in Chapter III.

Process (AHP) approach[8] so that the different Key Performance Indicators (KPIs) which will be defined ex-ante can be weighted. The weighted KPIs will be analysed within the evaluation model. model. To deal with the aforementioned qualitative data, namely the linguistic variables resulting resulting from the questionnaires, the fuzzy logic approach will be applied. The evaluation model's results will be pointed out on a three dimensional diagram so that every pillar may be taken into account individually, without altering the final result because of mean calculations. The risk assessment model considers the potential risks' quantifications, which will be calculated through the use of the Monte Carlo Simulation. The simulated results need then to be introduced into the previously developed evaluation model. The risk assessment model's results will hence be provided by a closed loop approach of both models and will point out the quantified risks expressed in percentages.

1.1.4 Manuscript Outline

This work's four inherent chapters are intended to answer the previously raised research questions. Its outline is depicted in Figure 19.

Since this thesis is performed 70% at Kuehne + Nagel, the first chapter of this thesis provides, beyond an introduction to the research topic, a short presentation of the company and of the department in which this study has been conducted.

Chapter two opens with a detailed literature review providing common understanding of the main subject of this thesis, i.e. sustainability. To evaluate an existing SC's sustainability performance, distinction will be made between the different domains served by Kuehne + Nagel and a KPI dashboard will be set up. In a subsequent step, the most important Multi Criteria Decision Methods (MCDM) and Decision Support Systems (DSS) on a modelling level will be analysed, resulting in the development of the evaluation model, supposed to give insight about the existent SC's sustainability performance. The chapter will be completed by a case study, proving the evaluation model's usability in a company's daily business.

The ensuing third chapter deals with the question of how to perform a risk assessment of a Sustainable Supply Chain (SuSC) towards a re-design process. To provide common understanding of what is to be understood by design and risk, a literature review will be conducted. As a next step, we will provide a short explanation of the most important existing risk assessment methodologies, analysed in accordance with their respective approaches, i.e.: quantitative, qualitative, and hybrid, resulting in the development of a risk assessment model. This third chapter will also be closed by a case study, proving the model's usability under real conditions.

The fourth chapter will provide a conclusion of the research provided within this work, and will purvey some suggestions for future studies and investigations.

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[8] This approach will be discussed in detail in Chapter II.

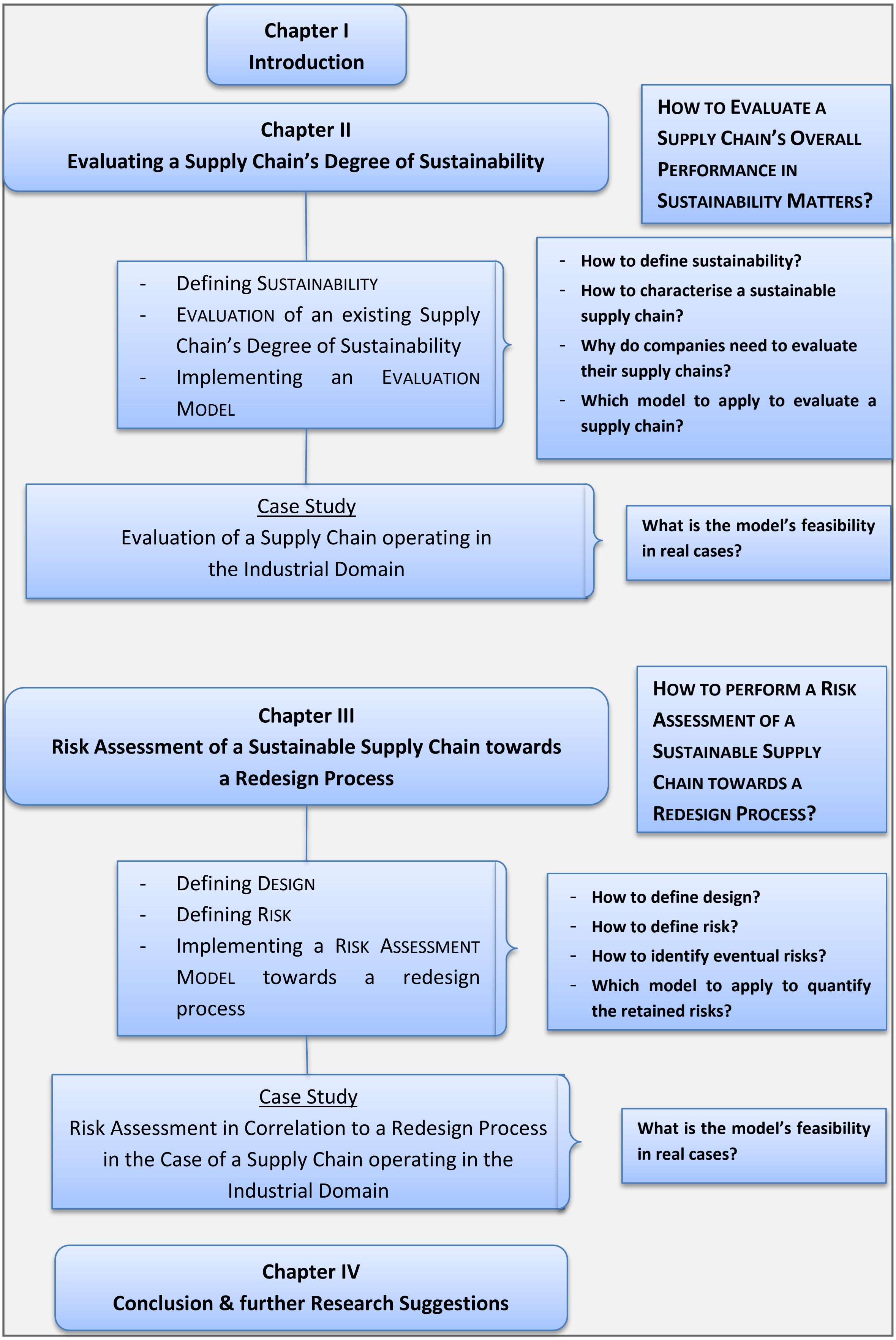

Figure 19 – Thesis Structure

Evaluating a Supply Chain's Degree of Sustainability

2.1 TOWARDS THE DEFINITION OF SUSTAINABILITY

In the 18th century, the keyword 'Sustainability' still remained unknown. Nevertheless, Thomas Robert (Malthus, 1798) already worried about exactly those issues. In 1798, under the name of J. Johnson, he wrote "*I said that population, when unchecked, increased in a geometrical ratio, and subsistence for man in an arithmetical ratio. […]. Those who were born after the division of property would come into a world already possessed. If their parents, from having too large a family, could not give them sufficient for their support, what are they to do in a world where everything is appropriated? We have seen the fatal effects that would result to a society, if every man had a valid claim to an equal share of the produce of the earth. The members of a family which was grown too large for the original division of land appropriated to it could not then demand a part of the surplus produce of others, as a dept of justice. It has appeared, that from the inevitable laws of our nature some human beings must suffer from want. These are the unhappy persons who, in the great lottery of life, have drawn a blank. The number of these claimants would soon exceed the ability of the surplus produce to supply"* (Malthus, 1798). He did not use the keyword of sustainability, but he clearly worried about the sustainability concept. He was sure that later generations would suffer from famines, plagues, or pestilences as nourishment would not suffice for every human, due to the fact that humanity would grow much faster than their subsistence.

In April 1968, some professionals from the fields of civil society, diplomacy, industry, as well as academic people met in Rome to discuss the problems of short-term visions in international affairs and the issues of limited resources. The Fiat Manager, Aurelio Peccei, and Alexander King, a Scottish scientist and OECD general Director, came together and brought the Non-Government Organisation (NGO) 'Club of Rome' into being. They achieved international recognition with their much-discussed report 'The Limits to Growth', which appeared in 1972 (Deutsche Gesellschaft Club of Rome, 2015). According to (Danilov-Danil'yan, et al.(2009), "*It was established that by the middle of the 21st century, even the most optimistic of the projected scenarios amounted to inevitable ecological collapse against the background of a deteriorating biosphere".* Contrary to the common opinion, they did not predict the world ruin but they analysed and presented simulated scenarios of the five subsystems [1] population, [2] production comestible goods, [3] industrial production, [4] defilement and pollution, and [5] the use of non-renewable natural materials (Meadows & Club of Rome, 1972).

2.1.1 Elkington's Triple Bottom Line (TBL) – Illustration of its inherent pillars

The keyword 'sustainability' has been used in an innumerable number of articles, while its definition deviates in each one. In order to define what one should understand by "sustainability", many authors quote Brundtland's definition of sustainable development being *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (Brundtland, 1987). In literature, some authors have defined the work of Brundtland (1987), also known as 'The Brundtland Report', being the beginning of an era in which people started worrying about sustainability. As stated above, we consider that the concept of sustainability has already been analysed long before the famous Brundtland Report has been written. Hassini et al. (2012), on the other hand, based their definition of sustainability on Elkington's (1997) "Triple Bottom Line" (TBL) declaring "*we define business sustainability as the ability to conduct business with a long term goal of maintaining the well-being of the economy, environment and society*", shown on **Error! Reference source not found.**. In his work, Elkington (1997) explains that business is seen as being sustainable if it complies with the TBL of **economic prosperity**, **environmental quality** and **social justice**.

Nowadays, companies try to foresee their customers' requirements so that they can be fulfilled as soon as they have risen. Effectively, "*higher requirements for the products lead to the need for constant innovation for company's competitive advantage"* (Deniaud et al., 2016). Brundtland's (1987) time related definition of sustainability is hence of high importance in a company's real environments and settings. This also includes vigilant examination of potential changes in national and international laws and requests. Many experts have expressed the opinion that sustainability will become an increasingly important issue in the European Economic Area. In fact, France is the first country in the world which has introduced the carbon reporting commitment on financial institutions. 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 (Louis, 2011). Many experts[9] are convinced that this kind of accounting will be enlarged and accepted by the European Union.

In his work, Elkington (1997) puts the question "*Is it a progress if a cannibal uses a fork?"* while he agrees on this matter and defends this opinion. The cannibals are used as a metaphor for business companies in nowadays fast changing capitalist economies in which it seems being normal that firms devour their competitors. In addition to this, the fork needs to be seen as metaphor for sustainable business and hence, for the progress into a new stage of modern culture. As, nowadays, there is no realistic alternative for capitalism Elkington (1997) enlarges the concept of sustainable business, which has mostly been limited to environmental matters. In his opinion, the aim of sustainable businesses may be achieved if economic prosperity, ecological quality, and societal justice are obtained. To reach this objective, he states that a revolution of thinking is necessary and explains that one should think in seven dimensions. Those dimensions are [1] markets, [2] values, [3] transparency, [4] life-cycle technology, [5] partnership, [6] time-perspective, and [7] corporate governance. The TBL's inherent three pillars are hence interrelated, interdependent and to some extend in conflict. In the following, we will analyse the three pillars framing Elkington's TBL and define what we understand by 'sustainability'.

2.1.2 The Economic Pillar

The 'Clarity of Objectives', introduced by Gimenez & Tachizawa (2012), is seen as vital and essential for the survival of any company. However, 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. Hill (2012) criticised *"the myopic focus on short-term financial gain"*, while Glenn Richey et al. (2009), Nikolaou et al. (2013), and Rao & Holt (2005) analysed several assumptions considering the financial performance. Lin (2013) and Visser (2010) 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. Rephrased, a company has a precise knowledge concerning its different costs and savings, but this is mostly the case on a product or service level or per department, but never on a supply chain level. This is due to the fact that one department or process will never be used for only a single supply chain, but one same department or process operates on

[9] Experts have been met on different conferences concerning green supply chains, as well as on internal and external company meetings.

several supply chains. This holds also true for the indicators 'average salary & costs of employees', 'IT Infrastructure / Technology Infrastructure' and 'Supplier Relationship'. For the latter, this might not be evident, but a company can have a long term and stable supplier relationship while it is possible that the supplier within a certain supply chain will change. In other words, the company operating on several supply chains will still work with the same suppliers, but in a point of view of the different SCs they will be replaced. Hence, concentrating on a SC level, the above mentioned indicators need to be rejected when concentrating on a SC level.

As many companies are certified according to ISO and EU standards, it is remarkable that the 'ISO 9001' Standard has not been alluded in a more frequent manner (Gimenez and Tachizawa, 2012; Sloan, 2010). In the same way, it is curious, that 'Productivity / Productivity Improvement' has been mentioned in only a few articles (Daniels, 2010a, 2010b; Rao and Holt, 2005; Sloan, 2010), but none of them included a definition of how productivity or its improvements should be measured. This is not evident, as the number of goods or services produced may not allow concluding on the quality of the considered products or services. The 'Existence of policy encouraging use of local contractors and suppliers' has only been introduced by Norman & MacDonald (2004). In our view, it needs to be differentiated between the 'Productivity / Productivity improvement' indicator on a quality base, and the 'quantity produced' indicator on the other hand. Nevertheless, this KPI, used by Daniels (2010a, 2010b), Rao and Holt (2005), and Sloan (2010), is, considered being redundant, since every SC is expected to be in a continuous change and improvement process, as the 'customer satisfaction' KPI requirements must be fulfilled. As a result, the continuous improvements of a SC become essential in providing the customer with a constant better product and service. The above mentioned 'Existence of polity encouraging use of local contractors and suppliers' indicator may be important in order to measure the company's support of regional growth, but is not useful in determining the degree of sustainability of a given SC.

'Total Quality Management (*TQM*) and Quality Management System in Use' has only been considered by few authors (Beamon, 2005; Gimenez & Tachizawa, 2012; P. Rao & Holt, 2005). TQM is a structured approach for improving the quality of products and services via continuous improvement. In addition to this, it is important to understand that the TQM Systems are often closely linked to a company's internal information technology (IT) infrastructure. While (Daniels, 2010b) and (Daniels, 2010a) gives more importance to the technology associated with production and consumption as a driving force, (Elkington & Trisoglio, 1996) and (Gimenez & Tachizawa, 2012) emphasise on the fact that sustainable development has mostly been defined around technology. Hence, TQM as well as the ISO standards require the continuous improvement. This means that companies, in order to ensure being re-certified in future, could be led into temptation to retain some of their improvements for a later state. It is important to understand that the TQM is not to be seen as a goal, but rather as a never ending improvement process aiming for the 'Zero Failure' motto. For this reason, neither the TQM nor the ISO standards may be used as indicators in this work and are thus neglected.

Hoejmose et al. (2012) and Nikolaou et al. (2013) mentioned the KPI 'Employees'. Hoejmose et al. (2013) took this KPI into consideration in order to classify a company's size, while Nikolaou et al. (2013) used it as a whole. An increase or decrease of a company's size is not meaningful in terms of sustainability, as this may have different reasons. This also holds true for its costs of employees. The KPIs considering the company's size or costs are therefore not significant in terms of economical sustainability. Consequently, such indicators need to be seen as a composition of both, the number of employees and the company's size.

Interestingly enough, only Glenn Richey et al. (2009) and Rao & Holt (2005) used the 'Performance and Efficiency' indicator. On the other hand, a LSP's performance and efficiency can be measured via sub-indicators, for example the supplier relationship can be measured by the number of contract agreements or those agreements' length in years (Hoejmose et al., 2012; Nikolaou et al., 2013). Another sub-indicator can be the orders fulfilment time, i.e. the period between placing an order and receiving the ordered products (Sloan, 2010). In addition, a company's performance and efficiency may also be measured via the product liability (ex. recalls), the complains and products' defect rate (Elkington & Trisoglio, 1996; Sloan, 2010), as well as the product and supply complexity (Elkington & Trisoglio, 1996; Hoejmose et al., 2012a). In this work, only the 'Complains' are determined being usable. In their article, Tseng and Chiu (2013) analysed most of those sub-indicators independently.

No manager will invest in sustainability if there is no visible return on investment (ROI). In fact, a visible or tangible ROI is mostly given in financial terms, i.e. the calculation of the time needed to amortise a specific investment and the estimated gains the company can touch after this amortisation. Since in European countries the government requires that public companies report their economic performance publicly, the KPI 'ROI in financial terms', used by Milne & Gray (2012), will be neglected in this work. On the other hand, as illustrated by Porter & Kramer (2011), giving the example of a company's reputation, a ROI can also be considered in non-financial terms. Despite most managers' attitude of only assessing tangible financial values, it seems evident for each businessmen that customer satisfaction impacting a company's reputation is a significant component of sustainability (Tseng & Chiu, 2013a). In this same manner, Nikolaou et al. (2013) and Rao & Holt (2005) considered the 'Product Responsibility' or the 'Product labels or awards (Nikolaou et al., 2013) also revealing a company's reputation. It is obvious, that the non-financial ROI is not sufficient for the survival of an enterprise. Several authors[10] have mentioned the financial part[11], but did not explain the included KPIs in their work.

In order to assess the financial impact of maintenance, Liyanage et al. (2009) revealed some key issues. Some of them consist of 'Insurances, compensations, and penalties'. This article presents a lack of explanations. Nevertheless, it seems to be evident that the amount of penalties or compensations paid as well as the increase of insurance costs gives an insight to a company's working structure and to its sustainability.

The 'stakeholder value' as well as the 'shareholder value' indicators have been considered by Bellizzi & Hasty (2003) and Elkington & Trisoglio, (1996). The data required for this indicator are as well quantitative as qualitative. In fact, the shareholder value is the company's value on the stock exchange, while the stakeholder value can be seen as the value given by the different parties. The latter can be estimated via a 'Likert scale questionnaire', whose answers are qualitative. This holds also true for 'Market Value & Market Share' indicator (Rao & Holt, 2005; Sloan, 2010). One may argue that 'stakeholder value' and 'market value' are synonymous. It is obvious that those indicators consider the 'direct economic impacts'. Above that, Nikolaou et al. (2013) considered the 'indirect economic impacts regarding reverse logistics systems', but they did not explain, what those indirect economic impacts consists of, or how they are measured.

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[10] Daniels, 2010a, 2010b; Glenn Richey et al., 2010; Hoejmose et al., 2012; Lin, 2013, 2013; Liyanage et al., 2009; Nikolaou et al., 2013; Rao and Holt, 2005; Rha, 2010; Sloan, 2010; Thipparat, 2011; Visser, 2010.

[11] The financial part includes: 'Financial Performance & Costs *(savings)*', 'Employees *(average salary – costs of / number of)*', 'Operating Expenses', 'Tied-up Capital for tools and other resources', Profit margin / Profitability Ratio', Costs of goods sold', Return on working capital / ROI', 'Taxes paid', 'Subsidies', 'Total spend on Non-Core Business Infrastructure', 'Costs of returned materials *(Reverse Logistics)*', 'Investment recovery *(sale of excess inventories / materials / …)'* and 'GDP per Capita'.

The above literature review revealed many different ways to consider the economical pillar of sustainability. The considered authors have defined a myriad of indicators and measurements whereas we consider most of them being inapplicable in this work. In fact, since this work concentrates on sustainability on a SC's base, and not on a company's level, it is evident that the above yield indicators cannot all be used. The retained indicators will be explained more in detail in section 2.3.1.

2.1.3 The Ecologic Pillar

As stated by Winter et al. (2014), 'Sustainable' as well as 'Green' topics are still at an early stage. Nevertheless, the most analysed part of those topics is the ecological one (Sloan, 2010). 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 (Elkington & Trisoglio, 1996; Gimenez & Tachizawa, 2012; Kurien & Qureshi, 2012; Rha, 2010a, 2010b; Sloan, 2010; Thipparat, 2011; Tseng & Chiu, 2013; Zhu et al., 2008). It is worrisome that only Rha (2010a) explicitly highlighted the continuous improvement in environmental performance resulting from the ISO standards. Lin (2013) defined the environmental regulations as being the external driving factors, regardless of whether the ordinances are domestic, governmental, or international. The 'Environmental Management System (EMS)' indicator has also been used quite often. It may be argued that some standards, as for example the ISO 14001 standard, are one possible EMS. In Tseng & Chiu's (2013a) analysis, the EMS has been defined as top criteria in their supplier evaluation model. Sloan (2010) also set up a supplier evaluation model. It's 'Environmental Sustainability Index' (ESI) contains 21 indicators, including 'Environmental Systems'. In his work, Sloan (2010) used the existing EMS as a sub-indicator, which can be found in the 'Institutions and Systems'. Thipparat (2011) and Gimenez & Tachizawa (2012), in contrast, have done a literature review, mentioning that other authors did use this indicator. Rha (2010a) and Rao & Holt (2005) have used the EMS via ISO14001 as well as via the 'total quality environment management' (TQEM) as an indicator for measuring the GSCM. The latter has become an important strategy for companies to generate profit and market advantages (Kurien & Qureshi., 2012). It is important to understand that 'GSCM' and 'Sustainability' are not synonymous. GSCM is in fact a part of sustainability. Hoejmose et al. (2012a) assert that companies in Business-to-Customer (B2C) sectors are more involved with GSCM than companies operating in Business-to-Business (B2B) sectors, as they get greater consumer pressure, media scrutiny, and the immediate visibility to stakeholders. As the Korean government implemented environmental regulations so that the companies adopt GSCM, Rha (2010b) carried out a research, analysing the relationship between GSCM practices and supply chain performance among Korean companies.

The '(Inter)-National Regulations and Standards' or the 'Total Environmental Quality Management' (TEQM) will, however be neglected in this work. As stated before, (inter-)national regulations as well as the Total Quality Management (TQM) refer to the continuous improvement process. The TEQM is based on the same system, including environmental issues in its requirements. In addition, since most companies do not interview their suppliers rather only require them to be certified by several regulations and standards, the '(2^{nd} tier) Supplier Environmentally Friendly Performance Evaluation' KPI will also be neglected in this work. Kurien & Qureshi (2012), Rha, (2010a), and Tseng & Chiu (2013b) give the advice to use indicators as 'Green Purchasing' or 'green manufacturing and packaging' in order to improve a company's ecological sustainability. It is obvious that those authors considered primarily manufacturing companies. LSPs do not produce any goods in the literal sense. Hence, from this point of view a LSP has not implemented a manufacturing process. Furthermore, Rha (2010b) and Li (2011) introduced the 'Eco-Design' indicator, consisting the design of products which contain less hazardous substances and materials, which need less energy while being produced, and which may be reused or recycled at the end of their lifecycle. Lin (2013) has the same understanding as he explains the importance of ‘Product recovery and reused products’. Thipparat (2011) and Lin (2013) suggest companies to cooperate with suppliers in order to achieve the common environmental purpose and to collaborate with customers for accomplishing the eco design issues.

Some authors mentioned that in most cases, the commitment of GSCM by senior managers as well as the support for GSCM by mid-level managers is required as the transformation of a SC into a Green Supply Chain (GSC) is normally perceived as a complex strategic matter (Gimenez & Tachizawa, 2012; Rha, 2010b; Thipparat, 2011). As mentioned before, no manager will accept to invest in sustainability or green matters, if there is no visible ROI. Most companies implement GSCM because of external pressures (Milne & Gray, 2012). The fact that a company ‘greens’ its supply chains has often the positive side-effect of saving financial resources too (Rao & Holt, 2005) as they use, for example, less energy and materials during their production procedures. One method to implement a more environmentally friendly working methodology, which is only done if the company’s managers consider this being profitable, is to implement the logic of ‘Lean’. Lean consists in a set of principles, tools and practices aiming in reducing waste – in the largest sense – to its minimum (Winter et al., 2014b). In the same approach, Kurien & Qureshi (2012) used ‘reducing waste and optimizing material’s exploitation’ as indicator for optimising the product design process. As stated by Winter et al., (2014), a company always takes the risk to confuse ‘green acting’ with ‘green washing’ when optimising its resources. That money can be saved by optimising the use of resources is to be seen as a positive side-effect. If financial savings is seen as the only reason for implementing resource optimisation, so that the company takes no other action to prevent the environment, the resource optimisation is clearly to be seen as green washing.

Many authors include the ‘Reduce, Reuse, Recycle (RRR)’-concept into the purpose of ‘Reverse Logistics’ (Liyanage et al., 2009; Nikolaou et al., 2013a; Sloan, 2010). No need to explain, that in those authors’ point of view, waste should be reduced to a minimum, and reused and recycled whenever possible. In addition to this, considering the RRR-concept, some authors also include the idea of reducing noise. The latter can also be seen as pollution (Kurien & Qureshi, 2012; Rao & Holt, 2005). Discussing the concept of reducing waste to a minimum, Milne & Gray (2012) list a series of concepts, directly related to footprints, which can also be seen as waste. Moreover, they explain that *“if producers do not transfer ownership of final products, but merely rent them, they have continuing incentives to design products that minimise material and waste streams”* (Milne & Gray, 2012). On the other hand, Sloan (2010) points out that waste management may be one indicator for companies to select their suppliers. Liyanage et al. (2009) dissert the ‘plant or facilities related issues’ including the implementation of various engineering strategies. In order to give an example they illustrate this idea: *“[…] modifying the material composition of products so that they generate less pollution and waste”*. According to Lin (2013), customers require *“green products which are manufactured using environmental friendly raw materials and green production processes”.* Hence, he used ‘Green Purchasing’ as indicator in his green performance evaluation model. According to Min & Galle (1997) and Rao & Holt (2005), green purchasing deals with waste reduction, minimisation of hazardous substances used, or environmental material substitution. In other words, they also accept the idea of the RRR-concept.

Tseng & Chiu (2013a) state that, *“Firms typically expect their supplier to go beyond environmental compliance and undertake efficient, green product design, life cycle assessment and other related activities”*. Consequently, in order to be sure that a supplier fulfils those requirements, a company needs to cooperate with its suppliers. Zhu et al. (2008) and

Nikolaou et al. (2013) have pointed out that some researchers have identified opportunities for suppliers to cooperate with their customers and even affect their environmental practices. Rha (2010b) also shares this opinion, stating that cooperation with suppliers and customers *"has become extremely critical for the organizations' to close the supply chain loop (Zhu et al., 2008)"*. Thus, according to Rha (2010b), a SC needs to be considered as a whole, i.e. from the second tier supplier to the end customer. He also defined suppliers' ISO14001 certification as external GSCM practices. This has also well be resumed by Towers & Ashford (2001), concluding that *"partnerships are an essential ingredient of the transformation process within a supply chain […]. The benefits derived from the added value gained by the flexible and adaptable virtuous operation responding to rapidly changing customer demands can be sustained with the planned use of mutual relationships"*. Thipparat (2011) agreed on this definition, stating that *"the scope of GSCM practices implementation ranges from green purchasing (GP) to integrated life-cycle management supply chains flowing from supplier, through to contractor, customer, and closing the loop with reverse logistics".* In order to measure the GSC, she identified 21 criteria from the literature, including 'second-tier supplier environmentally friendly practice evaluation'. On the other hand, Lin (2013) gives warning to the fact that firm supplier collaboration may be limited by human subjectivity and incomplete information. Despite this, he also argues that *"supplier / customer collaboration plays an important role in a successful environmental management programs"*. Rao & Holt (2005) debated that the involvement and support of suppliers may be crucial to achieving goals such as minimisation of hazardous waste. Therefore, companies would be increasingly managing their suppliers' environmental performance. Similarly, some authors used 'cooperation with customers' as an indicator for evaluating the GSC's performance of a company (Lin, 2013; Rha, 2010b; Thipparat, 2011). Gimenez & Tachizawa (2012) share this opinion, but they emphases that there is still a gap considering the implementation of supply chains' sustainability in practice, and its' desirability in theory.

Nowadays, sustainability issues are still fuzzy. Most companies have problems to understand, what sustainability really consists of. Accordingly, many companies concentrate on the most tangible part of the environmental sustainability, namely 'toxic emissions produced and hazardous exposure'. In academic as well as business areas, this indicator can be seen as the most used one for ecological measuring issues. In fact, beside the Kyoto Protocol, the most known carbon emissions regulation is the European Trading Scheme (ETS), which is based on the Kyoto Protocol (Mtalaa and Aggoune, 2009). A myriad of calculation methodologies have been implemented until now. This explains the fact that it is still not possible to compare different companies' CO_2(e) emissions produced while many enterprises are calculating their GHG emissions. According to Sloan (2010) and Kurien and Qureshi (2012) the supply chain operations reference (SCOR) Model has been changed in order to connect emissions to the originating processes and to provide a possibility to measure environmental performance. In an analogous manner, Liyanage et al. (2009) implemented the toxic emissions *(CO_2, NO_X, etc.)* as key issue for the assessment of environmental impact of maintenance and Sloan (2010) divided the environmental factors into six categories, including 'Air', referring to impacts such as carbon emissions and ozone depletion. Kim & Min (2011) divided the policy categories into 'Environmental Health' and 'Ecosystem Vitality', both including 'Air Pollution'. The sub-criteria of 'Ecosystem Vitality' are much more detailed than in most other cases. In fact, they distinguish between sulphur dioxide emissions per populated land area; nitrogen oxides emissions per populated land area; non methane volatile organic compound emissions per populated land area; etc., while most other authors only consider the minimisation of CO_2 and CO_2 equivalent (CO_2e) emission as indicator for calculating the environmental performance; they just named it differently. For example, Rao & Holt (2005) emphasise on the 'reduction of waste and emissions', while Nikolaou et al. (2013) named this same indicator 'emissions impact minimisation'. In order to calculate the production of GHG emissions, some authors also include the energy consumption (Liyanage et al., 2009; Nikolaou et al., 2013a; Sloan, 2010). On the other hand, Mtalaa and Aggoune (2009) proposed a formulation of a design problem *"which helps minimizing carbon emissions caused by transport"*.

(Milne & Gray, 2012) argue that emissions estimation may be useful in stimulating total emissions reductions, but above that, they may also be used for legitimating continuing unsustainable economic activity. It is crucial to be aware of the fact that each calculation includes assumptions which are the reason why a calculated result always differs from a measured one.

The output of a certain calculated amount of CO_2e cannot reflect the reality since it only considers (calculated) estimations but not a measurement. Nevertheless logistics providers such as Kuehne + Nagel are calculating and improving their production of GHG emissions, arguing that it is better to improve on an estimated base, than to do nothing at all. Another important insight into this issue is that *"One of the major sources of environmental concern is in relation to the distribution of products and from the emissions through their transportation. This concern is expected to increase faster than the growth of GNP [Gross National Product] in the industrialised World"* (Validi et al., 2014a). In this logic, they presented a model utilising boundary values for carbon emissions and costs. (Validi et al., 2014b) designed a low-carbon distribution system model, optimising the CO_2 emissions, the associated costs as well as the routes of the vehicles. As this indicator has been applied in an extremely frequent manner, not only in the academic field but also in a business environment, the 'CO_2(e) emissions produced' will also be introduced in this work.

As stated before, in order to calculate the production of carbon emissions, some authors include the energy use into their formulas. To deepen this idea, some authors also discussed the energy consumed provided by renewable energy sources. While Kim & Min (2011) considered them on a national level, stating that *"[…] countries with renewable energy sources such as hydropower and geothermal energy also tended to fare better than others without them in terms of EPI [Environmental Performance Index] scores (Yale Center for Environmental Law & Policy, 2010)."*, Sloan (2010) and Nikolaou et al. (2013) have considered this KPI in their respective GSC performance models. In summary, most authors using the energy consumption and / or the energy consumption generated by renewable energy sources did this in order to calculate the GHG emissions produced. According to the European Standard pr EN16258, the energy used for heating or cooling products while transport or storage is integrated into the CO_2 calculations, we will neglect this indicator within this work. The challenge about the consequences on ecosystems has also been analysed in (Daniels, 2010b) and (Daniels, 2010a). The fact that both issues, the access to water and sanitation, and the consequences on ecosystems cannot be measured on a supply chain level and that those issues are therefore out of scope in this work, does not mean that it should be regarded as unimportant. Sloan (2010) and Liyanage et al. (2009), in contrast, explained the importance of the 'water (re)used' indicator and implemented it into their respective evaluation models. In this logic, this KPI should be introduced into the evaluation model of this work as it is considered being essential in a LSP's environmental performance.

Contrary to the economic performance, up until now, most European governments do not require public reporting of environmental performance. Despite this, some companies already try to report publicly, even if most of them do this for marketing reasons. Li (2011) considered 23 critical factors for GSCM practices. One of them was entitled "*Applying LCA [Life Cycle Assessment] to carry out eco-report".* Sloan (2010) and Milne & Gray (2012) consider the Triple Bottom Line (TBL) being an important form of sustainability reporting while calling attention to the lack of existing standards. Besides this, they ascertained that the benefits of engaging in this type of reporting were not always clear for companies' managers. Most managers do not really know how to publicly report their environmental performance. *"The Global Reporting Initiative (GRI) is a non-profit, collaborative effort to develop standards of* *sustainability reporting. The latest reporting guidelines, issued in October 2006, detail how firms can communicate their environmental, social, and economic performance to the public (GRI, 2006)"* (Sloan, 2010). The GRI can also be seen as a 'Green Supply Chain Management' methodology. The GSCM has been used as indicator a few times. In principle, this fits into sustainability concerns but we consider GSCM being rather a methodology for administering daily business in an ecological way than as an indicator as such. Furthermore, the use of ecological indicators often results in GSCM. Similarly, the 'Commitment of GSCM by senior managers & support for GSCM by mid-level managers' is seen being redundant, as no company will implement GSCM if there is no commitment from its board of directors and top managers.

Tseng & Chiu (2013a) and Tseng et al. (2009) asserted that a company's research and development (R&D) capabilities may help to expand its existing technologies and to improve green R&D functions.

Many authors have challenged the green topic and suggested various methodologies to measure the ecological pillar of the sustainability concept. The indicators which come along with these methodologies also vary also according to the researchers' approaches and their different suggested models' specifications. Many indicators yield above are considered being important in sustainability concerns but have, nevertheless, to be neglected in this work. This is due to the fact that this work questions the degree of sustainability of a given SC, while some of the above mentioned indicators can only be considered on a country or on a company's base. The indicators which will be used to calculate the ecological matter of concerns of the SC's degree of sustainability will be explained more in detail in section 2.3.2.

2.1.4 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 (Frankental, 2001). It is conspicuous that nowadays, many societal indicators have been based on the 'Déclaration des Droits de l'Homme et du Citoyen[12]' (DDHC). For example, the 'Equal opportunity policies or programmes' has been analysed, beyond others, by Bellizzi and Hasty (2003) and Nikolaou et al. (2013) or the European Commission (2012; 2013; 2014). Another example, worth to be cited is the 'Number of children working' indicator. In the western European countries, this indicator is supposed to always indicate '0'. Even if the reality may be different, no company would admit having children employed as this is expressly forbidden by law and thus severely penalised. Nevertheless, Norman & MacDonald (2004) have introduced this indicator in their work. The 'Involvement and Contributions to Projects with Value to the Greater Community and Benevolence' indicators have been construed by Nikolaou et al. (2013) and Norman & MacDonald (2004), while Hoejmose et al. (2012b) only referred to the 'Benevolence' indicator. Moreover, the typical 'Quality, Safety, Hygiene and Environment (QSHE)' department's issues have been considered for measuring the societal part of sustainability. In this matter, the 'Occupational Health, Hygiene & Safety', 'Number of workplace injury / deaths per year', '(Anti-) Corruption and Compliances' as well as 'Codes of Conducts' are the most important ones to mention. It is crucial to obtain a common understanding of the term 'Sustainability', as up until now, the question of "**What is the exact meaning of 'Sustainability'?"** still remains.

[12] Declaration of the Rights of Man and of the Citizen

Sub-pillar 'Working Environment' (Work)

It is important to understand that a company must not only pay attention to its external reputation but also to the internal one. In this regard, Norman & MacDonald (2004) and Nikolaou et al. (2013) inserted an indicator to measure the 'percentage of employees represented by independent trade union organisations or other bona fide employee representatives'. Analogous, beyond other social performance indicators Norman & MacDonald (2004) inserted the 'percentage of employees covered by collective bargaining agreements'. In other words, concerns about a company's reputation lead to several actions increasing the employees' motivation, well-being and self-esteem. Evidence is given by Norman & MacDonald (2004), measuring how many employees surveyed agree that their workplace is safe and comfortable or how many workplace deaths a company has to register per year. Nikolaou et al. (2013) and Liyanage et al. (2009) agreed on this idea: while Nikolaou et al. (2013) count the number of employees injured during their respective working hours, Liyanage et al. (2009) contemplate companies' physical working environment.

Nowadays, most companies have a so-called 'Quality, Safety, Health, and Environment (QSHE) Department' consolidating the different QSHE tasks. This department is supposed to provide '*evidence of substantial compliance with Internal Labor Organizations'* (Norman & MacDonald, 2004). According to Norman & MacDonald (2004) this indicator has been published in some actual social performance reports. In addition, customers are taking an increasingly important role by requiring corporate compliance for health and safety standards (Liyanage et al., 2009). However, some authors mentioned the indicators 'health', 'hygiene' and 'safety', but they only explained the importance concerning social and work related indicators, while abstaining from elucidating their understanding of particularly those KPIs (Nikolaou et al., 2013; Sloan, 2010). This is also true for the *'hours of training per employee & existence of programs for skills management / long life learning'* indicator. This indicator is considered being highly important as the hours of training per employee as well as the existence of programs for skills management to support the continued employability of employees are the crux of the societal matter, especially concerning the working environment issue. Maslow's (1943) hierarchy of needs describing the pattern normally induced by human motivations, can be explained by Steere's (1988) quote: *'What a man can be, he must be'*. Indeed, the need of self-realisation and the need of security are inherent in every individual's character. To achieve this aim, trainings and skills management as well as long life learning need to be adopted and the feeling of a secured employment needs to be guaranteed.

Hill (2012) highlighted the importance of adult education for green jobs and, contemporaneously, emphasised the oppression to GSCM when adult education only supports the economic status quo. In his second proposition, Sloan (2010) explains that literature on Supplier Codes of Conduct (SCC) provides some evidence related to the fact that *"supply chains that explicitly measure social performance will perform better in all dimensions of sustainability".* One of those social performance metrics and indicators is the count of hours of safety training per employee. Obviously, Nikolaou et al. (2013) agreed on this idea, including training and education into their different indicator models, based on the global reporting initiative (GRI) principles. Gimenez & Tachizawa (2012) also put focus on the extension of sustainability to suppliers based on collaboration, whereat collaboration is supposed to refer to working directly with suppliers. This also includes providing them with trainings and support concerning the sustainability matter.

It has to be mentioned that only Nikolaou et al. (2013) were interested in 'net employment creation', 'internal communication with employees', 'existence of formal worker representation in management', and 'existence of programs to support the continued employability of employees'. It is lucid that there is a certain difficulty to measure or calculate those indicators. In the case of 'net employment creation', it might be hard to distinct if an employment has been created due to a person's retirement or job change, or if the position has newly been created. Furthermore, the 'internal communication with employees', can only be analysed via internal questionnaires. In other words, the data provided are subjective and the results may thus be intangible for many managers supposed to work with those outputs. The reason why the indicator concerning the representation of formal worker in management is not taken into account by other researchers may be due to the fact that this situation is quite rare. This is not the case for the existence of programs to support the continued employability of labourers. In fact, the current economic crisis – inter alia – has shown that labour unions advocated precisely for the reemployment of the concerned employees. For this reason it seems surprising that this indicator did not appear considerably more often.

'Occupational Health, Hygiene and Safety' has also been applied several times. Howbeit most companies own a so-called 'QSHE' department, i.e. 'Quality, Safety, Health, Environment' Department, considering the just mentioned indicator. Those departments also collect data about 'Number of workplace injury / deaths per year'. We consider that this indicator can also be calculated on a SC's base, even though, it needs to be extenuated. In fact, if there is a workplace injury or death, it is not possible for the company to find out on which SC the considered employee has operated at that explicit moment. For this reason, this specific KPI needs to be considered in an alleviated form. All indicators used in the sub-pillar Work will be explained in detail afterwards.

Sub-pillar 'Ethical Issues' (Ethics)

Before analysing this sub-pillar, we need to clarify that 'Ethics' will not be examined as a research issue in this work. In fact, 'Ethics' needs to be understood in the logic of implementing ethical principles into practice. At a first sight most articles dealing with sustainability neglect the societal part. Accordingly, one needs to read in parenthesis to find out that this more intangible section has been covered by many authors, even if this has been done in an unconscious manner. While Beamon (2005) noted that much of the corporate social responsibility (CSR) literature focuses on the economic, legal, and ethical responsibilities of a company, Roberts (2003) observed that, nowadays, the acronym CSR is well established in the business lexicon, but its actual meaning in practice remains a matter of debate. Both authors have analysed the ethical responsibilities in SCM, but only Roberts (2003) has emphasised the wider group of stakeholders which may have some interest in CSR. These stakeholders are not only suppliers and customers, but also all other business partners, like employees, board of directors, government, journalists, to name just a few. Since many companies accept CSR as a standard, containing the continuous improvement, this indicator will not be considered in this work.

It is evident that each business action taken is preceded by mutual trust. Visser (2010) proved that behaviour significantly impact a logistics collaboration decision. Consequently, some carriers as well as some LSPs do not exploit financial beneficial collaboration opportunities due to a lack of trust, commitment or confidentiality (Richey et al., 2010; Visser, 2010). Furthermore, Gimenez & Tachizawa (2012) identified norms, trust, and top management's enthusiasm being enablers of sustainable supply chain management (SuSCM). According to Towers & Ashford (2001), *"Trust can be seen as an outcome of good internal service quality within organisations and is seen as a key role within service provision as identified by Chenet et al. (2000)".* Even though, they animadvert that, in terms of linking the internal production control process to the external relationships, trust has not fully been considered. Hoejmose et al. (2012a) explain that "*much of the supply chain literature suggests that trust is multifaceted and a particular focus has been placed on two distinctive features: credibility and benevolence".* They highlight that benevolence "*is not focused on trust in the overall supplier, but rather with the individual supplier representative."* In other words, benevolence captures trust at a personal level. In a larger sense, trust can be seen as the consequence resulting from ‘moral norms’. *“Moral norms as a subset of social norms relate to interactions of fundamental importance for the functioning of society”* (Lenz, 2008). Lenz (2008) reminded that the required moral behaviour may conflict with the addressee’s self-interests and illustrated this with the well-known one-sided variant of the ‘prisoner’s dilemma game’. Liyanage et al. (2009) agreed with Keijzers (2002) that nowadays a company is forced to strive for global standardisation of not only for ecological, but also for social standards if it wants to be competitive in the global market.

The ‘equal opportunity policies or programmes’ indicator is the one which has been revealed the most often during the literature review. It needs to be alluded that this indicator may conflict with peoples’ self-interest, since by human nature one strives to accomplish more compared to others. Nevertheless even the European Commission implements directives in order to foster equal opportunity policies and programmes. In their Factsheets, Communication Papers and Press Releases, the European Commission argued and required the gender balance in business leaderships (European Commission, 2012; European Commission, 2013; European Commission, 2014). In addition to this, the DDHC stands for equal rights for every human being too. To ensure legal and proper way of working, many companies execute ‘(Anti) Corruption Campaigns’ (Gimenez & Tachizawa, 2012; Roberts, 2003b). Nikolaou et al. (2013) concentrated on the reverse logistics and found out that there is only a limited number of academic works evaluating reverse logistics’ social performance. In his work, he used ‘equal opportunity policies’ as well as ‘non-discrimination’ as indicator, but did not explain what those indicators consist of. Bellizzi & Hasty (2001; 2003), in contrast, proved that top sales performers are disciplined less severely than poor sales performers and that a subordinates’ gender may be used in making disciplinary judgments: While female managers disciplined salesmen and saleswomen in a quite uniform way, this was not the case for male managers. In their work, Bellizzi & Hasty (2003) showed that the discipline administered by male sales managers toward saleswomen was much less severe than toward salesmen.

To facilitate mutual respect among employees, ‘National Culture / Values’ (Daniels, 2010a, 2010b; Gimenez & Tachizawa, 2012), as well as ‘(Ethical) Code of Conducts’ (Brink, 2008; Daniels, 2010a; Roberts, 2003b) have been applied in many business environments. In their studies, Nikolaou et al., (2013), and Norman and MacDonald (2004) mentioned the ‘Involvement / Contributions to Projects with Value to the Greater Community / Benevolence’. Some companies want to contribute to projects with value to the greater community, as for example training programs or humanitarian projects (Nikolaou et al., 2013; Norman and MacDonald, 2004). Those indicators will, nevertheless, be neglected in this work. In fact, in a business perspective, it is hard to measure such an indicator as it is not possible to really estimate the outcome to the greater community resulting from such a working behaviour. Besides, it is evident that such contributions or involvements can only be done on a company level, but not based on a SC.

Norman & MacDonald (2004) listed some indicators found in several companies’ social reports. They classified them into 5 groups, namely [1] diversity, [2] unions / industrial relation, [3] health and safety, [4] child labour, and [5] community. The KPI “Child Labour” can be mentioned as an example for the before mentioned kind of KPIs which are inseparable as they are simultaneously related to the pillars ‘Work’ and ‘Ethics’. Surprisingly, Norman & MacDonald (2004) were the only researchers considering indicators like ‘percentage of staff who are members of visible minorities’, ‘existence of well-being programmes’ in order to encourage employees to adopt healthy lifestyles, ‘number of children working’ in the own company as well as in the contractors’ organisations or the ‘existence of policy encouraging local contractors and suppliers'. It is as well surprising that only Sloan (2010) considers 'healthcare benefits', 'supplier evaluation including social factors' and 'regulatory compliance' as important.

Nikolaou et al. (2013) used the indicators 'evaluation of respecting human rights' and 'prevention of discrimination'. Nowadays, one could argue that those KPIs are not efficient anymore, as each company respects the DDHC. One must concede that this is not always true as for example the freedom of opinion included in the DDHC is not always given. For this reason, Nikolaou et al. (2013) included 'employee training on practices concerning human rights' as indicator into their KPI Model. Gimenez & Tachizawa (2012) found out that supplier compliance are difficult to set up, compared to CSR codes of conduct. In their point of view, a company needs to enter into a collaborative partnership if it wants to implement CSR. Moreover, they stated that hierarchy relational norms would have an impact on code compliance, whereas marked governance would not. Roberts (2003) pointed out that some clothing companies are members of the Fair Labor Association (FLA), which binds them to an industry wide ethical code of conduct and to external monitoring of compliance. It has to be noted that the FLA is a worldwide association committing to ensure fair labour practices and safe humane working conditions (Fair Labor Association, 2012). Daniels (2010b), Gimenez & Tachizawa (2012) and Elkington & Trisoglio (1996) identify the diversification of cultures and human values as an enabler for implementing SuSCM. Effectively, the greater the number of persons employed in a company, the larger the probability that different national cultures and values meet within their daily work firm. It is important that each employee respects his colleagues. Daniels (2010a) explained that values, ethics and practices of a religious world view may indicate some insights into the economic and environmental behaviour. Furthermore, as stated before, this may lead to a non – financial ROI, namely the company's reputation. According to Roberts (2003), and Porter & Kramer (2011), external pressure and reputational concerns may be seen as drivers and success factors for ethical sourcing initiatives and thus for the optimisation of SCM, leading to SuSCM. Milne & Gray (2012) define sustainable development reports "*as public reports by companies to provide internal and external stakeholders with a picture of corporate position and activities on economic, environmental and social dimensions".* Hence, to increase their reputation, some companies report their societal performance publicly.

The indicators used to calculate the importance of the ethical sub-pillar in the matter of the whole sustainability issue will be explained more in detail in section 2.3.3.

2.1.5 Conclusion and Definition

As becomes obvious through the above analysis, the concept of sustainability is – in our opinion – more complex than presented by Brundtland (1987) or by Elkington (1997). In fact, we accept splitting sustainability into 3 main pillars, namely the [1] economical, the [2] ecologic and the [3] societal one, as displayed on Figure 20, but as we consider the societal pillar to be the least tangible one, we propose that it be grouped into two new sub-pillars, namely 'Working Environment' (Work) and 'Ethical Issues' (Ethics). In addition, we consider the relation to the factor 'Time', as introduced by Brundtland (1987) being of crucial matter. Hence, at this stage, it is legitimate to analyse the societal pillar via the detour of the newly introduced sub-pillars considering the working environment's concerns as well as the ethical issues.

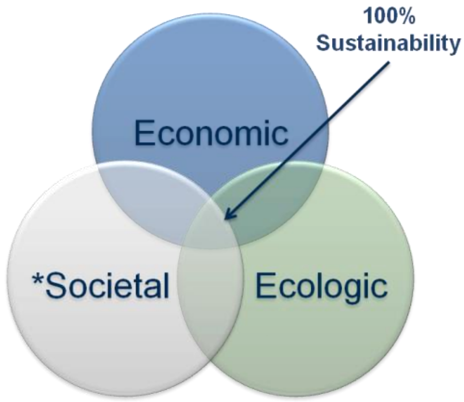


Figure 20 – Elkington's Definition of Sustainability

This analysis will help to answer the remaining question of "**How to define sustainability?**" The above analysis shows clearly that there are a myriad of different perspectives and approaches on the key-term 'sustainability'. For this reason it is of fundamental importance to give a clear vision of the approach that will be adopted in this work.

Elkington (1997)'s TBL has served as a base for the new definition of the term 'Sustainability', where the societal pillar has been split into its two newly defined sub-pillars, [1] work and [2] ethics. Moreover, it can be accepted that many authors have analysed the economical and / or the ecological pillar, while they neglected the societal one. The new TBL can actually be represented as follows in Figure 21:

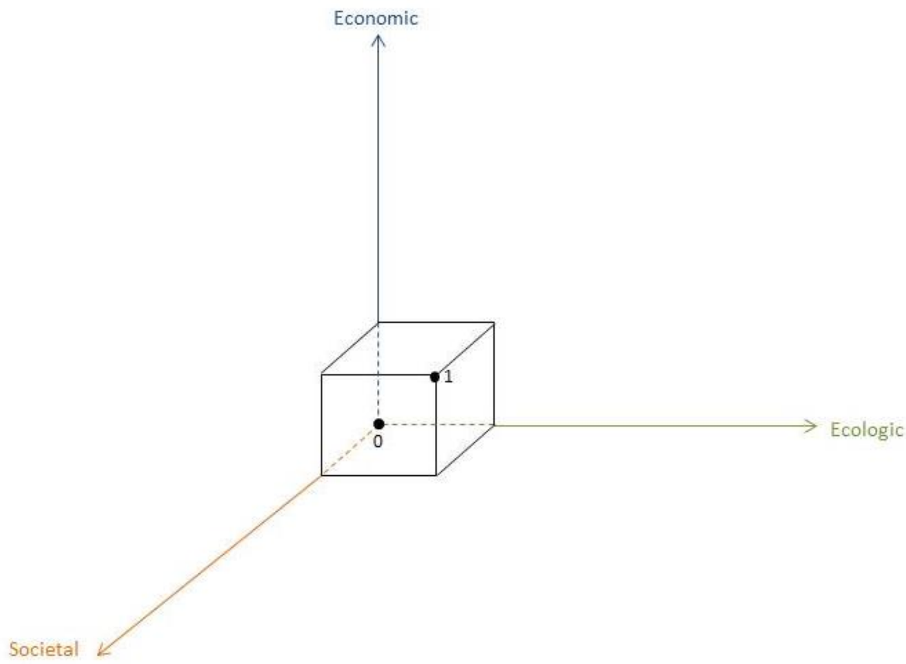


Figure 21 – Degree of Sustainability

Many references gathered[13] were considered being inadmissible and thus rejected in this work. It is however crucial to understand that although rejected, the indicators remain of importance. These indicators were simply not considered relevant for this work. In contrast to the economical and the ecological pillar, the analysis of the ethical one is two-fold: on the one hand, the labours' working environment needs to be considered, on the other hand, the ethical issues are also of major importance in this matter. Those two sub-pillars are not the only ones constituting the societal topic, but they have been considered being the most essential ones. Thus, those sub-pillars have to be considered as non-exhaustive for analysing the societal issues, but they will serve as a base for this study. We hence define **sustainability** as follows:

Sustainability is the interaction of the economical, the ecological and the societal pillar – whereas 'societal' is defined being a composition of the working and the ethical environment – in order to satisfy today's and tomorrow's needs, while being aware of the fact that the different needs will deepen over time.

As shown on Figure 21, a certain degree of sustainability is given as soon as there is interaction between the three defined pillars, Economic, Ecologic, and Societal. It is important to understand that "societal" is to be seen as the interaction of "working environment" and "ethical issues". The degree of sustainability may adopt two extreme values, namely 0 and 1 whereas 0 means that there is no sustainability at all, while 1 means that sustainability has been reached at 100%.

Inevitably, the question of "**What is meant by "Sustainable Supply Chain?**"" arises. Sloan (2010) declares a sustainable supply chain (SuSC) being "*operated in a way that generates*

[13] A table summarising the KPIs per pillar and per author is given in, Appendix 1 to 4

competitive returns on its capital assets without sacrificing the legitimate needs of internal and external stakeholders and with due regard for the impact of its operations on people and the environment". In his interpretation of SuSC, the continuous improvement has been neglected. As stated before, many authors based their definition of sustainability on Brundtland's (1987) definition, which is strongly related to exactly this continuous improvement. Both, Brundtland's (1987) and Elkington's (1997) definitions of sustainability are determined as highly pertinent. We hence define a **SuSC** as follows:

> **A sustainable supply chain** can be seen as a s**upply chain** implemented in a way that helps to **continuously improve** a company's **economic** and **ecologic welfare**, as well as its **internal** and **external societal achievements.**

At this stage, two major research questions emerge: "**Why do companies need to evaluate their SCs?**" and "**How to evaluate a SC?**"

2.2 EVALUATION OF AN EXISTING SUPPLY CHAIN'S SUSTAINABILITY PERFORMANCE

In 1957, Simon explained his view of an 'economic man', being someone who "*has a complete and consistent system of preferences that allows him always to choose among the alternatives open to him; he is always completely aware of what these alternatives are; there are no limits and the complexity of the computations he can perform in order to determine which alternatives are best; probability calculations are neither frightening nor mysterious to him*" (Brown, 2004). Actually, the human decision making process involves that different alternatives are usually considered in a sequential manner. The first alternative which is defined being satisfactory is normally the selected one. In this sense, Simon also explained his definition of an 'administrative man', being "*a kind of rational behaviour that is compatible with the access to information and the computational capacities that are actually possessed by organisms, including man, in the kinds of environments in which such organisms exist*" (Simon, 1957). It is obvious that people never have all information they would need to take the ideal decision – in economic terms it would also be called the "optimal solution" – linked to the *Homo Oeconomicus* theory described in microeconomics. To rephrase, humans are to be seen as administrative men (or women), using the information they have access to, in order to take a decision which actually will suffice and hence comply with the given requirements. Besides this, it needs to be highlighted that customers have different perceptions of the meaning of the terms 'right', or 'good'. To survive, it is essential for every company to understand and to meet its customers' needs and requirements. It is thus vital to analyse and evaluate the customers' exigencies as well as ones' own performances on a continuous basis, while being aware of the fact that the *Homo Oeconomicus* does not exist and hence, managers will never have all relevant information to fully optimise their performance or to meet all customers' needs.

In this section, we will discuss how to evaluate a SC's degree of sustainability so that a picture with sufficient detail of the considered SC can be provided. We will emphasise the importance of key performance indicators (KPIs), and classify them according to the considered market. The model which will be used within our case study is depicted in Figure 22.

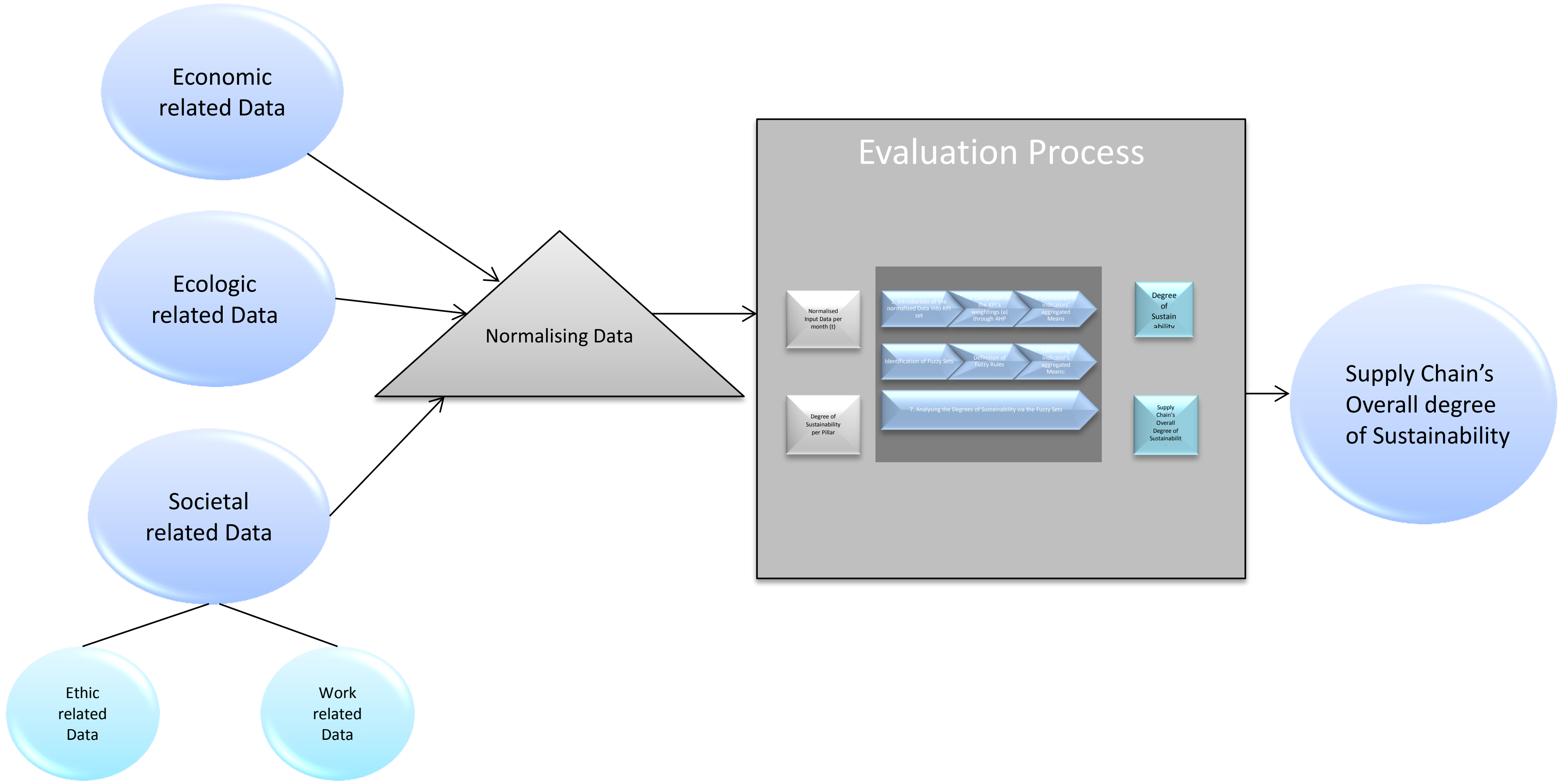


Figure 22 – The Evaluation Model (Black box)

2.2.1 Evaluation in a Business Environment

Logistics Service Providers (LSPs) need to analyse their SCs and to make a judgment about the out coming values concerning their respective performances. As such evaluations can be done in several different ways, different LSPs have various factors and metrics for evaluating their SC's performance. This makes it difficult to compare the performance of one LSP's SC to the performance of another LSP's SC.

Before a system can be evaluated, it is crucial to understand what the evaluation is related to. The calculation of CO_2(e) emissions is along with the CSR seen by many managers being the most tangible subject of the whole sustainability concept. For this reason companies pay close attention to this kind of calculation using the pr EN16258 standard which is accepted and hence adopted by many companies. The inconvenient part is – at least in the matter of sustainability – that this standard only considers the measurement of Greenhouse gas (GHG) emissions. Regarding the concept of sustainability as it has been defined before, the calculation and minimisation of GHG emissions is only one part of the whole sustainability concept. The other items are mostly considered under the umbrella of the companies' respective Quality, Security, Health and Environment (QSHE) departments and are thus not perceived being a part of the 'sustainability issue'. Up until now, there is no standard explaining how to measure a company's sustainability performance. Nevertheless, the Corporate Social Responsibility (CSR) is accepted by Kuehne + Nagel as well as by many other companies as being a kind of standard, while authors do not always agree on its' definition. The question of "What is meant by 'CSR'?" hence rises.

2.2.2 The importance of KPIs

During the literature review the conclusion was drawn that the societal pillar has been neglected in many works while the economic and the ecological ones have been considered to a greater or lesser extent. On this account, the societal pillar had to be analysed from another angle. While the economic and the ecological pillars will be analysed from a logistical point of view, the societal one has to be considered as such. We will therefore dissect the societal pillar into its two newly refined sub pillars, 'Work' and 'Ethics'. They will be analysed in broad terms in order to be tailored to suit the logistics topic afterwards. As a result, the existing KPI models, concerning the ecologic and the economic pillar will be integrated into our new '*Sustainability Performance Measurement Model'* including the societal issues. Thus the KPI Model's societal part will be analysed severally. The different KPIs will be collected and classified subsequently into two groups, namely (1) 'Work' and (2) 'Ethics'. Nevertheless, relating to the evaluation of those different KPIs, it is important to understand that some of those KPIs are actually dedicated to both pillars and are hence not severable. However, since the model cannot rate one same indicator in two different (sub-) pillars, it needs to be decided in which (sub-) pillar the considered indicator is to be included.

Berrah (1997) defined an indicator as a more or less valid statement measuring a process' or activity's performance (or the performance of a part of the considered process or activity). This statement may be real or simulated with respect to a predefined objective. Those expressions may be assessed in an evaluative manner, considering the wholeness of the system's objectives. They may be valued in the light of the considered business activity, process, or system. In addition, with regard to its functionality, an indicator is a measure which is assigned to an essential variable or a variable which is open to state action, describing the status of a part of – or a whole – process or a system's activity.[14]

As mentioned above, the indicators have been adopted via literature review. However, some articles, as for example Tseng & Chiu (2013a) or Zhu et al. (2008a) show a lack of explanations. It is not always apparent, in what manner the considered KPIs are relevant. On the other hand, Sarkis et al. (2011) neglect the well-known micro and macro economical assumption, stating that each stakeholder acts in a 'rational' way. Considering the stakeholders as human beings, since a company is always led by people, it is obvious that, as explained by Simon (1959), they will act *per se* in an irrational way.

The KPI Model, which will be presented subsequently, needs to be seen as a general model. It will be centred at a later state in order to enable case evaluations whereas the general model only enables the evaluation of the company as a whole.

2.2.3 Modelling a KPI set

Modelling a KPI set requires the experience of different persons, namely academic and professionals. Their different perspectives of one same topic are necessary to get the understanding of the general picture. The identification of KPIs is influenced by the different participants' background, experience and knowledge (Bossel & International Institute for Sustainable Development, 1999). For this reason, different interviews and discussions have to be held in both, the academic and the business environment.

Bossel & International Institute for Sustainable Development (1999) explained that intuitive learning is insufficient for handling various complex systems constructed by humans, such as production systems or the economy. To evaluate a supply chain, a KPI model needs to be set up, as indicators are, *de facto*, needed to give an orientation in a complex environment. This is the only way decision makers can understand upcoming occurrences and hence respond in an appropriate way. This also holds true, if the researcher only considers specific chain links. A good supply chain performance measurement model should include organisational and supply chain measures which are both, quantitative and qualitative. In addition to this, it needs to be easy to handle, which means that the amount of indicators measured has to be limited. Moreover, only a few key variables should be used in order to maximise its lucidity (Molnár et al., 2007). Bossel & International Institute for Sustainable Development (1999) share this opinion, criticising that many researchers use quite extensive lists of indicators to analyse specific problems. The result is that their KPI Models are excessive in a specific area but sparse or even neglecting other important scopes. The indicators are derived ad hoc and therefore without a theoretical framework reflecting the viability of the total system, as the model is only intended to evaluate the specific area of the researchers' interest. Thus, the evaluation of the KPI model does not reflect *"the total system, i.e. human society in interaction with its natural environment"* (Bossel & International Institute for Sustainable Development, 1999).

In this section, the internal use of KPIs will be explained in two stages. In a company acting in logistics service providing businesses, the KPIs need to be regarded from both, a domain based viewpoint as well as from an internal attitude.

[14] The original quotation in its context reads as follows: "*Un indicateur de performance est une expression – plus ou moins valide – qui mesure la performance de tout ou partie d'un processus ou activité d'un système (réel ou simulé), par rapport à un objectif. Cette expression est éventuellement exprimée de manière à être évaluée par rapport à la globalité des objectifs du système ; appréciée au regard du contexte de déroulement de l'activité ou processus ou système considéré. De plus : Du point de vue de sa fonctionnalité, un indicateur est une mesure associée à une variable essentielle ou à des variables d'action, décrivant l'état de tout ou partie d'un processus ou activité du système.*"

The use of KPIs in a business environment

On a first sight, one could assume that a company's most important issue would be the 'general costs', which is certainly an essential one, as every company needs to fulfil the economic exigencies in order to survive. In fact, Benjamin Franklin's (1748) well-known quote *"Remember that time is money"* is still appropriate but nowadays, the importance of a given indicator changes depending on the considered market. More importantly, it is obvious that every company needs to satisfy its' customers' requirements and demands in order to have and to preserve a financially strong and attractive venture. In his book, (Zsidisin, 2008) explained that *"the expectations of supply chain or channel members may extend beyond the quality of the supplied resources to those of dependability, reliability, security and responsiveness of the supply chain to mitigate any dislocations wherever they may happen in the chain."* In this logic, the internally used KPI sets are a synthesis of different indicators reflecting customers' satisfaction. It is evident that meetings and discussions about the KPI Model focus on customers' satisfaction, regardless of the specific markets and not on one specific domain. Hence, all different domains need to be taken into consideration.

In a business perspective the understanding of how KPIs are used is of crucial importance. As described above, the financial solidity as well as the customers' satisfaction are mandatory for every company. Many indicators are utilised for those aims while most managers are not aware of the relevance of many sustainability based indicators. Under the umbrella of 'QSHE' or 'Human Resources (HR)', many indicators are collected and evaluated for other reasons than sustainability. It is worth to point out that most managers have another understanding of the key word 'Sustainability' than the definition described earlier. Actually, many businessmen consider 'Green' and 'Sustainable' being synonymous, while in this work, we clearly differentiate between those two headwords as explained in paragraph 0.

The meaning of a KPI in a customers' point of view

It is crucial to bear in mind that the importance of a specific indicator will alter depending on the considered customer. In a same domain, customers may have different perspectives and priorities. This means that a specific KPI can be considered being of major importance for one customer while this same indicator will be neglected by another one, serving the same market. Furthermore, it should be taken into consideration that customers' demands change over time. Hence, a specific indicator which has been considered being of major importance by a particular customer may be neglected some years later by this same customer. A logistics service provider needs however to be able to measure its customers' satisfaction without developing tailor-made KPI sets. Besides this, nowadays, such an analysis needs to include sustainability issues too. It is evident that the defined KPIs need to be clustered according to the definition of sustainability based on the 3 pillars: 'economic', 'ecologic', and 'societal'.

In an economical point of view, many customers place greater importance to the costs. To achieve the best savings possible, many companies try to reduce their stocks to an absolute minimum. For this reason, they need their products to be delivered on time. Additionally, the service levels as well as products' and services' quality are gaining in significance. Consequently, the factor 'costs' is decreasing in importance compared to the past decades. In times where businesses are becoming more and more fast paced, the LSP's experiences concerning exception management becomes mandatory. This exception management actually includes not only quick responsiveness and immense flexibility, but also quick issues solving.

Indeed, several customers have outsourced their SC processes in order to concentrate on their core competencies. Consequently they depend on their logistics partners.

Since recently being “Green” has become crucial, customers’ demands are consequently rising. The most tangible indicator measuring the green way of working is the measurement of GHG production. Unfortunately, comparability of companies’ production of CO_2 or CO_2e is still impossible because of the different calculation methodologies used, but it is supposed that it is better to evaluate and improve the vaguely calculated GHG emissions than to exclude the topic completely. In this logic, the calculation of CO_2e emissions as well as its minimisation is considered being important regarding the ecological aspects. Hence, in some companies, vehicle drivers get trainings to improve their driving behaviour. It is important to mention, that this is not only done in a GHG minimising aspect, but also in security and proactive road performance issues as, in terms of LEAN management, waste has more different facets, i.e. noise pollution, waste of time or energy, etc. The literature review has shown that many companies are certified by several (inter)national ecological standards, which require not only the calculation of CO_2(e) emissions, but beyond others, they also request the RRR concept to be implemented. To do so, many companies record and analyse their energy used as well as their waste management and try to improve the results in a LEAN perspective (Verrier et al., 2014).

The meaning of a KPI on an ethical and workspace prospect

Maslow’s (1943) Hierarchy of Needs demonstrated everybody’s need of self-realisation. On that score, the working environment needs to be evaluated internally. In a perspective of long life learning, trainings and skills management are indispensable for employees to achieve personal fulfilment. Still in the approach of Maslow’s Hierarchy of Needs, it has been pointed out that the sense of security and assurance is of major concern for every individual. It is crucial to understand that in this work, the keyword ‘security’ is double twisted. On the one hand, ‘security’ needs to be understood in a ‘safety perspective’. Thus, both blue and white-collar workers should be out of any danger while exercising their profession. On the other hand, security means ‘secure employment’, which relates to the fact that employees possess open-ended employment contracts. Actually, nowadays’ customers do not only consider the product’s price, but also its value. The latter is to be understood in financial and in ethical terms simultaneously. Indeed, todays’ end customers require employee- and animal-friendly production and companies have no choice than improving their working processes and conditions in that way. The additional pressure and resulting additional impacts which can be caused by welfare organisations should not be underestimated.

In an ethical point of view, it is important to ensure ‘respect of values and cultures’ or ‘anti – xenophobia campaigns’ preventing all kind of discriminations. Mutual respect is, indeed, the most important factor to ensure an agreeable working environment. For this reason, a company should ensure equal opportunity policies or programmes to each labour. In addition to this, ‘equal rights and duties’ need to be evaluated in order not to emerge injustices, leading into disrespectful behaviours. It is evident that ethical concerns also include the increase of employees’ motivation. In order to encourage staff members to increase their productivity as well as their personal well-being, companies often revert to bonuses which can be either financial or substantive. In other words, they allow their labour benefits beyond those legally mandated. Company owners always have ethical issues to solve, if they calculate a specific salary. On the one hand, it is crucial to follow the principle of equal pay for work of equal value. On the other hand, it might be discouraging if on a same position, people are paid in the same way, despite the fact that one worker is much more productive than another one. A company bears not only the responsibility for its employees’ working conditions and for the respect of their safety and personal privacy, but also for every product they handle. Due to today’s technologies, the different products are tracked and traced through the entire SC. To rephrase, when entering an employment, a driver will lose a part of his privacy as he will be monitored during the time he performs his work as well as during his spare time. The goods are effectively tracked and traced in a constant manner. On the other hand, one could argue that this way of working improves the drivers' personal security: In case of an accident, it is clear when and where this accident happened so that assistance can quickly be requested. Nevertheless, a truck drivers accepts this kind of surveillance as, entering his employment, he signs a working contract including 'constant monitoring'. Thus, a company's owner always needs to consider the tightrope walk between legal, ethical and economic issues.

Conclusion

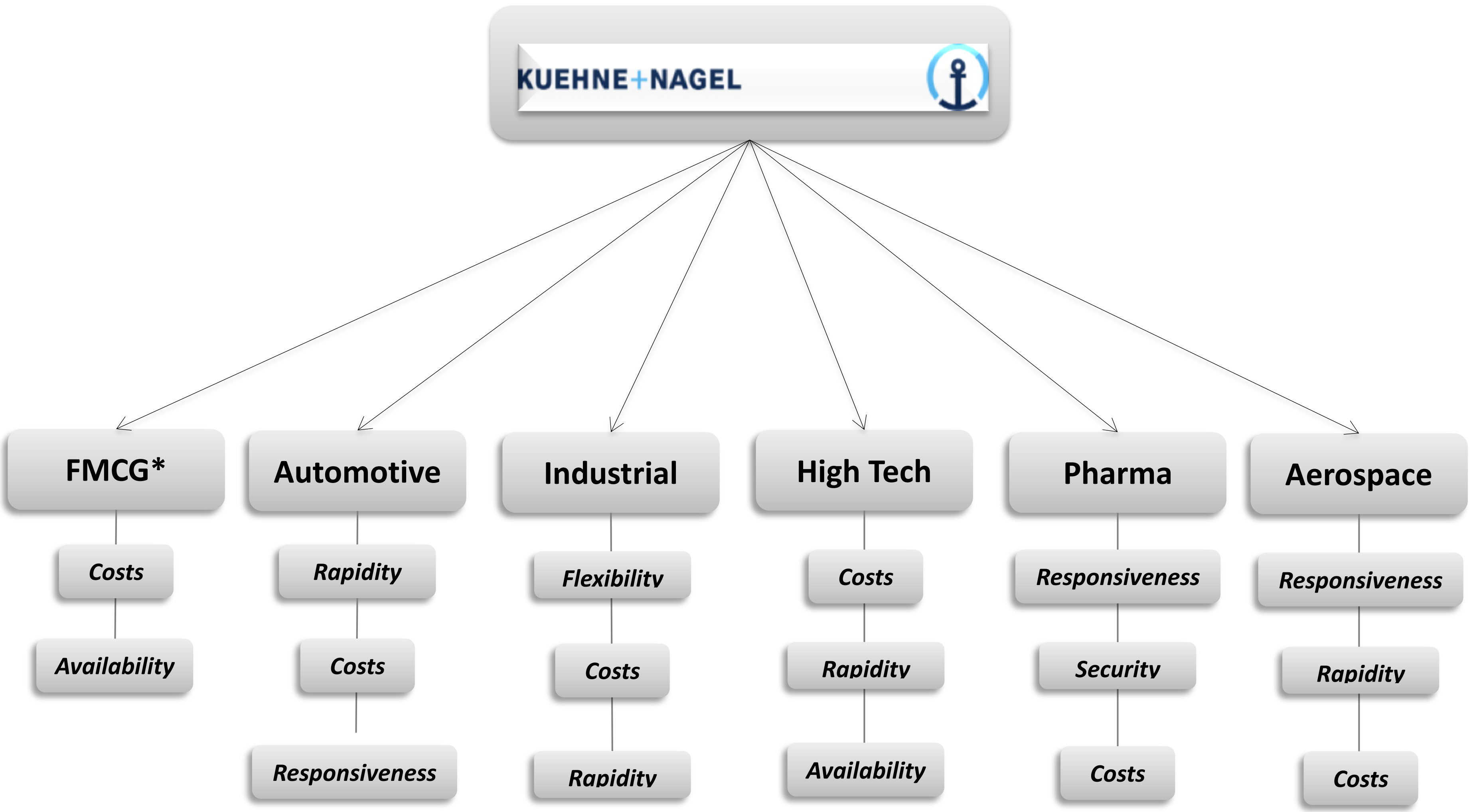
Through the above analysis, the importance of well used indicators becomes evident. Since a KPI set is to be seen as a synthesis of different indicators scrutinising customers' satisfaction, the understanding of their intended use is of crucial matter. On the other hand, managers need to take their decisions based on the information they have access to. To assimilate this information, well used indicators and measurements are extremely adjuvant. Another positive side effect is that mutual trust can be built between the company and its subcontractors if transparency concerning the results obtained through the analysis of the different indicators is provided. In this same logic, customers may gain in confidence so that customer loyalty can be reached and increased. Nonetheless, the use of indicators also shows up some drawbacks. Effectively, to analyse the different KPIs in an adequate manner, high-quality data is needed. The latter is achieved, especially via continuous track and trace. This may constitute severe issues on ethical or legal matters, putting the company owners into situations of ridge walks between legal, economic and ethical concerns. In other words, companies' owners always need to pay attention, not to violate the enterprise's environment to get the qualitatively best data so that an optimisation of their processes can be reached. Instead, they must settle for the satisficing concept, explained by Simon (1956), so that an improvement of their processes can be achieved.

2.2.4 The General KPI Model

In the case of Kuehne + Nagel most KPIs address the six different domains they serve. These domains are:

1. Fast Moving Consumer Goods (FMCG)
2. Automotive,
3. Industrial
4. High-Tech
5. Pharma
6. Aerospace

The most considered KPIs used per domain served by Kuehne + Nagel have been analysed and are elucidated on Figure 23 below. Those KPIs are not sorted by importance for the single domains as every company weight them in a different manner. Rephrased, the importance of an indicator depends on the considered customer's perception.



* FMCG = Fast Moving Consumer Goods

Figure 23 – Key Performance Indicators used per Domain served by Kuehne + Nagel

Fast Moving Consumer Goods

The FMCGs, as the name suggests, are products which are sold quickly and, normally, at rather low prices (as for example, soft drinks, food products, or toys). As its demand is high and nearly constant, the companies working with FMCGs normally operate push driven supply chains. It is evident that those companies focus especially on costs and on products' availability, i.e. short lead times, and big stock volumes. Furthermore, they try to implement better visibility within their SC, as an increase in visibility would support FMCG companies in replenishing facilities sufficiently. As a consequence the companies could offer higher availability while limiting their inventory levels.

Automotive

The mostly push driven supply chains observed in the FMCG sector can also be found in the automotive one, where standard vehicles are pushed to the market. The automotive industry uses the mass production of standardised goods, named 'Fordism', combined with the newer well known working methodology 'Lean'. Multi-use components are developed and pushed out to construct lines in large productions resulting in decreasing costs through economies of scale. The demand of standard vehicles is in a constant rise, and the customers' expectations changed over the last decades. The different parts need to be accessible in time as the production sequence may be interrupted otherwise. Such a breakdown would result in tremendous costs. In addition to this, today's customers became unwilling to wait for their new car, as they want it to be quickly available. For this reason, the most important factor in the automotive industry is the rapidity of materials' flows, directly followed by the indicators 'general costs', and 'responsiveness'.

Industrial

The conventional industrial network must not be responsive, as it is much more important to be flexible. The Business-to-Business (B2B) customers have different requirements in both, strategy and products. In fact, tailored solutions are expected in short time frames as industrial purchases are often linked with high monetary investments. It is hence difficult to forecast the demand and therefore the supply chain needs to be flexible. This type of network is often extremely sumptuously, resulting in a focus on current as well as future costs of the SC. However, the SC's flexibility as well as the material flows' rapidity have not to be neglected neither. It has to be alluded that the top-three mentioned indicators are closely linked and can therefore not be prioritised.

High – Tech

Analysing the high-tech industry, one could run the risk of considering the sector some years ago. In former times, the High-Tech industry was based intensely on research and development (R&D), but today, technological new products are developed and pushed to the market. Because of this technological development, intense competition and therefore a drastic value decrease of the products occur. On this account, the products need to be pushed fast out and to be distributed through as many channels as possible. It is evident that those companies' focus lies on overall costs, but also on transportation rapidity and product availability. It is important to understand that costs and products' availability are two factors balanced differently depending on the respective company and on the considered type of high-tech product.

Pharma

Pharmaceutical goods are of high value, whereas ’value’ means not only in financial terms. The complex production flow requires high responsiveness within the networks. Moreover, as secure handling of pharmaceutical products is of crucial importance to their usability, security means needs to be fulfilled throughout the entire SC. R&D is still a core competence of the pharmaceuticals manufacturer. New products are developed appropriate to the market-derived demand, thus, in a pulled approach. Once the product is ‘mature’, it will enter into a push-inspired supply chain. As the pharmaceuticals manufacturer over replenish their stocks and take the risk of obsolete inventories to ensure 100% on-demand outbound supply, they try to optimise their costs by transporting their products via sea-freight and in large bundles.

Aerospace

The factors ‘Responsiveness’ and ‘Speed’ are of high importance in the aerospace industry as the costs would explode if those factors were neglected. Aviation goods are often of very high value and must consequently be transported quickly and in a particularly responsive way. As the margins of the industry are severely low, managers try to minimise the transportation costs. Furthermore, replacement parts for damaged aeroplanes need to be available as quickly as possible because of the enormous costs a grounded aircraft implies.

2.3 THE SUPPLY CHAIN SPECIFIC KPI MODEL

Through the above analysis, an indicator set which should be considered in this work can be elaborated. This KPI dashboard will be explained hereafter. For the purpose of consistency and clarity, in our formulas, we will use i being the dummy value, defining the size of the considered sample, i.e. i = [1,n]. In addition, and for the same reasons, we will adopt the following syntax defining the discourse universe (Berrah, 1997):

U_o : ‘Identifier U_o’, ‘Type’, ‘Sub – Type’, ‘Step’, ‘Unit of Measurement’, ‘Area’.

For confidentiality reasons and for the ease of calculation, all values will be normalised. In other words, the set of potential values will be defined by N = [0,1]. This normalisation can be calculated via the ratio:

$$\frac{Variable}{Variable\ MAX}$$

The positive side effect of normalisation is that the data’s unit will disappear, which enables us to reckon up the different KPIs afterwards. For this reason, we convert linguistic values into numerical ones, whereas ‘very poor’ is set to 1 and ‘excellent’ is set to 5. The normalisation can hence also be calculated since the maximum variable ‘excellent’ consists of its quantitative value 5.

The data allocated to a month t can be calculated, in a subsequent step, via the average of all answers given by the different questioned experts. Linguistic values are defined as:

U_o : 'Identifier U_o', linguistic, ordered, $\mathscr{L}_O$ = {very poor ; poor ; medium ; good ; excellent}

Where $\mathscr{L}_O$ = Linguistic set of O.

The KPI dashboard will be set up according to our definition of sustainability, i.e. following its three inherent pillars Economic, Ecologic, and Societal, and the two sub-pillars Work and Ethics. 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)

2.3.1 Economic Related Indicators

In an **economic viewpoint**, it can be noted that measurements should be done through 4 KPIs, namely: [1] **C**osts (C), [2] **O**n **T**ime **I**n **F**ull delivery (OTIF), [3] Service **Q**uality (Q), and [4] **Ex**ception **M**anagement (ExM).

Costs (C)

The total costs of a specific SC cannot be seen at a first sight. In fact, in most cases the costs have been aggregated on department level. As one department works on several SCs, it is not possible to summate the different departments' costs in order to calculate the total costs of a specific SC. However, the Logistics Operational Spend (LOS) as well as the Logistics Management Spend (LMS) are allocated to every SC. To calculate the SC's overall costs, we may hence summarise the considered SC's LOS and LMS of the considered month. Thus, let U_C be:

U_C : Costs, Numerical, Real, 0.01, Euro, N = [0 , 1]

Let LOS_i be the operational costs allocated on customer's SC during the considered month t.
Let LMS_i be the managerial costs allocated to the customer's SC during the considered month t.
Let i be the i^{th} variable of the sample, whereas i = [1, n].

The total cost of a specific SC can thus be calculated as follows:

$$f(C) = \Sigma LOS_{i,t} + \Sigma LMS_{i,t}$$

On Time in Full Delivery (OTIF)

In the technical language, 'On Time in Full Delivery' (OTIF) means that the freight was delivered within the agreed timeframe and without any damages. The data considering the OTIF indicator can therefore be calculated via the percentage of freight, which has been delivered on time and in full divided by the total freight supposed to be delivered. Hence, let U_{OTIF} be:

$U_{OTIF:}$ On Time In Full delivery, Numerical, Real, 0.0001, Rate, N = [0 , 1]

Let Dg be the freight which was delivered in full and on time within the considered month t.
Let D be the freight supposed to be delivered within the considered month t.
Let i be the i^{th} variable of the sample, whereas i = [1, n].

The percentage of on time and in full deliveries can be calculated via:

$$f(OTIF) = \frac{\sum Dg_{i_t}}{\sum D_{i_t}}$$

Service Quality (Q)

Most companies have implemeted a 'QSHE – Department', where the different quality, safety, health and environmental indicators are defined and evaluated. Nonetheless, those KPIs cannot be used to assess the level of quality of a SC, as they are usually related to the company's internal actions and processes. It is important to bear in mind that some processes and actions taken are the same for many different SC's and that a myriad of sub-indicators define a SC's quality. For this reason, it is pertinent that experts rate the KPI concerning a SC's quality. This is done via the linguistic values 'very poor', 'poor', 'medium', 'good', and 'excellent'. Thus, let U_Q be:

U_Q : service Quality , Linguistic, Ordered, $\mathscr{L}_Q$ = {very poor ; poor ; medium ; good ; excellent}

Where $\mathscr{L}_Q$ = Linguistic set of Q.

As stated above, every qualitative value is converted into a quantitative one. 1 is set being 'very poor' while 5 is set being 'excellent'. The average of all questioned experts will hence be calculated and used for further computations.

Exception Management (ExM)

We define Exception Management (ExM) being the interaction of the [1] concerned employees' responsiveness (R), [2] the SC's flexibility (F) and the [3] labours' competences for solving issues (IS). Those competences are of higher importance for **reacting on any deviation** from standard processes. We calculate the ExM indicator by taking the average of its three inherent sub-indicators. As stated before, **all qualitative data are converted into quantitative ones**, so that the normalisation can be done and the average of R, F, and IS can be calculated. Thus, let U_{ExM} be:

U_{ExM} : Exception Management, numerical, real, 0.01, Average, N = [0 , 1]

The ExM of a considered month t can then be calculated via: f(ExM) = f(R_t, F_t, IS_t).

$$= \frac{R(x)_t + F(x)_t + IS(x)_t}{3}$$

– **Responsiveness (R)**

An employee's **R**esponsiveness (R) within a SC is measured via its' KPI. In many contracts, the maximal duration between the moment when a request has been submitted and the moment it has been responded needs to be less than a certain amount of working hours. In fact, several components like peoples' know-how, their understanding of the project, the back-up persons' understanding of the considered SC in case of holidays or sickness, etc. play an important role in this context, which could explain eventual deviations. In this work, we calculate the R indicator by dividing the requests which have been treated in time, by the total requests submitted. Therefore, let U_R be:

$U_{R:}$ Responsiveness, Numerical, Real, 0.01, Rate, N = [0 , 1]

Let D_{REQ} be the requests which have been treated in time, during the considered month t.
Let REQ be the requests submitted during the considered month t.
Let i be the i^{th} variable of the sample, whereas i = [1, n].

The percentage of on time responsiveness can be calculated via:

$$\text{f (R)} = \frac{\sum DREQi,t}{\sum REQi,t}$$

– **Flexibility (F)**

Depending on the considered domain, a SC needs to be more or less flexible according to customers' needs. Customers often have different requirements in respect of strategy as well as in regard to the considered products. Those customers' demand is difficult to anticipate and thus the supply needs to be designed in a flexible way. This is not to say that a manager should deviate from the process in a regular manner, but means that the process itself should be improved constantly. Nevertheless, a SC's degree of Flexibility (F) is often subjective as it depends on both, the product required as well as the customers' strategy. For this reason, it needs to be evaluated in linguistic terms. Therefore, let U_F be:

U_F : Flexibility , linguistic, ordered, $\mathscr{L}_F$ = { very poor ; poor ; medium ; good ; excellent }
Where $\mathscr{L}_F$ = Linguistic set of F.

– **Issues Solving (IS)**

SC's may be very similar but they are rarely identical. In addition, customers' requirements differ from one SC to another and may even differ within a same SC. Consequently the emerging problems a LSP has to face may vary enormously. The IS indicator depends heavily on the considered employees' successfully completed trainings, experience and understanding and knowledge of the relevant supply chain. Since both, experience and understanding are to be seen as highly subjective, we consider gathering those data by consulting experts' opinions. In this sense, let U_{IS} be:

U_{IS} : Issues Solving, linguistic, ordered, $\mathscr{L}_{IS}$ = { very poor ; poor ; medium ; good ; excellent }
Where $\mathscr{L}_{IS}$ = Linguistic set of IS.

2.3.2 Ecologic Related Indicators

In a company's daily business perspective as well as in an academic point of view, the ecological pillar can be considered as the most investigated one regarding sustainability matters. The key-word 'green' being often used as synonym for 'ecological' became a marketing action, involving a certain tangibility of the term. Its measurement should be performed via the three indicators [1] Co2(e) emissions (**GHG**[15]), [2] Waste Management (**RRR**[16]), and [3] **En**ergy **Us**ed (EnUs).

CO_2(e) (GHG)

Up until now, it is not possible to measure the CO_2 and CO_2e emissions produced. For this reason, every company calculating GHG emissions has implemented a calculation tool. Many carbon calculation tools are based on European standards such as the pr EN16258 standard. It is important to know that different GHG calculation tools may be certified according to the same standards while the results present more or less important variations. This is due to the fact that a standard usually allows several hypothesis and calculation methodologies. On the one hand a company may measure the different parameters included in its calculations but on the other hand the standard also accepts the usage of default parameters. In addition to this, each and every company uses its own defined assumptions, which may differ enormously. De facto, if each LSP would use the same standards, formulas, and the same assumptions for their different carbon emission calculation systems, the comparison of CO_2 and CO_2e emissions calculated by different enterprises would be extremely simplified. In this manner, companies could guarantee more transparency and consequently increase their customers' confidence. The latter could obviously support buying decisions by taking providers' GHG emissions into account.

The GHG calculation tool used in this work is the Global Transport Carbon Calculator (GTCC). Its calculation methodology is based on the pr EN16258 standard for road-and airfreight, and on the 'Clean Cargo Working Group' (CCWG) methodology for carbon calculations in case of sea-freight. In addition, the tool is ISO 14064-3 certified. The calculation tool is based on the continuous improvement concept, which can be seen as a common denominator of most international standards. The drawback of this continuous improvement is that the methodology itself may change over a certain period of time. This entails that long term studies cannot be conducted with this tool as the different results cannot be compared anymore when the calculation methodology has been modified. Nevertheless, since in our case study, we will use the period from 2010 to 2013 and as the tool's inherent methodology has not been changed during this timeframe, the GTCC may be used without hesitation.

The emerging results are, as described above, normalised and introduced into this work as the sum of Tons-Kilometers (TKM) of CO_2e emissions produced per lane[17] during the considered month t. Let U_{GHG} be:

U_{GHG}: GHG Emissions Produced, Numerical, Real, 0.01, TKM, N = [0,1]

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[15] **G**reen**H**ouse **G**as Emissions (GHG) is used as synonym of CO_2e

[16] As described in Chapter II, section 2.1.3, waste management is considered in the '**R**educe, **R**euse, **R**ecycle' (RRR) approach. For this reason, we use its acronym for the waste management indicator.

[17] In logistics, the pre-, main-, or on-carriages are called "lane".

The GHG emissions produced are calculated on a lane base. This means that, in order to get the general CO2e emissions produced during the execution of the whole SC, the different results emerging from the pre-, the main-, and the on-carriages needs to be calculated via:
Let i be the i^{th} variable of the sample, whereas i = [1, n].

$$f(GHG) = \sum TKM_{i,\,t}$$

Within Kuehne + Nagel, the last mile is considered via the assumption: **Last mile = 20km.** This assumption will also be accepted in this work.

Waste Management (RRR)

It is not possible to measure the waste produced by the different actions taken for a specific SC. For this reason, it makes sense to calculate the average of garbage produced per Full Time Equivalent (FTE) assigned to a specific SC. To do so, the company's total waste needs to be broken down per FTE and the results have to be allocated to the considered SC and to the considered month t.

Let U_{RRR} be:

U_{RRR} : Waste Management, Numerical, Real, 0.0001, tons of waste per assigned FTE, N = [0,1]

$$f(RRR) = RRR_t \cdot \alpha_t$$

where RRR = Total Waste produced during the considered month t
and α_t = Percentage of FTEs dedicated to the considered SC during the considered month t

Energy Used (EnUs)

The Energy Used (EnUs) during the execution of a SC cannot be measured neither. Actually, there is not only the direct energy used which needs to be taken into account, but also the indirect one. The indirect energy used can be defined as the use of kitchen equipment, toilet lightings, etc. As those areas are of major importance concerning the societal pillar, videlicet, the sub-pillar 'Working Environment' (Work), it is evident, that those areas need to be taken into account too. Nevertheless, as the data will not provide the information of where the energy has exactly been used (i.e. in offices, storage spaces or leisure areas), we will consider the average per Full Time Equivalent (FTE) assigned on the considered SC of the entire energy used during a respective month t.
Let U_{EnUs} be:

U_{EnUs} : Energy Used, Numerical, Real, 0.01, kWh of energy used per assigned FTE, N = [0,1]

$$f(EnUs) = TNRG_t \cdot \alpha_t$$

$TNRG_t$ = Total amount of Kilowatt hours of energy used during the considered month t
and α_t = Percentage of FTEs assigned to the considered SC, during the considered month t

2.3.3 Societal Related Indicators

The investigation yielded that it is more complicated to find adequate indicators for measuring the societal part of sustainability. This is mainly due to the fact that the societal pillar is the less concrete one. Nevertheless, the difficulty of measuring the societal pillar cannot result its negligence, as this would falsify the end result in a considerable manner. In order to provide both a better palpableness and a better understanding of the societal pillar, we split it into its two sub pillars Working Environment, named 'Work' and Ethical Issues, named 'Ethics'. Thus, the labours' respective working conditions as well as the ethical issues related to their employments need to be measured in the same logic than the economical and the ecological areas.

Working Environment related Indicators

In European countries, the broad terms of employees' working conditions are legally determined. Company owners may accord additional advantages, as, for example, additional holidays, etc. but those cannot be considered in terms of sustainability. In fact, to get sustainability, both employees and companies should benefit from enhanced working conditions. The indicators used to analyse the working environment should therefore consider the well-being of all stakeholders. We hence consider that a company should analyse the indicators [1] Trainings per Employee to Improve Skills (**LLL**[18]), [2] **S**ecurity of **E**mployment (SE), and [3] **H**ealth, **S**ecurity and **S**afety (HSS).

- ***Trainings per Employee to Improve Skills (LLL)***

In most companies, employees are trained so that they may improve their professional skills and *savoir-faire*. It is evident that this KPI can easily be measured, as the human resource (HR) department normally stores this kind of information. The latter do not only consider the specific work sequences as trainings concerning security and safety, compliances, or hygiene are not less important in the matter of improving the working environment. Nevertheless, as people advance in their job position, they will not necessarily stay in the same department. If there is personnel change within a department, the trainings allocated to the considered division need to be reallocated. It is hence evident, that this kind of reallocation cannot be tracked within a company. For this reason, we consider the average of trainings given per assigned employee within a month t. Let i be the i^{th} variable of the sample, whereas i = [1, n].

Let U_{LLL} be:

U_{LLL} : Trainings per Employee, Numerical, Real, 0.01, Hours of Training per Assigned FTE, N = [0,1]

$$f(LLL) = \sum LLL_{it} \cdot \alpha_t$$

LLL = training hours given during the considered month t
and α_t = Percentage of FTEs assigned to the considered SC during the considered month t.

- ***Security of Employment (SE)***

The question to be answered by this KPI is: In case of reorganisation of the company, will there be redundancies? Or may labour have to change the department to avoid them losing their employment. The Security of Employment (SE) can obviously not be measured via numerical variables as it considers peoples' subjective opinion about how they perceive their situation. For this reason, let U_{ES} be:

U_{SE} : Security of Employment, linguistic, ordered, $\mathscr{L}_{SE}$ = { very poor ; poor ; medium ; good ; excellent }

[18] Trainings are often considered being actions for '**L**ife **L**ong **L**earning'. We are therefore using this acronym.

Where $\mathscr{L}_{SE}$ = Linguistic set of SE.

– ***Health, Security and Safety (HSS)***

The Health, Security and Safety (HSS) indicator is twofold. On the one hand, it considers the products' security on the other hand it regards the labours' safety. The merchandises have to be delivered on time and without any damage. In case of high valued goods or pharmaceuticals, the security restrictions are much more severe as in case of FMCG's, for example. To rephrase, the level of security highly depends on the considered commodities. The workers' safety could be measured via the hours of security trainings passed, the obligation of wearing safety shoes, working gloves, safety helmets or vests, or via the amount of accidents within the different considered departments. It is not possible anymore to find out the details per months in a retroactively manner, but since we need to use the same methodology for the whole case study, we could gather the data via questionnaire or calculate this indicator in another way. For this reason, we consider the number of accidents or incidents resulting in either material damage or human injuries, and calculate the average per assigned FTE within a given month t.

Let i be the i^{th} variable of the sample, whereas i = [1, n].
Thus, let U_{HSS} be:

U_{HSS} : Health Security and Safety, Numerical, Real, 1, Number of Accidents per assigned FTE, N = [0,1]

$$f(U_{HSS}) = \sum Acc_t \cdot \alpha_t$$

where ACC = Accident or incident during the considered month t
and α_t = Percentage of FTEs assigned to the considered SC during the considered month t.

Ethical related indicators

To our knowledge, the ethical sub-pillar has been neglected in former works until now. In order to measure how far ethical principles have been implemented into a company's working procedures, we suggest using three essential indicators, namely, [1] Gender Equality (GE), [2] **A**ctions taken against **X**enophobia and **D**iscrimination (AXD), and [3] actions taken to increase **Em**ployees **Mo**tivation (EmMo).

– ***Gender Equality (GE)***

Nowadays, Gender Equality (GE) is considerably gaining in importance. In order to improve a company's performance, the European Commission has voted a female quota of 40% objective in non-executive board-members positions in publicly listed companies. One of the main economic arguments is that greater gender diversity would have the potential to improve a company's performance (European Commission, 2013).

However, in this work, the indicator 'female quota' would be useless. Effectively, in this work, we consider sustainability from a SC angle. In the logistic sector, stricter in the operational field, it is clear that only few women will apply for a specific operational logistics vacancy like warehousing or transportation for example. A gender quota could never be reached, as only few women would apply for warehouse or truck driver vacancies. For this reason, we suggest to measure GE via the employees' salary.

Every company will consider this kind of data being highly confidential. It is hence not surprising that this data needs to be requested in an anonymised way. In other words, the records are not handed out as raw data, but are clustered and treated as shown in Figure 24. The handed out average salaries can then be compared.
Hence, let U_{Salary} be:

U_{Salary} : Salary, Numerical, Real, 0.01, Average Salary in Euro, N = [0,1]

$$f(Salary) = \frac{1}{W\beta} \sum Salary_{iw\beta t} - \frac{1}{M\beta} \sum Salary_{im\beta t}$$

Let i be the i^{th} variable of the sample, whereas i = [1, n],
and Wβ = Number of female workers within the cluster β,
and Mβ = Number of male workers within the cluster β,
and $Salary_{iw\beta t}$ = Salary of a female employee included in cluster β during the considered month t,
and $Salary_{im\beta t}$ = Salary of a male employee included in cluster β during the considered month t.

If the above formula results in a negative number, the average salary of female workers within the cluster β is less than the average salary of male workers within this same cluster. If the result of the above equation is zero, male and female workers of a given cluster β have the same average salary. Finally, if the result is a positive number, the average salary of female workers within the cluster β is greater than the average salary of male colleagues within this same cluster.

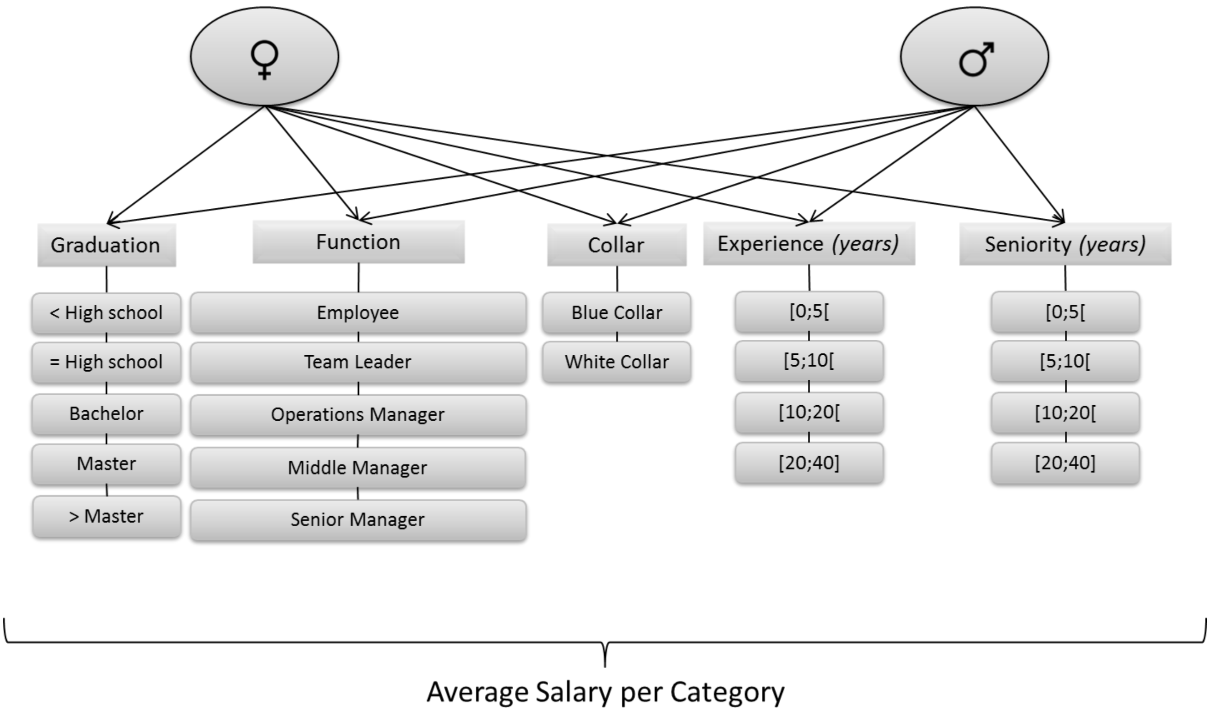


Figure 24 – Composition of the Clusters to calculate the Difference of Salary Indicator

For confidentiality reasons, we integrated those results, being the differences of salaries, into a linguistic set named DifSalary:
Let $U_{DifSalary}$ be:

$U_{DifSalary}$: Differences in Salaries, Linguistic, Ordered,
$\mathscr{L}_{DifSalary}$ = { very poor ; poor ; medium ; good ; excellent }

Where $\mathscr{L}_{DifSalary}$ = Linguistic set of DifSalary

The other data entering into this KPI are the **assessment of the abidance concerning the Female Quota (FeQuo)**, as well as the **employees' subjective opinion about how they perceive the situation within the company considering gender equality (SubGE)**, which are both measured in a qualitative way, i.e. via questionnaires**.**

Let U_{FeQuo} be:

U_{FeQuo} : Abidance concerning the Female Quota, Linguistic, Ordered, $\mathscr{L}_{FeQuo}$ = { very poor ; poor ; medium ; good ; excellent }

Where $\mathscr{L}_{FeQuo}$= Linguistic set of FeQuo

Let U_{SubGE} be:

U_{SubGE} : Subjective opinion about Gender Equality, Linguistic, Ordered, $\mathscr{L}_{SubGE}$ = { very poor ; poor ; medium ; good ; excellent }

Where $\mathscr{L}_{SubGE}$= Linguistic set of SubGE

Hence, by providing the above mentioned indicators, experts may assess the GE indicator in a qualitative manner. Their responses will be converted into quantitative ones afterwards, so that:

U_{GE} : Gender Equality, Linguistic, Ordered, $\mathscr{L}_{GE}$ = { very poor ; poor ; medium ; good ; excellent };

where $\mathscr{L}_{GE}$= Linguistic set of GE

- ***Actions Taken Against Xenophobia and Discrimination (AXD)***

Many companies, especially large concerns, are exposed to the risk of racism and xenophobia. To measure this kind of indicator, as no labourer only works on one single SC, we could count the total number of known actions taken against xenophobia and discrimination (AXD) and to break this number down to the number of employees working on the considered SC. Nonetheless, one has to take into account that in those cases, there is always an unknown number of unreported cases. We suggest that an expert's feeling about the situation may be more confident than the number of reported cases. The unreported ones could be estimated, but even experts may not dare to estimate such important values. We hence suggest evaluating the AXD indicator in a linguistic manner. Let U_{AXD} be:

U_{AXD} : Actions taken against Xenophobia and Discrimination, linguistic, ordered, $\mathscr{L}_{AXD}$ = { very poor ; poor ; medium ; good ; excellent}

Where $\mathscr{L}_{AXD}$ = Linguistic set of AXD.

– ***Actions Taken to Increase Employees' Motivation (EmMo)***

Depending on the company, the board of director attaches more or less importance on actions taken to increase employees' motivation (EmMo). To achieve such a growth of motivation, financial bonus can be paid. Depending on the local legislation, this may be considered improper or even illegal. To show their respect concerning their employees' hard work during a certain period, some companies organise summer celebrations, Christmas dinner or after-work events. In addition to this, they may give some chocolates for Easter or Christmas. Another possibility to show respect in a more personal interaction is to congratulate the labourers for their birthdays: Those data are easy to get, as every employee has to leave day and place of birth in the Human Resource (HR) department. In short, no limits are set to imagination in regard to motivate employees. According to this, it seems logical to evaluate the EmMo KPI in linguistic terms. Let U_{EmMo} be:

$U_{EmMo:}$ Actions taken to increase Employees' Motivation, linguistic, ordered, $\mathscr{L}_{EmMo}$ = {very poor ; poor ; medium ; good ; excellent }

Where $\mathscr{L}_{EmMo}$ = Linguistic set of EmMo.

2.3.4 Conclusion

Simon (1991) manifested that because of what he called the 'cognitive limits', human minds cannot handle and decompose all the information needed to optimise any system in the best possible manner. For this reason, a KPI dashboard is to be seen as one essential condition for managers to take decisions, no matter, if those determinations are taken on an operational, tactical or strategic level. In addition, as it is evident that theory is not always transferable into practice, we had to perform an analysis of the KPIs used in a company's daily business. This company related examination gave us the same results than the academic literature review, namely that most indicators had to be neglected. In fact, they were either not relevant for our concerns of evaluating an existent SC's degree of sustainability, or they have been considered being redundant. Consequently, we set up a new KPI dashboard, based on sustainability matters, which includes 13 different indicators across all (sub-) pillars. The used KPI Set is summarised on Figure 25.

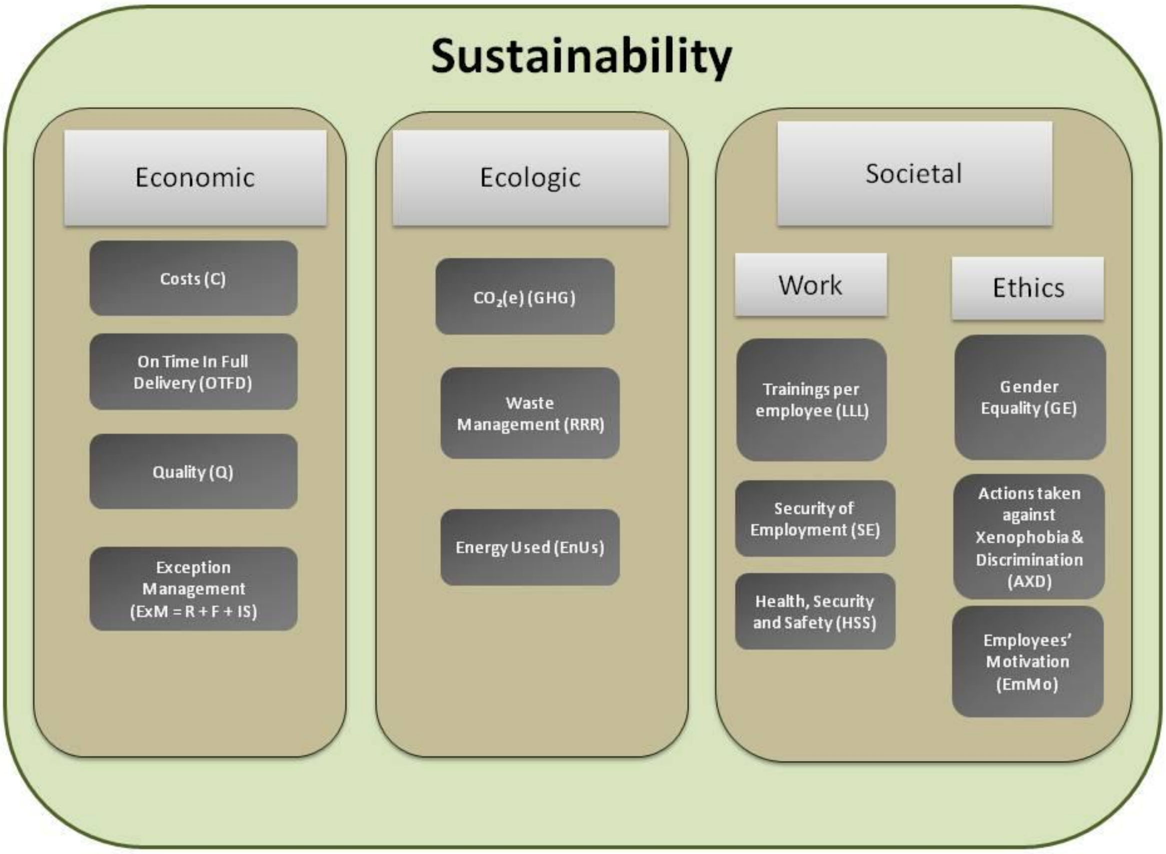


Figure 25 – Indicators measuring Sustainability within a Supply Chain

The data required by the indicators are, as explained above, either quantitative or qualitative. The syntax defining the discourse universe per indicators as well as the indicators' inherent formulas are summarised in Table 3.

To assure the calculation of a SC's degree of sustainability, it is indispensable that the different KPIs may be reckoned up. Besides, the problem of getting the needed data remains. It is well known, that most companies do not publish most of the data (e.g. difference of salaries) as it is considered being highly confidential. Other indicators are simply not recorded as such because managers do not consider them being meaningful for the company's daily business (e.g. Actions taken against Xenophobia and Discrimination). This proves the real systems' inherent kaleidoscopic complexity, which, again, leads to Simon's (1991) cognitive limits and the necessity of aggregating the indicators used. To overcome the problem of confidentiality and to retain comparability of different SCs degrees of sustainability, we suggested normalising the required data. However, the gross data need to be revised, adapted, and aggregated so that an analysis of the indicators, and thus, an existent SC's degree of sustainability can be calculated. To provide such an analysis, we first need to examine several methodologies supposed to aid in aggregating the indicators avowed in section 2.3 . To develop an evaluation model, it is not sufficient to determine the indicators to be used, but we also need to figure out, what methodologies might be pertinent. The extracting of the most important methodologies yielded by a literature review will be explained hereafter.

Uo	Identifier Uo	Type	Sub-Type	Step	Unit of Measurement	Area	Formula
U_C	Costs	Numerical	Real	0.01	Euro	N = [0 , 1]	$\Sigma LOS_{it} + \Sigma LMS_{it}$
U_{OTIF}	On Time In Full delivery	Numerical	Real	0.0001	Rate	N = [0 , 1]	$\frac{\Sigma Dg_{it}}{TD_t}$
U_Q	Service Quality	Linguistic	Ordered	$\mathcal{L}_Q$ = {very poor ; poor ; medium ; good ; excellent}			$\mathcal{L}_Q$ = Linguistic set of Q
U_{ExM}	Exception Management	Numerical	Real	0.01	Average	N = [0 , 1]	$\frac{R(x_t) + F(x_t) + IS(x_t)}{3}$
U_R	Responsiveness	Numerical	Real	0.01	Rate	N = [0 , 1]	$\frac{\Sigma DREQ_{it}}{\Sigma REQi_t}$
U_F	Flexibility	Linguistic	Ordered	$\mathcal{L}_F$ = { very poor ; poor ; medium ; good ; excellent }			$\mathcal{L}_F$ = Linguistic set of F
U_{IS}	Issues Solving	Linguistic	Ordered	$\mathcal{L}_{IS}$ = { very poor ; poor ; medium ; good ; excellent }			$\mathcal{L}_{IS}$ = Linguistic set of IS
U_{GHG}	Greenhouse Gas Emissions Produced	Numerical	Real	0.01	TKM	N = [0 , 1]	$\sum TKM_{i,t}$
U_{RRR}	Waste Management	Numerical	Real	0.0001	Tons of Waste per Assigned FTE	N = [0 , 1]	$RRR_t \cdot \alpha_t$
U_{EnUs}	Energy Used	Numerical	Real	0.01	kWh per Assigned FTE	N = [0 , 1]	$TNRG_t \cdot \alpha_t$
U_{LLL}	Trainings per Employee	Numerical	Real	0.01	Hours of Training per assigned FTE	N = [0 , 1]	$\sum LLL_{it} \cdot \alpha_t$

Uo	Identifier Uo	Type	Sub-Type	Step	Unit of Measurement	Area	Formula
U_{SE}	Security of Employment	Linguistic	Ordered	$\mathcal{L}_{SE}$ = { very poor ; poor ; medium ; good ; excellent }			$\mathcal{L}_{SE}$ = Linguistic set of SE.
U_{HSS}	Health Security and Safety	Numerical	Real	1	Accidents per assigned FTE	N = [0 , 1]	$\Sigma ACC_t \cdot \alpha_t$
U_{GE}	Gender Equality	Linguistic	Ordered	$\mathcal{L}_{GE}$ = { very poor ; poor ; medium ; good ; excellent }			$\mathcal{L}_{GE}$= Linguistic set of GE
U_{Salary}	Salary	Numerical	Real	0.01	Average Salary in Euro	N = [0 , 1]	$\frac{1}{W\beta} \Sigma\ Salary_{iw\beta t} - \frac{1}{M\beta} \Sigma\ Salary_{im\beta t}$
$U_{DifSalary}$	Differences in Salaries	Linguistic	Ordered	$\mathcal{L}_{DifSalary}$ = { very poor ; poor ; medium ; good ; excellent }			$\mathcal{L}_{DifSalary}$ = Linguistic set of DifSalary
U_{FeQuo}	Abidance concerning the Female Quota	Linguistic	Ordered	$\mathcal{L}_{FeQuo}$ = { very poor ; poor ; medium ; good ; excellent }			$\mathcal{L}_{FeQuo}$= Linguistic set of FeQuo
U_{SubGE}	Subjective opinion about Gender Equality	Linguistic	Ordered	$\mathcal{L}_{SubGE}$ = { very poor ; poor ; medium ; good ; excellent }			$\mathcal{L}_{SubGE}$= Linguistic set of SubGE
U_{AXD}	Actions taken against Xenophobia and Discrimination	Linguistic	Ordered	$\mathcal{L}_{AXD}$ = { very poor ; poor ; medium ; good ; excellent}			$\mathcal{L}_{AXD}$ = Linguistic set of AXD
U_{EmMo}	Actions Taken to Increase Employees' Motivation	Linguistic	Ordered	$\mathcal{L}_{EmMo}$ = {very poor ; poor ; medium ; good ; excellent }			$\mathcal{L}_{EmMo}$ = Linguistic set of EmMo.

Table 3 – Discourse Universe and Formula per Indicator

2.4 Decision Support Systems in Respect of Multi-Criteria Decision Making (MCDM) Methods

Simon (1959) is famous for his theory of bounded rationality. Because of those cognitive limits, he suggested that economic decision-making should be based on the 'satisficing' approach, where 'satisficing' is actually adapted from 'satisfaction' and 'sufficient' (Simon, 1959). We agree on his statement that the classical and most known economic assumption of the omniscient *Homo Oeconomicus* is not given in reality. He contradicts the classical economic theory of companies and individuals maximising their profit from a certain option for action, and we must "*[…] expect the firm's goals to be not maximising profit, but attaining a level or rate of profit […]. Firms would try to 'satisfice' rather than to maximise*" (Simon, 1959). In this logic, to get a satisficing analysis of the evaluated degree of sustainability, we need to aggregate and evaluate the different indicators identified in section 2.3. To do so, we may use several decision support systems, whereof we will describe some of them hereafter.

2.4.1 Decision Support Systems – on a Managerial Level

Analysis of Variance (ANOVA)

ANOVA is often used in order to determine if a class of data can be defined being pertinent or not and is generally employed to test given hypotheses (Halpin, 1991). Basically, ANOVA is a statistical method that detects the different components of variance. "It is used for the evaluation of differences between experimental data from different treatments. The square root of the quotient of the sum of squares of the variants and the mean square of the error variance is equal to t, and the corresponding probability, at each degree of freedom, can be read from a t-distribution table" (Rédei, 2008).

Badie et al. (2011) explain that ANOVA helps to compare groups of data for statistical significance. The observed variance of a particular group of variables is split into components explaining the possible sources of variation, while Buckless & Ravenscroft (1990) criticise the fact that ANOVA only indicates if there are differences between group means, but it is not expressive on the source of the differences among means. In addition, there are practical limits as while the studied effects may grow in linear manner, the data needed to perform this study so will grow exponentially (Paul, 2005). Moreover, the sample needs to be a Gaussian distribution and the different observations in each sample have to be independent, as this those are strong hypothesis given by the model. Furthermore, the population in which the samples are selected from, need to have certain homogeneity of variance (Gu, 2013; Lüpsen, 2015).

Balanced Score Card (BSC)

Because of the above mentioned cognitive limits, business managers need mathematical supporting models to take their daily decisions in a profitable way. One well-known decision-making supporting model is the balanced scorecard (BSC), which has been used in several academic works. While Kurien & Qureshi (2012) criticise the difficulties managers may have by implementing a BSC for measuring the company's GSC performances as the traditional BSC does not consider environmental measurements, Xian et al. (2013) observe that SC performance evaluation is not fully measurable in existing literature using BSC. Abernethy et al. (2005) stated "*It is also assumed that an organization's strategy can be articulated and communicated unambiguously throughout the organization. While research has examined implementations of BSCs […] and assessed the causal* *links between leading and lagging indicators […] it is silent on how key success factors (KSFs) and the relations among them are articulated"* (Abernethy et al., 2005).

The BSC uses both, financial and non-financial data to provide an overview of the company's performance. The logic behind a BSC may be explained by its' four components, namely [1] traditional financial perspective, [2] Customers' satisfaction perspective, which is the final reason for every product's or service's success or fail, [3] learning and growth perspective, and [4] internal business process perspective (Hans Böckler Stiftung, 2011). Weber et al. (2002) remodelled the BSC in terms of contents and structure so that it meets the requirements of logistical networks.

The original BSC's inherent complexity depends on the company's purposes. One of the BSC's advantages is that it is easy to implement since in most cases, the only tool needed is Excel. Moreover, contrary to classical methods of financial health of a company, it gives a better picture of the company's objectives and if the latter have been achieved or not. Additionally, it has to be mentioned that the BSC does not only consider the short term goals, which is often the case for financial issues, but the picture shown to managers considers short term, medium term, and long term aims. Another benefit is that managers can see more or less immediately if the different implemented actions will help to reach the desired effect. Nevertheless, there are also some limitations. As the BSC is based on four different perspectives, the objectives of each perspective need to be clearly stated through meetings, which may be very time consuming. In other words, the BSC is not a tool to solve problems quickly, as there is permanent interaction between the different perspectives. A company consists in quite more than only the [1] financial, the [2] customer, the [3] learning and growth, and [4] the business process perspectives. It is important to understand that the abovementioned four approaches do not show an overall view of the company (Kaplan, 2008).

The balanced scorecard presents a wide range of metrics which may easily be adapted. It enables a strengthened management of the entire SC, as it provides a better control. Though, the interfaces are not optimised, and there is no coordination along the SC. The main detriments are, however, the fact that causes and effects of certain events are not visible, and the absence of synchronisation of management metrics and processes (Lindner, 2009).

Supply Chain Operations Reference (SCOR) Model

Since the Supply Chain Operations Reference (SCOR) model consists of a reference model with standardised processes including a glossary of common supply chain terminology (Meyr et al., 2002), a common understanding between companies using this methodology is thus ensured. The model needs to be seen as a systemic approach which helps decision makers to understand the company's inherent processes and to identify essential characteristics that lead to customers' satisfaction, as the model defines the level of interaction between the different processes and how they are configured from the first tier supplier to the end customer (Huang et al., 2005). The SCOR Model helps managers in identifying and hence eliminating superfluous practices, which enables an improvement of the entire supply chain's configuration (Li et al., 2011). The SCOR model's inherent processes can be divided into three hierarchical levels, namely [1] process definitions, [2] process type, and [3] process category. Level 1, process definitions, consists of the five management processes [1] Plan, [2] Source, [3] Make, [4] Deliver, and [5] Return, which consider the information and physical flows. This also results in the fact that not all processes of the entire SC are included. The considered ones are subdivided into process categories, elements, tasks and activities (Hwang et al., 2010; Kasi, 2005), enabling companies to examine their SCs. At the second level, the model differentiates between make-to-stock (MTS), make-to-order (MTO), and engineer-to-order (ETO) products. The third level, the underlying processes of level 2 need to be described, as those underlying processes differ from one company to another.

It is difficult to develop a SC performance measurement system including all the different influences of a SC. The advantages presented by the SCOR model are, above all, the standardised documentation and metrics which enables a clear communication between SC participants, and the fact that processes which have to be measured are well defined as from the beginning. In addition to this, benchmarking and best practices with other companies are facilitated. Nevertheless, an overall performance measurement is still difficult. Furthermore, the model is difficult to understand due to its high level of abstraction and it presents no flexibility when the measures change (Lindner, 2009). Because of its high complexity, a number of its determinants and parameters are probably extremely time-consuming. Additionally, the SCOR Model hypothesises does not address the fields in which training is needed.

Conclusion

Literature review has yielded many methodologies, whereas the ones, we considered being the most interesting for this work, have been described above. A summary of the different methods' advantages and disadvantages is given in Table 4.

In this work, the case study will refer to a SC acting in the industrial domain. Nevertheless, this study could be enlarged afterwards, by referring to several different SCs, to demonstrate the different degrees of sustainability between customers belonging to a specific domain, as well as to evince the differences between different domains degrees of sustainability. To do so, the ANOVA methodology seems being pertinent, as it is helps to find out, if significant discrepancies in the adoption of SuSCM practices exist between economic domains. As, because of time issues, this thesis does not enable long time studies including SCs from all different economic domains served by Kuehne + Nagel, the ANOVA methodology will not be used in this work. In other words, this methodology seems interesting for further investigations on this dissertation's topic.

In the perspective of continuous improvement, Kuehne + Nagel uses the BSC which could be easily altered to fit to the present case study. The main drawback of this methodology is that it is highly time consuming. Although it would optimally fit into this work, the evident fact that business managers' and experts' daily business is to be seen as Kuehne + Nagel's priority forced us to choose a methodology, which is less time consuming for the different involved parties. Those same time related issues are valid for the SCOR model. In contrast to the BSC methodology, the SCOR model requires many explanations as it is difficult to understand due to its high level of abstraction. The implemented evaluation model should easily be usable by Kuehne + Nagel's managers. It is therefore predictable that several time-consuming meetings would be required to assure every involved person's understanding of the model if the SCOR methodology would be introduced.

During internal meetings, it has been argued that the ANOVA methodology should be used for further investigations on the present topic, but that we should, at this level, consider decision support systems which are based on a modelling level to implement the calculation of a SC's degree of sustainability.

<table>
<tr><th colspan="2">Decision Support Systems: Managerial Level</th></tr>
<tr><th colspan="2">ANOVA</th></tr>
<tr><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Easy to understand
Easy to use</td><td>ANOVA indicates if there are differences between group means, but is not expressive on the source of the differences among means
Data needed grow exponentially
Population must be a Gaussian distribution
Observations must be independent in each sample
Homogeneity of variance is required for the population, the samples are selected from</td></tr>
<tr><th colspan="2">BSC</th></tr>
<tr><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Easy to implement
Gives a better picture of the company's objectives
Gives a better picture of the achievement of the different objectives
Considers short, middle and long term goals
The taken actions' consequences are immediately visible</td><td>Objectives need to be clearly stated through meetings – time consuming
Permanent interaction between the different perspectives and stakeholders is required
The four predefined approaches do not show the overall view of the company</td></tr>
<tr><th colspan="2">SCOR</th></tr>
<tr><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Standardised documentation and metrics, and hence
Clear communication between SC participants
Processes which have to be measured are well defined as from the beginning
Benchmarking & Best Practices with other companies are facilitated</td><td>An overall performance measurement is still difficult
Difficult to understand as high level of abstraction
No flexibility when measure changes
Some determinants and parameters may be extremely time-consuming
The model assumes, but does not address the fields where training is needed</td></tr>
</table>

Table 4 – Summary of Decision Support Systems on a Managerial Level

2.4.2 Decision Support Systems – on a Modelling Level

Analytical Hierarchy Process (AHP)

Ho (2008) declared the AHP being one of the most used methodologies concerning Multi Criteria Decision Making (MCDM). According to Loken (2007), AHP and Multi-Attribute Utility Theory (MAUT) *"[…] rest on different assumptions on value measurements and AHP is developed independently of other decision theories. […]The major characteristic of the AHP method is the use of pair-wise comparisons, which are used both to compare the alternatives with respect to the various criteria and to estimate criteria weights".* Saaty (1980) stated that the Analytical Hierarchy Process (AHP) methodology is almost as well known as MAUT, which will be discussed below. Effectively, in his work, Ho (2008) listed some authors, who concentrated on specific areas of, beyond others, logistics, environment, manufacturing or higher education. What is common to all those authors is that they used AHP combined with another methodology. As resource allocation plays an essential role in maintaining and improving performances, decision makers face multiple and often opposed objectives (Ho et al., 2006).

Three main processes are inherent in AHP, namely [1] the hierarchy construction, [2] the priority analysis, and [3] the consistency verification. Ho et al. (2006) structured the AHP process as shown on Figure 16 below. Saaty (2008) explained that the *"Analytic Hierarchy Process (AHP) is a theory of measurement through pairwise comparisons and relies on the judgements of experts to derive priority scales. It is these scales that measure intangibles in relative terms"*. In fact, each pairwise comparison requires answering on how much an attribute A is more important than an attribute B, relative to the overall objective (Kahraman, 2008). This pairwise comparison provides the advantage that AHP is easy to use as managers may weight coefficients and compare alternatives one by one and therefore relatively easily. In fact, its ability to structure complex, multi-attribute, multi-person, and multi-period problems hierarchically is one of the biggest advantages of AHP. In addition, it is simple to understand and therefore easy to use (Shahroodi, et al., 2012). The model's structure "*[…] facilitates communication of the problem and the recommended solutions"* (Shahroodi et al, 2012). Furthermore, as AHP is not as data intensive as other methodologies it is practicable in real life decision making problem analysis. Hilmola (2006) explained that AHP is not limited to tangible properties so that it can deal with qualitative and quantitative criteria. However, Hilmola (2006) pointed out that rank reversal exists in AHP as the order of superiority of the different alternatives a decision maker has, may change if a new one is added to the hierarchy. The fact of adding new alternatives may produce new information too, so that one may need to justify the order (Hilmola, 2006). Furthermore, because of that pairwise comparison, the model may become extremely large (Antil et al., 2013). The fact that AHP does not consider uncertainties or risks can be seen as further limitation of the AHP methodology (Yusuff & Poh, 2001).

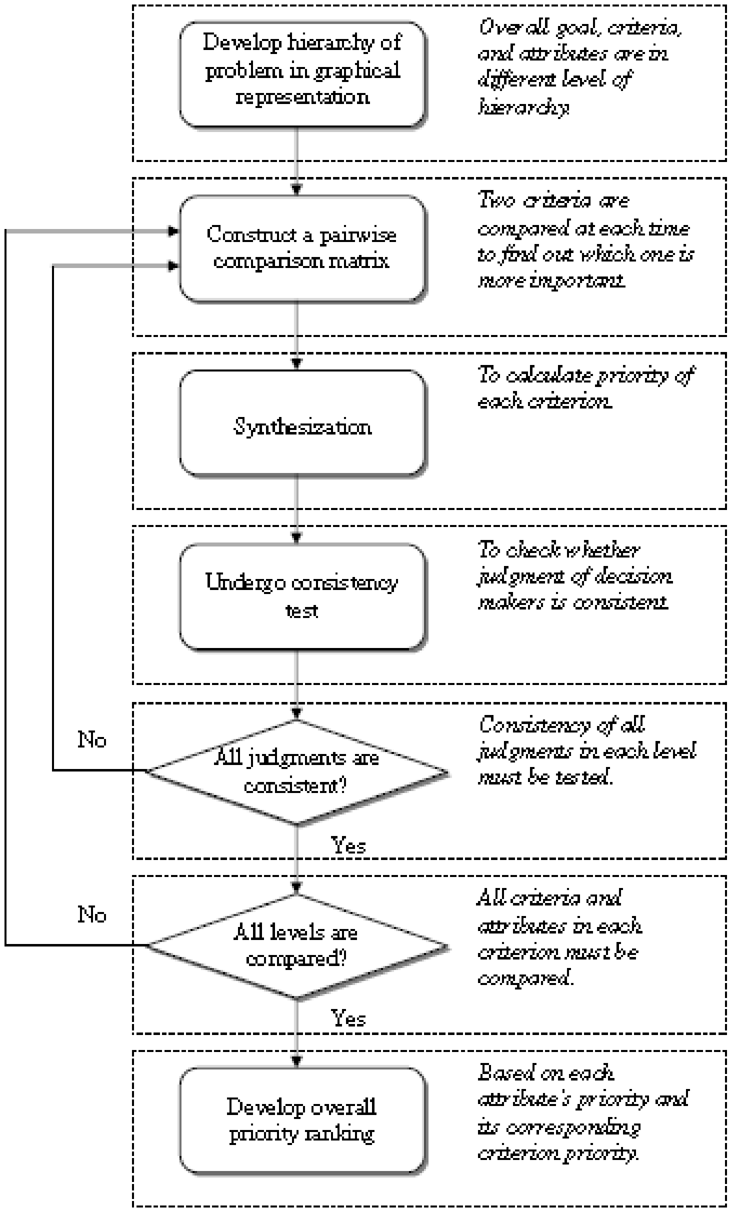


Figure 26 – AHP Methodology by (Ho et al., 2006)

Fuzzy Logic (Fuzzy Set Theory)

Karwowski & Evans (1986) stated that a decision maker's mental model of a problem he wants to solve is mostly imprecise and vague. This issue of vagueness and imprecision has been gathered in an extend range: the information provided by the production management environment may also be vague and therefore not measurable in a precise manner. The same problem can be verified as a result of experts' subjective point of view considering the problem to be solved (Grabot & Caillaud, 1996). According to Karwowski and Evans (1986), the fuzzy logic can be applied to bypass the different modelling gaps occurring in production management's decision models. The fuzzy logic has been used in many vague systems, which have no clear boundaries (Skubic, 1998). Chen, et al. (2006) have analysed supplier selection issues by using a fuzzy decision-making approach, whereas Peidro et al. (2010) have modelled SC uncertainties by fuzzy sets. In the point of view of Wang & Raz (1990), linguistic data can provide more information than the classical binary methods used if quality control is not feasible by using variables. In this same logic, Glushkovsky & Florescu (1996) described the use of fuzzy set theory in well-known quality tools, (such as Pareto Analysis, Cause-and-Effect diagrams, statistical control charts, etc.), when linguistic data is available. Contrary to the binary Boolean logic, the fuzzy logic, considers different 'degrees of truth', which allows a gradual membership to a given set. According to Borne et al. (1998) the first propositions going in the direction of non-crisp value analyses have appeared before the 1940's. Natural language is hard to translate into absolute terms, as words like 'almost', 'more or less' etc. are in common use in everyday life. This kind of words cannot be translated into the absolute terms of a Boolean logic, thus, 0 or 1. Nevertheless, the fuzzy logic includes 0 and 1 as extreme values along with the values defining the various states of truth (Bouchon-Meunier, 2003). Serchuk (2005) explains that the fuzzy logic should be used in cases where a certain vagueness or uncertainty is given so that classical logic and probability theory are shown to be inappropriate for the required reasoning.

The Fuzzy Set Theory is closer to the way human brains are working as the Boolean logic, as *"one of the most important facets of human thinking is the ability to summarize information 'into labels of fuzzy sets which bear an approximate relation to the primary data.' Linguistic descriptions, which are usually summary descriptions of complex situations, are fuzzy in essence"* (Dubois & Prade, 1980). One important disadvantage of the Fuzzy Set Theory is that the out coming results, which will always be a fuzzy set, may confuse laypersons. If a manager wants to get one single correct value, the fuzzy logic may not be used (Dubois and Prade, 1980; Bouchon-Meunier, 2003). Moreover, the methodology has severely been criticised by Elkan (1994) who stated that fuzzy logic had only been efficaciously used in control systems, but not in expert systems - an argument rejected by Serchuk (2005). Howbeit we agree on Elkan's statement that experts are needed to define the meaning of a linguistic classification. In fact, the definition of what is to be seen as 'good', 'medium', or 'poor' needs to be done in a pertinent manner. Thus, when using linguistic assessments, a close collaboration between Fuzzy Set Users and experts is required.

Multi-Attribute Utility Theory (MAUT)

Many authors have suggested the Multi-Attribute Utility Theory (MAUT) to serve as decision support system (DSS) in real-world problems, since, in most cases, a decision maker needs to choose among several alternatives. If an alternative is considered being acceptable or not depends on how well it scores on each relevant characteristic, and the relative importance of these properties (Wallenius et al., 2008). The MAUT methodology involves in fact the comparison of different alternatives which have all own strengths and weaknesses (Gass & Fu, 2013). It is to be considered as a structured methodology used to handle the adjustments among multiple objectives, which can help decision makers to find the best solution for a given problem by determining a utility to every possible effect (Gass & Fu, 2013). The methodology is based on the theory of expected utility theory. The latter states that "*if an appropriate utility is assigned to each possible consequence and the expected utility of each alternative is calculated, then the best course of action is the alternative with the highest expected utility" (*Ananda & Herath, 2005). According to Von Winterfeldt & Fischer (1973), an alternative can be represented either as a vector of multi-attributed outcomes, or as a matrix.

The key benefit of this methodology is that it takes uncertainties into account which is not a common quality for most MCDM methodologies. The fact that it is a rather understandable and comprehensible model which enables to integrate the preferences of each alternative at every level of the calculation technique is equally important. A main drawback of MAUT is that it is rather complex and extremely data intensive due to the huge amount of data that may not be available for many decision makers' problems. In addition, as decision makers need to be accurate, the model requires strong assumptions at each step. In short, MAUT can only be used if there is enough data obtainable, and if the considered problems analysed present significant uncertainties (Dyer, 2005; Wallenius et al., 2008).

Conclusion

Despite the fact that AHP might become extremely large due to the pairwise comparison, and despite the fact that risks and uncertainties are not considered by the AHP methodology, we consider this methodology being rewarding for our case study. Since we only have defined thirteen KPIs, the size of the model is supposed to remain manageable and easily understandable. In the same manner, the Fuzzy Logic is perceived as highly interesting because of its closeness to the human way of thinking. This is, above all, of great importance for the subjective and qualitative data albeit the latter will be converted into quantitative ones. We consider that some KPIs are highly subjective and need hence to be calculated in a manner enabling the use of the human way of thinking. In addition, as the system will not have clear boundaries this methodology may help to circumvent this issue. Nevertheless, the Fuzzy Logic will not be used as such. We will use the reasoning behind the methodology, i.e. we will convert qualitative data into quantitative ones, and introduce fuzzy sets which will help to accurately survey the obtained results. Effectively, the Boolean logic adopting only the values 1 and 0, meaning “true” or “false” would not be helpful in this work. This point will be elucidated more in detail in section 2.5 . Even though, experts need to assess the linguistic classification, this is probably not as time consuming as the BSC methodology previously described.

Discussions with Kuehne + Nagel’s managers resulted in the agreements that the MAUT methodology is an interesting one, given the fact that this methodology has often been used to solve problems concerning the green concept, as explained before. On the other hand, it was also concluded that this method might be difficult to implement on real cases, as it requires strong assumptions at each step. The latter might falsify the real end results. In addition, as MAUT is considered being extremely data and hence time intensive, managers doubt its’ usability and realisation in daily business. A summary of the different methods’ advantages and disadvantages is given in Table 5.

Decision Support Systems: Modelling Level	
AHP	
Advantages	**Disadvantages**
• AHP facilitates communication of the problem and the recommended solution • Practicable in real life decision making problem analysis, as not as data intensive as other methodologies • AHP may deal with qualitative and quantitative data, as it is not limited to tangible properties	• Rank reversal exists • Need to justify the hierarchical order • Model may become extremely large due to pairwise comparison • Risks and uncertainties are not considered by the AHP methodology
Fuzzy Logic	
Advantages	**Disadvantages**
• Close to the human way of thinking • Can treat imprecise and vague information • Treats both, quantitative and qualitative data • Different degrees of truth are considered • Can be used if the system does not present clear boundaries	• Experts need to define the meaning of linguistic classifications • The results will always be fuzzy sets but no unique values, which may be confusing for laypersons • A close collaboration is needed between experts and designer when using linguistic assessments
MAUT	
Advantages	**Disadvantages**
• Takes uncertainties into account • Understandable and comprehensible	• Rather complex model • Extremely data intensive • Strong assumptions required at each step

Table 5 – Summary of Decision Support Systems on a Modelling Level

2.5 Implementation and Application: Case Study at Kuehne + Nagel Luxembourg

In the following, we will elucidate how the different indicators have been calculated and explain the model we used to evaluate an existing SC's degree of sustainability. The KPIs will be compiled so that the end result can be calculated. The Evaluation Model's objective is to provide information about the SC's degree of sustainability at a certain point in time. In other words, the end result provided by our evaluation model will be a snap-shot picture of the current 'As-Is' situation. A similar model has been implemented by Piluso et al.'s (2010) fuzzy logic based approach to assess sustainability within the chemical domain. To find out if there is continuous improvement, this calculation needs to be done on a regularly basis and the end results need to be analysed. To simulate this, we will consider the SC from the Customer on the short term timeframe from 2010 to 2013 and examine if there was an improvement in terms of sustainability, even though, we are aware that during this timeframe, sustainability has not been considered by Kuehne + Nagel as it has been defined in this work. The timeframe from 2010 to 2013 has been chosen because of several reasons. In fact, from 2007 until 2013, the Customers' business has completely been handled in Luxembourg. As from the end of 2013, the operational part of this commerce has been handed out to another Kuehne + Nagel Branch. This has been done because of strategic reasons. On the other hand, most people who were on this project from 2010 until 2013 are still employed at Kuehne + Nagel, even though they are not operating on this SC anymore. However, due to personal changes, several persons, responsible for the customer C's business between 2007 and 2013 are not employed within Kuehne + Nagel anymore. It is evident, that data gathering is easier if the concerned people may be interviewed directly, albeit this is coupled with several conference calls and business trips.

Background

The following case study is intended to respond to the question about the model's feasibility in real cases. To do so, we consider the SC of one of Kuehne + Nagel's customers operating in the industrial domain in a B2B environment. For confidentiality reasons, the customer's name will not be revealed. Therefore he will be referred to as 'the Customer' hereafter. The model is intended to provide the considered SC's degree of sustainability. For simplicity reasons, the Customer's SC will not be entirely taken into consideration, but we only consider the part Kuehne + Nagel is responsible for. The model would also fit to the entire supply chain, as the end result depends solely on the data entered, but for time concerns, it is not possible to take the whole SC into consideration. The analysis and interpretation of the end result need hence to be seen as an evaluation of the degree of sustainability of a SC served by Kuehne + Nagel, and thus, in the **point of view of Kuehne + Nagel.**

2.5.1 Case Study

The input data consist of economic, ecologic and societal related data, which are normalised and introduced into our evaluation model in order to calculate the SC's degree of sustainability. Opening the black box, we get an insight to the model itself, which is shown in Figure 27. Here, one can see the process used, which consists of seven sequenced steps beginning with the introduction of the normalised data into the KPI dashboard and ending with the analysis of the degrees of sustainability via the fuzzy sets. The attended end results are the degree of sustainability per pillar as well as the SC's overall degree of sustainability.

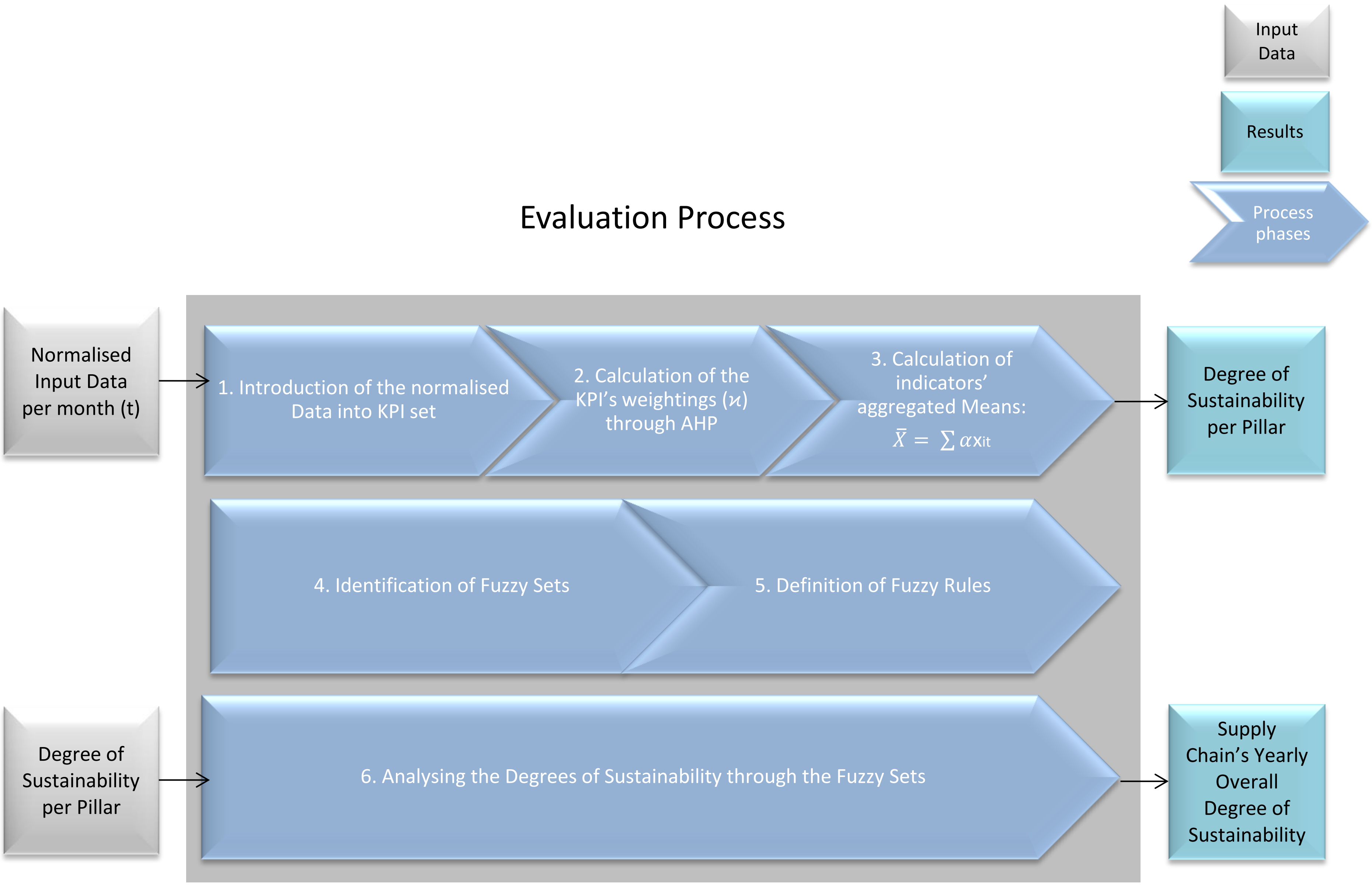


Figure 27 – The Evaluation Model (White Box)

As previously described, we defined sustainability being "*the interaction of the economical, the ecological, and the societal pillar – whereas 'societal' is defined being a composition of the working and the ethical environment – in order to satisfy today's and tomorrow's needs, while being aware of the fact that the different needs will deepen over time*". To calculate the degree of sustainability, we consider that each of the three inherent pillars should be taken into consideration. The formula resulting from this concept is hence:

Let **S** be the degree of Sustainability.
Let **Econ** be the outcome of the indicators assigned to the economic pillar.
Let **Ecol** be the outcome of the indicators assigned to the ecologic pillar.
Let **Soc** be the outcome of the indicators assigned to the societal pillar.
Let **W** be the outcome of the indicators assigned to the sub-pillar Work.
Let **E** be the outcome of the indicators assigned to the sub-pillar Ethics.
Let **KPIi** be the KPI assigned to the considered (sub-) pillar; **i = [1,4]**

$$\mathbf{S = f(Econ, Ecol, Soc)}$$
$$\mathbf{S = (Econ_{KPIi}; Ecol_{KPIi}; Soc_{KPIi})}$$

$$\text{Whereas: } \boldsymbol{Soc = f(W;\ E)} = \mathbf{(W_{KPIi}; E_{KPIi})}$$

In section 2.3.1, we defined the different KPIs associated to the three pillars Economic, Ecologic, and Societal, and discussed the formulas[19] of how the specific KPIs are calculated. The different indicators are recapitulated per pillar hereafter in Table 6.

		Societal	
Economic	**Ecologic**	**Work**	**Ethic**
Costs (C)	Energy Used (EnUs)	Health, Security and Safety (HSS)	Actions taken against Xenophobia and Discrimination (AXD)
Exception Management (ExM) *(= R, F, IS)*	CO_2e emissions (GHG)	Security of Employment (SE)	Actions taken to increase Employees' Motivation (EmMo)
On Time In Full Delivery (OTIF)	Waste Management (RRR)	Trainings per Employee (LLL)	Gender Equality (GE) *(= DifSalary, FeQuo, SubGE)*
Service Quality (Q)			

Table 6 – Recapitulation: Indicators per Pillar

The data collected are normalised as we need to dispose of the values' dimensions, so that they can be compiled afterwards. The positive side-effect of this normalisation is that we are not restricted by any confidentiality obligations. As discussed previously, the normalisation will be executed via the formula:

$$\frac{Variable}{Variable\ MAX}$$

[19] The assigned formulas are reminded in Appendix 5.

As described in section 2.3, the data required to fill the defined indicators are either quantitative or qualitative. While qualitative data need to be evaluated by experts, quantitative data are gathered internally at Kuehne + Nagel. However, as some data have not been tracked during the considered timeframe, they also need to be valued by experts. Table 7 reminds the KPIs requiring quantitative data. The normalised results of the quantitative KPIs are presented in Annexe 5.

		Societal Pillar
Economical Pillar	Ecological Pillar	Sub-pillar Work
C	EnUs	HSS
ExM: R	GHG	LLL
OTIF	RRR	

Table 7 – Indicators requiring quantitative data

The questionnaires used to gather the data required for the qualitative KPIs have been pre-tested in the Network and Supply Chain Engineering (NSCE) department to ensure their validity and reliability. The experts have been questioned afterwards either in face-to-face meetings or via phone conferences. The form has not been send via e-mail for explanation reasons. Those explanations were rather time consuming since most managers are not used to deal with, for example, the societal indicators, unless they are employed in the human resources or quality domain. In addition, as most managers have only a limited amount of time to fill such a questionnaire, they prefer answering the questions in face-to-face meetings or via phone. An expert is defined being a manager who was in charge of the Customer's SC during the considered time frame. Only 11 experts have been asked to answer the questionnaires considering the qualitative indicators. The reason is twofold: [1] The amount of experts considering the Customer's SC is restricted, and [2] some managers who were in charge of the Customer's SC during the considered time frame, from 2010 to 2013, are not working at Kuehne + Nagel anymore.

As discussed before, every data need to be normalised. This holds also true for the qualitative data. To do so, the qualitative data are all requested via a 'Likert scale questionnaire', asking thus "On a scale from 1 to 5, where 1 means "poor" and 5 means "excellent", how would you evaluate…?". The maximum is hence equivalent to 5, and the aforementioned formula used for normalisation can be applied. Table 8 reminds the indicators demanding qualitative data. The normalised results of the quantitative KPIs are presented in Annexe 7.

	Societal Pillar	
Economical Pillar	Sub-pillar Work	Sub-pillar Ethics
ExM: F	SE	AXD
ExM: IS		EmMo
Q		GE

Table 8 – Indicators requiring qualitative data

Estimated KPIs

Some indicators have been assembled by distinct sub-indicators. The latter are often not of the same type, i.e.: some have a qualitative character, while others are quantitative. This is the case for the Exception Management (ExM) indicator, as well as for the Gender Equality (GE) one. Nevertheless, those two main indicators are handled in entirely different ways.

The Exception Management KPI is compiled by its sub-indicators Responsiveness (R), Flexibility (F), and Issues Solving (IS). While the R indicator consists of quantitative measures[20], the F and IS KPIs consist of qualitative data, valued by experts via a five-point Likert Scale. Those KPIs needed to be estimated during the considered time frame, as Kuehne + Nagel did not measure them. The aforementioned 11 experts were in distress because they were not able to give precise disclosure about how the situation was in a precise month some years back. Thus, to get the most realistic results, we asked them to answer as accurately as possible and calculated the average of all given answers. The normalised results of the ExM indicator are presented in Annexe 8. As explained in 2.3.1, the service Quality (Q) indicator has been evaluated in the same manner. The results of the Q KPI are indicated in Annexe 7.2.

The GE indicator, as described in Section 2.3.3 , is based on its three inherent sub-indicators, namely Difference of Salary between male and female workers (DifSalary), the Female Quota (FeQuo) in Kuehne + Nagel, and the Subjective evaluation of Gender Equality (SubGE) within Kuehne + Nagel. While the FeQuo has been provided by the Human Resource Department, the DifSalary has been calculated and provided to the experts. For confidentiality reasons, those results will not be displayed in this work. Since the DifSalary is of high confidentiality because of the relatively precise data used to explain the calculations, it is reasonable that this indicator has been assessed by only one expert, namely Kuehne + Nagel Luxembourg's National Manager. Since it is not possible to receive the data from all different workers within Kuehne + Nagel employed during the timeframe used for this case study, hence, between 2010 and 2013, the other indicators, FeQuo and SubGE have been assessed by the Human Resource Department and the Working Council. In a first step, the average of the given answers considering the FeQuo and SubGE indicators has been calculated. In a second step, we calculated the average of the three sub-indicators, namely DifSalary, FeQuo, and SubGe, to get the most realistic end result for the GE KPI. Those results are presented in Annexe 7.6. In addition to the above mentioned reason, we consider the societal related data being the same for every SC. In fact, since those KPIs consider Kuehne + Nagel's internal atmosphere which is considered not to change with the contemplated SC, those same experts have been asked to assess the other societal indicators Security of Employment (SE)[21], actions taken Against Xenophobia and Discrimination (AXD)[22], and actions taken to increase Employees' Motivation (EmMo)[23].

---

[20] $f\,(U_R) = \frac{\sum_{f=1}^{Q} DREQ}{TREQ}$,
Whereas D_{REQ} = the requests which have been treated in time;
REQ = [1 , Q]
and T_{REQ} = the total requests submitted.

[21] The results are given in Annexe 7.3
[22] The results are given in Annexe 7.4
[23] The results are given in Annexe 7.5

Calculating an existent Supply Chain's Degree of Sustainability

To guarantee that the model for calculating a SC's degree of sustainability is practicable for every supply chain, i.e. no matter the considered domain, the different indicators needed to be weighted. To implement those weightings, we use the "Analytical Hierarchy Process" (AHP) methodology. The AHP is a top-down decision model. The different criteria and alternatives used need to be independent (Petrillo et al., 2012). It could be argued that some indicators have strong relationships, but we consider them in a separate manner. As an example, if there are actions taken against xenophobia and discrimination, this probably has a positive influence on affected employees. Nevertheless, we argue that, regarding the employees' motivation indicator, this is not the only influencing factor. The factors are assumed being independent, even though there is interaction between the different pillars. Exemplifying, we suggest that increasing employees' motivation has probably direct impacts on the exception management indicator. This does not pose any problems, since the AHP's pairwise comparison is only performed within a regarded pillar.

As described before, to weight the different KPIs in order to calculate the degree of sustainability of a SC operating in the industrial domain, we based the weighting calculations on the AHP model. The AHP hierarchy construction requires that different experts answer on how much an attribute A is more important than an attribute B, relative to the overall objective (Kahraman, 2008). In our case, this overall objective is the degree of sustainability. The AHP considers not only the Customer's SC, but every SC in the industrial domain. For this reason, 28 Kuehne + Nagel internal experts operating in this economic sector have been interviewed either at personal meetings or by phone calls. Since the weightings should not be tailored to the considered customer, but should apply to the sector the customer belongs to, only 3 of the questioned experts have worked on the Customers' SC during the considered period. In fact, even within a certain domain, customers prioritise the KPIs in a different way. To get a general applicable reference, it is important to interrogate different experts of this same domain, but having different point of views, i.e. working on different customers.

In a first step, the pairwise comparison and relative weight estimation took place. This is done with respect to their relative importance towards their control criterion based on the principle of AHP (Saaty, 1980). The scale for this pairwise comparison suggested by Saaty (1980) is shown in Table 9.

Intensity of importance a_{ij}	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong or demonstrated importance
9	Extreme importance
2, 4, 6, 8	For compromise between the above values

Table 9 – Semantics Scale suggested by Saaty (1980)

Discussions with internal experts as well as with the Cluster for Logistics Luxembourg revealed, to base the semantics scale on only 6 points, since most managers are used to this scale.

The main argument was that a 9-point scale would be oversized if managers were asked to give accurate answers about the importance of indicators they are not used to deal with. The appealed indicators are primarily the societal ones.

We hence used a modified AHP methodology, asking experts: “On a scale from 1 to 5, which indicator is more important in the industrial domain, to conduct to sustainability? If you suggest that both indicators are equally important, please assess the weighting being ‘0’. 1 means, that KPI_i is slightly more important than KPI_j and 5 means that KPI_i is of greatest importance compared with KPI_j.” Since the questions have been asked in 2 ways, namely KPI_i versus KPI_j and KPI_j versus KPI_i, the questionnaire which is shown on Figure 28, was filled beyond the range of the expert’s vision to ensure they could not check the answers they previously gave.

KPI	-5	-4	-3	-2	-1	0	1	2	3	4	5	KPI 2
Actions taken against Xenophobia												Actions taken to increase Employees' Motivation
Actions taken against Xenophobia												Gender Equality
Costs												Exception Management*
Costs												On Time In Full Delivery
Costs												Service Quality
Actions taken to increase Employees' Motivation												Actions taken against Xenophobia
Actions taken to increase Employees' Motivation												Gender Equality
Energy Used												GHG emissions*
Energy Used												Waste Management
Exception Management*												Costs
Exception Management*												On Time In Full Delivery
Exception Management*												Service Quality
Gender Equality												Actions taken against Xenophobia
Gender Equality												Actions taken to increase Employees' Motivation
GHG emissions*												Energy Used
GHG emissions*												Waste Management
Health, Security and Safety												Security of Employment
Health, Security and Safety												Trainings per Employee
On Time In Full Delivery												Costs
On Time In Full Delivery												Exception Management*
On Time In Full Delivery												Service Quality
Security of Employment												Health, Security and Safety
Security of Employment												Trainings per Employee
Service Quality												Costs
Service Quality												Exception Management*
Service Quality												On Time In Full Delivery
Trainings per Employee												Health, Security and Safety
Trainings per Employee												Security of Employment
Waste Management												Energy Used
Waste Management												GHG emissions*

Figure 28 – The AHP Questionnaire

The questionnaire shown in Figure 28 also presents negative values. Those have been introduced to show which of the indicators is considered being more important, and at what proportion. To calculate the indicators' weighting, only absolute values are used. As an example, if in the first row, the expert indicates that Actions taken against Xenophobia and Discrimination is more important than Actions taken to increase employees motivation, assessing this importance being 3 on a scale from 1 to 5, the cross will be introduced into the row "-3". Nevertheless, the calculations will consider the absolute value of $|-3| = 3$.

The scale used for our pairwise comparison, as shown in Table 10, deviates thus from the one suggested by Saaty (1980).

Intensity of importance a_{ij}	**Definition**
0	Equal importance
1	KPI_i is slightly more important than KPI_j
2	KPI_i is a bit more important than KPI_j
3	KPI_i more important than KPI_j
4	KPI_i is much more important than KPI_j
5	KPI_i is of greatest importance compared with KPI_j

Table 10 – Semantics Scale used

The judgments have been used to calculate the respective indicators' weightings. Since we rate each main pillar being $\frac{1}{3}$ of the overall sustainability, as shown on Figure 29 , the pillar's inherent indicators need to add up to 100%. The resulting weightings per indicator within the different pillars are indicated in Table 11.

Economic *(100%)*	
OTIF	0.41395
C	0.28837
Q	0.22326
ExM	0.07442
Total:	100%

Ecologic *(100%)*	
GHG	0.62500
RRR	0.22059
EnUs	0.15441
Total:	100%

Societal *(100%)*			
Work *(50%)*		**Ethics *(50%)***	
HSS	0.41216	EmMo	0.72956
SE	0.37162	GE	0.15094
LLL	0.21622	AXD	0.11950
Total:	100%	*Total:*	100%

Table 11 – Weighted Indicators per Pillar

As discussed above, we consider that each main pillar values $\frac{1}{3}$ of the overall sustainability. This is important to ensure the comparability of different SCs within a certain domain. The comparison could not be drawn if companies could quantify the pillars' weight instead of the weights of their inherent indicators. In fact, if a company does not consider the societal pillar, for example, they would just adjust the pillars' weightings in order to get a higher degree of sustainability. Nevertheless, since the indicator's importance may vary enormously depending on the considered domain, they need to be weighted separately, even though, this implies that SCs from different domains cannot be compared.

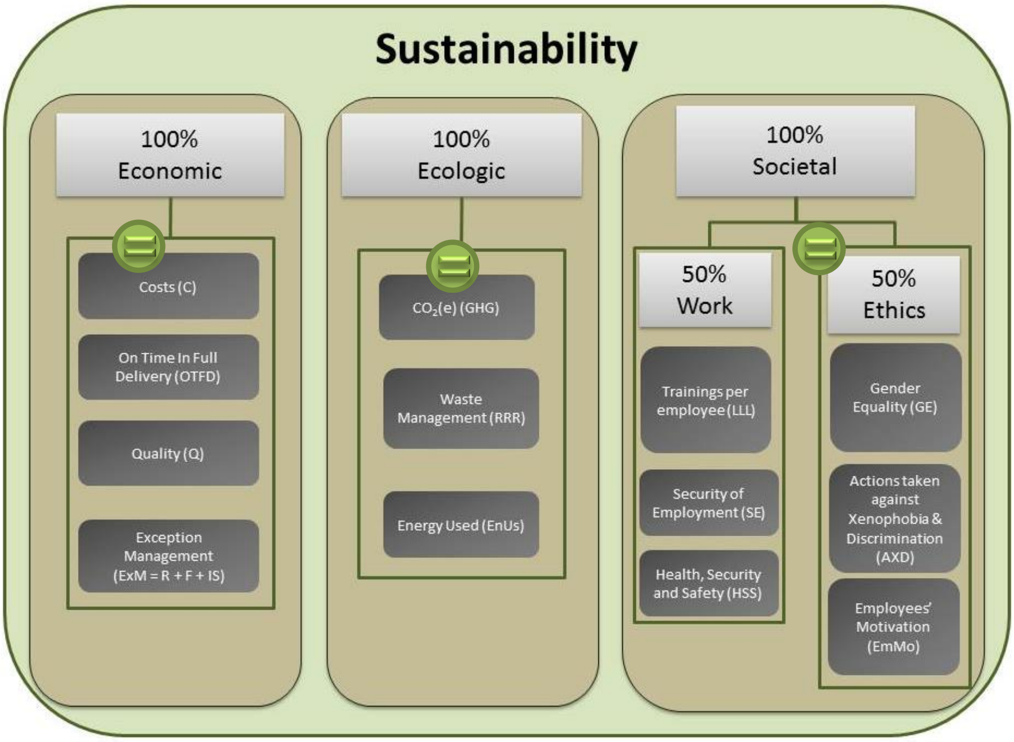


Figure 29 – Sustainability: Weighted Pillars

It is not possible to only calculate the average of the used KPIs to get the SC's overall degree of sustainability. In fact, some indicators are defined being close to excellence if their calculated limit is close to zero, while others are considered being close to excellence if the limit approaches infinity. In other words, the latter's normalised data need to approach 1. The end result would hence be falsified because of the offset due to the indicators different meanings and the clear overall impression of the SC's degree of sustainability could not be provided.

To overcome this issue, we classified the indicators into the two abovementioned groups and converted the values of the indicators which should be close to zero via the formula: 1 - KPI_j. In fact, by altering the indicators requiring the data being minimal to be optimal, every indicator is seen being close to excellence when the normalised data approaches to 1. As indicated in Table 12, the considered indicators are thus: C, GHG, RRR; EnUs, and HSS.

Limit should approach 1	Limit should tend to 0
OTIF	C
Q	GHG
ExM	RRR
SE	EnUs
LLL	HSS
GE	
AXD	
EmMo	

able 12 – Classifying Indicators

The next calculation step consists of calculating the pillar based sustainability performance, including the different KPI's weightings calculated before[24]. The intermediate results per pillar are shown in Annexe 9. Finally, since every pillar has the same level of importance, we calculated the aggregated mean value of the three main pillars to receive the Customer's SC's overall degree of sustainability on a monthly basis. The implemented model can be summarised as depicted in Figure 30.

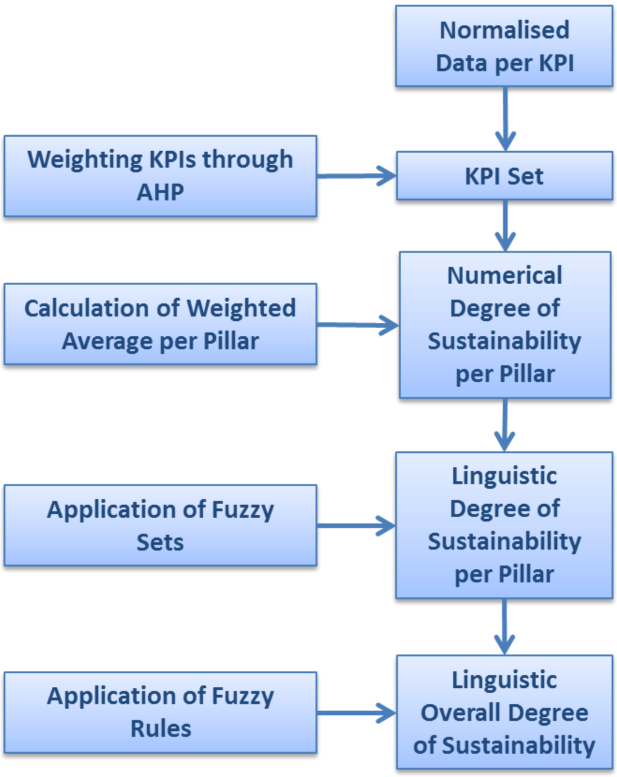


Figure 30 – Evaluation of an existing Supply Chain's Degree of Sustainability: Methodology Used

Degrees of Sustainability – Results

As discussed in 2.5.1 the results consider the Customer's SC but are analysed in the point of view of Kuehne + Nagel. For this reason, indicators like Costs (C), On Time In Full delivery (OTIF), Greenhouse Gas Emissions (GHG), to name only these, are provided by the Customer to evaluate Kuehne + Nagel's overall performance and can be used for this case study. However, the data required by the societal pillar, namely Security of Employment, (SE) Health, Security, and Safety (HSS), Trainings per Employee (LLL), and Gender Equality (GE) indicators are gathered internally at Kuehne + Nagel. If solely the Customer's data had been used for each indicator, i.e.: also for the societal pillar, the analysis would need to be done in the latter's point of view. This is to say, this case study needs to be seen as an example: since the model depends on its data provided, each SC can be analysed either in the point of view of the logistics service provider (LSP), or from client's perspective.

The waste (RRR) and the Energy Used (EnUs) indicators depend on Kuehne + Nagel's facilities and employees. Since neither the number of employees, nor the square meters of

[24] The calculated weightings are presented on page 76

facilities used have changed in a considerable manner[25], it is logic that the RRR and EnUs indicators remain relatively constant during the considered time slot. On the other hand, the GHG indicator accounts for 62.5% of the ecological performance. In other words, if one of the remaining ecologic KPIs would substantially fluctuate, this oscillation would not be visible in the overall economic pillar. Nevertheless, an extreme off-peak of the ecological pillar appears in July 2010 as shown in Figure 21.

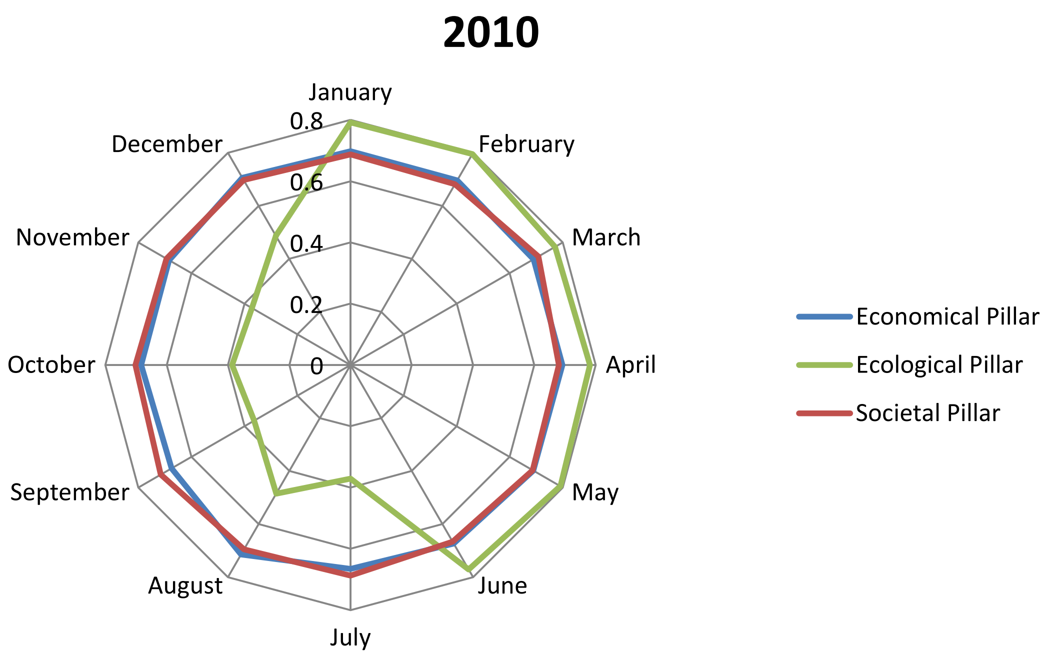


Figure 31 – Supply Chain's Degree of Sustainability 2010

These profound results do not appear during the periods from 2011 to 2013, as shown in Figure 33[26], Figure 25[27], and Figure 27[28]. As described above, this is a consequence of the great priority given to the GHG indicator in the ecological pillar. Since we converted the economical pillar's inherent KPIs via the formula 1 - KPI_j, it is important to understand that this aforementioned outlier, in reality, represents a peak, which is due to an extreme increase of the GHG emissions during the second semester of 2010, starting in July. This intensification in terms of CO2e emissions can be explained by the fact that one of the Customer's German factories have been closed resulting in a shift of the entire network. While the number of production sites has decreased, the different points of delivery remained the same. The consequence was thus an elevation of the amount of Tons-Kilometers (TKM). As it can be observed in Figure 22 to and Figure 33, the situation has not entirely been stabilised in 2011.

[25] the facilities remained the same during the whole period, and the number of Full Time Equivalent (FTEs) ranged from 475 to 537

[26] Figure 33 is presented on page 86

[27] Figure 25 is presented on page 87

[28] Figure 37 is presented on page 88

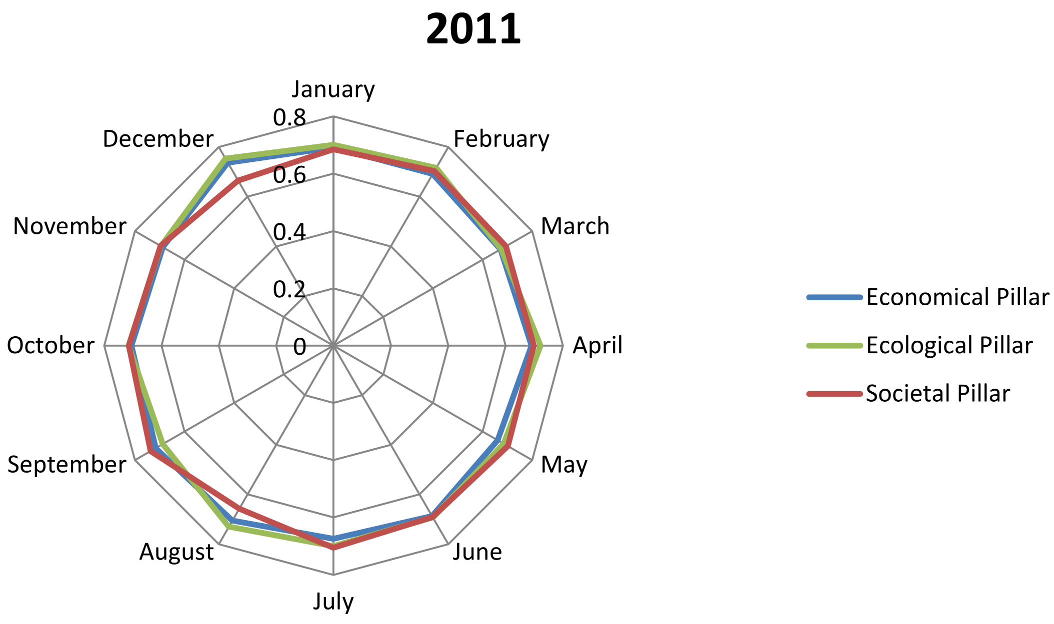


Figure 32 – Supply Chain's Degree of Sustainability 2011

Effectively, a closer look evokes that there are still slight variations, resulting in a star-shaped economic and ecological curve. In addition, it becomes obvious that also the societal curve presents some variations.

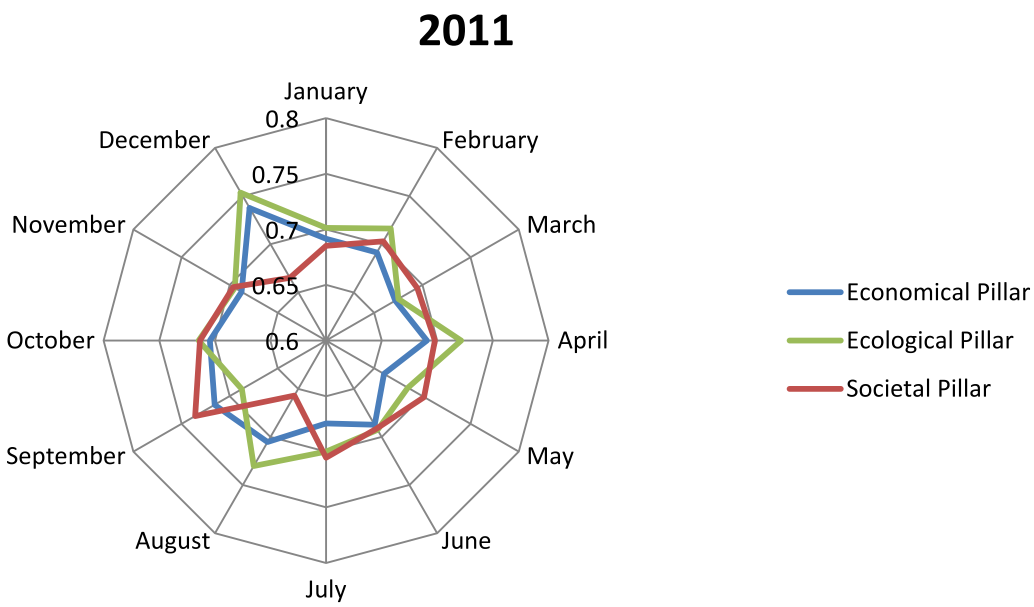


Figure 33 – Supply Chain's Degree of Sustainability 2011 – a closer look

The alterations can be explained by the simple fact that the Customer's products are subject to seasonality effects. While in August, several factories are closed because of annual holidays, in April and December, the production, and hence, the transportation of goods are decelerated because of various bank holidays subsisting during those months. In addition, since the German site has been closed in 2010, many volumes have been exchanged between the different remaining plants until end of 2011.

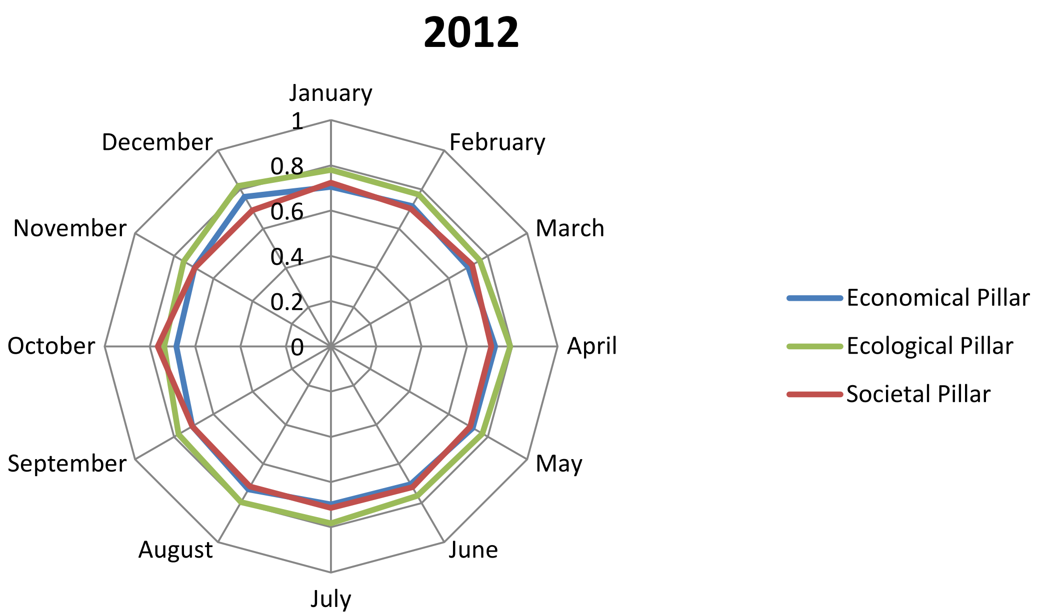


Figure 34 – Supply Chain's Degree of Sustainability 2012

The seasonality effect can also be seen if we take a closer look to the chart provided by the analysis done for 2012, as indicated in Figure 25.

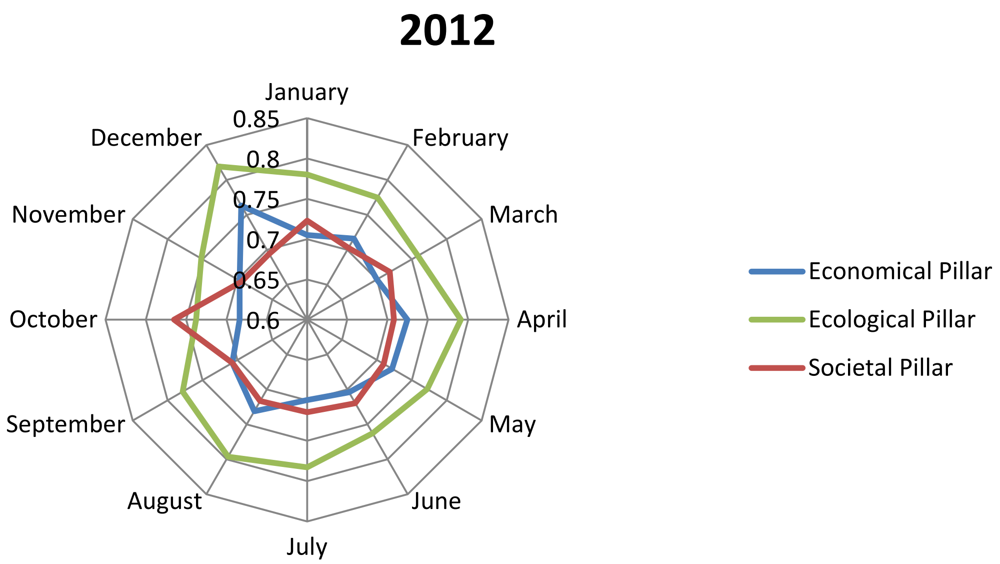


Figure 35 – Supply Chain's Degree of Sustainability 2012 – a closer look

During the last trimester, the Customer began to restructure three of its factories, but the ecological consequences have not fully been visible in 2013 yet, as it is presented in Figure 26.

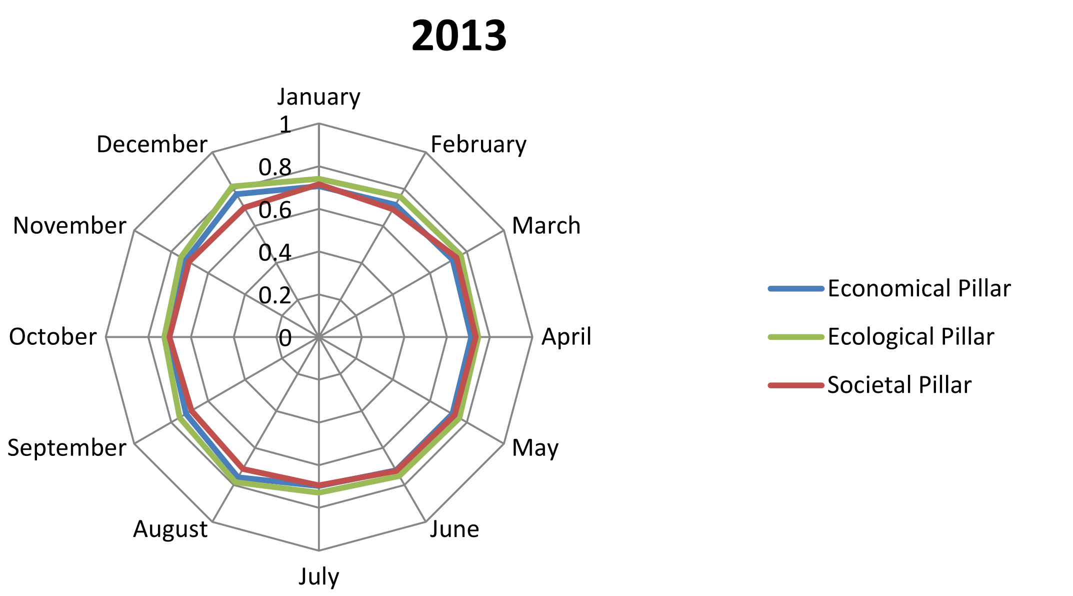


Figure 36 – Supply Chain's Degree of Sustainability 2013

A closer look to the analysis done for 2013 is shown in Figure 37 below.

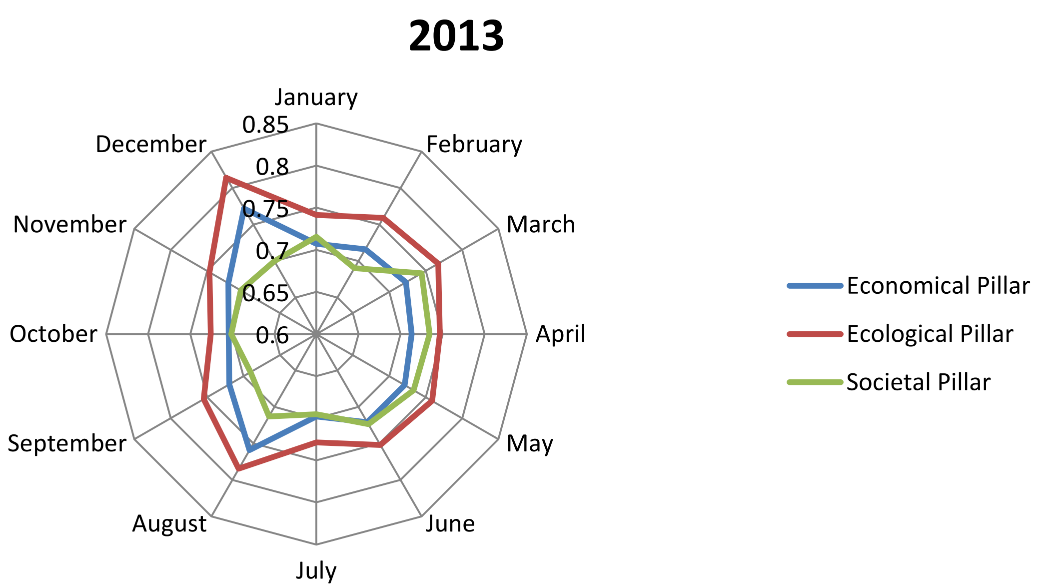


Figure 37 – Supply Chain's Degree of Sustainability 2013 – a closer Look

The economical pillar is composed of its four inherent indicators, namely Costs (C), On Time In Full delivery (OTIF), Quality (Q) and Exception Management (ExM). The monthly results of 2010 are shown in Table 13.

Year	Month	Economical Pillar	Ecological Pillar	Societal Pillar	Mean Value
2010	January	0.6977	0.7913	0.6869	0.7253
2010	February	0.6963	0.7950	0.6819	0.7244
2010	March	0.6896	0.7710	0.7080	0.7229
2010	April	0.6915	0.7813	0.6799	0.7176
2010	May	0.6889	0.7908	0.6869	0.7222
2010	June	0.6732	0.7710	0.6660	0.7034
2010	July	0.6657	0.3707	0.6873	0.5746
2010	August	0.7141	0.4849	0.6956	0.6315
2010	September	0.6744	0.3629	0.7153	0.5842
2010	October	0.6832	0.3868	0.7020	0.5907
2010	November	0.6838	0.3715	0.6941	0.5832
2010	December	0.7058	0.4876	0.6975	0.6303
2010	**Average**	**0.6887**	**0.5971**	**0.6918**	**0.6592**

Table 13 – Degree of Sustainability of the Customer's Supply Chain in 2010

It is visible that some severe fluctuations appear in the C indicator between July and August 2010, as shown in Annexe 9.1. Nevertheless, taking a closer look to the economic performance of 2011, 2012 or 2013, shown in Table 14, Table 15, and in Table 16 respectively, it becomes obvious that it is rather stable during the whole considered timeframe, while the costs are subject to seasonality effects.

Year	Month	Economical Pillar	Ecological Pillar	Societal Pillar	Mean Value
2011	January	0.6914	0.7012	0.6852	0.6926
2011	February	0.6915	0.7165	0.7031	0.7037
2011	March	0.6719	0.6751	0.6947	0.6806
2011	April	0.6908	0.7215	0.6979	0.7034
2011	May	0.6601	0.6849	0.7018	0.6823
2011	June	0.6874	0.6928	0.6912	0.6905
2011	July	0.6745	0.6999	0.7055	0.6933
2011	August	0.7054	0.7301	0.6572	0.6976
2011	September	0.7157	0.6875	0.7360	0.7131
2011	October	0.7046	0.7146	0.7133	0.7108
2011	November	0.6878	0.6947	0.6962	0.6929
2011	December	0.7375	0.7535	0.6652	0.7187
2011	**Average**	**0.6932**	**0.7060**	**0.6956**	**0.6983**

Table 14 – Degree of Sustainability of the Customer's Supply Chain in 2011

Year	Month	Economical Pillar	Ecological Pillar	Societal Pillar	Mean Value
2012	January	0.7053	0.7802	0.7230	0.7362
2012	February	0.7163	0.7750	0.7030	0.7315
2012	March	0.7000	0.7588	0.7187	0.7258
2012	April	0.7246	0.7911	0.7077	0.7411
2012	May	0.7219	0.7722	0.7100	0.7347
2012	June	0.7039	0.7625	0.7197	0.7287
2012	July	0.6995	0.7831	0.7147	0.7324
2012	August	0.7308	0.7962	0.7162	0.7477
2012	September	0.7072	0.7782	0.7073	0.7309
2012	October	0.6836	0.7376	0.7652	0.7288
2012	November	0.6966	0.7515	0.6942	0.7141
2012	December	0.7635	0.8193	0.6944	0.7590
2012	**Average**	**0.7128**	**0.7755**	**0.7145**	**0.7343**

Table 15 – Degree of Sustainability of the Customer's Supply Chain in 2012

Year	Month	Economical Pillar	Ecological Pillar	Societal Pillar	Mean Value
2013	January	0.7070	0.7413	0.7153	0.7212
2013	February	0.7160	0.7591	0.6902	0.7218
2013	March	0.7228	0.7671	0.7443	0.7447
2013	April	0.7134	0.7467	0.7347	0.7316
2013	May	0.7211	0.7589	0.7334	0.7378
2013	June	0.7210	0.7520	0.7235	0.7322
2013	July	0.6978	0.7288	0.6951	0.7073
2013	August	0.7590	0.7846	0.7129	0.7522
2013	September	0.7195	0.7548	0.6904	0.7216
2013	October	0.7042	0.7257	0.7011	0.7103
2013	November	0.7207	0.7466	0.7038	0.7237
2013	December	0.7719	0.8143	0.6999	0.7620
2013	**Average**	**0.7229**	**0.7567**	**0.7120**	**0.7305**

Table 16 – Degree of Sustainability of the Customer's Supply Chain in 2013

The C indicator actually values only 28.84% of the economic pillar and is compensated by the pillars' other inherent KPIs. Effectively, the OTIF indicator considers 41.40% of the economic cornerstone, being hence its most important indicator. Since it shows only minimal variations during the whole time frame from 2010 to 2013, it seems securing the economical pillar's rigidity on an acceptable level.

The ExM as well as the Q KPIs are rather stable, but since experts assessed them being of minor value (the ExM only considers 7.44% and the Q values 22.33% of the whole economic abutment) the existing variations are of negligible consequences concerning the overall objective. In addition, Kuehne + Nagel's quality performance has been assessed being constantly very high during the four considered years, so that the ExM's data have only minor influence on the economical overall performance. In other words, the fluctuations which appear in the economic stake are substantially compensated through its OTIF indicator.

It is important to allude that Kuehne + Nagel did not evaluate its sustainability performance as we characterised it within this work. For this reason, most of the two sub-pillars, work and ethics' inherent indicators needed to be assessed by experts. Most experts cannot remember how the situation exactly was in a specific month some years ago, their assessments may slightly adulterate from the real situation. Nevertheless, the major points are still considered being in line with the realistic situation of the considered time frame, as there were no considerable changes until today. In addition, the societal pillar depends solely on Kuehne + Nagel's internal ethical and working environment, explaining the importance of interpreting the results of the Customer's SC's sustainability performance in the perspective of Kuehne + Nagel. When looking at the overall results, i.e. the overall SC's degree of sustainability per year, the societal pillar seems being highly consistent.

Since the ethical sub-pillar's inherent data are, as stated above, very consistent throughout the entire period from 2010 to 2016. Nevertheless, taking a closer look to the charts, as clearly visible in Figure 33, the societal pillar indicates a downward movement in July 2011 which can be explained by the fact that firstly, there have been accidents, dropping down the HSS indicator, and secondly, there have been performed much less trainings than for example in July of the same year. Those two indicators value 41.21%, and 21.62% respectively of the working environment pillar. The SE indicator values 37.16% of the sub-pillar work. As it can be seen in Table 13, Table 14, Table 15, and Table 16 above, the SE indicator is quite high during the whole timeframe. This is due to the fact that, Kuehne + Nagel's employment politics which are quite employees friendly did not change. Effectively, if a reorganisation of the company cannot be avoided because of economic reasons for instance, the company tries to execute the less possible redundancies. Labour may have to change the department within the same location to avoid that their contracts will be denounced, but they will not get decruited. The biggest influences on the analysed societal pillar are hence provided by the working accidents which have occurred within Kuehne + Nagel. Even though the working environment sub-pillar constitutes only 50% of the whole societal pillar, the variations of the aforementioned indicators' inherent data appear in a quite visible manner. In October 2012, as it can be deduced from Figure 35 on page 85, the societal pillar presents a peak, which can be explained in the same way: First, during this month, no accidents occurred[29] and second, compared to other months of the considered year, many training sessions have been performed[30].

It may be difficult for managers to analyse the monthly degrees of sustainability per pillar in numerical terms. We therefore consider the different pillars by implementing fuzzy sets so that managers can handle linguistic values, which might be easier to understand. The latter are defined as shown in Table 17.

[29] According to Table 15 (page 89) the HSS indicator yields 1 in October 2012, meaning that no accident occurred in October 2012.

[30] According to Table 15 (page 89), the LLL indicator shows the value 0.9615: The closer this value reaches 1, the more trainings have been provided.

Value	Meaning
[0; 0.2[	Very poor
[0.2 ; 0.4[	Poor
[0.4 ; 0.6[	Medium
[0.6 ; 0.8[	Good
[0.8; 1]	Excellent

Table 17 – Fuzzy Sets

In a further step, we will analyse the SC's overall degree of sustainability. It is important to understand that the determination the three pillars' mean would engender compensation, so that it would not be possible anymore to see the concrete pillars' degree of sustainability. It would not be possible to find out what pillar needs to be corrected so that the overall degree of sustainability may be improved. For this reason, we still separate the sustainability's three inherent sub-topics, by calculating the average per pillar and per year, as shown in Table 18. The defined fuzzy rule set is given in Table 77, in Annexe 6.1.

Average	Economic	Ecologic	Societal
2010	0.6887	0.5971	0.6918
2011	0.6932	0.7060	0.6956
2012	0.7128	0.7755	0.7145
2013	0.7229	0.7567	0.7120

Table 18 – Calculated Averages: Degree of Sustainability per Year

Since we defined sustainability **S = ($Econ_{KPIi}$; $Ecol_{KPIi}$; Soc_{KPIi})**, this table needs to be read as follows:

- The degree of sustainability of 2010, S_{2010} = (0.6887; 0.5971; 0.6918)
- The degree of sustainability of 2011, S_{2011} = (0.6932; 0.7060; 0.6956)
- The degree of sustainability of 2012, S_{2012} = (0.7128; 0.7755; 0.7145)
- The degree of sustainability of 2013, S_{2013} = (0.7229; 0.7567; 0.7120)

While the average calculated for the ecologic and the societal performances are slightly higher in 2012 than in 2013, it is the exact opposite considering the one calculated for the economical pillar. Even though, the difference's amount is less than 0.01 regarding the societal issues, it is still existent. It is important to remind that all data have been normalised. In other words, **a difference of 0.001 of the average performance of a certain pillar might seem marginal and hence negligible, but one should keep in mind that this minor value in expressed in normalised terms hides an important value if considered as gross data.**

Nevertheless, the SC's overall degree of sustainability in **2010** is to be considered as **medium but close to good**. In fact, while the economical and the societal pillar reach values between 0.6 and 0.8, the ecological one only reaches 0.5971, which is close to 0.6. It is obvious that the ecological pillar needed to be corrected in order to get an improved overall degree sustainability. This has effectively been done in 2011. *De facto*, the ecological pillar has passed the 0.6 mark, while the economical and the ecological pillar have also been corrected, although marginally. In 2011, the SC's overall degree of sustainability passed to **good**. In **2012**, all three pillars have been enhanced, adding up respectively 0.0196, 0.0695 and 0.0189 points on the scale from 0 to 1. This amelioration was quite not sufficient to rise to an overall degree of sustainability being excellent, but it is to be seen as **good and closer to excellent.** Regrettably, this trend could not be hold in **2013**, when the ecological pillar attenuated by 0.0188, from 0.7755 to 0.7567 and the societal pillar decreased by 0.0025 from 0.7145 to 0.7120. Nevertheless, this is not dramatic, as the three pillars and accordingly, the overall degree of sustainability remain **good**, residing in the set [0.6 ; 0.8[. The Evaluation Model developed within this chapter provides the considered SC's degree of sustainability at a certain point in time.

Since we defined the degree of sustainability being located somewhere between the two extreme values (0, 0, 0) and (1, 1, 1), each calculated degree of sustainability can be found within a box, as presented in Figure 21 on page 39. The degree of sustainability per month can hence be shown in a three-dimensional network.

In Figure 38, the degrees of sustainability are shown on a monthly basis, whereas the years are separated by colours. We introduced larger spots to emphasise the different yearly average sustainability performance.

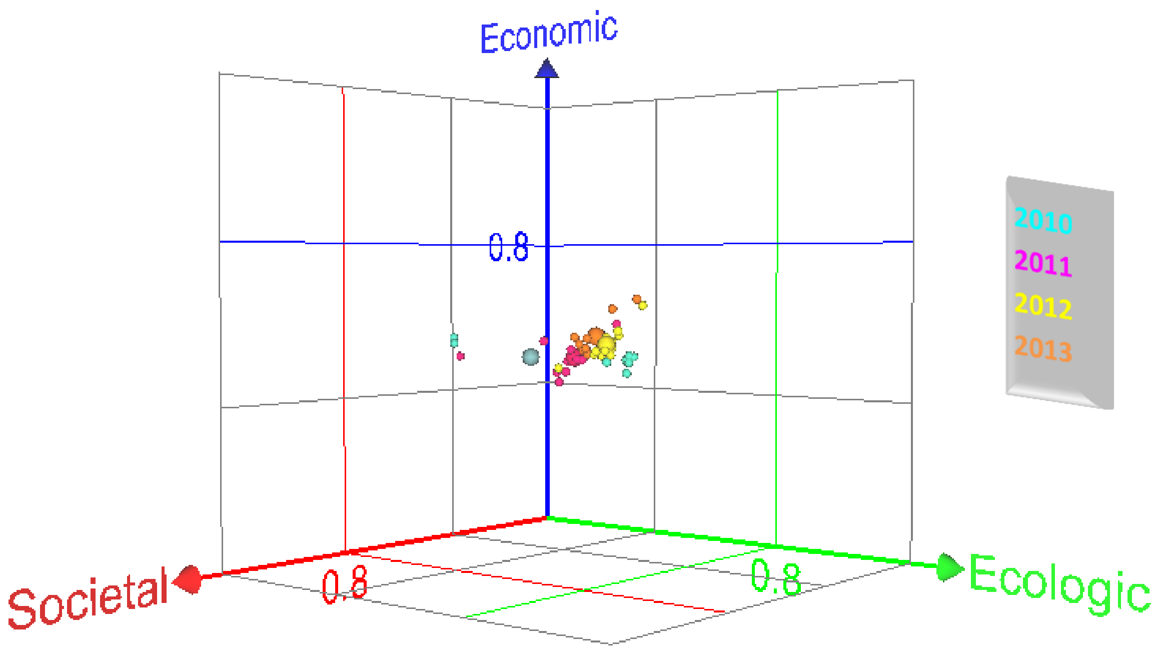


Figure 38 – Degree of Sustainability per Month: 2010 – 2013

Since the chart becomes unclear, when all different years are introduced, we suggest taking a look on the different years' results individually.

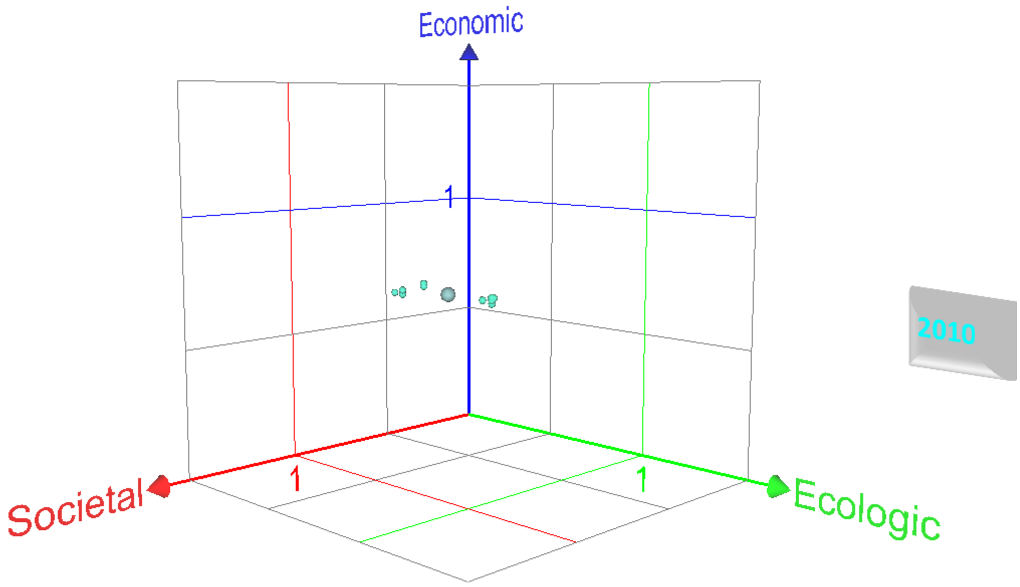


Figure 39 – Degree of Sustainability per Month: 2010

As discussed previously, the first semester of 2010 presented a rather acceptable ecologic performance which could not be held in the second one. As a consequence, the overall sustainability per month could not come closer to excellence, i.e. the upper extreme being [1, 1, 1] but descended and became closer to the negative extremum *videlicet* the point of origin [0, 0, 0]. A closer view on the sustainable performance of 2010 is given in Figure 39.

Since the degrees of sustainability of the first semester of 2011 are extremely close, it is difficult to identify them on the chart. Nevertheless, the problem concerning the ecologic pillar which has just been outlined is still apparent. In 2011, the situation has been, as can be seen on Figure 30. There are only few outliers, while most of the months present degrees of sustainability being close to the average of the year (represented by the bigger dot).

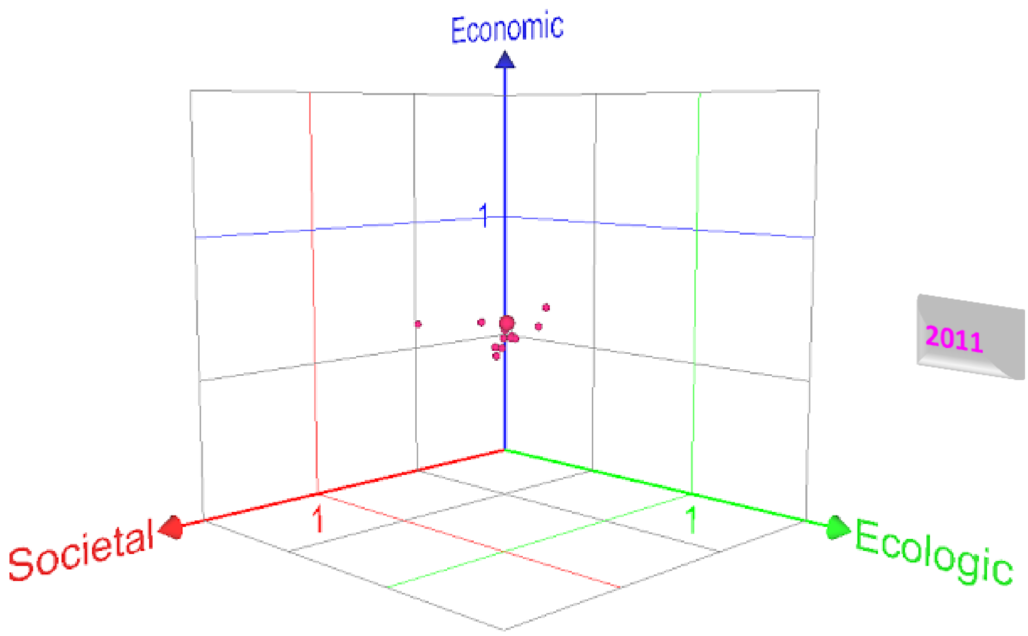


Figure 40 – Degree of Sustainability per Month: 2011

In 2012, the degree of sustainability has been enhanced marginally and stabilised. In fact, only two outliers can be perceived in 2012, while all the other calculated degrees of sustainability are close to their mean value, as it can be appraised in Figure 41. The SC's overall degree of sustainability has in fact been improved via the enhancement of each of the three pillars.

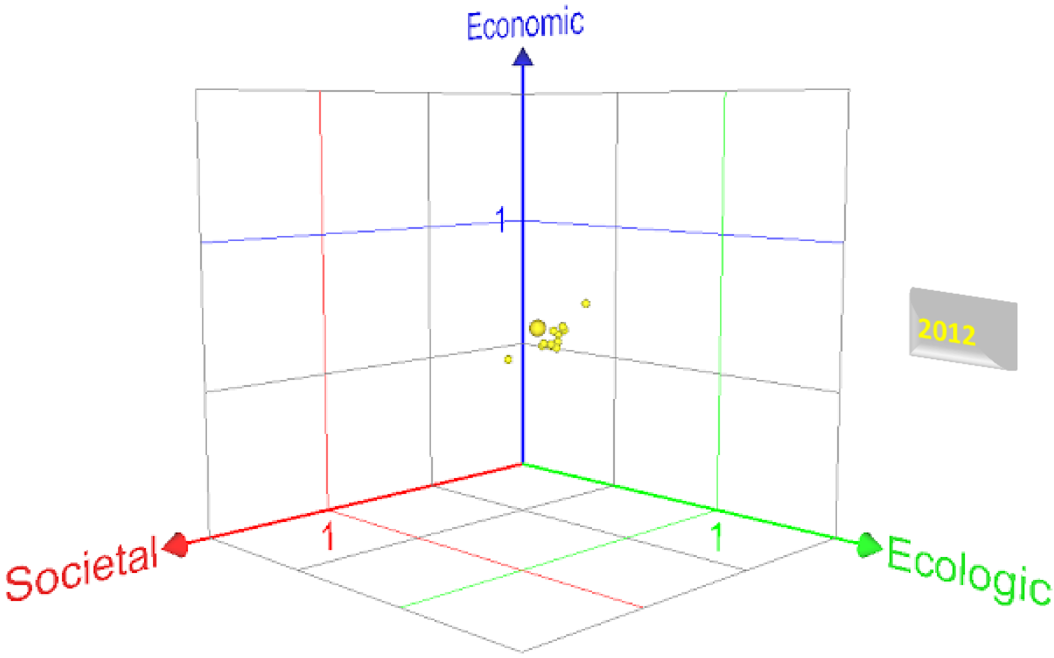


Figure 41 – Degree of Sustainability per Month: 2012

In 2013, the degree of sustainability was still stable, even though the economical and the societal pillars have marginally decreased. As described previously, the overall degree of sustainability is still good. In addition, Figure 42 shows two outliers, which are highly positive since they are the closest to the optimum being [1; 1; 1].

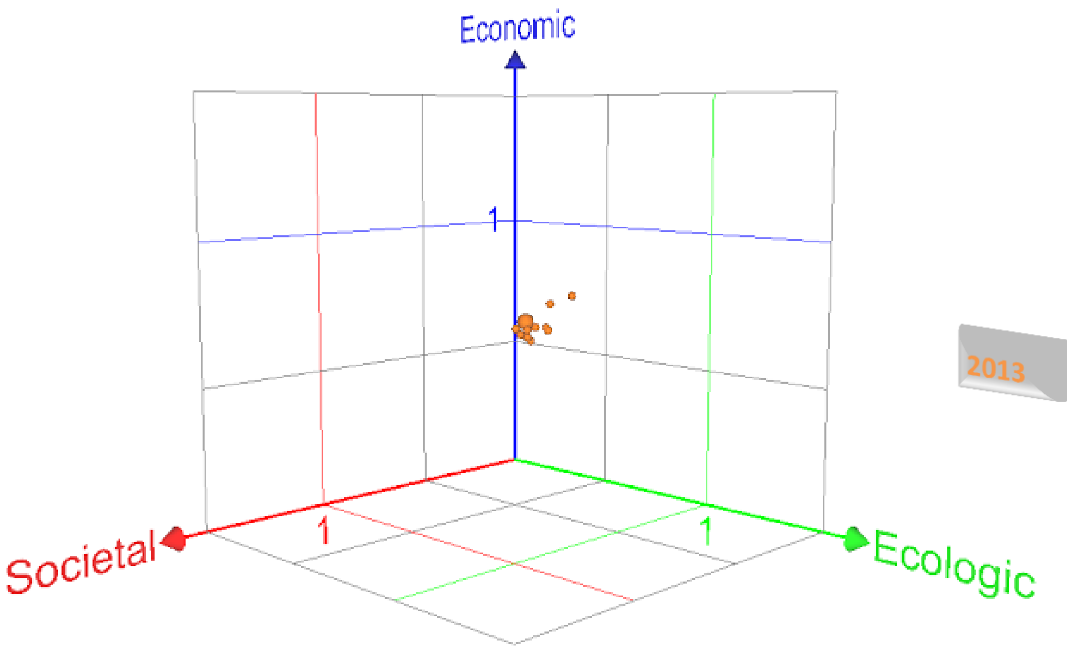


Figure 42 – Degree of Sustainability per Month: 2013

Through Figure 43 and Figure 44, it becomes obvious that the average degree of sustainability of 2010 is lower than the ones of the other considered years. Moreover, it becomes apparent that in 2011 the main reason for the increase of sustainability is the consequence of a better ecological performance, while in 2013 the improvement is mainly due to the economical pillar.

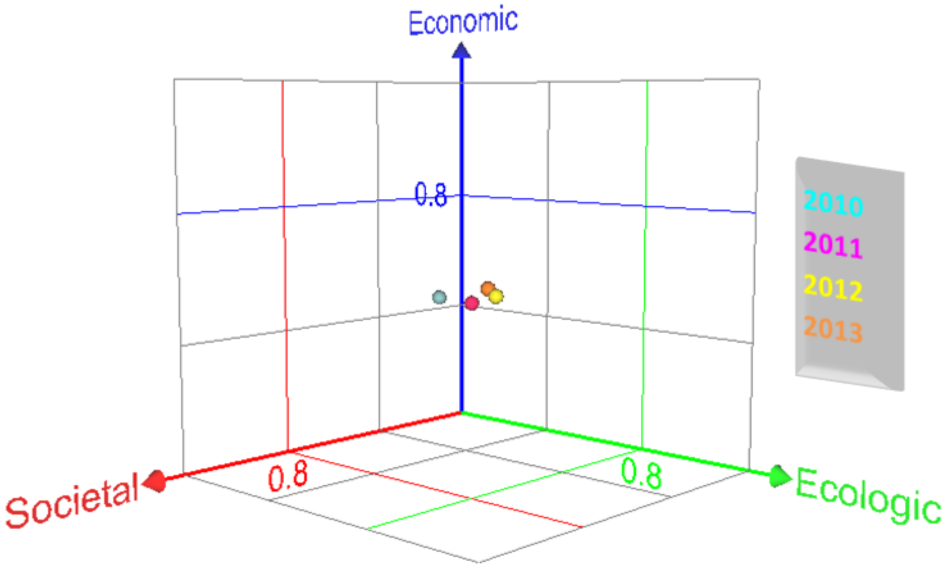


Figure 43 – Average Degree of Sustainability per Year I

Viewed from another angle, as shown in Figure 44, it is still difficult to determine the highest average degree of sustainability of the considered time frame. Indeed, while the calculated average of 2013 seems being higher at a first glance, it is nevertheless not as close to ecological excellence as the one calculated in 2012.

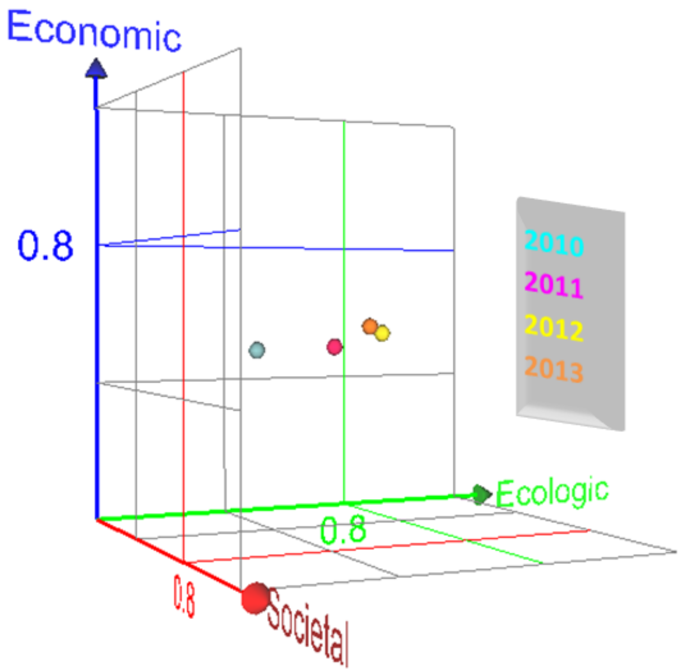


Figure 44 – Average Degree of Sustainability per Year II

Since business people usually work with average values, most managers would prefer to calculate the average of the three pillars, as shown in Table 19. They would then classify the results according to the fuzzy sets.

	Economic	Ecologic	Societal	Average – compiled
2010	0.6887	0.5971	0.6918	0.6592
2011	0.6932	0.7060	0.6956	0.6983
2012	0.7128	0.7755	0.7145	0.7343
2013	0.7229	0.7567	0.7120	0.7305

Table 19 – Degree of Sustainability: Overall Averages

By calculating the compiled average, as shown in Table 19, it becomes obvious that the results have been falsified. In fact, while the overall degree of sustainability of 2010 has been defined being medium but close to good according to the fuzzy sets defined above, the compiled average would declare this degree being good.

In an academic point of view, this approach cannot be accepted as the average value might be a compensation of excellent results in one pillar, and poor outcomes in another one. For this reason, it is preferable to take a closer look to the values based on the Cartesian logic, i.e. taking into account the different pillars in a three-dimensional reasoning.

2.6 Conclusion

In the present chapter, we provided a definition of sustainability based on the approaches provided by Elkington (1997) and Brundtland (1897). In a subsequent step, we developed a model to evaluate a SC's degree of sustainability at a certain point in time. This model is based on the three pillars of sustainability to which we assigned 13 indicators. The models' input data consist of either objective or qualitative data. Managers may be confused by the fact of using subjective data, but this subjectivity can be alleviated through the use of many different experts' opinions. The application of the AHP methodology helps companies to weigh the different indicators deployed within this model. It is important to emphasise that the KPI's weightings need to be the same within a given domain so that comparability can be guaranteed.

Since managers usually work with average values, they tend to calculate the overall average of the three pillars' degrees of sustainability and try this result by using the predefined fuzzy sets. Nevertheless, we proved that this approach would falsify the model's end result. We therefore conclude in considering the three pillars individually and to apply the fuzzy sets on each pillar. The resulting linguistic degrees of sustainability per pillar can then be analysed via the application of the fuzzy rules. One positive side effect of this method is that it can be seen at the first glance which pillar the company needs to improve, so that a better overall degree of sustainability may be achieved.

In the business environment, the next logical step is the improvement of the current As – Is situation, followed the redesign of the latter. For this reason, it becomes of utmost importance to understand what design exactly means and which risks the company might have to face.

Risk Assessment towards a Redesign Process

As explained in the prior chapter, 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*.

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 the previous chapter, we evaluated 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. Therefore, a new risk assessment approach will be set up.

The research questions which emerge are:

- How to **define design**?
- How to **define risk** and what are its **different concepts**?
- What are the inherent **risks of re-designing** a SC?
- What is to be understood by **risk assessment** in the matters of **sustainability**?

To answer those questions, we will define the main key words through literature review and set up a tool to assess the risks emerging from a SC's re-design, intended to improve its actual degree of sustainability.

Up until now, Kuehne + Nagel has not implemented a general risk assessment model yet. If a customer requires risk estimations within his project, a new tailored model will be implemented, i.e. there are many different models considering the risks which may appear within a SC. A general model which could slightly be modified to suit to the specific customers' needs does not exist yet. To save time without suffering from losses in terms of quality or customers' satisfaction, a general model needs thus to be implemented. In addition, since Kuehne + Nagel has not considered sustainability as defined within this work, it is evident that a risk assessment model considering the risks related to the overall degree of sustainability has not been implemented yet. In this sense, the added value provided by this chapter 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. This alternation will be further discussed in section 0. To introduce the model, as depicted in Figure 45, we will first discuss some relevant quantitative, qualitative, and hybrid risk assessment methodologies, and subsequently discuss their applicability for our purpose.

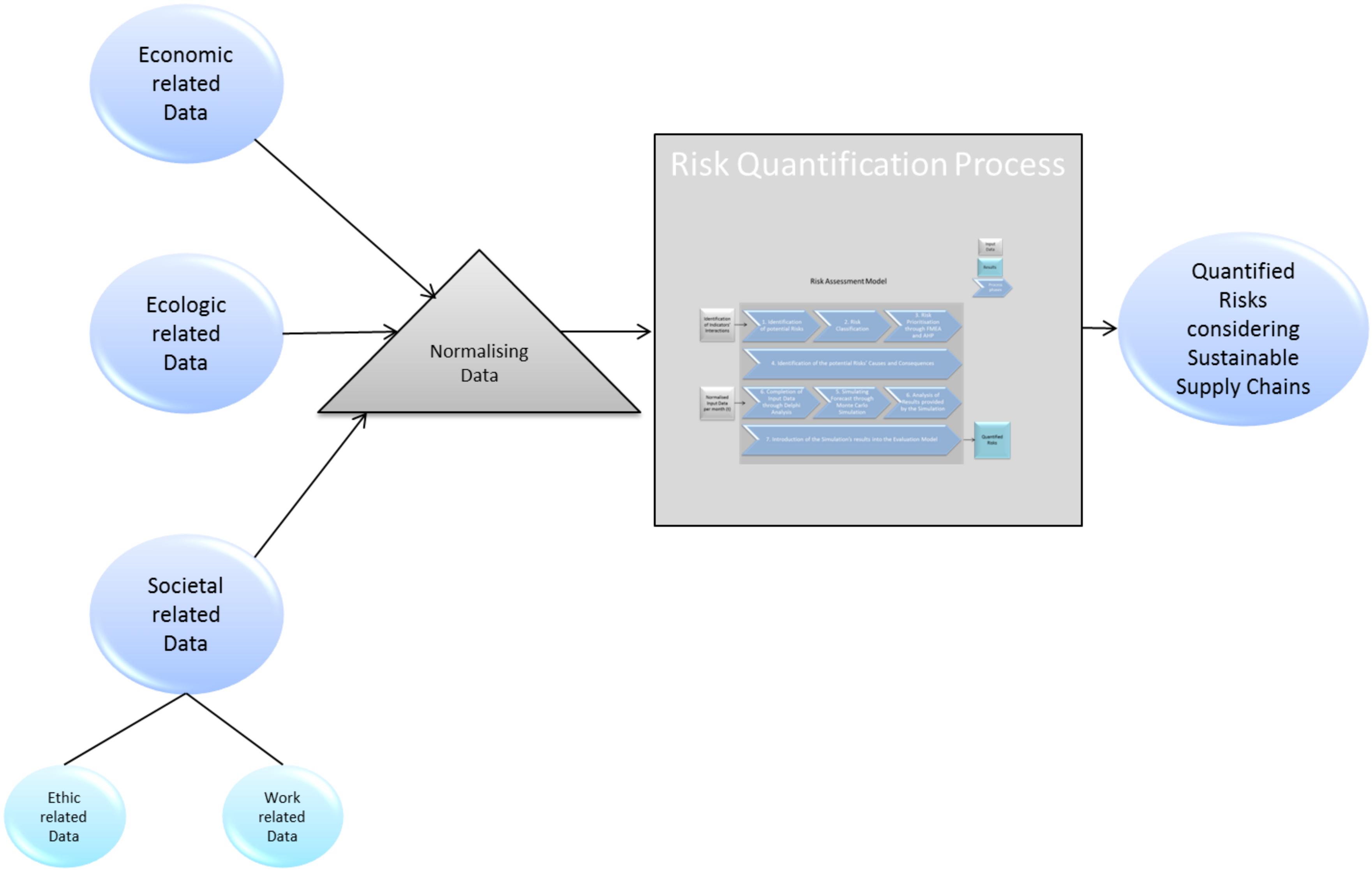


Figure 45 – Risk Quantification Model (Black Box)

3.1 TOWARDS THE DEFINITION OF DESIGN

Most people think about the design of arts, architectural design, IT systems design, games design or fashion design, what has also been discovered by Maier & Fadel (2009). Nevertheless, each and every product, service or system needs to be designed so that it may be implemented and launched to the market. In addition, the considered product, service or system has to be improved and hence, to be "re-designed" afterwards. This re-design phase consists in determining human needs so that a design solution can be found to the previously defined problem via creativity, scientific principles and technical knowledge (Simon, 2008). In managers' daily business, the cradle-to-grave approach is generally accepted: The improvement or "re-design" phase will be repeated until the product, service or system is taken from the market.

Nevertheless, one fundamental question arises: **What is actually meant by 'design'?**

3.1.1 Understanding the Design Concept

The literature does not yield a perfect definition or one single model explaining what design is exactly about. Zhang et al. (2012) explain that *'researchers agree that it is a process, but disagree on what kind of process it is. Some have considered it as a rational problem-solving process, others as a reflective process, and still others as an evolving process between knowledge and concept'*. Miller (2004) defines design being "*the thought process comprising the creation of an entity",* whereas this entity may be of physical (objects), temporal (events), conceptual (ideas), or relational (interaction between entities) concerns. In other words, design is the process used to create this entity which may be palpable or not (Miller, 2004). In the same logic, Gero & Kannengiesser (2004) assert design being a result-oriented, decision-making, exploration and learning activity operating in a situation which depends on the perception of the concerned designer. The outcome of this situation will be the description of a future engineering system. Design is to be seen as an activity of creation, consisting of a sequence of deliberations and various activities such as reasoning, writing, drawing, modelling, making conversations, *et cetera.* Zhang (2014) and Miller (2004) agree on the fact that the nature of the design process, which is frequently understood being a linear sequence of events, is actually a highly complex and versatile set of ideas and thoughts. Nevertheless, it must be emphasised that systems, subsystems and details, which may be considered being the first outputs of design, often need to be examined in a synchronous manner, resulting in a change of the original big picture of potential solutions. Miller (2004) elucidates that the importance of this change "*[consists of] a natural part of the maturation process and that the successful completion of this process, which often begins as a mere figment of our imagination, culminates as sensible reality in time and space."* Further, he exemplifies that without creation, the process of designing is either incomplete or unreasonable (Miller, 2004). Each design process needs hence to include its own sequence of creation.

In spite of those perceptions and findings, a crucial question still remains in a natural manner: **What does 'Design' exactly means?' and 'What is meant by design in a logistics perspective?'**

3.1.2 Defining Design

As discussed, various interpretations have been discovered during the literature review. The fact that there is a myriad of different definitions of design, as already stated by Zhang (2014), means that there is no agreement to the question of how to define the keyword "Design". Nevertheless, most aspects are particularly appealing when seen in relation to this work. For instance, the fact of seeing design as a process including constraints, knowledge and transformation seems being of particular interest for this work. In addition, it is of great importance to define "Design" in a way that fits to all the different domains. We base our definition of **design** on (Zhang, 2014):

> **Design should be seen as a process of thinking, whereas in a first step, a need or dissatisfaction should be identified. This need or dissatisfaction should be translated into a KPI dashboard, and its' associated functions, so that the current state of the art can be improved. To do so, the designers' technical and scientific knowledge is required since they need to solve potential subjects of constraints and limitations.**

Through the growth of industrial societies, the ability to design has been considered as a specialised skill (Cross, 2000). The identification of the current state of the art may be the very first step of an entity's creation, in which the respective entity may be an object, an event, a system, or a relation (Miller, 2004). In other words, the improvement of the current state of the art may consist of the design of a very new entity. The design process can be illustrated as follows on Figure 46.

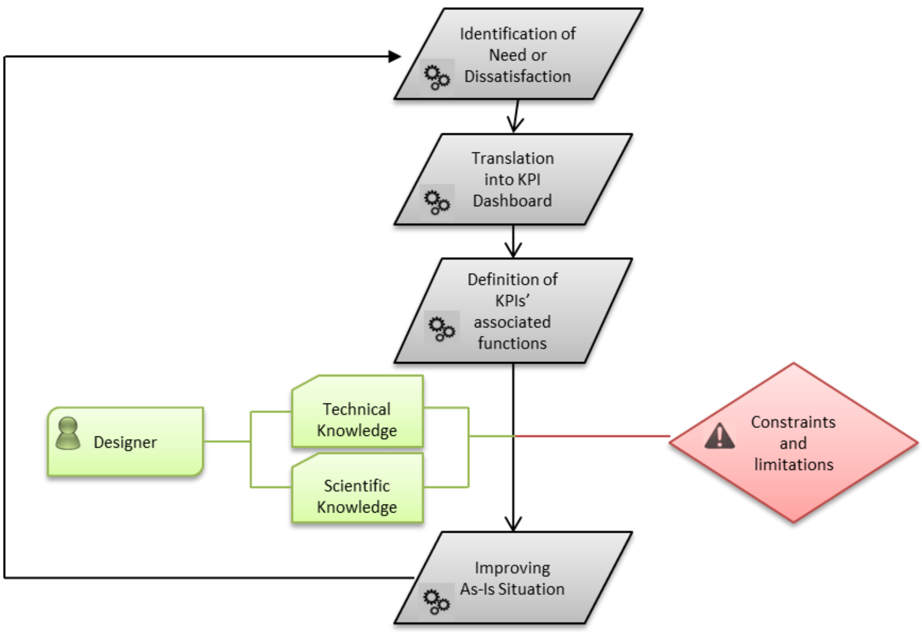


Figure 46 – Design Process

3.1.3 Design in a Logistics Perspective

Bossel & International Institute for Sustainable Development (1999) defined several categories of systems. According to them, a SC is a "*non-isolated system*". Slats et al. (1995) explained that a logistic chain may be seen as *"a system whose constituent parts include suppliers of materials, production facilities, distribution services and customers, all linked together via the feed-forward flow of materials and the feed-back flow of information"*. In section 1.1.3 we explained that a SC may be seen as a complex system including a multitude of sub-systems. This system may change during the elaboration of the design processes. The aim of every SC is to procure raw materials, which are converted into finished goods; the latter are then distributed to the customers so that they can fulfil their orders. Since companies want to improve their production efficiency and their products' quality, they usually adopt a wider approach, beyond their boundaries, and consider the design and re-design of their entire SC (Baiman et al., 2001). Based on well-performed SC (re-)design, and because of an adoption of a wider perspective Benetton (Chopra & Sodhi, 2004), Hewlett Packard (Lee, 1993; Lee & Billington, 1995), Toyota (Federgruen, 1993) and Chrysler (Fine, 2000) have recorded real success stories.

A SC needs to be continuously modified due to a perpetual changing logistics environment and customers' increased performance expectations (Andersson & Rudberg, 2007; Skintzi, 2007). On the other hand, and with the same argument, a SC changes its system structure to adapt itself in a Schumpeterian logic to changes occurring in its respective environment; i.e. they adapt to external changes just like plants, animals or ecosystems do (Nelson & Winter, 2004). This can be seen as a natural adjustment process and in this regard, a SC could be categorised being a "Self-Organising System", whereas this self-organisation is due to SC design. Because of the aforementioned perpetual changes, SC managers need to innovate and to reassess and to redesign their existent working methodologies and strategies. The re-design of a SC can be done at three different tiers, which are:

1. The short term tier, considering the operational level involving production scheduling on an hour-to-hour basis
2. The mid-term tier, which can be considered being the tactical level, considers the basic supply planning: this planning normally considers the monthly improvement of products' and services' flows of a given SC network
3. The long term tier, which is typically performed once every few years, for example when the concerned company needs to expand its capabilities.

Design on a strategic level consists in formulating the SC via a decision making processes. Those decisions concern the size and location of the company, as well as the ideal number of suppliers, distributors and plants to be applied. Companies can be confronted to location and design problems in diverse situations: managers can decide to expand some of the company's activities to new geographical areas or to merger two companies. Furthermore, the capacity limits of a given facility may be reached or a facility may become obsolete. Another reason for such long term design decisions may be customers' decreasing demand for the considered product (Thanh et al., 2008). To rephrase, every nodes and flows of the considered SC as well as its different inherent relationships and alliances are defined on a strategic level. It is important to understand that the design of a SC includes a myriad of decisions. Meixell & Gargeya (2005) and Chopra & Meindl (2007) explain that a SC design problem embrace many decisions, affecting the number and location of fabrication facilities, the amount of capacity at each facility, the selection of each market to one or more locations, as well as the supplier selection for semi-finished products, single parts, and materials.

According to Chopra & Meindl (2007), the terms 'network design' and 'supply chain design' have been used as synonyms of strategic supply chain planning. Graves & Willems (2003) grouped those decisions into three categories:

i. Traditional design decisions
ii. Product and process design decisions
iii. Decisions which allow responsiveness to variability and risks or uncertainties

Each decision tier has its own models and solving procedures. A decision at a certain level may become either a requirement which has to be satisfied or a lower level's aim which should be achieved. According to Schmidt and Wilhelm (2000) and Vidal and Goetschalckx (1997), most books or journal papers on logistics and production management point out these considerations.

In the case of logistics, the entity to be created is well known in advance. The possible constraints and limitations may therefore be anticipated in a relatively precise manner. Nonetheless, this does not mean that the potential inherent risks are known in advance. In fact, constraints like the used vehicle's maximum payload or the considered warehouse's maximum storage capacity are well known in advance, while risks like eventual border closings due to the actual refugee crisis, resulting in increased lead-times and inflated costs can only be considered through assumptions. We therefore define **Design in a logistics perspective** as:

A design process intended to implement a new SC or to improve an existing one. To do so, the designers' technical and scientific knowledge are required to translate the existent needs into a KPI dashboard and its associated functions while keeping an eye on emerging risks, constraints and limitations

3.1.4 Design Procedures' Right to Exist in Companies

Geoffrion and Powers (1995) stated that *"The corporate status of logistics has changed dramatically during the last two decades. Within many companies, it has gone from a neglected and disdained function to a highly visible one respected for its profit impact and key strategic role"*. Logisticians and logistics executives generally agree that questions like "How many stocking points should be implemented, and where exactly should they be located?"', or "Where should the factories be located?", as well as "Which customers should by served by which stocking point?" cover the most important strategic logistical challenges (Geoffrion & Powers, 1995).

Foo et al. (1990) focused on the product design from a materials logistics point of view by using a conceptual methodology. They state that the ideal product should have a minimum number of possible inherent parts, standard or "preferred" parts, and a modular and reusable physical architecture. In addition, the ideal product should present a limited set of end item configurations, as well as a modular bill-of-materials (BOM) structure (Foo et al., 1990). In their work, Germain et al. (1994) examined the relationship between logistics technology adoption and organisational design practices. In addition, they discussed 36 logistics technologies used by several organisations. Fawcett & Closs (1993) discussed the findings of their analytic examination of the interrelationship between company's perceptions of economic globalisation, its emphasis of logistics and manufacturing considerations in the design and management of global manufacturing networks, and its competitive and financial performance. Vidal & Goetschalckx (1997) presented an extensive literature review of strategic production-distribution models, basing their research on mixed integer programming (MIP) models.

Industrial engineers are the ideal professionals to design and integrate logistics, transportation and distribution systems (Petersen, 1993). Logistics and SCM need to be considered as an international business venture. Some authors focused on the managerial approaches for global SC design. Kogut (1985) argued the importance of flexibility in global corporations as a riposte to fluctuations in exchange rates and complexities in competitive proceedings. In addition to this, the process of designing an inclusive logistics model may be seen as one of the main benefits as companies are forced to define and to precisely understand their logistics principles and functions. One typical side effect is the cost reductions, which may pass from 5 to 15% (Geoffrion and Powers, 1995). In this same logic, Goetschalckx et al. (2002) examined a company's savings potential generated by the incorporation of strategic global SC networks' design, including the determination of tactical production-distribution allocations and transfer prices. To do so, they elaborated two different models. While the first model is based on a bilinear programming formulation, the latter is based on primal decomposition methods for the mixed integer programming conception. However, both models are supposed to generate and discover the optimal solution. However, because of different reasons like time constraints or the scarcity of expertise in research matters, most companies need to operate with the satisficing principle described by Simon (2008).

One of the most intelligible strategic problems an LSP has to face is the optimisation of an entire SC. The strategic design of a SC requires managers to decide on the number, location, capacity, and type of production plants (Vidal & Goetschalckx, 1997). Immediate logistics questions should be answered directly and consistent manner, and should therefore be based on the strategic logistics plans of the company. However, managers do often react in a spontaneous manner, based on 'intuitive' knowledge instead of leading systematic investigations including 'what-if-scenarios' before giving answers to these questions (Goetschalckx et al., 2002). Duties and taxes have also significant impacts on international distribution models (Geoffrion and Powers, 1995).To improve production efficiency and the products' quality, companies often adopt a wider perspective and consider the design and redesign of their entire supply chain (Baiman et al., 2001).

Internal discussions with senior managers and several experts[31] yielded that customers have different reasons for claiming a redesign of their SCs. It is important to understand that a simple change in a SC does not necessarily consist in a redesign of the considered SC. It can be assumed that the reasons of why to redesign an existent SC do not change according to the considered domain but according to the customer and that one reason for redesigning a SC may appear more often in one domain than in another one. The aforementioned discussions also yield that the difference between a simple change and a redesign consists in the fact that redesign has a strategic background. As for

[31] Those experts work in the Integrated Logistics (IL) department within Kuehne + Nagel and have not been questioned within the case study of chapter 2.

example, the creation of additional employments is a change which is not always influenced by strategic reasoning. A redesign however, is mostly preceded by strategic choices such as new commercialisation strategies, reorganisation or merger of the company, change of the procurement policies, and so on. Hence, the fact of distributing a product via a retailer B instead of a retailer A is to be considered as a change, while the fact of changing the retailing strategy is to be seen as a redesign. This is the case if, for example, a product has always been distributed via retailers and will now be sold via e-commerce. Changing the procurement policies does not mean that a supplier will simply be replaced by another one, while this may result from the new procurement policies.

To complete the above literature review, semi-structured interviews have been conducted with a group of 14 Kuehne + Nagel internal experts, working in the IL (Integrated Logistics) department. In addition, we examined the Network and Supply Chain Engineering (NSCE) project database, including every project served by this department during the timeframe of 2007 to 2016. We analysed the database's inherent 782 re-design projects, which have been completed between 2008 and 2015. The 15 most important key-drivers leading to a re-design of the SC have been determined. Effectively, those 15 key-drivers, which are listed in Table 20, constitute almost 75% out of the total amount of identified levers for action.

1.	The company wants to reduce the costs
2.	The company wants to identify and understand eventual synergies
3.	The company wants to improve its inherent structures' & performances' transparency
4.	The company is running out of space
5.	The company wants to reconfirm its centre of gravities (COGs)
6.	The SC needs to be adapted to new sales or market requirements
7.	Lead-times need to be reduced
8.	The (upstream) suppliers will be changed
9.	The company merges with a competitor
10.	A new product will be launched
11.	The product allocation will be shifted
12.	One or several activities will be outsourced
13.	The market grows in a specific region
14.	The company wants to evaluate its SCs
15.	New production facilities have been implemented

Table 20 – Sub-drivers for redesigning a Supply Chain

All companies require a certain level of internal transparency and visibility. To improve the overall transparency of the SC, it needs to be evaluated and re-designed, if applicable. The company may need to reorganise its whole structure, resulting in a process of redesigning existing SCs. As from the moment a certain level of transparency is achieved, the company can try to reduce its costs, such as inventory costs, logistical costs, or overall costs, to name just a few. Furthermore, if the company's lease is ending or if the company is running out of space, managers need to re-examine the SC's structure as well as the different plants and storage locations. The existing stock can thus be verified and the answer to the question "How logical is the current situation?" can be given. If the firm's capacity is reached, the need to expand increases and may result in reconfirming the centres of gravity (COG) or even in reviewing the entire SC. In addition, the company needs to readapt its SC to new sales or market requirements, such as reduced lead-times. One impetus behind lead-time reduction is for example that the enterprise has reliability issues, affecting customers' satisfaction in a negative way. In such a case, a redefinition of a COG or a change of suppliers might be appropriate. It is evident that these changes require a SC redesign. Another occasion to conduct a company to readjustment its SC is that the considered firm may have taken over a competitor. This has often big impacts on the existing SCs which need to be reviewed and to undergo radical changes. Inbound and outbound flows, storage capacities, information flows as well as distribution of demand are affected in such cases. COGs need to be (re-) defined which often have repercussions on the different flows, production and storage capacities, etc. This holds also true if a new product has been introduced, a product allocation changed, or if one or several activities have been outsourced. In case of merger, a company may temporise such big changes so that the current structure may be kept. The impact of merger is to be minimised, but a redesign is often eminent due to capacity issues. A similar explanation of why to reorganise an existing SC is a market's growth in a specific region. This often leads to difficulties with performance, costs, and lead times. The supply lanes to these markets are put under pressure which may also endanger existing markets and new production facilities may need to be implemented. Multi-stage models for supply chain design and analysis can, according to Beamon (1998), ordinarily be separated into four categories, namely:

1. Deterministic analytical models with known and specified variables,
2. Stochastic analytical models having at least one unknown variable which is assumed to follow a particular probability distribution,
3. Economic models
4. Simulation models

The reasons why customers want to redesign their SCs may differ enormously. After all, the question of **how a SC can be redesigned** then arises.

3.1.5 Conclusion

The keyword design can be defined in many different ways. To contemplate it from the angle of logistics, we defined it as a process of thinking, which is initiated by the identification of a need or dissatisfaction and which adheres to technical and scientific knowledge so that the potential subjects of constraints and limitations can be solved. Regardless of the matter to be designed or redesigned, this is to say, regardless if the (re-)design process considers tangible products or intangible services, we agree with Zwolinski & Brissaud (2008) that the redesigning approach may be "*very promising sustainable end-of-life strategies for the future of a sustainable world*".

The issues affecting the SCs are changing much faster than decades ago. The different SC's indicators need therefore to be monitored on a much more regular base than in former times. SC managers need to be more flexible and responsive to redesigning the different networks they are responsible of. They need to operate at the lowest costs possible and, simultaneously, they need to provide the best service quality to their customers so that the customers' loyalty can be assured. Additionally, customers may have many different reasons for claiming their SC to be redesigned, and those reasons are by far not just of financial matters, since the second tier and end-customers' requirements changed over time.

Every design and re-design includes risks, which need to be assessed *a priori*. In the following, we will discuss those risks as well as their evaluation. The aforementioned question of how a SC can be redesigned will not be answered within this work, since this would go beyond the scope of this study. Nevertheless, giving response to this question via subsequent studies is seen as required.

3.2 DESIGN DECISIONS ALLOWING RESPONSIVENESS TO UNCERTAINTIES AND RISKS

Designing a SC goes hand in hand with taking a wide range of decisions. As stated above, Graves & Willems (2003) grouped SC design decisions in three categories, namely [1] traditional design decisions, [2] product and process design decisions, and [3] design decisions allowing responsiveness to uncertainty and risks. The traditional design decisions concern foremost the characteristics of the facilities of each SC node, as well as the number, location and sizing of the plants and equipment, and the interrelations between the different SC nodes, i.e. the product flows and transport modes. The product and process design decisions' aim is to interface the market objectives with the SC performance. The design decisions which are intended to lead a SC being responsive to uncertainty and risks concern *inter alia* the SC managers' potential of being flexible, responsive and capable to solve issues. In accordance to our definition given of design in a logistics perspective, we will, for the purpose of this study, focus on the third category of design decisions, namely **the design decisions allowing responsiveness to uncertainty and risks**. Effectively, the traditional design decisions (Roozenburg & Eekels, 1995; Zhang, 2014), as well as the product and process design decisions (Von Stamm, 2004, 2008; Zhang, 2014) have to a great extend been analysed.

3.2.1 Risk Management in the Logistics' Environment

Nowadays, globalisation and severe competition lead to strong movements in industry. This results in highly customer-specific products, shorter lead times, and higher quality of products and services, as well as to fast technological progress and increased uncertainties and risks. Severe competition is often translated to highly volatile markets, short product life cycles and increased customers' requirements. In this context, the notion of postponement has highly attracted attention since the 1950's, when it has been introduced as an approach to reduce uncertainty and costs in managing operations (Lusch, 2006; Wooliscroft, 2006). Supply chains, which formerly have functioned in a rather autonomous way, now face many dangers in both the global and the domestic market (Dittmann, 2014).

As the risk related terminology varies from one company to another (Kelliher et al., 2013), confusion may be caused. This is probably due to the fact that risk and uncertainty have been used as synonyms in some academic researches (Oeser, 2012), while others explain the interleaving between these two keywords. **The question arises whether the inherent concepts of risk and uncertainty are identical, or not?**

Concepts of Risk

One of the earliest examples of decreasing organisational vulnerability via judicious procurements is given in the old testament of the bible (Froot et al., 1994). This is to show that risk and its' management is neither a new nor a modern concept. In fact, every human being actually encounters and manages risks on a daily basis in his personal and professional life. The meaning of risk has however changed enormously over time. "*The idea of risk originated in the mathematics associated with gambling in the seventeenth century. Risk referred to probability combined with the magnitude of potential gains or losses. In the eighteenth century, the idea of risk as a neutral concept, taking account of both gains and losses, was employed in the marine insurance business. In the nineteenth century, ideas of risk emerged in the study of economics. The twentieth century has seen the concept of risk move on to refer only to negative outcomes in engineering and science, with particular reference to the hazards posed by modern technological developments in the offshore, petro-chemical and nuclear industries"* (Frosdick, 1997). Nowadays, people and companies prospect for scientific and reliable methodologies to identify and manage risks. Business environments have changed in a considerable manner and thus globalisation of markets and extended competitive pressures may be observed these days (Harland et al. 2003; Wagner & Bode, 2009) and today's companies and LSPs have more than ever to face various risks while handling their SCs (Kleindorfer & Saad, 2005; Tang, 2006), since the companies activities became more complex than decades ago.

In Simon et al.'s (1997) point of view, a risk can be defined being the likelihood of the occurrence of an uncertain set of circumstances or an uncertain event that would have disadvantageous effects on the accomplishment of a project's targets. According to Mitchell (1999), a risk may be seen as the subjectively determined expectation of loss, while Rowe (1980) explained that risk should be defined as *"the potential for realizing unwanted negative consequences from causal events".* In the same way, Miller (1992) explains that risk is related to the variance in performance or outcomes that cannot be forecasted ex-ante, while Harland et al. (2003) define risk being *"a chance of danger, damage, loss, injury or any other undesired consequence"*. Referring to March and Shapira (1987), risk relates to inimical variations in business outcome variables like costs or revenues, while Lowrance (1980) stated that risk should be seen as a measure of the probability and the severity of unfavourable effects. In the same logic and in Chiles & McMackin's (1996) words, the keyword 'risk' refers to the possibility of loss. In financial writings, the concepts of 'yield' and 'risk' appear very often. *"Usually if the term 'yield' were replaced by 'expected yield' or 'expected return', and 'risk' by 'variance of return', little change of apparent meaning would result'* (Markowitz, 1952).

According to Wildavsky & Dake (1990), risks contain cultural bias which best predict risk perception findings. This statement has been elaborated by Frosdick (1997), explaining that "*risk blindness may occur because the analyst's cultural bias prevents him identifying the risk simply because he either cannot see it or considers it inherently acceptable".* This same ascertainment has also been made by several managers within Kuehne + Nagel Luxembourg. The Royal Society (1992) has obviously the same view arguing that risk is socially constructed and has various means to different people in distinct contexts, but they also admitted that many engineers and scientists tend to regard risk as an objective matter by trying to quantify and manage it. Many tools have been developed for quantifying and managing risks, such as the Failure Mode and Effect Analysis (FMEA), the Cost Benefit Analysis (CBA), or the Risk Benefit Analysis (RBA). Those methods are accepted by many managers but are, nevertheless, severely criticised as the elements of human judgments have been replaced by assumptions with mathematical formulas (White, 1995). If a risk has to be seen as objective or subjective is not a matter of this work, while the different methodologies used to measure and manage them will be discussed on a later stage.

According to Wagner & Bode (2008) 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. Zsidisin (2008) 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'*". Wagner & Bode (2009) 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, Ouabouch & Amri (2013) 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"* (Gaudenzi & Borghesi, 2006).

Moore (1983) emphasised that risk comprises the possibility of a loss as well as the hope of a gain. Hence, the negative connotation of risk, as understood by most entrepreneurs (Hood & Young, 2005; March & Shapira, 1987) is not necessarily adopted by every researcher. The negative connotation of risk is in particular present in large engineering projects, where the consequences of failure can have an enormous magnitude (Frosdick, 1997), such as in Pharma SCs. Knight (2012) separated measurable and non-measurable uncertainty, whereas measurable uncertainty can be understood as risk. Thus, while risk is measurable via probabilities and estimations, the probabilities of uncertainties' outcomes are completely unknown. Yates & Stone (1992), in contrast, explain that any anticipation of risk needs a certain degree of uncertainty concerning the prospective outcomes. They argue that if the probability of the concerned outcomes is known, there is no risk, whereas Slack & Lewis (2001) deem both arguments correct: In their work, uncertainty is seen as a key-driver of risk. Nevertheless, they admit that risks may be minimised through prevention, mitigation and recovery strategies, whilst uncertainty may not be purged. In other words, uncertainty can be seen as immeasurable, whereas risk is understood being measurable as well as manageable.

Because of the myriad of different definitions given for "Risks", there have been many diverse views and analysis of the latter. Zsidisin et al. (2000) analyse risk in the perspective of procurement and supply, whereas others focus on purchasing strategy selection (Aliahmadi et al., 2006). On the other hand, Cousins et al., (2004) have analysed strategic risks by emphasising environmental risks. Noruzi (2010) amplifies the notion of risk in combination with trust, explaining that trust is to be seen as a risky commitment since there is a risk of betrayal. This breach of confidence may be alleviated due to non-disclosure agreements, sanctions, and legal regulations, but they still remain latent. Although, risk may be analysed in many different manners, Manuj & Mentzer (2008) explain that the risk assessment and its following prioritisation are usually based on two components, namely (1) the consequences or potential losses in the event of the analysed risks have materialised, and (2) the probability of occurrence of this materialisation.

The underlying concepts of the term risk are hard to define and to assess, even though it is frequently used and easily understood in everyday language. The reason for the widespread, miscellaneous and at times contradictory definitions of risk can be sourced to the evolving change of its nature, its meaning, and its intended application (Heckmann et al., 2015). In his work, Taleb (2007) used the metaphor of the black swan to describe an event that is threefold. The considered event is in fact [1] an outlier, [2] has an extreme impact, and [3] can only be predicted *ex-ante*, i.e. holding a retrospective but not a prospective predictability. He highlights that if one would ask a portfolio manager for his definition of 'risk', the latter would provide *"a measure that excludes the possibility of the Black Swan – hence one that has no better predictive value for assessing the total risks than astrology"* (Taleb, 2007). In other words, the Black Swan Theory makes the unknowns far more relevant than the knowns, raising the complexity of the subject matter of risk to a new level.

In a socioeconomic context, the future cannot be known since it is still to be created (Dequech, 2000). Dequech (2000) highlights that *"several decades ago, Knight and Keynes, each in his own way, discussed uncertainty as a notion distinct from something else, which Knight called risk. This distinction has been rejected by several mainstream subjective probability theorists […]. Other scholars have insisted on the relevance of the distinction – some of them are mainstream economists who nevertheless neglect uncertainty […]"*. It becomes clear that risk and uncertainty have often been used as synonyms while academics of different scholars cannot agree on the keywords' definitions. To take decisions, Ellsberg (1961) highlighted that the desirability of the payoffs and the relative likelihood of events are not the only factors to be considered. Ellsberg's (1961) urn experiments show that some information is hidden, but not inexistent at the moment of decision. Consequently, while ambiguity usually remits to a situation in which the uncertainty about probabilities is due to lack of information, uncertainty (as it is comprehended in standard subjective probability theory) may be measured by probability. In his work, Shackle (1972) argues against the use of probability distributions if there is fundamental uncertainty. In fact, the issue is not that there is not enough information which may help assigning the probabilities to eventual events. Dequech (2000) argues that some events are simply not imaginable in the present and that, for this reason, relevant information cannot all be known when decisions need to be taken. Furthermore, it cannot be known what the complete information really consists of.

In the perception of Rao & Goldsby (2009), a risk can only occur if there is exposure and uncertainty. Liberatore et al. (2013) also distinguished risk from uncertainty, explaining that disaster management decision makers need to take their decision under risk or uncertainty coming from different resources. Furthermore, they explain that humanitarian logistics is related with uncertainty due to *inter alia* unpredictable demand in terms of timing, geographic location, and type and quantity of considered articles. In their work, Etner et al. (2012) consider uncertainty being uncertainty having no assigned probabilities, whereas risk is to be seen as an uncertainty having clear allotted probabilities. Peidro et al. (2010) yield that several authors have grouped uncertainty into three categories, namely [1] demand uncertainty, [2] process / manufacturing uncertainty, and [3] supply uncertainty. Another well-known approach is the differentiation of aleatory and epistemic uncertainties. Aleatory uncertainties are normally derived from a systems' intrinsic coincidence. These kind of uncertainties can thus not be reduced as it is out of any company's control. Epistemic uncertainties, in contrast, are the resulting consequences of an absence of precise and accurate information. The fact that in most cases people do not know how many containers remain in the inventory at a given time has undoubtedly to be seen as an epistemic uncertainty. Those uncertainties may be diminished by information procurement, but this may be extremely time-consuming and hence inept (Vojdani & Rösner, 2012). Heckmann et al.

(2015) point out that under certainty all parameters are deterministic and known while decision making in a situation of uncertainty means that decisions have to be taken despite a lack of information concerning the verisimilitude that parameters may change.

Conclusion and Definitions

Some projects are hard to predict since some of its inherent elements cannot be controlled. The myriad of vicissitudes which may occur during the entire project impede its development and design, resulting in reasonable doubts concerning the trustworthiness of the calculated results. There is little likelihood that the predictive values represent the real situation. To get a consistent project development, managers may therefore not only take into account their desirable results, but also the undesired elements, able to disturb the project's required outcome. In other words, managers need to include eventual risks which could impact the principal goals into their project development process.

As illustrated by the above literature review, 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 (Jüttner, 2005; Khan & Burnes, 2007). The human perception seems being closer to the negative connotation, than to the perception of danger and opportunity (March & Shapira, 1987). In fact, risks are usually neither identified, nor treated during management processes but they are assessed independently. Hence, managers need to assemble the different risks with the considered project's critical endeavours.

Even though, in the understanding of several managers, risk has a negative sense, 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.

It is important to understand, that risks occur in every relationship. Closer relationships between companies may result in more dependencies between the latter, what, in turn, could contribute to disturbance transfer within the network. The derogations or sudden events will inevitably result in different consequences to the different firms of the eligible network. In other words, the networks have not only one common risk, but the different risks need to be analysed from the different perspectives (Hallikas et al., 2004). In addition, we see uncertainty being a part of risk, as we agree on the fact that a risk can only occur if there is exposure and uncertainty. In this work, we agree with Kelliher et al. (2013), arguing that **uncertainty,** is to be understood as:

"a shortfall of knowledge or information about what kinds of outcome may occur, the factors which may influence future outcomes, and the likelihood or impact of various outcomes." (Kelliher et al., 2013)

It is hence obvious that in this work, risk and uncertainty are not seen being synonymous. The understanding of both keywords is essential for the understanding of the following Supply Chain Risk Assessment (SCRA). Since clarification about the keywords' meanings is provided, the question of **what is meant by Supply Chain Risk Management (SCRM)** arises.

3.2.2 Managing Supply Chain Risks

According to Foerstl et al. (2010), the separate research stream on Supply Chain Risk Management (SCRM) has only recently arisen. SCRM strategies may be operated in a reactive or proactive way. A reactive SCRM consists of acting after a risk has materialised. This needs to be done extremely quickly as a delay can cause serious consequences for each member of the SC. Effectively Figure 47 shows that over a period of time , one materialised risk may cause further unforeseeable risks, which may be even more severe than the originally materialised risk.

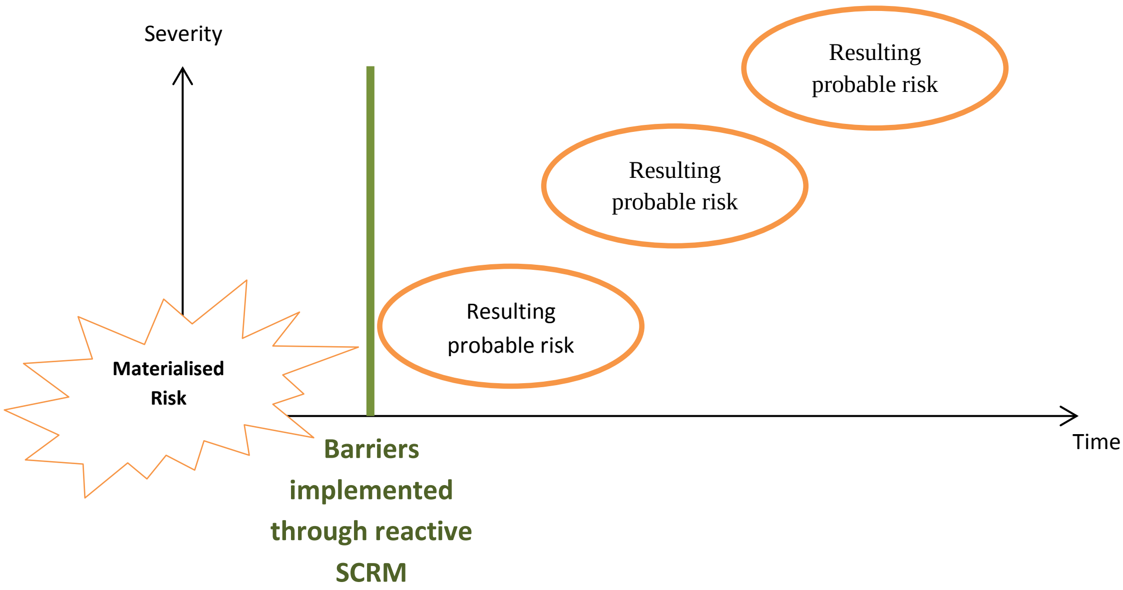


Figure 47 - Reactive SCRM

It is necessary to manage risks in a reactive way when a *"supply chain operates without worrying about risks on a day to day basis but reacts to mitigate when the difficulty or disruption strikes"* (Dani, 2009). Before considering risk mitigation solutions, companies should nevertheless try to quantify the risks they face, even though only few companies perform such an evaluation (Dittmann, 2014). On the other hand, since today's SCs became highly complex, it is almost impossible to evaluate each and every risk that could arise. As there is a myriad of inherent risks, the risks to be considered must be prioritised. In other words, as it is not possible anymore to consider every possible inconvenience, managers need to react on problems. Nevertheless, the most probable risks are handled in a proactive manner (Dani, 2009). Some definitions of SCRM yield during the literature review are shown in Table 21.

	Definitions SCRM
(Jüttner, Peck, & Christopher, 2003)	"Supply chain risk management aims to identify the potential sources of risk and implement appropriate actions to avoid or contain supply chain vulnerability. Consequently, it can be defined as: "the identification and management of risks for the supply chain, through a co-ordinated approach amongst supply chain members, to reduce supply chain vulnerability as a whole."
(Norrman & Jansson, 2004)	"The focus of supply chain risk management (SCRM) is to understand, and try to avoid, the devastating ripple effects that disasters or even minor business disruptions can have in a supply chain."
(Jüttner, 2005)	"Risk in supply chain centres around the disruption of 'flows' between organisations. These flows relate to information, materials, products and money. They are not independent of each other but clearly connected. A key feature of supply chain risk is that, by definition, it extends beyond the boundaries of the single firm and, moreover, the boundary spanning flows can become a source of supply chain risks.",
Jüttner, 2005b	"The remit of SCRM as a managerial activity can be defined as: 'the identification and management of risks for the supply chain, through a co-ordinated approach amongst supply chain members, to reduce supply chain vulnerability as a whole."
Jüttner, 2005b	"SC vulnerability is defined as 'an exposure to serious disturbance arising from supply chain risks and affecting the supply chain's ability to effectively serve the end customer market."
(Gaudenzi & Borghesi, 2006)	"The aim of risk management is the protection of the business from adverse events and their effects (Borghesi, 1985)"
(Gaudenzi & Borghesi, 2006)	"[…] a process that supports the achievement of supply chain management objectives. In this sense, risk management is "an integral part of supply chain management" (Christopher, 2004)."
(Tang, 2006)	"The management of supply chain risks through coordination or collaboration among the supply chain partners so as to ensure profitability and continuity. […] one can address the issue of SCRM along two dimensions: Supply Chain Risk - operational risks or disruption risks. Mitigation Approach - supply management, demand management, product management, or information management."
(Berg, Knudsen, & Norrman, 2008)	"The core of supply chain risk management is to understand, and try to avoid, the devastating ripple effects that disasters or even minor business disruptions can have in a supply chain."
(Wagner & Bode, 2009)	"If anything can go wrong, it will" says Murphy's Law. If this holds true, a good risk management approach is to avoid activities that are risky and "can go wrong."
(Essig, Hülsmann, Kern, & Klein-Schmeink, 2013)	"SCRM aims at reducing a supply chain's vulnerability as a whole and can be divided into several process-oriented steps. In this regard, conclusions can be drawn from various theoretical approaches."

Table 21 – Definitions: Supply Chain Risk Management

The SCRM can be seen as a process aiming at reducing all the deviations from the normal or expected (Svensson, 2002). Effective management of risks became one of the main concerns for any company in order to survive and succeed in a rival business environment. The SCRM has thus risen as a natural enhancement of SCM. To implement such a SCRM process many companies use the Six Sigma approach and other tools they are familiar with (Eckes, 2001). To assess potential risks, it is crucial to understand not only the considered SC's processes and nodes but it is also essential to understand the risk itself. In fact, the risk needs to be evaluated so that it may be reduced afterwards. A manager needs to be aware that a risk can always be reduced to a minimum but it is not possible to eliminate it entirely. Some events – such as accidents, strikes or 'force majeure' events – are beyond the control of the company. In other words, while an ex-ante estimation of SC vulnerabilities is extremely difficult in nowadays' complex global economy, it is becoming increasingly important too (Sheffi, 2005). Christopher (2003) indicated that the different risk factors could be yield by asking the right questions, namely 'What drives the risk?', 'Where is the risk?', and 'What is the risk associated with?'. In addition, he pointed out that Supply Chain Risks (SCR) and their inherent factors may be identified in various ways, depending on the managers' perspective. Potential risks are thus identified during the design phase of a supply chain and the issue's probability as well as its possible impact are estimated and ranked in terms of significance. In a second step, managers try to find remedies before the concerned issue occurred so that it may be avoided. As this is not always possible emergency plans are elaborated to minimise the impact's importance. However, *"if a risk never materializes, it becomes very difficult to justify the time spent on risk assessments, contingency plans, and risk management. The probabilities of many of these events [risks] occurring can be difficult, if not impossible, to derive with any precision"* (Zsidisin et al., 2000). Hence, many companies will weigh the financial loss if damage occurs against the investment of money, time, and labour required to prepare a contingency plan minimising the damages. On the other hand, *"despite recent unprecedented challenges, it appears that many supply chain executives have done very little to formally manage supply chain risk"* (Dittmann, 2014). In fact, Dittmann (2014) explained that none of the surveyed companies used outside expertise in evaluating risks for their SCs, and that most of them did not quantify risks when they outsourced their production. In addition the majority of the companies surveyed had risk managers employed, either in their legal or compliance departments, but rather all of those internal functions ignored SCR. His most surprising finding was that "*100 percent of [the questioned] supply chain executives acknowledged insurance as a highly effective risk mitigation tool, but it was not on their radar screen nor in their purview"* (Dittmann, 2014). Dittmann (2014) concludes that the heart of the problem consists in the fact that only few managers are compensated or promoted in their daily business to rigorously manage risks

To manage their risks, companies are supported by international standards like ISO31000 or ISO28000. The ISO 31000:2009 standard provides fundamentals, a framework as well as a process for managing risks. Its advantage is that is can be used by any company, no matter what size it has or what sector it serves. It provides guidance for internal and external audits by assisting in increasing the likelihood of achieving predetermined aims or by supporting the improvement of opportunities' and threats' identification. Managers may allocate the given resources for risk treatment in a more pertinent manner (ISO 31000 - 2009). In the same logic, the ISO 28000:2007 standard indicates the requirements for a security management system. This norm recognises that SCM is linked to many other activities, which are controlled or influenced by external organisations, affecting the SC's security. The ISO 28000:2007 stipulates that those other aspects need to be considered immediately once they have an influence on the SC's security management. Just as the former described ISO 31000, the ISO 28000 may be used by any enterprise or LSP. The main objective of this norm is to support companies in creating, implementing, and improving their security management procedures. In addition, since the use of this norm is attested by an accredited audit company through a certificate, a company using this norm can demonstrate that it is significantly involved to the SC's security (ISO 28000 - 2007).

Conclusion and Definition

The very first step of the development of a risk management process consists in identifying the internal and external environments. After that, eventual risks need to be detected (Manuj & Mentzer, 2008). Nevertheless, despite this fact there is only limited literature addressing the issue of risk identifications in SCs, although the field of Supply Chain Risk Management (SCRM) has evolved (Kouvelis et al., 2006). According to Neely et al. (2002) a measurement system should always be linked to the specific objectives of the SC, taking into account the importance of the fact that the measures used need to be focused on their respective achievements. In addition, we agree with Dittmann (2014) suggesting that *"once a risk management plan is developed, it can become a competitive advantage because so few firms have one".* It is determining that all the different members working on the SCRM process have a common understanding of not only the SC and its inherent risks, but also of the measures and actions to be taken. To clarify, we define SCRM as follows:

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.

It is important to indicate that we will neglect the risks emerging on a daily business in our SCRM model. Those risks should definitely be considered within a company, but the model is supposed to assess the risks occurring in case of a SC's re-design which is performed in order to increase the SC's overall degree of sustainability. In this manner, the risks emerging on a daily business are considered being redundant within this work.

3.2.3 The inherent risks of (Re-) Designing a Supply Chain in Sustainability Matters

One risk can be declared being the "general environmental uncertainties", including political instability, government policy instability macroeconomics fluctuations, social peril, and natural uncertainties (Miller, 1992). As for example, natural uncertainty including appearances such as earthquakes, floods, or fires would certainly decrease the productive capacity of companies operating in the concerned region (Miller, 1991). In the same logic, the actual refugee crisis slows down the operational part of logistics transportation at the different European frontiers. The just enumerated risks are of huge importance in the logistics domain but nevertheless, they will be neglected in this work since they are not under a company's control. In fact, they may not be minimised by a company's actions taken, but the enterprise can only choose to stay on that market and to take the risk, or to avoid it by leaving the considered business field. However, Dittmann (2014) points out that a crisis needs to arise to motivate companies' action. In fact, risk planning may frequently fall to the lowest position on the priority list, if there is no crisis threatening.

Harland et al. (2003) assert that *"There have been a variety of different focuses in research into risk management in purchasing and supply, but little in supply networks"*. Nonetheless the issue to be analysed in this work considers the (re-)design of a SC, i.e. the SC's inherent networks in the perspective of Kuehne + Nagel. Before we can face this problem of redesigning a SC, the inherent risks need to be identified and assessed.

Risk Classification

According to Dittmann (2014), SC experts at UPS Capital who are specialised in risk mitigation, define two forms of risk: the day-to-day risks, provoked by the normal business, and the disruptions, which usually cannot be predicted, such as epidemics, tsunamis or terrorism. Nevertheless, enterprises should brace themselves to this kind of situations with a risk management process, mitigating and minimising the impact of such events. Due to increasing dynamism and uncertainty in business environments, the matter of risk becomes actually a key affaire of any company. Some Kuehne + Nagel internal managers indicate that risks should be classified because their origins may differ enormously. Effectively, literature review has yield that risks in supply chains may have 3 roots:

- Natural events such as earthquakes, heavy storms, or volcanic eruptions leading to partial or complete breakdowns in transportation (Tang, 2006)
- Operational fluctuations like fluctuations in supply, demand and prices (Christopher & Lee, 2004; Jüttner, 2005)
- Crisis created by human beings, such as terrorist attacks, economic recessions or unethical business practices (Kleindorfer & Saad, 2005).

Also, the above mentioned reasons for redesigning a supply chain may make it vulnerable for risks. It is essential for a firm to classify its risk in a coherent manner, as ambiguity leads to confused risk reporting and management and accordingly, impedes a proper Enterprise Risk Management (ERM) (Kelliher et al., 2013). Kelliher et al. (2013) advised against possible confusions, explaining that one firm may allocate a failure of a project to operational risks, while another one may relate this event being a strategical risk. Nevertheless, a company cannot just apply the knowledge gained from its own perspective to a SC context since the performance of a SC relies on dependency, bargaining, negotiation, and persuasion across the concerned companies, the SCRM differs from a company's internal risk management (Jüttner, 2005). Moreover, the different aims to be achieved may, in this context, be impeded because of goal incongruence and misunderstandings between different companies' philosophies. Further, Rao & Goldsby (2009) examined the literature to develop a taxonomy of risk sources which can be used by managers to measure and evaluate vulnerabilities of their enterprise and SC.

Since networks may cause the transfer of risks between companies, the risks need to be analysed from different perspectives. In fact, even if a network aims at purging or mitigating some risks, others may appear or increase. However, this always depends on the network's background, i.e. the companies, their domains, their economic status or cycles, etc. It is therefore not possible to give a panacea comprising one complete risk assessment or evaluation model. To rephrase, the network's inherent companies need all to analyse their risks from their own perspective, since they are usually related to their objectives and targets (Hallikas et al., 2004).

3.2.4 Risk Assessment with Regard to Sustainability

If business people discuss about risk assessments, it becomes clear that most of their arguments are based on financial matters. This was confirmed by Knox & Maklan (2004), who highlighted in their case study that *"in most of our respondent companies, risk is managed separately by the finance department and is not fully integrated with CSR. Each respondent confirmed that finance undertakes formal risk assessment and that neither the process nor the management actions arising from it are managed within the CSR function"* (Knox & Maklan, 2004). In this sense, Porter & Kramer (2011) clearly emphasised that an enterprise needs to worry about non-financial risks too. A company's value is not only counted in pecuniary terms but also in more intangible assets, such as the company's reputation or how it implemented the CSR issues. Thomas (2006) explained that non-financial risk assessments may force managers to incorporate diverse uncertainty factors into their decision making processes. In the same logic, Porter (1985) and Porter & van der Linde (1995), explain that such a company can improve its overall competitiveness through the consideration of societal matters.

Morhardt et al. (2002) elucidated the importance for companies to get involved with non-financial risk management while accepting sustainability being based on its three inherent pillars. Their arguments were, beyond others, compliance with the regulatory requirements which may become stricter in future, the compliance with the industry environmental codes, or the promotion of stakeholder relations. In addition, they accentuated the benefits resulting from adhering to societal norms, and the competitive advantages constituting the consequences from the enterprises' external perceived environmental endeavours. The non-financial management may consequently serve as a base to handle environmental and societal risks. Effectively, it may be used to assess eventual impacts during the execution of the processes. In addition, it may assist companies to benefit from new occasions when identifying eventual non-financial risks, leading to enhanced sustainability and profitability (Bernstein, 1996; Porter, 1985). According to Carter & Jennings (2004), irresponsible supplier behaviour of any kind can be transmitted to the buying company, causing negative advertisement, as well as reputational damage and statutory obligations. In fact, Cousins et al. (2004) and Russo & Fouts (1997) identified several damage potential of unfavourable sustainability incidents, as for instance commitments for damage, non-compliance fines, negative media exposure, pressure group imminences, or the loss of corporate reputation.

Nowadays, sustainability becomes more and more connected to the SCRM discourse. Most of these works, as for example Campbell & Scott (2013), Christopher et al (2011) and Matten (1995), bear on the environmental pillar, neglecting the societal issues. On the other hand, Anderson (2006) for example, assembled chemically harmful substances, decreasing ecosystem services, boycott risks, and social justice risks and classified them into the category of sustainability risks. Since we defined sustainability being based on the Triple Bottom Line (TBL) and on the time factor, we cannot agree on this classification. In our point of view, the chemically harmful substances are a matter of the environmental or the working environment pillar, depending on the substances' related risks. The decreasing ecosystem services needs to be rated as an environmental risk, whereas the boycott risks can either be allocated to the economical, or the ethical issues matters, depending once again on the type of risk analysed. The social justice risks belong clearly to the ethical pillar. In short, we consider that the different risks cannot be allocated in one only category.

Companies usually have tools to deal in an effective way with most of the traditional financial risks in a business operation (Bischoff, 2008). For this reason, Wong (2014) highlighted the significance in developing environmental and social risk management so that corporate sustainability may be increased. In his article, he highlighted the fact that environmental and social concerns are usually viewed as intangible enigma which needs to be articulated and managed in an accurate manner to reach the goal of corporate sustainability. In addition, just like Porter (1985), Porter and Van der Linde (1995), or Morhardt et al. (2002), the need of a systematic and strategic non-financial risk management system needed to achieve the overarching goal of improving the company's overall competitiveness by moving closer to sustainable development, has been discussed in Wong's (2014) paper. He also admitted that risk assessment in sustainability matters has become extremely complex and needs to balance several conditions, perspectives, and variables across an enterprise. The author argues that *"integrating environmental and social risks is critical to the effective management of a company's real risks, and to improved resource allocation for enhancing corporate sustainability. This demands the quantification of environmental and social risks in an atypical manner"* (Wong, 2014)*.*While we admit this statement, we do not agree on the idea that this quantification would require to identify, measure, and monetise the risks just as traditional ones, i.e. commodity prices and credit risks, as suggested by Wong (2014).

According to Yilmaz & Flouris (2010), the companies will not be able to determine the time frames or the anticipations for managing sustainability, but shareholders, federal and state agencies, and consumers will promote its evolution. In their point of view, sustainability is not to be seen as a reactive response to environmental or regulatory threats. They therefore developed the Enterprise Sustainability Risk Management framework, based on the TBL concept. They indicate that this framework can protect, create, and enhance business value through measurement and management of sustainability threats and opportunities, as well as helping businesses to effectively respond to the growing expectancy of the corporate stakeholders via the guidance to managers on how to set up a holistic and systematic sustainability risk management process. The process needs to generate the risk indicators, sources, and objectives and must report the systems needed to ensure effective handling of sustainability risks and enhanced overall organisational performance and values. Their Enterprise Sustainability Risk Management Framework is depicted in Figure 48.

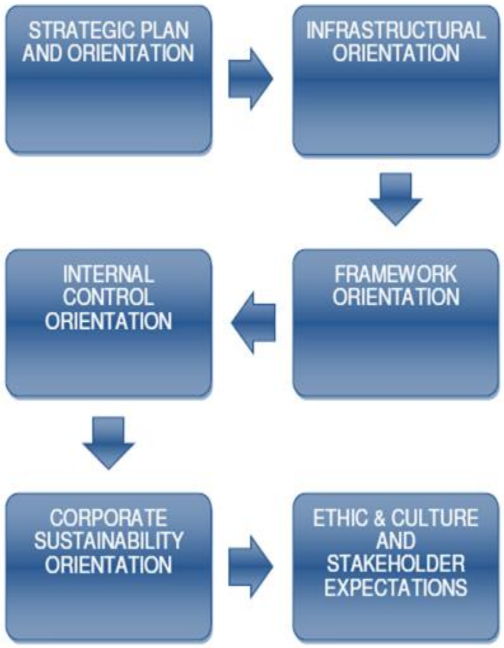


Figure 48 – Enterprise Sustainability Risk Management Framework by (Yilmaz & Flouris, 2010)

Yilmaz and Flouris (2010) proclaim that integrating sustainability considerations into existing systems and processes would be the most effective way to embed sustainability into corporate business, unlike creating new systems and processes. We agree on their statement, revealing that "*Current sustainability risks are* considerably *different from old risks. For this reason, more holistic and enterprise-wide approach needs to managing corporate sustainability risks"* (Yilmaz & Flouris, 2010). In addition, they suggest *"to go beyond compliance and legal liabilities, businesses have to integrate risk management based philosophy and culture into core business functions of the company"* (Yilmaz & Flouris, 2010). We consent to their idea that sustainability management will only be achieved if managers recognise the resulting values. For this reason, cultural change within the business needs to be attained, so that sustainability management based benefits may be provided.

Even though this model takes into account the three pillars of sustainability, we criticise that it is, nevertheless, only taking into account the financial perspective. Indeed, the given formula:

$$TBL = \text{Financial Performance} - \text{Risk Cost (Environmental Performance} - \text{Risk Costs (Societal Justice)}$$

is only related to the monetary costs but neglects the non-financial risks which may occur. As stated before, we consider that a risk may occur in various forms, i.e. financial and non-financial.

Foerstl et al. (2010) also used the term sustainability in the sense of the TBL and also discussed the competitive advantage companies could gain through the correct use of the CSR concept within the purchasing and supply management. They analysed how companies address the challenge of meeting their beneficiaries' sustainability requirements in an efficient manner, whilst they handle the risks of corporate reputational damage in an appropriate way. They found out that there are first – mover advantages if companies implement a structured sustainability risk assessment and the consequent supplier selection and development, which helps to successfully handle a sustainable portfolio of suppliers. In addition, they suggest that there are two types of positive performance outcomes resulting from sustainable purchasing supplier management, namely (1) a more profound mitigation of corporate reputational risk, and (2) increased operational performance. They assessed the probability of occurrence of a negative incident related to sustainability on a selection of only four indicators, scilicet (1) physical properties of the supplied product, (2) the related product process, (3) the supplier's geographic position, and (4) the supplier's past performance records. The assessment of those KPIs has mainly been carried out on a qualitative basis. In a next step, depending on the kind of the element analysed or service procured, the assessment KPIs have been assigned different weights. We regret that Foerstl et al. (2010) did not give more detailed information about the indicators assessment and weightings. One of their conclusions given is that external responsiveness positively affects sustainability risk identification, assessment and alleviation strategies, which on the other hand, positively affect risk and operational performance. However, we agree on their accentuation, declaring that their findings may be particularly appropriate to the chemical industry. Furthermore, they criticise that *"one may doubt whether the purchasing volume is a reliable indicator to approximate corporate reputational damage caused if suppliers do not adhere to sustainability standards"* (Foerstl et al., 2010). We agree on Foerstl et al.'s (2010) suggestion that further research should be elaborated and tested in order to find out whether the sustainability risk assessment method presented in their work is valuable in different industry sectors.

Another model which has been elaborated recently is the Risk, Resilience, and Resource Management (TripleRM) Sustainability Model introduced by Krishnaswamy (2015). The TripleRM sustainability model is based on the FMEA and the Sustainability Framework for Risk Analysis models, expanding these concepts by including resiliency and resource management. The TripleRM Sustainability Model's goals are threefold: It intends (1) to help identifying, assessing and mitigating the risk of failure of infrastructure systems, (2) to prioritise projects via a comparative analysis of quantified ex-ante and ex-post risk applications of relieving sustainable solutions, and (3) to help distributing the resources – and all this in regard to the TBL. However, the model is also based on strong assumptions stating that first, corrective measures will always help to reduce the risks, second, preventive actions on a particular system will always help to reduce the risk, and third, that any remedial measure will never impact any other system in an negative way. In other words, the hypothesis state that every action taken will always have a positive impact on the referred system, and that there is no interaction between the different systems. We cannot agree on those premises, knowing that the sustainability issues are strongly interrelated.

In summary, we agree with Yilmaz and Flouris' (2010) declaring that: *"Integration and a holistic approach are the key concepts for both a successful business and sustainability".* Even though the sustainability matters gain in importance, the monetary issues still prevail. Nevertheless, we consider that an enterprise's overall performance, hence the pecuniary as well as the nonmonetary one, may be enhanced if sustainability risks are mitigated. In addition, we remain convinced that today's needs will deepen and consequently alter over time. The logical consequence is that the risks will also change due to the different sustainability systems' evaluations. For this reason, companies must henceforth pay special attention to the complex interrelations of sustainability and the inherent risks by using light assumptions which are able to simplify reality but do not render the risk calculation model too simplistic. To set up such a model, we need to analyse existing risk assessment methodologies, and to assembly them in a pertinent way.

Managers need to be aware of the fact that risks can appear in many different forms. It is precisely for this reason that they cannot assess and evaluate every potential risk but need to prioritise them. In addition, most indicators used to measure the SC's performance are interrelated, which may entail risks which cannot be identified at the first glance. To address this issue, companies classify the potential risks and try to analyse them in terms of categories. In this work, we will adopt the idea of classifying the different risks, but adjudged the Customers' classification being inadequate for our purpose of investigating the risks in terms of sustainability. This will be explained in detail in section 3.4.2.

There is a myriad of methodologies accepted of how a risk needs to be evaluated and classified, but there no panacea to be used to assess every possible risk. The methodologies aimed to quantify and assess specific risks depend not only on the latter's type but also on the data the company has access to, to provide the required calculations. Those data may be hard to monitor because of the risk matters' level of abstraction.

3.3 RISK ASSESSMENT METHODOLOGIES

As technologies have taken off in recent years, companies see themselves exposed to a growing number of hazards and risks, which became a growing issue for today's companies (Wharton & Ansell, 1992). The development of efficient SCRM is a critical undertaking requiring multiple know-how skills and expertise in several areas. According to Marmier (2014), there are some risks or accumulation of risks may have such enormous consequences that the company would question about its further viability. Usually, they have implemented preventive measures to overcome eventual risks, to organise its business and to ensure the company's survival. He explains that companies could use the Business Continuity Management (BCM) to designate such measures as well as the conditions for their implementation. Effectively, to mitigate the assessed risks, a company needs to know what options are available to alleviate them, and what are the costs and benefits of each of those options (Dittmann, 2014). To address this endeavour correctly, several methodologies may be used. But first of all, it is important to understand that a materialised risk is rarely due to one single event. The multitude of events occurring consecutively is also called the Swiss Cheese Model of Accident Causation. The analysis of such a materialised incident consists of three steps: first, the chain of events from the cause of harm to the undesirable consequence has to be identified; second, the barriers which were supposed to stop the chain of events need to be detected; and last, the reasons for failure of each of those miscarrying barriers have to be denominated (Turksema et al., 2007).

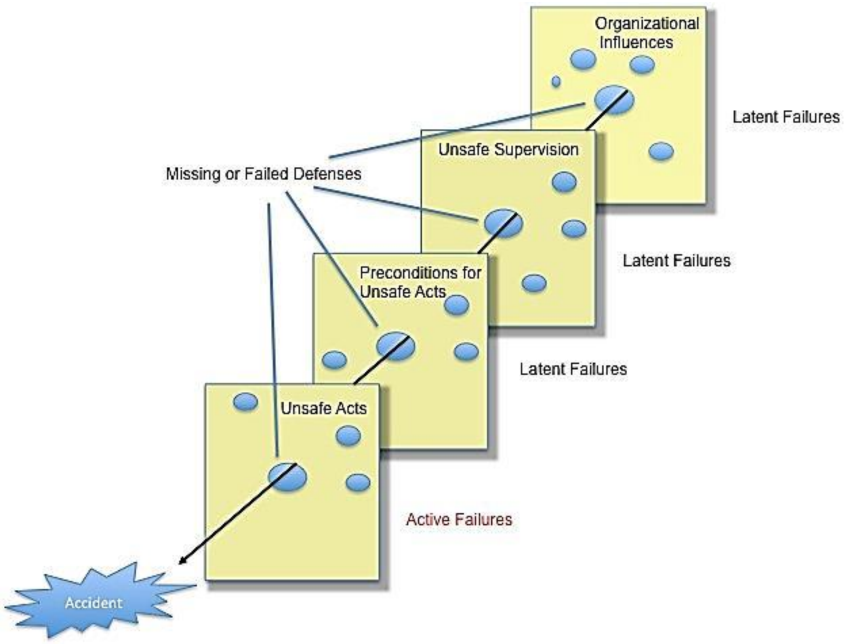


Figure 49 – Swiss Cheese Model of Accident Causation by (Greller, 2013)

The concept of probability as well as the use of statistical databases became essential to the assessment of risk. The risk assessment procedure can be either quantitative or qualitative depending on the available data and on the level of detail required (Bennett et al., 1996). Internal interviews with the QSHE Department yielded that the process of risk assessment may be broken down into three stages, namely [1] Risk Identification, [2] Risk Estimation, and [3] Risk Examination. This clearly follows the logic provided by the Supply Chain Risk Leadership Council (SCRLC) (2011), as illustrated in Figure 50. Because of time concerns, we will only take into account the risk assessment in this work, i.e. the risk treatment and mitigating will be out of scope.

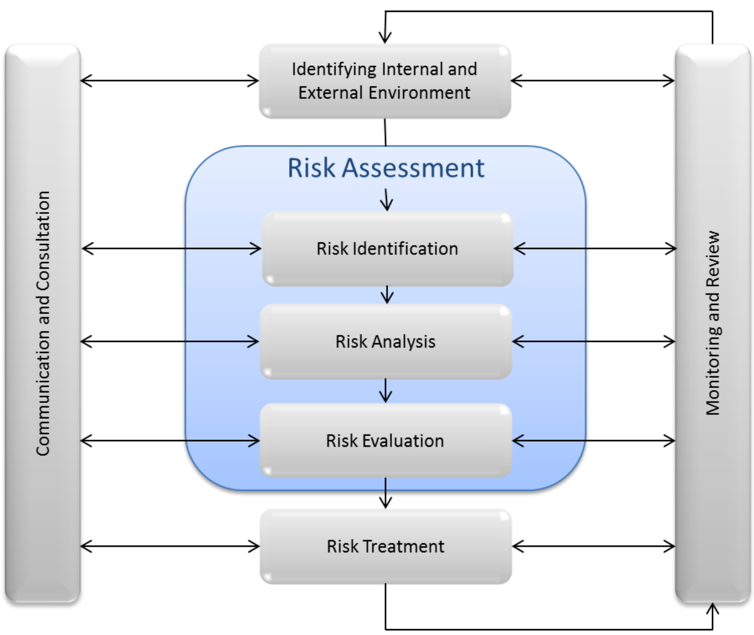


Figure 50 – Risk Management Process by (SCRLC, 2011)

In his literature review Tang (2006) examines quantitative models for managing SCR on a strategic and an operational level, while Zailani (2009) surveyed SCRM literature in terms of the types of risks, the unit of analysis, the industry's sectors, as well as the risk management process or strategies addressed. Tang (2006) found that most of the analysed models were designed for managing operational risks. Nevertheless, some of those strategies have been adopted by professionals since the aforementioned strategies may increase SCs efficiency in terms of handling operational risks. In addition they may render SCs more robust in terms of managing disruption risks. Zailani (2009) classifies SCRs into operational accidents, operational catastrophes, and strategic uncertainty. She stated that *"understanding the types of risks and their probability of occurrence as well as the associated impacts is a starting point for companies to develop effective risk management"* (Zailani, 2009). Risk assessment is not simply a scientific calculation implicating probabilities of loss of tangible or physical assets, but it also considers intangible founds. Those unsubstantial capitals, such as reputation, trust, credibility or status may be damaged if a risk materialised. The corporate social capital can hence be affected (Harland & Knight, 2001). To implement the tasks of risk management, i.e. specifying risk sources and vulnerabilities, assessing and mitigating risks, Kleindorfer & Saad (2005) formulate a set of 10 principles, derived from the industrial risk management and supply chain literatures. One of those principles is "*Good crisis management is not enough; linking risk assessment and quantification with risk management options ex ante is of fundamental importance in understanding the potential for ultimate harm to the organization from supply chain disruptions and for evaluating and undertaking prudent mitigation"* (Kleindorfer and Saad, 2005). This invades the famous quote given by Peter Drucker, saying *"If you can't measure it, you can't manage it"* (De Run et al., 2008). Without risk quantification a common atmosphere of alarm could thus get perceptible in both, the company and the whole SC but this will not be transmitted towards the most cost-effective resources of mitigating unwanted and worst case scenarios (Rice et al., 2003).

March and Shapira (1987) and Fischhoff et al. (1981) analysed managers' demeanour towards risks and conclude that managers are quite impassible to anticipations concerning the probabilities of potential outcomes since they either do not trust, or do not understand precise probability estimations. Effectively, March and Shapira (1987) found out that managers usually define risk in terms of "maximum exposure" or "worst case" instead of "expected loss". The way managers deal with risks is, furthermore, affected by performance targets which have usually been set by companies' board of directors. In fact, March & Shapira (1987) assert that such performance targets could induce managers to become more risk averse in cases when their performance is above a certain target level, or alternatively more risk prone in cases when their performance is below the aforementioned target level. In addition, since many companies tend to reward managers for accomplishing excellent outcomes but not for taking excellent decisions, entrepreneurs usually make clear distinction between taking risks and gambling (March and Shapira, 1987). Nevertheless, even though companies conceive the importance of risk assessment programs, most of them only invest little time and resources for reducing supply chain risks (Zsidisin et al., 2000 and Zsidisin et al., 2004). Rice et al. (2003) explained that it is extremely difficult for companies to justify several risk reduction plans since it is very difficult to obtain pertinent estimations regarding the probabilities of potential incidents' materialisation. In the same logic Kunreuther (1977) declares that companies are liable to overlook disruption risk if there is no accurate SCR assessment as businessmen usually neglect potential but unlikely events. For this reason only a few enterprises take adequate measures to decrease SC disruption risks ex-ante. This has also been explained by Repenning & Sterman (2001) who denominate their work "*Nobody Ever Gets Credit for Fixing Problems that Never Happened".*

Literature review revealed that there exist many types of risk assessment methodologies. In this work, we will differentiate between (1) quantitative, (2) qualitative, and (3) hybrid risk assessment methodologies. Nevertheless, authors disagree on the classifications' definitions. As an example, Marhavilas & Koulouriotis (2008) classify the Bow Tie Model[32] being a hybrid technique, while Frosdick (1997) has classified this same methodology being a qualitative one. On the other hand, Talon et al. (2009) as well as Chan & Wang (2013) classified the Bow Tie Model being a quantitative risk assessment methodology. In this work, we define the classifications as follows:

- **Quantitative** risk assessment methodologies are based on mathematical or statistical relations which rely on data recorded through past events. The risks are considered as numerical quantities.
- **Qualitative** risk assessment methodologies are based on analytical estimation processes and on the management's expertise. They are to be seen as the process of evaluating the likelihood and effects of identified risks (PMBOK, 2000). The risks are considered in linguistic terms, i.e.: "very low", "low", "medium", "high", "very high".
- **Hybrid** risk assessment methodologies are highly complex because of their *ad hoc* character preventing a wide dissemination (Marhavilas & Koulouriotis, 2008). They are both semi-quantitative and semi-qualitative.

3.3.1 Quantitative Risk Assessment Methodologies

Quantitative risk assessment methodologies usually include a comprehensive and systematic methodology to evaluate eventual risks. They often obligate managers to quantify the probabilities of a specific undesired events' occurrence, as well as the magnitude of the associated consequences and outcomes. Most risk assessment methods discussed in the literature lean on heavily statistical approaches or require high-quality data.

Annualised Loss Expectancy

The Annualised Loss Expectancy (ALE) is well known in the business environment since it commonly endeavours to assign financial values to the elements of risk assessment as well as to the assets and endangerments of a risk analysis (Bistarelli et al., 2006). Focusing on Returns on Investment (ROI) (Chan & Wang, 2013), it requires managers to estimate the yearly probability of an eventual undesired event as well as the expected financial damage resulting from the undesired event. Just as current risk management processes, ALE requires managers to analyse their company's assets, threats, and vulnerabilities in a careful manner before they may take any decision. The ALE methodology requires managers to appraise the probabilistic harm from different types of events, so that they may decide to only invest into risk-mitigation techniques which cost less than the anticipated loss in asset value (Butler, 2003).

One key feature of this methodology is that it can directly be used in a cost-benefit analysis. The SLE gives a measure of the harm of a single threat, while the ARO represent the likelihood of a threat to occur in a given period of time. The ALE tries hence to

[32] The Bow Tie Model is the aggregation of the Fault Tree Analysis (FTA) and the Event Tree Analysis (ETA) methodology. This methodology is discussed in paragraph 0 of this chapter.

consider both the likelihood and the harm of each menace. It is effective in helping managers to estimate the expected loss from a specific vulnerable event. However, the above indexes do not consider if a company has implemented barriers for reducing an undesired event's probability of occurrence or for decreasing its damage caused. The methodology requires the estimation of economic impacts of all possible undesired events before finding the most effective mitigation methodology (Butler, 2003). The main drawback is that ALE tempts security managers to make precise security investment recommendations while they base their decisions on imprecise information, such as appraised probabilities or estimated economic loss in intrinsic values. In addition, because of the fact that every undesired event needs to be evaluated in financial terms, most managers are probably struggling to specify the economic loss of an undesired outcome such as loss of reputation or impacts on workers' productivity (Butler, 2003). As explained by Porter & Kramer (2011), those kinds of impacts may be of major importance for the considered enterprise, since the non-financial value of a companies' reputation, may damage its accounts in a considerable manner. Nevertheless, this is hard to quantify by managers. This is *a fortiori* the case, if the managers' line of thought is strongly finance related. Butler (2003) explains that supporter of the ALE methodology recommend that investments in risk mitigation methodologies should have the highest net benefit, the greatest ALE reduction and simultaneously, the lowest costs. Anderson (2008) supposed that most managers consider the results calculated via the ALE methodology being unreliable since the method produces estimates of risk. In other words, he believes that the calculations' inputs are shaped in a way that they produce acceptable results.

Monte Carlo Simulation

T he Monte Carlo Simulation (MCS) method has been elaborated by Ulam and Von Morgenstern in 1944 during the so-called 'Manhattan Project', a research work to develop the first atomic bomb (Kochanski, 2005; Root, 2003). Nowadays, the direct simulation of the problem of interest is often called 'Simple Monte Carlo' or 'Crude Monte Carlo' to distinguish it from other more complex and refined methods. Nevertheless, those refined methods' names may be misleading since the simple MCS is often the appropriate method (Owen, 2013). In fact, if the variable X is a discrete random variable with a probability mass function named p, and if "*Y = f(**X**) is a quantity that can be averaged, such as a real number or vector, we can apply simple Monte Carlo"* (Owen, 2013), which is usually based on statistical distributions such as the Laplace-Gauss, Chi-squared, Fisher-Snedecor, Student, exponential, gamma or log-normal distribution.

According to Marmier (2007), the Monte Carlo Methodology considers calculating a quantitative value using probabilistic assessment techniques. It is mainly used as forecasting methodology, which relies on repeated random sampling to compute numerical results and which is applicable and adaptable to several scientific domains (Wyrozębski & Wyrozębska, 2013 and Zio, 2013). In fact, the main objective of this methodology is to solve any issue having a probabilistic interpretation by using randomness. Since the MCS is very flexible, there is almost no limit to the analysis handling empirical distributions (Zio, 2013). Its aim is in fact to estimate a population[33] expectation by the corresponding sample expectation. This issue has been studied in depth in the probability and statistics environment (Owen, 2013). One of the greatest advantages of MCS is that the sample's inherent values may be used to get an approximate idea of the error, calculated via the difference between the estimated average and the exact one: $\hat{\mu}_n - \mu$[34]. Since usually, users are more interested in a good estimation of the

[33] The term "population" is to be understood in the statistical language and does not concern the population in the sense of people or public.

[34] Where $\hat{\mu}_n$ is the estimated average and μ is the exact average

exact average µ than in the good estimation of the calculation error (also known as standard deviation σ), a rough idea of the latter is generally sufficient (Owen, 2013). Another benefit of the MCS is, that it is easily understood by non-mathematicians (Raychaudhuri, 2008) enabling managers to extend and develop it for companies' aims. However, the methodology also presents some disadvantages. First, it is usually not possible to render a MCS by hand, but it generally requires a computer based tool for the calculations to be made. Those calculations may require much more time than calculations required by analytical models. Nevertheless, the analytical model might only be understood by mathematicians, and are therefore not usable in companies' daily business. The main drawback may be that managers always need to be aware of the fact that the results are not to be taken as exact values, but they consider estimations depending on the number of repeated tests used to provide the output statistics (Earl & Deem, 2008; Zio, 2013). In addition, considering that most managers have only limited mathematical skills, it might be difficult to decide and argue the concerned variables' statistical laws.

Petri Nets

The Petri Nets (PN) methodology has first been introduced in 1962 by C. A. Petri in his doctoral thesis entitled "Kommunikation mit Automaten" (Bobbio, 1990; Yen, 2006). The PN methodology is to be understood as a mathematical formalism for modelling current systems and their behaviours in a mathematical way. According to Wang (2007), the *"theoretic aspect of Petri nets allow precise modelling and analysis of system behavior, while the graphical representation of Petri nets enable visualization of the modelled system state changes".* Typical situations that can be represented by PN are synchronisation, sequentiality, concurrency and conflict (Bobbio, 1990). A PN is, in fact, a directed bipartite diagram, including two kinds of nodes, namely transitions and places, connected to each other by arcs (Petri, 1962; Yen, 2006).

The PN methodology's main advantages lay in the fact that PN have a certain cleanness which permits managers to describe most systems in terms of simple concepts in a graphical manner (Peterson, 1977). According to Strümpel (2003), unlike analytical models, complex system structures may be analysed via simulation models such as PN. Furthermore, simulation models such as PN may be elaborated in a way that they are closer to reality than analytical models since they do not take into account simplifying assumptions concerning distributions, randomness, or independence (Strümpel, 2003). Since, nowadays, there are many different types of PN, such as for example the original PN (Petri, 1962), the Environment/Relationship-Nets (Ghezzi et al., 1991), the coloured PN (Jensen, 1993), the recursive PN (Haddad & Poitrenaud, 2007), the (averted) PN may be implemented at various levels of abstraction. In addition, if PN are implemented early in the development life cycle, required changes may be detected relatively inexpensively. Nevertheless, according to Schubert & Schwill (2011), the generated PN may become extremely large so that its analysis may turn out being difficult. Moreover, there is no way to keep a trace of synchronisation between two dynamically created processes through PN, which is due to their static structure Haddad & Poitrenaud (2007). Even though such a synchronisation is possible with coloured PN, the number of processes being delineated through the different colours needs to be finite (Jensen, 1993). This leads to another drawback, namely that risk assessment team needs to know the different averted PN in order to find out which one to use in their specific case. However, one of the key disadvantages of this methodology may be the fact that, unlike analytical models, it is not guaranteed that the ideal solution may be determined (Strümpel, 2003).

Corollary

Literature review revealed that most risk assessment methods and methodologies lean on heavily mathematical or statistical approaches and are solely understood by mathematicians. The most interesting quantitative risk assessment methodologies which concern the sustainability issues and which can also be understood by non – mathematicians, have been presented here above. The Annualised Loss Expectancy (ALE) is often used in the business environment, and some of Kuehne + Nagel Luxemburg's departments are no exception. The ALE may directly be integrated into a cost-benefit analysis, since it focuses on return on investments (ROI). It is hence particularly based on financial terms. Another well-known risk assessment methodology is the Monte Carlo Simulation (MCS), which is based on statistical theories. The MCS may easily be understood by non-mathematicians and requires less time exposure than many purely analytical models. Even though the results are not exact values but can only be considered as estimations depending on the samples' sizes, the MCS may be implemented in daily business issues without hesitation. The third methodology presented here above is the Petri Net (PN) methodology. This methodology allows systems to be described in a graphical way, using simple concepts and accordingly helps to analyse complex system structures. Since they do not use the simplification assumptions, generally exploited in analytical models, the PN are usually closer to reality than the commonly accepted analytical calculation models. For this reason, some of Kuehne + Nagel's departments use the PN methodology to get a better knowledge of the various systems concerned and to obtain common understandings. Nevertheless, this methodology may turn unpractical because they may become extremely large, resulting in difficulties to analyse the regarded systems. In addition, it is likely that the optimum solution will remain unnoticed despite deep analysis of the considered problem.

A summary of the highlighted quantitative risk assessment methodologies is given in Table 22.

Annualised Loss Expectancy	
Advantages	**Disadvantages**
• Can directly be used in a cost – benefit analysis • May help managers to estimate the expected loss from a specific undesired event	• Requires estimation of economic impacts of all possible vulnerable event before finding the most effective mitigation methodology • Managers may be enticed to make precise security investment probabilities or estimated economic loss in intrinsic values • Decisions are based on estimated values • Intangible potential losses are hard to evaluate in financial terms. • Calculations' inputs may be shaped in a way that they produce acceptable results
Monte Carlo Simulation	
Advantages	**Disadvantages**
• The sample's inherent values may be used to get an approximate idea of the calculation's intrinsic error • Applicable and adaptable to several scientific domains • May solve any problem having a probabilistic interpretation • Very flexible methodology • Almost no limit to the analysis considering empirical distributions • May be easily understood by non-mathematicians • May be used in companies' daily business • May be extended and developed for companies' specific purposes	• Cannot be calculated manually – computer based tool is needed • Calculations may require more time than analytical models • Decisions are based on estimated values • The model's credibility depends on the considered sample's size • Difficulty to decide the variables' statistical law
Petri Nets	
Advantages	**Disadvantages**
• Systems can be described in terms of simple concepts • Systems can be described in a graphical manner • Allows to analyse complex system structures • Closer to reality than many analytical models • May be implemented at various levels of abstraction • Required changes may be detected relatively inexpensively	• PN may become extremely large • Analysis may turn out being difficult • Trace of synchronisation between two dynamically created processes through PN cannot be kept • Risk Assessment Team needs to know the different averted PN in order to find out which one to use • The optimum solution cannot be detected for certain

Table 22 – Summary of Quantitative Risk Assessment Methodologies

3.3.2 Qualitative Risk Assessment Methodologies

The efficacious implementation of an extensive quantitative risk assessment requires the existence of good quality data and crucial knowledge and skills of the risk assessment team. Hence, if there is no data available, the implementation of such a quantitative risk assessment would not be feasible. In fact, in situations of constraints, such as limited knowledge about risk emergence, insufficient data quality, inadequate expertise, many companies execute hybrid or qualitative methodologies, such as the easy-to-perform point estimation approach (Huss et al., 2000; Tuominen et al., 2003) to evaluate their potential risks. Nevertheless, the use of those methodologies is as well appropriate in a company's risk assessment implementation. However, managers may feel safer by evaluating the risks via calculations in a more progressed phase of the implementation process. The usefulness of qualitative risk assessment methodologies is not to be underestimated in the sense of helping risk managers to set priorities or to make policy decisions (Coleman & Marks, 1999). The most interesting qualitative risk assessment methodologies for sustainability purposes will be explained here after.

Delphi Survey

As from the original elaboration of the Delphi Survey, it has experienced several changes resulting in different variants. Nowadays, we distinguish between three different Delphi Surveys, namely [1] the Classical Delphi, characterised by its five features anonymity, iteration, controlled feedback, statistical group response, and stability in responses, [2] the Policy Delphi, whose aim is to generate policy alternatives by utilising a structured public dialogue, and [3] the Decision Delphi commonly used to make decisions concerning social developments (Hanafin, 2004; Plochg et al., 2007). In this work, we will focus on the Classical Delphi, whose main purpose is to collect, assort, and rank data and to find a broad agreement from a group of experts (Häder, 2009). The Delphi Survey Process is depicted in Figure 51.

Since the results provided by a Delphi Survey may be considered being subjective, the analyst needs to pay attention not to influence the respondents by his own point of view. In fact, the way how questions are elaborated may affect the respondents' answers (Ekionea et al., 2011). In the same approach, Kuehne + Nagel's internal experts suggest that the responsible analysts should pay attention to obtain a wide variety of different ideas and concepts through the first questionnaire. They argue that respondents could become disappointed, feeling forced to choose between options they cannot agree with. In addition, the analyst needs to explore eventual disagreement, since the Delphi Survey's end result could provide a false agreement in case of ignorance of discrepancies (Häder, 2009).

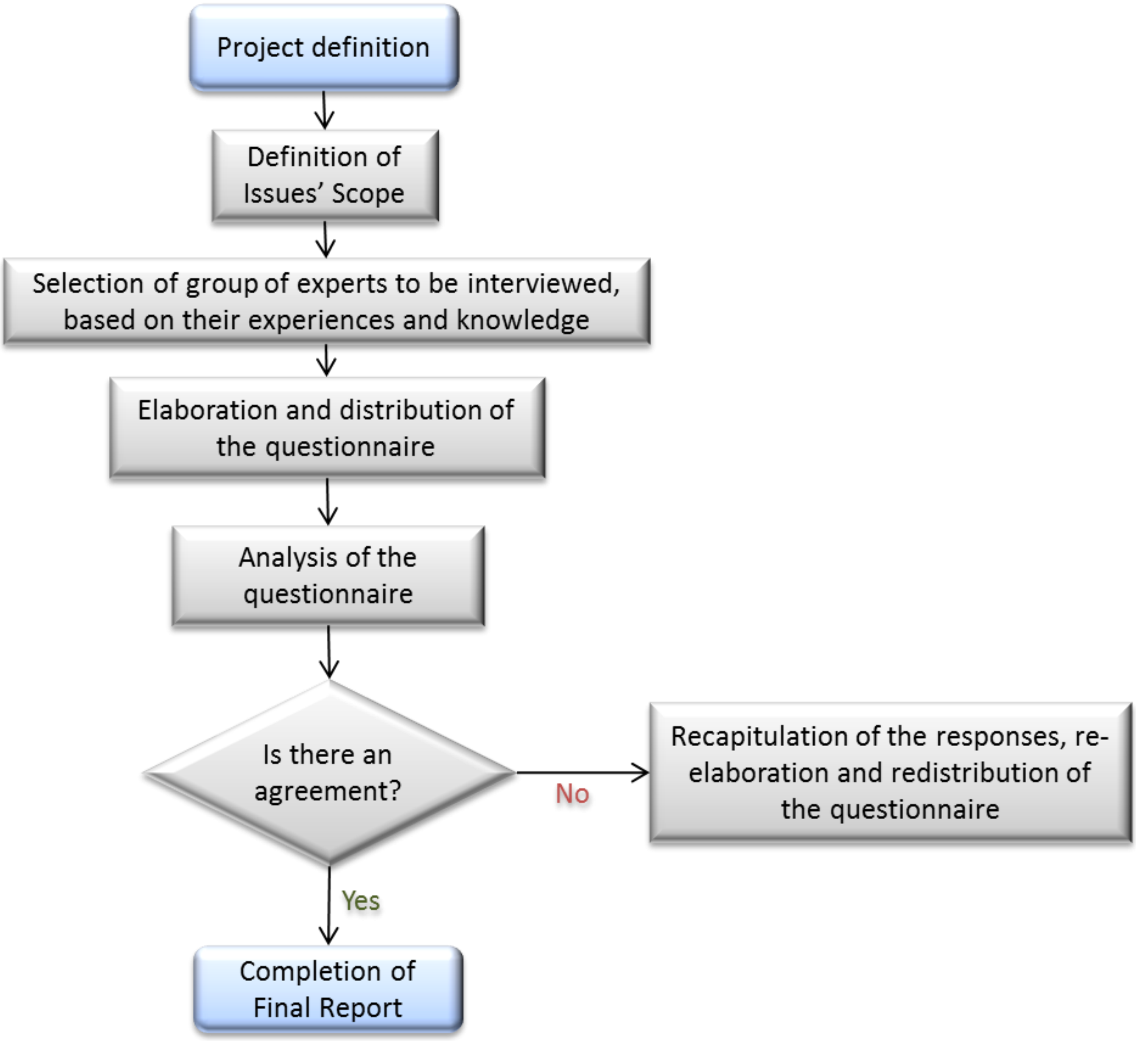


Figure 51 – The Delphi Survey Process

One main advantage of the Delphi Survey consists of the aforementioned anonymity. Effectively, according to Kuehne + Nagel's internal experts, people have the courage of being honest since they have the possibility to modify their views as they learn from the provided feedbacks. The anonymity can alleviate the social pressure prevailing in face to face discussions (Ekionea et al., 2011) and to reinforce individuality because of the isolated emergence of ideas and concepts (Boberg & Morris-Khoo, 1992). In addition, equal consideration of the respondents' contributions can be guaranteed (Boberg and Morris-Khoo, 1992). Another positive characteristic of this methodology is that the questionnaires allow to involve more experts than face to face meetings, reducing thus the participants' time and eventual costs of travelling to meetings in case of geographically dispersion (Häder, 2009; Somerville, 2008). On the other hand, the criticisms yield through literature review cannot be neglected. Those include the method's tendency to produce influenced consensus and the time required because of the need to wait for the questionnaires to be answered (Boberg & Morris-Khoo, 1992). Also, the analysts have to keep in mind that the Delphi Survey, just like all qualitative risk assessment methodologies, cannot provide empirical proofed results, even though, *"proponents of the method argue that rigor is an inappropriate criterion for naturalistic inquiry. The trustworthiness and authenticity developed through perception-checking opportunities inherent in the method are appropriate"* (Boberg & Morris-Khoo, 1992).

Failure Mode and Effect Analysis (FMEA)

Companies may use the Six Sigma methodology to manage their risks. One tool frequently used in Six Sigma is the Failure Mode and Effect Analysis (FMEA), which is adopted to design, to review and to control products or processes (Werdich, 2011). In addition, the FMEA is seen as one of the most common Quantitative Risk Assessment (QRA) methods (Samadi, 2012). It consists in a procedure which is used to ascertain where a given process is likely to fail. Beyond, it gives information about the reasons of eventual failures. Each failure mode is identified via an incremental approach. The effects of each potential failure are analysed and measures are devised so that the failure may be impeded. FMEA is based on an event chain accident approach (Samadi, 2012). Effectively, an accident normally appears because of many successive events due to which risks have materialised. In order to calculate the risk via the FMEA methodology, the three components [1] Severity (Se), [2] Occurrence (Oc), and [3] Detectability (De) are multiplied and result in a risk priority number (RPN):

$$\boldsymbol{RPN = Se \cdot Oc \cdot De}.$$

FMEA is hence a tool which may be used in both, a preventive and curative way to enable managers to understand when, where, why, and how a process or procedure could be miscarried. Carlson (2014) represented the high level timing for FMEAs as shown on Figure 42. Actually, he explains that commonly, FMEAs should be envisaged early in the product development process, when design and process changes can easily be implemented. Concept FMEAs should be executed when the different concept alternatives are considered, but before the design or process concepts have been chosen. System FMEA should be executed when the system configuration is defined and should be terminated before the system configuration has been completed. Design FMEAs should be initiated once the design concept is ascertained and should be done before the design configuration has been performed. Finally, Process FMEAs should be started when the manufacturing or assembly process has been initiated at the concept level, and should be completed before the manufacturing or assembly process' deadline (Carlson, 2014).

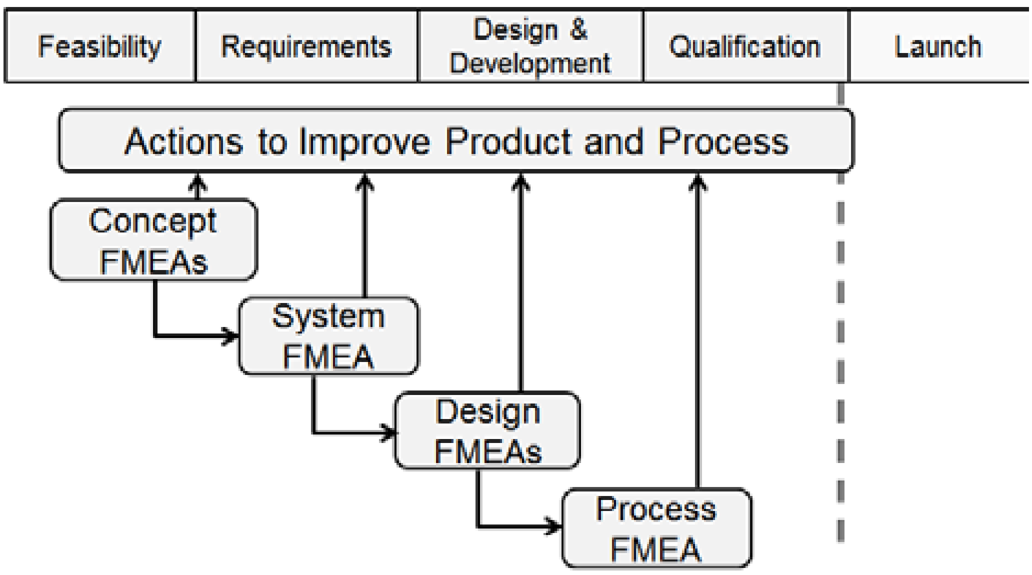


Figure 52 – Failure Mode and Effect Analysis and Stage Gate Process - High Level by Carlson (2014)

One of its main advantages is its structured and detailed approach, which requires considering every potential or known failure (Werdich, 2011). In addition, the FMEA analysis helps improving designs for products and processes via higher reliability, increased quality, enlarged safety, and consequently, improved customer satisfaction. In a business point of view, the fact that it contributes to cost savings as the development time and (re)design as well as the warranty costs are decreased are seen as a positive side effect (Bergman and Klefsjö, 2010). Potential product or process failure modes are therefore early identified and potentially eliminated. However, FMEA's disadvantages cannot be neglected. Firstly, because of its used top-down method it discovers only major failure modes in a given system. Furthermore, as FMEA is normally implemented by a whole team (Werdich, 2011) it is evident that the tool is just as powerful as its team behind. Issues which go beyond the different team members' knowledge cannot be detected or solved. Another limitation is the balancing act of choosing an effective scope: many failure modes will be missed if the FMEA is not carried out in an adequate detail level. In this same logic, if the scope is too large, there are too many details analysed and the team will lose time by contemplating so-called "potential risks", which will for certain never materialise. The FMEA process has therefore to be broken down into small segments so that they become manageable and easily understandable (Werdich, 2011). Another drawback is that many companies see the FMEA as a static model. In fact, the FMEA needs to be updated periodically in order to identify the new potential failures and to develop the corresponding new control plans.

Hazard and Operability Study (HAZOP)

The hazard and operability (HAZOP) study is an effective and systematic approach whose methodology is based on brainstorming techniques. The ISO 31010 suggests the use of parameters and deviation guidewords to identify hazards in facilities, equipment, and processes (Utne et al., 2014).In general, the HAZOP technique requires the analysed system being broken down into well-defined subsystems, considering as well the functional process flows between those subsystems. The systematic and critical examination of HAZOP has been developed to detect hazards and operability problems during the design or redesign phase of a system. To use this methodology, it is important to have a complete and detailed knowledge of the system and its inherent procedures (Catmur et al., 1997). Each subsystem is matter of a multidisciplinary group of experts' discussion. Fuchs et al. (2011) illustrated the HAZOP analysis process as shown on Figure 53. The examination of a HAZOP study needs to be seen as a creative process, which is carried out under the direction of a supervisor. The latter has to assure a comprehensive ascertainment of the considered system using logical and analytical thinking. The identified problem needs to be recorded so that subsequent assessment and solutions can be submitted. HAZOP is divided into 4 subsequent steps, namely [1] Definition, [2] Preparation, [3] Examination, and [4] Documentation and follow-up (British Standards Institution, 2001).

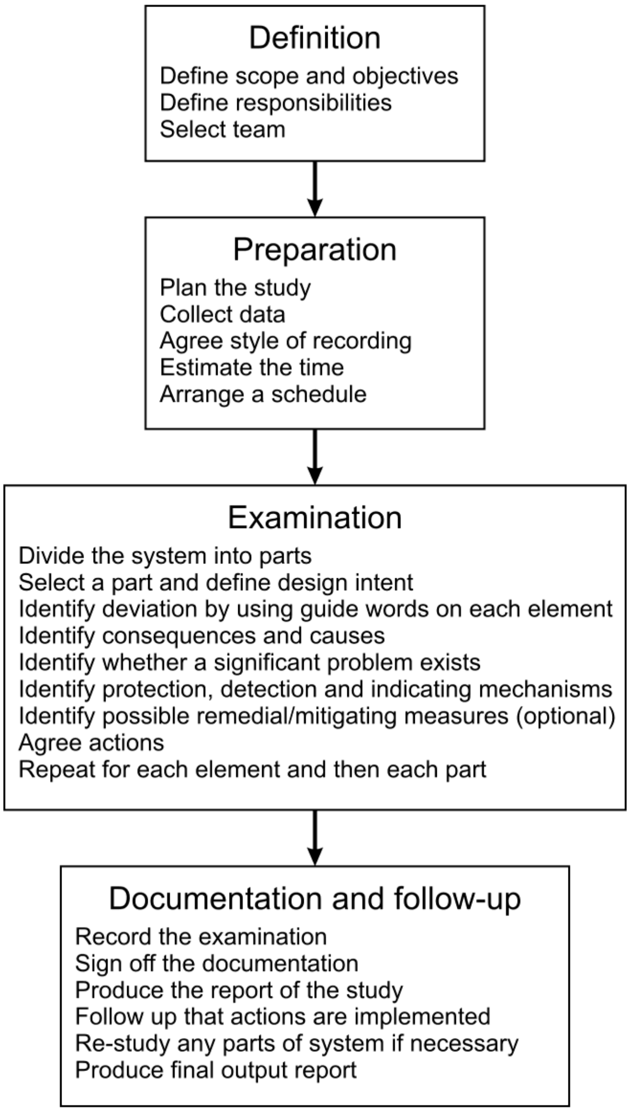


Figure 53 – The Hazard and Operability Analysis Process illustrated by Fuchs et al. (2011)

The HAZOP methodology's main advantage is that it can help managers if they have to deal with risks which are difficult to quantify, such as the risks related to human performances and behaviours, or uncertainties which are difficult to detect, and therefore difficult to analyse or to predict. Moreover, its systematic and comprehensive methodology is seen as extremely valuable in the business environment. In fact, managers perceive HAZOP as more simple and intuitive than other frequently used risk management tools (Fuchs et al., 2011). Nevertheless, there are also some disadvantages, as for example the fact that the technique is not able to rank or prioritise the yielded risks. Furthermore, the technique has no possibility to evaluate risks which are due to interactions between different parts of a system or process. In addition, to assess the effectiveness of controls, the HAZOP methodology needs to be linked to another risk management tool (Fuchs et al., 2011). To rephrase, the HAZOP methodology does not focus on the functionality of the control systems: If a control system fails (even only partially), there is an enormous amount of potential failures which remain unexpected.

'What if' Methodology

The 'What if' Methodology can be seen as a brainstorming of what can go wrong and considering the likelihood and consequences of a realisation of such situations, forecasting thus different possible scenarios. Scenarios have been used by government planners, military consultants, and company managers as effectual tools supposed to help in decision making facing uncertainty and risks (Mietzner & Reger, 2005). Scenarios are a set of stories build around constructed plots, which can formulate several perspectives on complex events. Roubelat (2000) defined scenarios as follows: *"In theory, scenarios are a synthesis of different paths (events and actors' strategies) that lead to possible futures. In practice, scenarios often merely describe particular sets of events or variables".* The scenarios need to be discussed by a team, comprising several experts, maintenance employees, operating and design engineers, and safety representatives. Based on their past experiences and knowledge of similar situations, each member and expert participates in the fault finding process via a scenario thinking approach. The boundaries are defined and it is ensured that each team member has the right information and understanding of the system to be discussed. The aforementioned system is reviewed step by step and analysed via a form which is similar to the one shown in Table 23.

Team Members			Date	
What if?	Answer	Likelihood	Consequence	Recommendation
...	...	...	...	...

Table 23 – 'What If' Methodology

The answers given to these questions create the basis for subsequent decisions and judgments concerning the acceptability of a given risk and for determining following steps for the unacceptable risks. To avoid that potential problems are missed, the 'Recommendations' section will be filled out at the end, when every potential source of danger is identified. The last step of this methodology consists in summarising and prioritising the hazards and in assigning the responsibilities (Dougherty, 1999).

The What If Analysis allows hence the foresight of the outcome of a given decision in an accurate manner while decreasing the risks which are normally associated with those decisions. Also, it helps managers to reduce the amount of time concerning the decision making process. In fact, managers can use real data and they don't have to collect new ones for the different envisaged scenarios. Decisions can thus be taken in a short amount of time since the What If Analysis is based on updated data records. In addition, as the different scenarios may be analysed in an accurate manner, decisions which could harm the business can be sorted out while the ones that may benefit the company can be highlighted. In fact, the scenario thinking allows managers to open up the mind to hitherto unimaginable possibilities and question traditional convictions of a company. The use of scenarios can change the company's culture, and coerce managers to revise radically the assumptions on which they have grounded their strategies (Mietzner & Reger, 2005). The continuous improvement of an enterprise's inherent strategies is thus promoted. Nevertheless, Golfarelli et al. (2006) yield some drawbacks of the What If Analysis. According to them, only few tools offer what-if capabilities, which, in addition were generally limited to a specific utilisation. Additionally, the model is only as strong as the team of experts working with it. Since the What If Analysis obeys to a relatively unstructured approach, the results might be incomplete if the working team is not composed by experts. Nevertheless, even experts may have problems when evaluating the probability of an event to occur; simultaneously, such evaluations are mostly subjective and depend hence to experts' past experiences. The more negative experiences such an expert has lived, the more pessimistic the given scenario will be evaluated. Naïve approaches may make projects more expensive and expose them to even higher risks of failure. Another point to allude is that even if the time for decision making may be reduced, the practice of scenario assessments is very time consuming. Further, a deep understanding of the analysed system is absolutely necessary while using the What If Analysis. The system needs to be simplified in order to be modelled afterwards: Data and information from different sources need to be collected and analysed, which makes the scenario building even more time consuming. This may become extremely difficult in intricate companies (Mietzner & Reger, 2005). Managers may be disheartened to implement what-if projects. The effort for proving the reliability of the simulation model may be demanding not only in terms of money (Golfarelli et al., 2006), but also in terms of time. In fact, *"[…] facing what-if project without the support of a methodology and of a modelling formalism is very time-consuming, and does not adequately protect the designer and his customers against the risk of failure"* (Golfarelli et al., 2006).

Corollary

utilities of an outcome in a linguistic way, using for example "low", "medium", and "high". Lowder (2008) discusses that *"other writers assume that quantitative RA [Risk Assessment] is objective and numerical while qualitative RA is subjective and non-numerical. […] this common view is mistaken. Both types of RA are numerical and both types are compatible with objective and non-objective estimates of probability.[…] different methods can be used for different risks"* .

Effectively, the Failure Mode and Effect Analysis (FMEA) is commonly used in companies since, on the one hand, it is quite simple to be implemented, and on the other hand, it may contribute to time and cost savings. Nevertheless, it employs numerical data while being classified as qualitative risk assessment methodology. Even though potential vulnerabilities are early detected, only major failures may be determined because of its top-down approach. In addition, the FMEA methodology is only as strong as the team using it: issues which surpass the different team members' knowledge cannot be detected, nor solved. In other words, the different team members need to be thoroughly chosen.

The classical Delphi Survey, on the other hand, is commonly used to collect, assort, and rank data and to find an agreement from a group of experts. It's most important inherent feature is the given anonymity, which holds many advantages, such as the alleviation of social pressure which may be felt by the respondent, or the latter's honesty in answering the questions posed. Nevertheless, even though the experts find an agreement, the latter is still based on subjective opinions. The Delphi Survey may thus not provide empirically proven results.

This is also true for the Hazard and Operability (HAZOP) study. In fact, this methodology is based on brainstorming techniques, using parameters and deviation guidewords to identify eventual events or combination of events having an impact on the company's overall performance or reputation. The investigator needs to assure a comprehensive determination of the considered system and to record the identified eventual hazards. The HAZOP Study is a systematic and comprehensive methodology, which helps managing risks which are difficult to quantify. However, this methodology cannot rank, nor evaluate the identified hazards and risks. In addition, potential failures may remain unexpected, which is one of the methodology's main drawbacks.

Like the HAZOP study the What – If methodology is also based on brainstorming techniques, which include experts from different specialisation fields. The What – If the analysis and forecast of different eventual scenarios and helps to create the basis for subsequent decisions and judgments concerning the acceptability of a given risk or for determining the following steps for the unacceptable ones. It is generally accepted that this methodology, which promotes the continuous improvement, allows the foresight of an event's outcome in an accurate manner and permits therefore to reduce eventual risks. In addition, since real data can be used for analysing the different future scenarios, decisions can be taken in a more accurate manner. However, there are only few tools being able to handle what-if features. Also, many efforts are required to prove the reliability of the simulation model, which, additionally, needs to be updated on a regular basis. Hence, the model is only as strong as the team behind the model. The latter needs thus to be composed by experts who have to prove deep understandings of the system to be analysed. Like the other methodologies presented above, the 'What – If' methodology provides mostly subjective evaluations. Table 24 summarises the different qualitative risk assessment methodologies which have been discussed in this section.

Delphi Survey	
Advantages	**Disadvantages**
• Anonymity guarantees respondents' honesty and enforces individuality • Anonymity alleviates social pressure prevailing in face to face meetings • Anonymity guarantees equal consideration of the respondents' contributions • More experts may be involved in Delphi Survey than in traditional face to face inquiries • Time and costs for travelling to meetings can be saved	• There is a tendency to produce influenced consensus • Time required because of the need to wait for the questionnaires to be answered • Empirical proofed results cannot be provided
Failure Mode and Effect Analysis	
Advantages	**Disadvantages**
• Structured and detailed approach • Helps improving design for products and processes • Contributes to cost savings • Development time, (re)design and warranty costs may be decreased • Potential failures are early identified • Continuous improvement is promoted	• Only major failure modes are detected in a given system • Tool is just as powerful as its team behind • Only as strong as the team behind the model • Choosing the right scope may be a balancing act • Failures may remain undetected or team may lose huge amounts of time • Needs to be updated regularly

HAZOP	
Advantages	**Disadvantages**
• Helps to manage risks, which are difficult to quantify • Systematic and comprehensive methodology	• Risks are neither ranked, nor prioritised • Risks cannot be evaluated • Needs to be linked to another tool to access effectiveness of controls • Potential failures may remain unexpected
What If	
Advantages	**Disadvantages**
• Allows the foresight of the outcome in an accurate manner • Allows the decrease of risks • Reduces time used for decision making process • Real data can be used for analysing different future scenarios • Decisions can be taken in a more accurate manner • Continuous improvement is promoted	• Only few tools offer “what-if” capabilities • Model is only as strong as the team behind • Relatively unstructured approach • Team needs to be composed by experts • Only as strong as the team behind the model • Evaluations are mostly subjective • Scenario assessments are time consuming • Deep understanding of the system to be analysed is required • Data and information need to be collected from different sources • Many efforts are required to prove the reliability of the simulation model • Needs to be updated regularly

Table 24 – Summary of Qualitative Risk Assessment Methodologies

3.3.3 Hybrid Risk Assessment Methodologies

Bow Tie Model

The Bow-Tie Model (BTM), also known as ‘Barrier Diagram’, is used by companies world-wide across several industry sectors (Lewis & Smith, 2010). The BTM is a combination of two complementary techniques, namely the Fault Tree Analysis (FTA) and the Event Tree Analysis (ETA). In other words, the BTM uses both techniques, while they focus on opposite sides of a given undesired event. As their names suggest, the FTA helps to identify eventual causes for faults or risks of a particular system, while the ETA helps to identify eventual events, that is to say undesired outcomes and consequences of possible failures. Both are systematic methods conceived to find out how a particular situation can arise and what may ensure from a critical event (Clifton, 1990). This graphical technique uses logic diagrams to exercise the identification of risks’ causes and effects. The FTA has first been introduced in 1961 (Lee et al. 1985) and can be shown as follows:

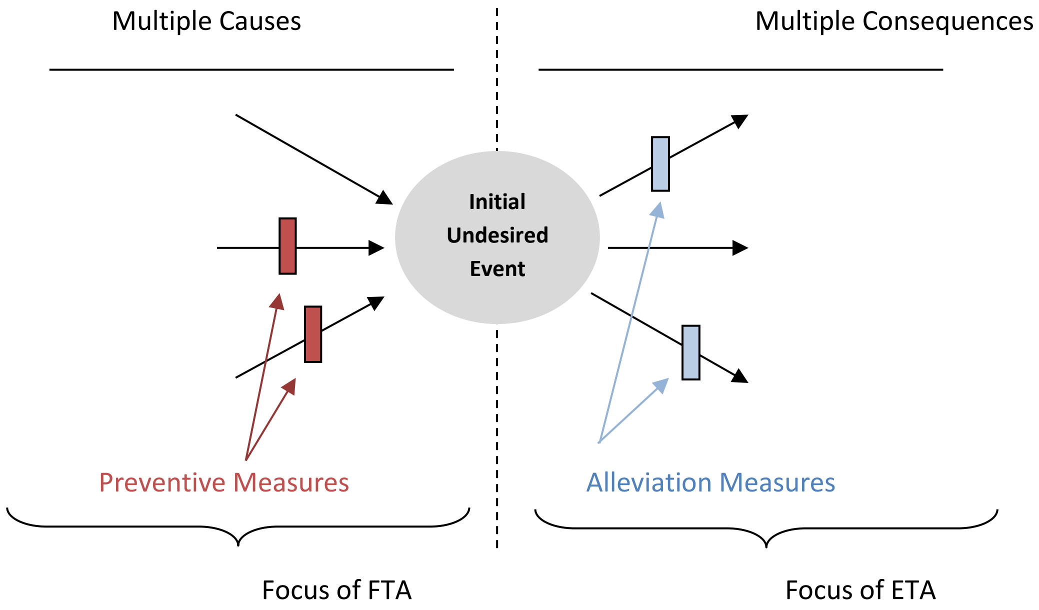


Figure 54 – Bow Tie Model: Fault Tree Analysis & Event Tree Analysis

While Fault Trees (FT) move backwards, starting from a given failure via all possible causes, the Event Trees (ET) move forwards, starting from a failure showing the accident's sequences. The FTA-ETA Method gives managers qualitative insights, so that sequences can be quantified and hence, probabilities of particular situations or events can be approximated (Takaragi et al, 1983). In most cases a disaster does not appear because of one single failure, since they normally take place because of a combination several incidents. Howbeit, the FTA – ETA approach assumes that each branch of a tree embeds mutually exclusive events which are independent of one another. As FT and ET include many judgements, analysts have to ascertain the problem's structure as well as the importance of the various branches.

The fact of illustrating the hazard as well as its causes and consequences in a visual manner fosters common understanding and clear communication at all levels of a company, i.e. members from senior management as well as operations personnel, as well as controlling institutions. The big picture can be guaranteed and the sequence of events and previous incidents are kept. As a picture is worth a thousand words, unnecessary or lower importance barriers may be reduced (Lewis & Smith, 2010). In addition, the communication between the different stakeholders is encouraged and stimulated. In fact, people will take responsibilities in case their proposed action is taken. Besides, the issue of lack of ownership can be avoided. Another point to allude is the fact that the BTM is less labour intensive than other traditional techniques, which can also be seen as a gain of efficiency (Treytl & Himmelbauer, 1996). Furthermore, the volume of safety analysis may be reduced since the spots where resources should be focused for risk reduction can be identified (Hack, 2004) and since the workforce involvement allows every participant to see why their tasks are critical for risk control (Lewis and Smith, 2010).

The systems' simplification via the BTM helps discovering pertinent information concerning the process logic. However, as a simplification always imports a certain loss of information or data, some appearing characteristics of the whole system may be lost (Čepin, 2011b, 2011a). As stated before, the BTM's approach assumes that each branch of a tree incorporates mutually exclusive and independent events. For that reason, the model fails in identifying common cause failures, partial failures or time delays (Bell, 1989; Steward, 1990). Moreover, the BTM is not able to quantify the level of risk in absolute terms. In fact, it cannot be used for complex inter-relationships analysis. Further, Lewis and Smith (2010) explained that if a company wants to identify individual protections for every line of every section of every unit of the process facility, then the BTM will not be helpful.

Fishbone Diagram

The Fishbone Diagram is generally used to evaluate the causes and sub-causes of a given event, i.e. to identify potential risks of a business or process. Those diagrams are usually used to illustrate and communicate the relationships between several causes which may lead to an undesired event. A *conditio sine qua non* is that a team, including all relevant experts is composed. This team analyses the given problem via a research of the main cause variables. To do so, they use the “6M”, namely (1) Management, (2) Machine, (3) Material, (4) Man *(in the sense of human being)*, (5) Methodology, and (6) Milieu *(in the sense of working environment)* (Mahto & Kumar, 2008; Syska, 2006). Within those six main influencing factors, sub factors need to be ascertained. The latter will be scrutinised through the five “why” questions (Syska, 2006). For each “why?” an answer needs to be found. By this mean, it can be ensured that a problem will be considered in detail. By focusing on an escrow issue the problem’s real cause, which is frequently hidden by other indications or symptoms, may de facto be revealed (Suske, 2010). Upon completion of the diagram the team adopts the problem’s main cause, which will be discussed, analysed and tested. If the given main cause turns out being not as relevant, the next possible cause needs to be treated in the same way (Syska, 2006).

One of the model’s main advantages is that it is, because of its visual representation, easy to understand and to apply (Syska, 2006). In addition, it allows a thoughtful analysis which avoids that any possible main cause might be missed. The team is focused on the big picture while it may search for possible influencing factors leading to an undesired event. Moreover, it shows sub-causes and fields of vulnerabilities before they lead to major difficulties. On the other hand, the simplicity of a fishbone diagram, which is often seen as an advantage, can also be interpreted being a drawback. In fact, because of this simplicity and since reality is usually very complex, the analysing team may have difficulties to represent the really interrelated nature of the problems’ causes and effects. Also, because of the reality’s complexity, the diagram may become extremely large in space. Otherwise, the team may not be able to investigate the relationships between the different causes and effects as detailed as intended. The major drawback is probably that the model is quite time consuming since it is very likely that the team expends a great amount of time and energy in theorising potential causes while many of them have no significant impact on the problem to be solved. In addition, the model treats the potential causes in an equiprobable manner, while in reality, their probabilities and hence their priorities may differ flagrantly (Kanti Bose, 2012).

Corollary

The Bow-Tie Model (BTM), a combination of the Fault Tree Analysis and the Event Tree Analysis, helps to identify the eventual causes for faults or risks of a particular system and the eventual outcomes or consequences of an undesired event. The BTM can be shown as logic diagram, which enables common understanding and fosters clear communication not only at all levels of the company but also between all the different stakeholders. Since the BTM is less labour intensive than other traditional techniques, a gain of efficiency can be guaranteed and a lack of ownership can be avoided. Moreover, the volume of safety analysis may be reduced because the required simplification of the system. On the other hand, analysts need to keep in mind that a simplification always imports a certain loss of data or information. Another negative aspect is that the model is based on strong assumptions of mutually exclusive and independent events for each branch of the considered tree.

The Fishbone Diagram is easy to understand and to apply since it simplifies reality. As stated above, this simplification may also be considered being a drawback because of its consequential loss of information. Since the undesired event's sub-causes are shown, the situation can be viewed as overall picture, notifying the different fields of vulnerabilities. The model's inherent concern is that it may be difficult to represent the interrelated nature of the defined issues' causes and effects and that the potential causes are usually treated in an equiprobable way. A summary of the different hybrid risk assessment methodologies is given in Table 25.

Bow Tie Model	
Advantages	**Disadvantages**
• Common understanding and clear communication at all levels of the company is fostered • Communication between different stakeholders is encouraged and stimulated • Big picture can be guaranteed (team will lose itself in details) • Sequence of events and previous incidents are kept • Issue of lack of ownership can be avoided • Less labour intensive than other traditional techniques (gain of efficiency) • Volume of safety analysis may be reduced • Simplification of the system helps discovering pertinent information concerning the process' logic	• Simplification always import a certain loss of information or data • Only as strong as the team behind the model • Assumption of mutually exclusive and independent events is taken for each branch of the considered tree • Cannot identify common cause failures, partial failures, or time delays • Level of risk cannot be quantified in absolute terms • Cannot be used for complex inter-relationships analysis • Cannot be used to identify individual protections for every line or every section of every unite of the process facility
Fishbone Diagram	
Advantages	**Disadvantages**
• Easy to understand and to apply • Simplifies reality • Avoids that any possible main-cause might be missed • Big picture can be guaranteed • Sub-causes are shown • Fields of vulnerabilities are shown	• Simplicity leads to loss of information • Only as strong as the team behind the model • Difficult to represent really interrelated nature of the problems' causes and effects • Diagram may become extremely large in space • Time consuming • Potential causes are treated in an equiprobable manner

Table 25 – Summary of Hybrid Risk Assessment Methodologies

3.3.4 Conclusion

The above analysis of risk identification and assessment models shows clearly that there is no antidote which might be used, so that every risk could be identified and counteracted at once. Some failures or risks can simply not be prevented, such as the so called '*Force Majeure'*, or human failure. Nevertheless, the fact of choosing the right model is of crucial importance. This is albeit, highly dependent on the project, the company, or the system to be analysed. A short summary of the different tools analysed above is given in Table 22, Table 24, and Table 25.

As stated before, the risk assessment model to be used depends on the considered risks as well as on the data which the company can access. In this work, we consider the risks which may occur through the improvement of an existent SC's sustainability performance. The models to be used to assess those risks need therefore to be consistent with our purpose. The Bow-Tie Model (BTM) as well as the Failure Mode and Effect Analysis (FMEA) seem being of high value for the risk assessment in this specific case. Even though, BTM needs to be compiled with at least one risk mitigation methodology so that the different barriers may be set up. We consider this model being of high interest for the risk mitigation phase, but inappropriate for the identification and evaluation of the different risks. The Fishbone Diagram's inherent disadvantages, on the contrary, causes discomfit resulting in a rejection of this methodology for our aim. In fact, we consider that the loss of information due to the model's simplicity may represent a big concern for companies which base their internal strategy on the continuous improvement concepts. Because of the difficulties to represent the real interrelations of causes and effects, via the Fishbone Diagram, its advantages cannot outbalance its disadvantages. This also holds true for the Hazard and Operability (HAZOP) methodology, which, in addition contains the risk that potential failures may remain unexpected.

As stated above, it is not possible to identify all potential risks. Nevertheless, the predictable ones should not be neglected. The What-If methodology, however, is used in practice within Kuehne + Nagel. Even though its' drawbacks cannot be denied, we consider that a modified what-if method may be of high importance for our risk assessment model.

3.4 Risk Assessment Model: Implementation and Application at Kuehne + Nagel Luxembourg

3.4.1 Background

In their work, Von Neumann & Morgenstern (1953) demonstrated that an individual will always prefer actions that maximise the expected utility. In fact, they verified that an individual is rational if and only if a real-valued function *u* there exists. The latter is defined by potential outcomes in a way that every preference is distinguished by maximising the expected value of *u*, which can be defined as the individual's utility. They did not claim that the individual has the deliberate wish to maximise their utility function *u*; they only stated that it exists. This is perfectly consistent with Simon's (1959) concept of satisficing, adopted in this work. Being aware of the fact that the utility function of a given indicator will never be maximised, the best case would nevertheless be the maximisation of an event's positive outcome. However, it is not possible to calculate the company's utility per expected outcome because of the high amount of unknown-unknowns and known-unknowns. It would be important to know, the exact deviation of one indicator, due to the variation of one other indicator. However, this is not feasible since the indicators defined in our model have interdependencies not only among themselves but also with other indicators, external to our model. In addition, managers usually ignore indicators that are not directly related to their daily business or the customers' satisfaction.

The following case study is intended to respond to the question about the risk quantification model's feasibility in real cases. To do so, we consider the SC of the Customer operating in the industrial domain in a B2B environment. As already mentioned in Chapter II, the customer's name will not be revealed for confidentiality reasons. For simplicity reasons, the Customer's SC will not be entirely taken into consideration, but we only take into account the part Kuehne + Nagel is responsible for. The model would also fit to the entire supply chain, as the simulation depends solely on the data entered, but for time concerns, it is not possible to take the whole SC into consideration.

To correctly assess the SC's inherent sustainability risks, it is imperative to first consider the existing interrelations between the indicators defined ex-ante. As explained before, those interrelations cannot be considered via assumptions, nor neglected because this would render the model being escapist and therefore useless for companies.

To identify those interactions, managers need to gather the right information. Four kinds of information can be identified, namely (1) Unknown-unknowns, (2) Unknown-Knowns, (3) Known-Unknowns, and the (4). Those four kinds of information have been explained more in detail by Logan, (2009) and Pisani-Ferry (2013) in the chemical and the political domain respectively, and are depicted in Table 26. The unknown-unknowns are data, managers are not aware that they do not know them. The unknown-knowns can be gathered via discussions or questionnaires. Effectively, managers may have unconscious knowledge and are able to give answers to questions, they were sure not to be able to. The known-unknowns are defined as so-called noises within the Six Sigma methodology. The noises consider the intangible information, i.e managers know that these kinds of information exist but they cannot quantify or handle them. The known-known are the data and information, the managers are aware of. They know the different inherent factors and can handle them. While the factors included in a risk assessment model may be classified being known-knowns, the intentionally excluded ones can be either classified as known-unknowns or unknown-knowns. The unknown-unknowns are not identifiable or quantifiable. For this reason, they cannot be assumed and therefore not be introduced into the model.

		Consciousness	
		Unknown	**Known**
Information	**Unknown**	**Unknown – Unknowns** “We do not know, what we do not know” *This information is not available* Ex.: *Force Majeure*	**Unknown – Known** “We do not know, what we actually know” *Unconscious knowledge can be converted into known-known when asking the right questions* Ex.: A specific Formula
	Known	**Known – Unknown** “We know, what we do not know” *This information is not available* Ex.: The risks actual magnitudes	**Known – Known** “We know, what we know” *This information is known* Ex.: Costs

Table 26 – Types of Information

3.4.2 Case Study

In the following, we will provide a stepwise elucidation of the risk quantification model depicted in Figure 45. Its end result will consist of a risk quantification, which is intended to support managers’ decisions in risk assessment and risk mitigation issues. In the approach of continuous improvement, the model is to be considered as infinite. Effectively, since it implies the previously presented Evaluation Model, the Risk Quantification Model needs to be considered as a continuous loop. Nevertheless, the last phase of the risk quantification model is not to be seen as the last phase of the whole risk assessment process, as it will be described more in detail in a later stage.

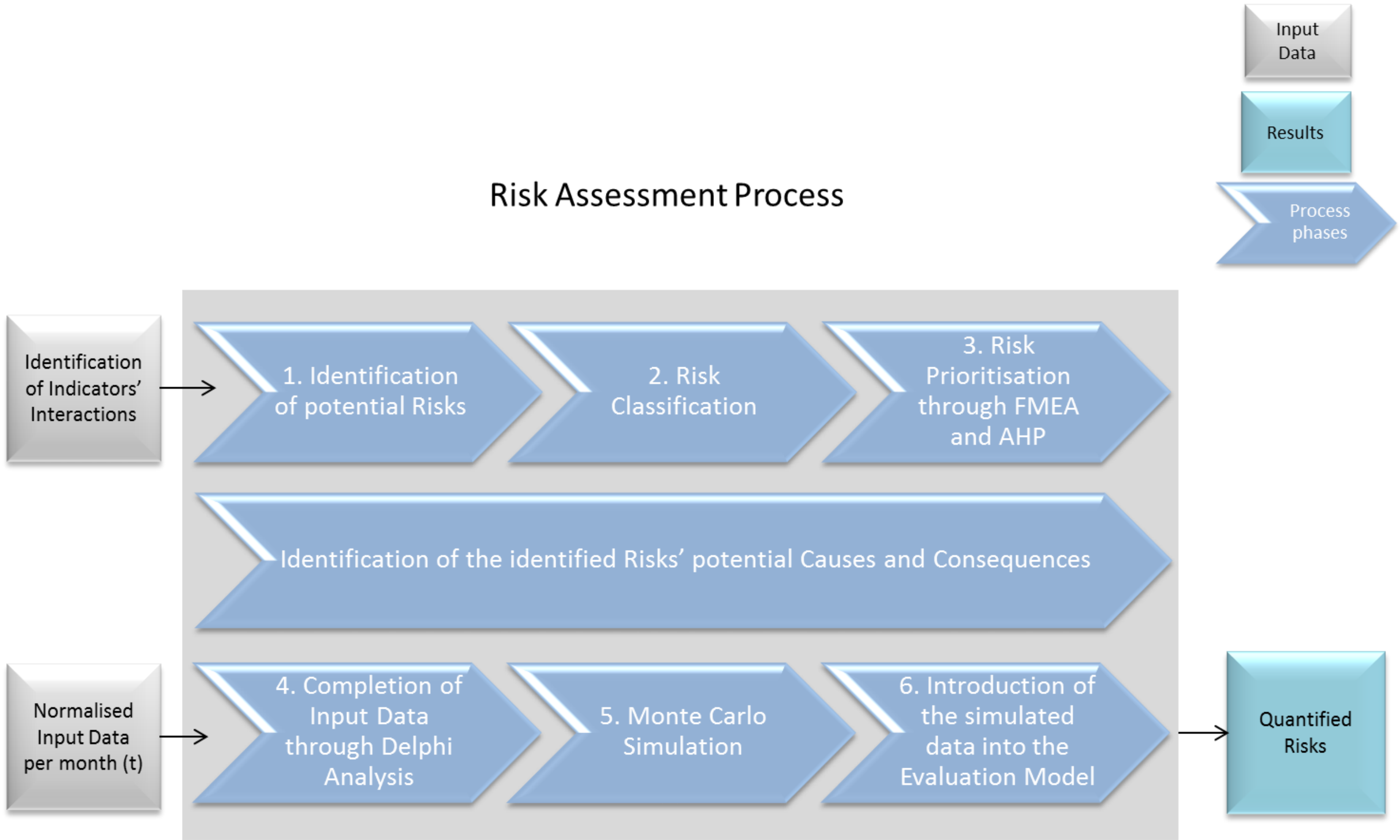


Figure 55 – Risk Assessment Process (White Box)

Our risk assessment process consists of six different steps, based on the indicators' interactions. It is important to understand that those interactions are specific to our case study. In another system evaluated by this risk assessment model, there may be no identified interactions between the different indicators. However, it can be assumed that such a system holds interactions which can be classified as unknown-unknowns. We therefore consider that 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 thus differ from one case to another. The classification of the gathered information into known-knowns, unknown-knowns, known-unknowns and unknown-unknowns is to be seen as important. Effectively, the unconscious knowledge (unknown – known), may turn into conscious knowledge (known-knowns) if the analysts pose the right questions to the right interviewees. This classification is usually done in an intuitive manner, within the data collection and information gathering processes, present within every process step. 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 of our risk assessment model will then be the consignment of quantified risks.

The end result provided by our risk assessment model will be a snap-shot picture of the 'As-Is' situation. To implement the case study, we will consider the Customer's[35] historical data on the short term timeframe from 2010 to 2013. This timeframe has been chosen because of the same reasons discussed in Chapter II.

Identifying the Indicators' Interactions

Sodhi et al. (2012) highlight that Supply Chain Risk Management (SCRM) generally relates to risks which occur from the interconnected flows of materials, information, and financials in supply chains. In this sense, we consider that every alternation of one specific indicator presents consequences on at least one other KPI. The key is to distinguish the causes and consequences of such a modification. Effectively, if for example the kilowatt-hours of **energy used decrease**, the fact that the **costs** will **decrease** too is to be seen as a **consequence**. Contrariwise, the improvement of the costs indicator will not lead to less energy used. From the **point of view of cost reduction**, the **decreased energy used** needs thus to be seen as a **cause**, not as a consequence. In this logic, every first tier consequence leads to at least one second layer effect. Indeed, in most cases the consequence of one indicator can be converted into a cause of another KPI's alteration, providing thereafter a *circulus vitiosus*. For this reason, we neglect the causal interactions and only take into account the consequences of a given improvement.

As explained before, a risk may consist of a positive or negative effect, leading to our suggestion that every consequence may harbour a certain risk. To put it in Hofmann et al.'s (2014) words, *"risk is equated with variance and therefore has both a downside (loss) and an upside (gain) potential."* In chapter II, we evaluated the Customers' SC's overall degree of

[35] This case study is based on the same Customer as the case study performed in Chapter II.

sustainability in the point of view of Kuehne + Nagel Luxembourg. The indicators' interactions and the different risks need therefore to be analysed in this same point of view. In addition, as explained by Foerstl et al. (2010), *"firms which outsource production to suppliers cannot transfer the risk related to unacceptable environmental and social standards at the supplier premises, but must seek active management of the supply base for sustainability."* This means that even though Kuehne + Nagel engages subcontractors to execute the transportation, this may not lead to the conclusion that the company hands over its responsibility.

We suggest that the techniques to be used in this specific case are a composition of the HAZOP and the What If methodologies. Indeed, to find the potential interactions between KPIs, several brainstorming meetings with experts[36] 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 shown in Figure 53. 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.

- **Costs**

If the costs indicator (C) is improved, i.e. the costs decrease, the company might be exposed to a **decrease** of its On Time In Full delivery (**OTIF**) performance. Indeed, the company could consider engaging cheaper Logistics Service Providers (LSPs) who may not be able to fulfil the customers' OTIF requirements or they could decide to hire less qualified and hence cheaper employees. Because of this same reason, the Service Quality (**Q**) as well as the Exception Management (**ExM**) indicators could also **deteriorate**. In addition, even if the already employed workers have no explicit proof, they normally notice that costs are reduced. In the event of financial retrenchments, employees would fear redundancy for economic reasons, resulting in a **decrease** of the Security of Employment (**SE**) indicator. Furthermore, by reducing the costs, the number of **working accidents** could **explode** since the number of preventive measures could be reduced to the minimum required by the laws.

- **On Time In Full Delivery**

To improve the OTIF performance, the company might be forced to engage more expensive LSPs, resulting in a cost increase, i.e. a **decrease** of the **financial performance**. Since it may be expected that more expensive LSPs also provide a better service, the **Q** indicator could **raise**. Furthermore, it might be useful to convey the goods by plane instead of using another transport mode to provide a faster shipment and to improve the OTIF KPI. In other words, the indicator measuring the CO_2e emissions (**GHG**) could **deteriorate**. We need to keep in mind that every maritime or air cargo shipment needs to be transported by truck on the pre- and on-carriages, as well as on the last mile. Because of the reloading and transhipment and the eventual storage periods, the influence of the change of transport mode on the C indicator cannot be neglected, resulting again in a decline of the C KPI. Nevertheless, this second decline of the C indicator needs to be seen as second level consequence and should therefore not be taken into consideration in this analysis. Even though the executing company works with subcontractors, the company's

[36] The group of 12 experts questioned within the case study of chapter 2 has been enlarged by 2 more persons.

own employees have been trained so that their planning competences may be enhanced. Nevertheless, since this can be seen as a cause, the enhanced Trainings per Employee (LLL) (LLL) indicator needs to be neglected. On the other hand, the company considers its labourer labourer being well trained, so that a better OTIF indicator results in a **decreasing** of its associated KPI **LLL**. On the other hand, a better OTIF may result in an **improved SE** indicator. In fact, the better the performance of the OTIF indicator, the more the customer will be satisfied and the lower the probability that the company will lose the considered client. The logical consequence is that the company's employees feel more comfortable about their job, which probably results in an **increased SE** indicator.

– **Service Quality**

To improve the service quality, the company could hire more qualified and experienced people, being more cost intensive. However, the better the service quality, the less the company needs to deal with claims. Nevertheless, this improvement is to be seen as a secondary consequence and is therefore neglected in this analysis. We then retain that the **C** indicator could **adulterate**. The aforementioned better qualified employees may also **increase** the **OTIF** and **ExM** KPIs, increasing ergo the customers' satisfaction. Notwithstanding this, the company will not replace each and every employee, i.e. the actually employed employees should be trained so that they can provide a better service quality. In other words, to improve the Q indicator, the **LLL** KPI could be **elevated** as well, resulting again in higher costs and hence in an inferior C indicator as secondary consequence. As explained before, the **SE** KPI is supposed to **increase** since the employees do not fear losing their jobs if the customers are satisfied.

– **Exception Management**

To analyse the ExM, the same logic has been used as for the OTIF and Q indicators. To improve the ExM KPI, the company could invest in more expensive employees raising consequently the **costs** and **downgrading** its indicator. As explained in detail in section 2.3.1, the ExM consists of its three inherent indicators, namely Responsiveness (R), Flexibility (F) and Issues Solving (IS). The more responsive the employees and the more flexible the processes in use and the better the employees can solve eventual issues, the more the customers will be satisfied. The **SE** indicator could then **enhance** due to improved customers' contentment. The fact that the LLL indicator should rise as well in order to ameliorate the three sub-indicators R, F, and IS, is to be seen as a consequence and will therefore not be considered here in.

– **CO_2 equivalent**

To reduce their volume of produced CO_2 equivalent (CO_2e) emissions, companies may either change the quality of their transport mode used, or change the transport mode itself. In the case of using a higher standard of the same transport mode, i.e. use an EURO 5 instead of an EURO 3 truck, the **C** indicator should **descend** since the higher the quality of the LSP's materials, the more expensive their services will be. In the case of changing the transport mode itself, the potential **deterioration** of **OTIF** needs to be taken into account. Effectively, the transportation of goods will be much slower if it is carried by rail than if it is handled as airfreight, even though the CO_2e emissions produced may decrease enormously. On the other hand, since nowadays customers want to shop with clear conscience, they might be more satisfied if they know that the shipment of their goods produced less GHG emissions. As described before, this increased customers' satisfaction may lead to an **improved SE** indicator.

– **Waste Management**

To ameliorate the Waste Management (RRR) indicator, companies try to diminish the rubbish they produce. It should be clarified that the company needs to pay per ton of waste produced. Albeit, the price per ton of waste which will be recycled is less than the one considering the deposit charges, both types of waste need to be paid. Hence, by reducing their volumes of waste produced, the companies may **improve** the **C** indicator. In addition, since in some cases, the companies need to transport their waste themselves to the landfill sites or incineration facilities, a better waste management could result in a **better GHG** indicator. In addition, companies may opt for specific trainings to contribute to employees' awareness of waste separation and waste avoidance. In other words, the **LLL** indicator may **progress** too.

- **Energy Used**

The most obvious consequence of improving the Energy Used (EnUs) indicator is the **amelioration** of the **C** KPI. The less energy a company uses, the more the costs of energy will decrease. Using the same logic as in the analysis of the RRR indicator, the **LLL** indicator may get **better** since the company could opt for special trainings intended to sensitise the labourers to turn off the lights when leaving the coffee kitchen or toilets, or when being the last to go home from the office. The less manifest consequence of improving the EnUs KPI is the potential increase of working accidents and thus a slight **decline** of the Health, Security, and Safety (**HSS**) indicator. Indeed, the risk of accidents is higher if there is less illumination in- and outside the facilities; especially in wintertime when it gets dark early.

- **Trainings per Employees**

If a company offers more training sessions for its employees so that its Trainings per Employees (LLL) KPI can be revised, the most evident consequence is that the overall costs of any SC may increase, leading to a **worsening** of the **C** indicator. On the other hand, the more the employees are trained, the better their performance on their respective positions. For this reason, the **OTIF**, the **Q,** and the **ExM** indicators should get become further **recovered**.

Through specific drivers' trainings the **CO_2e emissions produced** should be decreased, **improving** the considered KPI. This holds also true if subcontractors are engaged, since the company may hold trainings at its' subcontractors' facilities and properties. Specific trainings could also help to foster the employees' awareness of green and sustainable thinking. One side effect could be the reduction of **waste** and **energy used**, **improving** the respective indicators.

In addition, the **SE** indicator could **increase** as no company would invest in trainings if the considered employees would be replaced, or if the number of employees would be downsized in the short terms. In addition, depending on the trainings' topic, the course may be a base for a better comprehension of preventive measures so that the number of accidents per employee could be downsized, resulting in a **better HSS** indicator. Another point to allude is the fact that managers' attention could be called through trainings, so that the female quota and hence the Gender Equality (**GE**) indicator could be **raised**. Furthermore, assuming that employees' self-esteem might be increased because of specific on-the-job trainings (Maslow, 1943), employees' motivation could be raised. Accordingly, the company may decide to **reduce** the actions taken to increase Employees' Motivation (**EmMo**).

- **Security of Employment**

The security of employment could be amended by engaging less contract workers. This, of course, could increase the **costs** and in all likelihood **diminish** its indicator. On the other hand, since permanent employees are semiskilled, they are more experienced and should be more productive than contract workers. Thus, if less contract workers are engaged, the daily business needs to be handled by permanent labourers, resulting in the fact that the **Q** and **ExM** indicators could **increase**. In addition, it has been noticed that contract workers do not care as much about proper material handling as permanent employees. It is therefore likely that the number of accidents per employee would decrease, i.e. the **HSS** indicator could change for the **better**. However, a higher performance of the SE indicator could result in more motivated employees. So, as stated before, the company bears the risk of **downgrading** its **EmMo** KPI.

– **Health, Security and Safety**

The less the number of accidents a company has to register, the more the rate of employees' absences can be mitigated. In this sense, the costs can be reduced, which provides a **better C** indicator. Normally, every employee has a so-called 'back-up' person, which is supposed to take over the daily business of the employee in case of absence (either for holidays or for sickness reasons). As discussed in the analysis of the SE KPI, permanent employees are semiskilled and are considered to be more experienced and productive than contract workers. In this case, the back-up person can be compared to a contract worker. The back-up person has still their own daily business to be done and needs to accomplish the missing employee's work as well. As a logical consequence, downsizing the rate of employees' absences may result in **better OTIF**, **Q**, and **ExM** performances.

– **Gender Equality**

In section 2.3.3, we explained that the Gender Equality (GE) indicator is composed by its three sub-indicators Differences of Salaries (DifSal), the Female Quota (FeQuo), and the employees' subjective opinion about how they perceive the situation within the company considering gender equality (SubGE). To improve the GE KPI, the salaries need to be streamlined, the female proportion of male and female employees should be similar and the employees need to have the feeling of being treated identically. In the second chapter, we evaluated the degree of sustainability, including the GE indicator. We found out that within the different clusters[37], male and female workers draw a similar salary. For this reason, we consider that the **C indicator** would probably **remain the same**, even though this might be different in other companies. In addition, the female quota is quite high within Kuehne + Nagel's white collar departments. Unfortunately, it is not possible to raise the female quota in the warehouse-keeper positions, since women cannot be forced to work in such positions. In fact, according to bibb.de, approximately 89% of articles of apprenticeship for warehouse-keepers are held by male students since 2005 (Bibb.de, 2013). Nevertheless, the GE indicator can be raised via its sub-indicator considering the employees' subjective opinion (SubGE). If the subjective opinion about how employees perceive the situation within the company considering gender equality is improved, this might have positive influences on at least female workers' motivation as well as on the overall working atmosphere. The company could therefore decide to provide fewer actions to improve employees' motivation, resulting in a **decreasing EmMo** indicator.

– **Actions Taken against Xenophobia and Discrimination**

To improve its Actions Taken against Xenophobia and Discrimination (AXD) the company needs to invest in elucidation. In fact, people are normally afraid of the things they do not know or they do not understand. Therefore, by explaining the differences, some peoples' amalgams such as "Muslims are terrorists" could be mitigated and discrimination could be extenuated. In other words, to minimise xenophobia and discrimination, action plans need to be elaborated and measures need to be taken. As the costs will rise through such measures the **C** indicator will inevitably **downgrade**. However, we consider that people working in a good atmosphere will be more productive and precise, and deliver a better quality of their tasks. In this logic, the **OTIF**, **Q** and **ExM** KPIs would **improve** through the betterment of the AXD indicator. Moreover, the

[37] The compositions of the clusters have been explained on page 53.

company could decide to provide brief trainings sessions, such as courses regarding the code of conduct or best practice methodologies so that xenophobia and discrimination can be prevented. In other words, the **LLL** indicator could **increase** through the improvement of the AXD KPI.

As explained before, we consider the point of view of Kuehne + Nagel Luxembourg. Since in Luxembourg, people are used to work with and to live alongside many different cultures, the discrimination and xenophobia issues are not as widespread as in other countries. For this reason, managers could confuse AXD and GE indicators: if gender equality has not been reached, this could be understood as one kind of discrimination. However, since we clearly explained on page 57 of this work how we measure the **GE** indicator, we consider that the latter would **not be influenced** in case of an improvement of the AXD indicator. Nevertheless, the resulting good working atmosphere could increase employees' motivation. As explained before, such an increased motivation could lead the company to perform fewer **actions** intended to **increase employees' motivation**, **adulterating** its KPI.

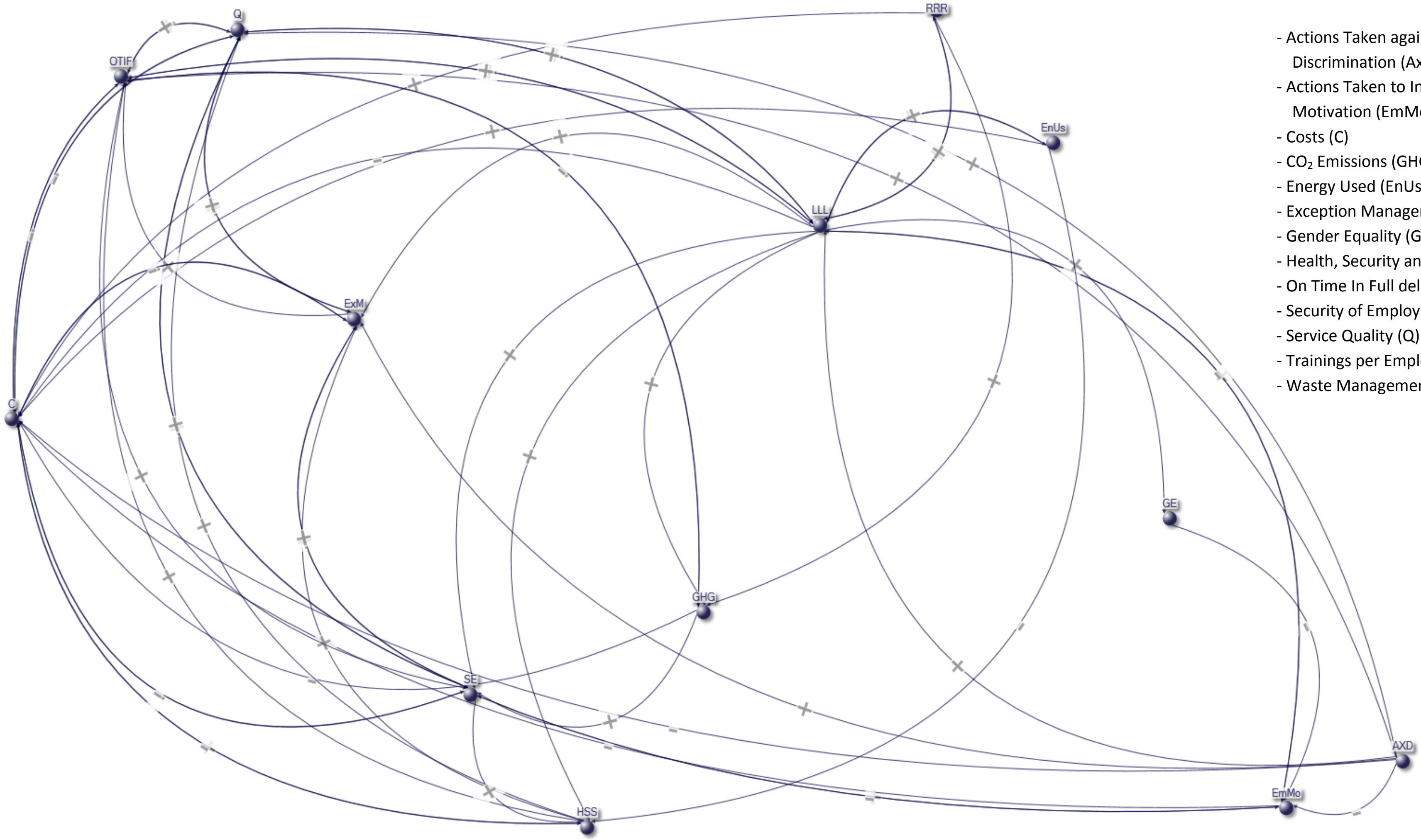
- **Actions taken to increase Employees' Motivation**

Most actions a company can take to increase employees' motivation lead to higher costs, resulting in a **declined C** indicator. Those measures could lead to a higher feeling of security of employment since most labourers reason that a company would not motivate its employees if the board of managers would consider replacing most of them in the short term. Furthermore, the company could **increase** the on-the-job-**trainings** considering any kind of new skills the employee needs to have so that he is able to increase his productivity. Indeed, this would increase the labourers' self-esteem which, according to Maslow, is one of the five motivational human needs (Maslow, 1943). In addition, in a business environment, the costs are considered being the most important indicator. In other words, as long as the company takes such actions the labourers might not fear to lose their jobs because of economic reasons, leading thus to an **increased SE** indicator.

- **Conclusion**

By analysing the different indicators' interactions, it becomes obvious that the improvement of one indicator **may** always result in **either positive or negative side effects**. A summary of those interactions is given in Figure 46. In fact, while the enhancement of one indicator may have positive effects on one other KPI, it may contemporaneously have negative ones on still another indicator. **Those spin-offs then constitute the eventual risks' outcome the company has to deal with**. In case of undesired spin-offs a proper risk assessment is of high significance, since managers need to know what they must expect in order to take adequate decisions. It is important to understand that the first tier consequence inevitably leads to another second tier implication which, in turn, will lead to third tier side effects, etc. It is not possible to assess a vicious circle's inherent risks. Managers must therefore be satisfied with analysing in detail the first two layers' consequences. In any case, since companies need to strive for continuous improvement (Marmier et al. 2013) the risk assessment process will be followed by a risk mitigation process, which in turn will result in a new risk assessment. Figure 46 will be translated in a more clearly arranged table on a later stage[38].

[38] Please see page 154.



Considered indicator

Positive influence

Negative influence

- Actions Taken against Xenophobia and Discrimination (AxD)
- Actions Taken to Increase Employees' Motivation (EmMo)
- Costs (C)
- CO_2 Emissions (GHG)
- Energy Used (EnUs)
- Exception Management (ExM)
- Gender Equality (GE)
- Health, Security and Safety (HSS)
- On Time In Full delivery (OTIF)
- Security of Employment (SE)
- Service Quality (Q)
- Trainings per Employee (LLL)
- Waste Management (RRR)

Figure 56 – Indicators' Interactions

The Customer's Risk Classification

Risks may appear in different forms. Companies with global supply chains face not only the risks dealing with quality and safety challenges, supply shortages, legal problems, security issues weather and natural disasters or terrorism, but, also to longer lead times, political or / and economic vicissitudes in a source country or changes in economics such as exchange rates (Dittmann, 2014). On the other hand, managers cannot handle all information needed to assess every possible risk because of the cognitive limits, which have been described by Simon (1991). In addition, since nowadays, risks have increased in number and criticality registers of identified risks need to be broken down into more manageable clusters (Marle & Vidal, 2011). To carry out the Supplier Risk Assessment (SRA), the Customer has clustered the different identified risks as shown in Table 27.

Risk	Description
Country Risk	Risks related to the country of manufacture. In this risk assessment, Transparency International's Global Corruption Index (TIGCI) is being used to define the risk level. Transparency International's Index was chosen because corruption correlates strongly with other problems as bad governance, illegal logging, health, poor education and poverty.
Commodity Risk	Risks related to different types of raw materials used by the Customer's production processes. The criteria for evaluating the risk are the following: - Sustainability risk related to the primary raw material - Health and Safety, and Environmental risks related to the manufacturing process - Risks related to the product safety - Reputational risk to the Customer and its customers
Supply Chain Complexity	Risks related to the complexity of the SC from the primary raw material to the product supplied to the Customer, considering: - The number of tiers - The number of suppliers in each tier The geographical extent
Price volatility	- Risks related to unexpected price increase
Quality	Risks related to substantial quality deviations impacting the Customer's products. Substantial deviations in suppliers' performance impacting the Customer's delivery capability
Safety / Product Safety	Risks related to several dangerous situations or deficiencies in safety and / or accidents. *(ex.: Suppliers refuse to accept the Customer's safety requirements; Suppliers constantly ignore the Customer's safety instructions; Suppliers' employees are not aware of agreed safety practices; Suppliers' do not respond to the Customer's safety questions; Suppliers do not comply with the Customer's product safety requirements; …)*
Suppliers' Availability / Continuity	Risks related to the fact that suppliers are not able to supply the Customer or to continue their business, impacting the Customer's production or delivery capability.

Risk	Description
Financial Uncertainty or Dependency	Risks related to the fact that: - Suppliers have severe financial difficulties, Suppliers are heavily dependent on the Customer
Intellectual Property Rights (IPR) Risks	Risks related to the fact that the suppliers' IPR approach is conflicting with the Customer's, limiting the Customer's production or purchases from other suppliers
Competition Situation	Risks related to the fact that the supplier is a direct competitor to the Customer
Social Risks / Human Rights Related Risks	Examples: - Growing socio-economic and political instability; civil and political rights are not guaranteed; risk of labour disputes / stakeholder disputes - Employees' working conditions / human security is not secured *(employees' safety is in danger or employees are not treated with dignity and respect)* - Freedom of association and collective bargaining of employees is restricted *(not by law)* - The enterprise engages in or supports the use of forced or compulsory labour *(Personnel required to pay 'deposits' or lodge identification papers upon commencing employment, salary withholds, social benefit withholds)* - Employees' rights are not guaranteed, but there are excessive working hours, minimum salaries are not meeting the legal minimum and / or definition of a living wage - Child labour *(any person less than 15 years of age, unless the minimum age for work or mandatory schooling is stipulated as being higher by local law)* Corruption and bribery

Risk	Description
Environmental Risks	Risks related to: - Supplier has operated in breach of environmental law *(e.g.: air emissions exceed local regulatory requirements)* - Environmental Management System *(e.g.: Supplier has lost ISO 14001 certificate)* - Environmental permits *(e.g. Supplier has operated in breach of environmental permit)* - Sustainable products *(e.g.: genetically modified elements; conflict minerals; palm oil used in suppliers products)* - Pollution *(Evidence of pollution resulting in negative impact on soil, water, air, and biodiversity – such as pulp mill effluent discharge exceeds permit limits and results in dead aquatic wildlife downstream)* - Climate *(e.g. source and emissions related to fuels and energy used by the supplier)* - Waste *(e.g. Waste disposal methods, including hazardous waste)* - Water *(e.g. Production unit located in water stressed region)* - Forest *(e.g. Wood cannot be verified as coming from sustainable and legal sources: The origin of wood is not known and illegally logged wood can enter the SC)* - Biodiversity *(e.g. Suppliers operation linked to the destruction of biodiversity such as natural forests converted to plantations* - NGO Campaigns *(e.g. Environmental groups targeting a specific supplier or industry sector which can have a negative impact on the Customer's business or reputation)* - Natural disaster or accidents *(e.g.: impact on supply or safety of supplier products)*

Table 27 – The Customer's Risk Classification

Identification and Own Classification of Potential Risks

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?'. To do so, Kuehne + Nagel Luxembourg relies on different risk identification techniques, such as brainstorming, SWOT-analysis or scenario analysis.

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. Participants need to collaborate so their different ideas, views, and reasons for worrying become clear. It is important that the group of participants share experiences arising from different perspectives and backgrounds, so that most of the potential risks may be uncovered. The project owner should guarantee that the participants' ideas will not result in an abasement, which in turn would lead to demotion and thereafter, demotivation (Chapman, 1998). A cross-functional group of managers from different departments will then discuss the results yielded from the brainstorming sessions within assisted workshops.

Another technique used by Kuehne + Nagel Luxembourg is the Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis. 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.

In some circumstances, Kuehne + Nagel Luxembourg refers to scenario analysis, which is a particularly valuable methodology to identify strategic risks if there is an ill-defined initial position. A scenario is explained as precisely as possible, and a cross-functional team tries to answers several 'what if' questions. Managers and participants need to allow their imagination to run free, so that several varied scenarios of equally probable futures can be drawn. Those tales are explained in full detail and oriented to actual decisions so that unknown and unexpected risks can be discovered. Effectively, some risks having a high total impact maybe existent within a single event. Through the scenario analysis, more different events can be imagined so that more different risks can be discovered.

The risks yield quantity may be vast, so that managers may have difficulties to keep the overview of all the different detected eventualities. One possibility to retain the overall view is to classify the risks into different categories. Since the customers' classification is oriented towards a supplier risk assessment, we will not adopt his classification. It is nonetheless important to categorise the different risks according to our core topic, so that the leitmotif of this work can be attested. 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 57.

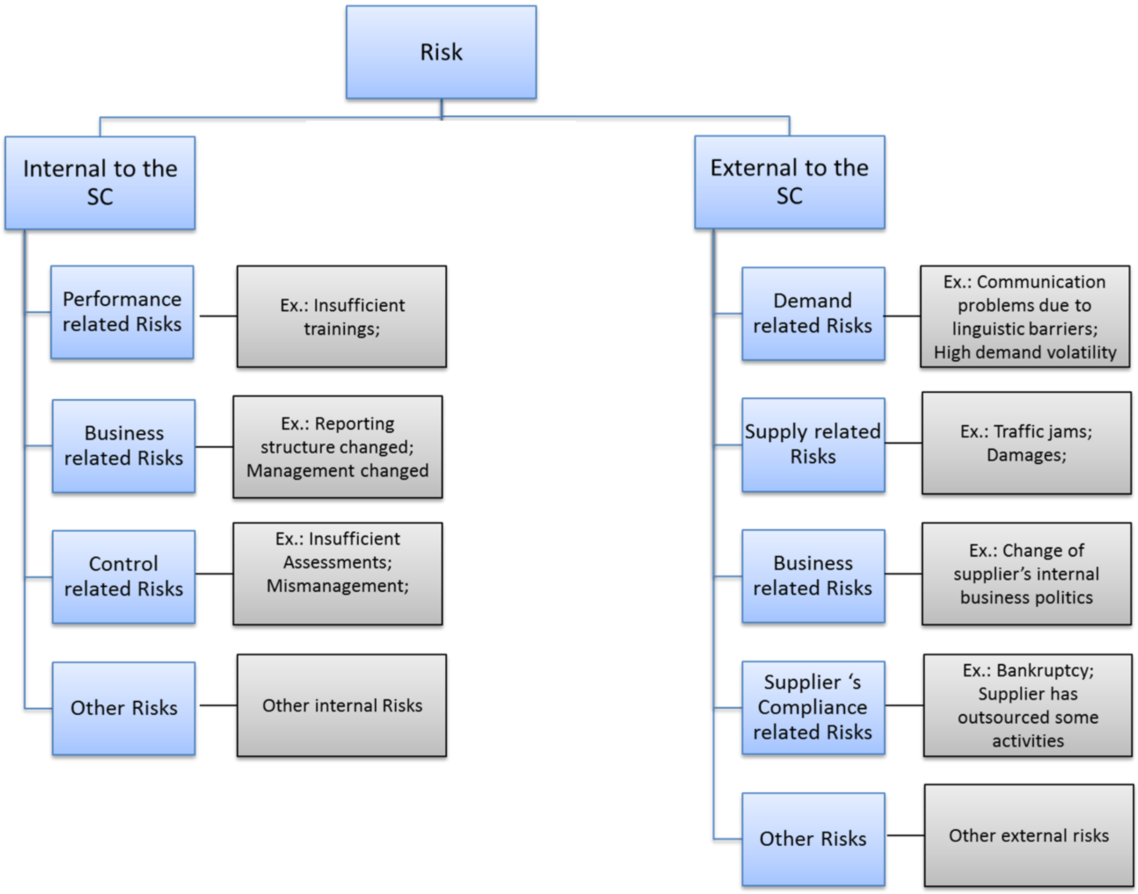


Figure 57 – Own Risk Classification

In section 3.2.1 we explained that risks may appear either as an occurrence of an event, or as an occurrence of a combination of events having a certain impact on the company's overall performance or reputation. To identify the possible events or combinations of events occurring resulting from the improvement of one indicator, we gathered the different indicators' interactions. In fact the **indicators' interactions** may generate **potential risks**, arising from the effort of improving the SC's degree of sustainability. Nevertheless, we must keep in mind that every risk assessment has an inherent subjective component. In fact, while some executives are risk-averse and may strive for significant tight and severe evaluations, managers who are more adventurous may not evaluate the same risk being as seriously or fatally as their colleagues having risk revulsions (Dittmann, 2014).

Prioritisation of the eventual Risks

It is not possible for a company to identify all potential risks. In fact, *"they are embedded in a web of values that emphasize the benefits and denigrate the consequences"* (Frosdick, 1997). According to Marle et al. (2013), objectives may be interdependent or contradictory, including the impossibility of being *"completely exhaustive when identifying them*". In addition, a company cannot dedicate enough resources to mitigate all identified risks and needs therefore to possess a certain approach to designate the most important ones (Dittmann, 2014).

In this work, the main risk to be considered is the risk of a deterioration of the degree of sustainability. This degree of sustainability has been evaluated in the previous chapter through the analysis of 13 different indicators. It becomes clear that the considered risk is strictly related to the risk of an indicators' performance's adulteration. Those risks may be categorised as "**Internal Performance Risk**". On the other hand, managers need to be aware of the fact that each of the above presented risk categories may have consequences on the overall degree of sustainability. We suggest that the risks related to the deterioration of the degree of sustainability should be prioritised, so that companies may have a clear picture of which risks should be addressed first and which ones are too unlikely to materialise to worth the effort.

The Failure Mode and Effect Analysis (FMEA) methodology, as previously described, is one of the most common quantitative risk assessment methods used (Dittmann, 2014). 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). Those indicators are usually described on a 10-point scale, where 1 is lowest and 10 is highest (Bergman & Klefsjö, 2010). For consistency reasons, we will apply a 5-point scale to evaluate the three elements Se, Oc, and De. *De facto*, the experts who assessed the aforementioned three factors are the same who evaluated the importance per indicator in chapter II, through the modified Analytical Hierarchy Process (AHP) analysis, based on a 5-point scale, completed by the factor 0 (0 meaning "equally important" in our AHP study[39]). We adopted this shortened scale since discussions with internal and external experts yield that, most managers are used to this scale. On the other hand, they asserted that bigger scales could be oversized if managers were asked to give proper answers about the importance of indicators they are not used to deal with. Since we accept that an amendment of those same indicators may lead to potential risks, and that the latter are also based on those same KPIs, we accept the same arguments for evaluating the Se, Oc, and De factors on a 5-point scale, where 1 is defined being lowest and 5 is seen being highest. The factors calculated via the AHP are shown in Table 11[40].

Let $\varkappa_{KPIi}$ be the priority factor of the considered indicator, calculated via the AHP as shown in Table 11 and repeated in Table 28. The formula for calculating the RPN is hence:

$$\mathbf{RPN}_{KPIi} = (\mathbf{Se}_{KPIi} \cdot \mathbf{Oc}_{KPIi} \cdot \mathbf{De}_{KPIi}) \cdot \varkappa_{KPIi}$$

Whereas Se_{KPIi}, Oc_{KPIi} and De_{KPIi} are to be seen as the FMEA's inherent factors, Severity, Occurrence, and Detectability respectively, and $\varkappa_{KPIi}$, is to be understood as the priority factor calculated via AHP in Chapter II. The results are shown in Table 28. The prioritisation calculated via the FMEA technique has been modified because of the multiplication with the $\varkappa$ factor, calculated via the AHP in Chapter II. Effectively, 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. Since, in this work, we consider the risk assessment, i.e. the risk identification, its analysis, and its evaluation, the risk treatment will not be considered within this thesis. It is therefore important to calculate the RPN value per pillar by summing the according indicators' RPN values as shown in Table 28.

39 Please see Figure 29 on page 75
40 Please see page 78

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

Table 28 – Risk Priority Number per Indicator

It is important to keep in mind that the societal pillar has been divided into its two sub-pillars Work and Ethics, which both value 50% of the societal issues. The RPN per pillar gives insight to what pillar should be assessed first, as shown in Table 29.

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.

	RPN
Ecologic	26.25
Societal	15.97
Economic	11.24

Table 29 – Risk Priority Number per Pillar

Identification of the Potential Risks' Causes and Consequences

We determined strong interactions between the different indicators *videlicet* every amendment of one indicator may have consequences to at least one other indicator, as it can be consulted in Figure 46. 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 30. 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:

- Increase of the OTIF performance
- Increase of the Q performance
- Increase of the ExM performance
- Increase of the GHG performance *(i.e. decrease of the GHG emissions)*
- Decrease of the RRR performance *(i.e. increase of the volume of waste)*
- Decrease of the EnUs performance *(i.e. increase of the energy used)*
- Increase of the LLL performance
- Increase of the SE performance
- Decrease of the HSS performance *(i.e. increase of the recorded accidents per employees)*
- Increase of the AXD performance
- Increase of the EmMo performance

In fact, if the company has invested to enhance its On Time In Full (OTIF) delivery indicator, the costs have increased and hence, its indicator's performance has decreased. The consequences of an increased OTIF indicator can therefore be seen as the cause of an impaired Cost (C) indicator. Nevertheless, an increased OTIF indicator is neither the only, nor the most significant cause, leading to a decreased C indicator. In this logic, the causes can thus be introduced as a cause of an undesired event into the Fault Tree Analysis (FTA) of the BTM.

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 ↑								

Table 30 – Summary: KPI's possible Interactions

Data Completion via Delphi Method

As described before, Kuehne + Nagel has not considered sustainability in the way we defined it within this thesis. It is therefore evident that some data have not been gathered. On the other hand the unknown-knowns may simply not be monitored. Effectively, the probabilities of a risk's materialisation as well as its magnitudes always depend on known-knowns, known-unknowns, unknown-knowns, and unknown-unknowns. Hence, factors included by the model, factors excluded by the model, and factors which are unknown to the analysts, while the latter may concern both, the unknown-knowns and the unknown-unknowns.

Both, the magnitudes and the probabilities are clearly to be seen as knowns-unknowns. It is therefore not possible to monitor the magnitudes, which are however inalienable to our risk quantification model. To approach this problem, we gathered the magnitudes via a modified Delphi questionnaire. The Delphi Method, as depicted in Figure 58, 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"* (Vidal et al., 2011). Effectively, the Delphi Method can be seen as a systematic and interactive approach, which anonymously relies on a panel of a group of independent experts (Häder, 2009; Linstone & Turoff, 2002), and which is, according to (Skulmoski et al., 2007) *"well suited as a research instrument when there is incomplete knowledge about a problem or phenomenon"*.

Our research methodology has been based on a three-rounded modified Delphi process. Effectively, since the group of 14 interviewed experts are the same during the whole PhD project, anonymity could not be guaranteed. 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.

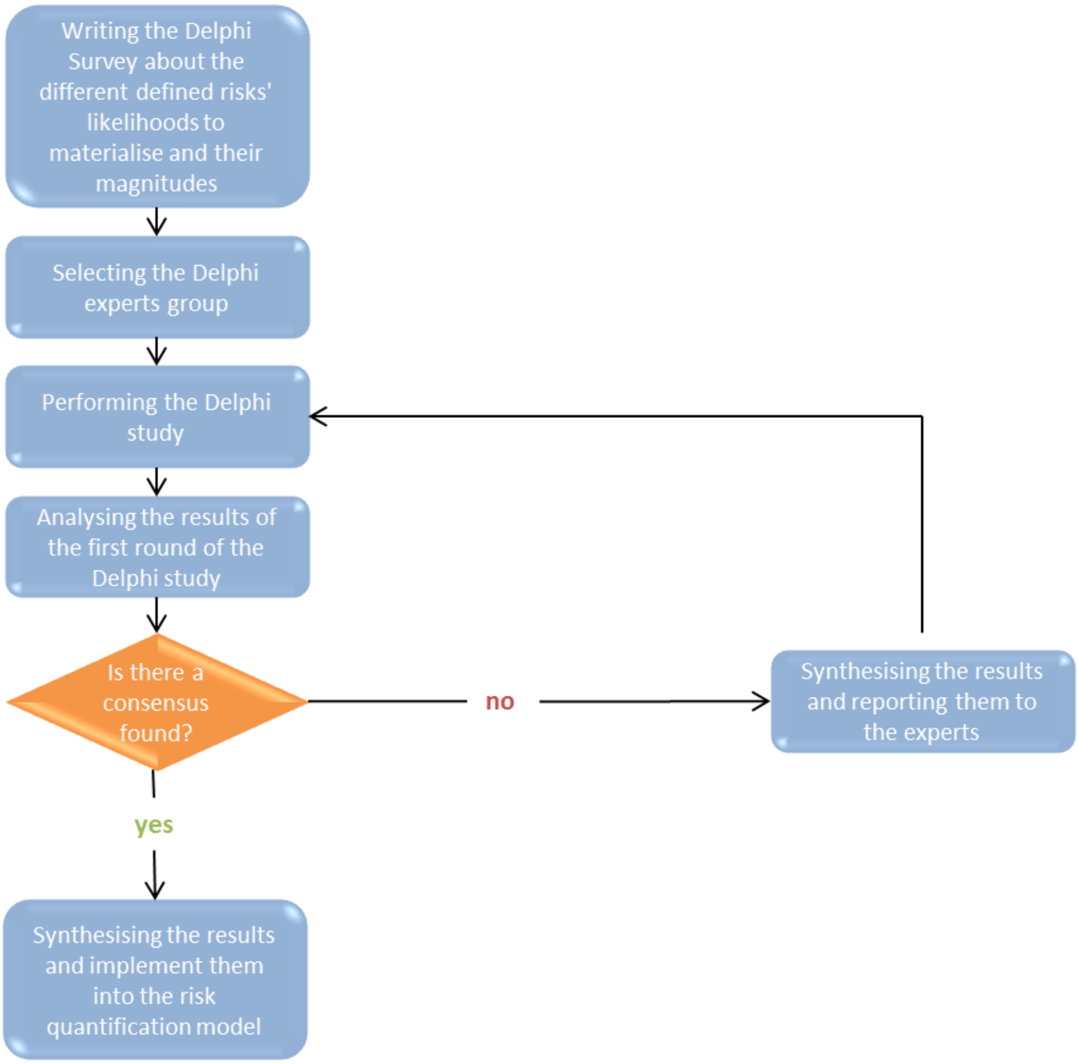


Figure 58 – Delphi Study: Our Research Methodology

Simulating the Variables through Monte Carlo Methodology

The Monte Carlo Simulation (MCS) is usually employed on normal distributions. The Laws of Large Numbers (LLN) are used as primary justification for using MCS. The LLN theorem asserts that the larger the probability sample's size, the more the sample's statistical characteristics tend to reflect the characteristics of the original population. Hence, the LLN may guarantee stable long-term results considering the averages of random events[41]. Additionally, the Central Limit Theorem (CLT) states that the summation of independent random variables following the same statistical law – no matter if those statistical laws consider discrete or continuous distributions – leads to a random variable whose probability distribution approaches a Laplace-Gauss distribution, commonly referred to as normal distribution (Tribout, 2013). Furthermore, it explains that $\hat{\mu}_n - \mu$ owns approximately a **standard normal distribution** with mean 0 and variance 1 having the density function[42]:

[41] For more detailed information about the LLN, readers are referred to (Rousseau-Egele, 1979).
[42] For more detailed information, readers are referred to (Tribout, 2013).

$$\forall\, z \in \mathbb{R}, \varphi(z) = \frac{e^{-\frac{1}{2}z^2}}{\sqrt{2\pi}}$$

Nevertheless, discussions with experts yield that if the variables' distribution cannot be detected, experience has shown that a triangular distribution is more realistic than a normal distribution. Our calculation methodology is presented in Figure 59.

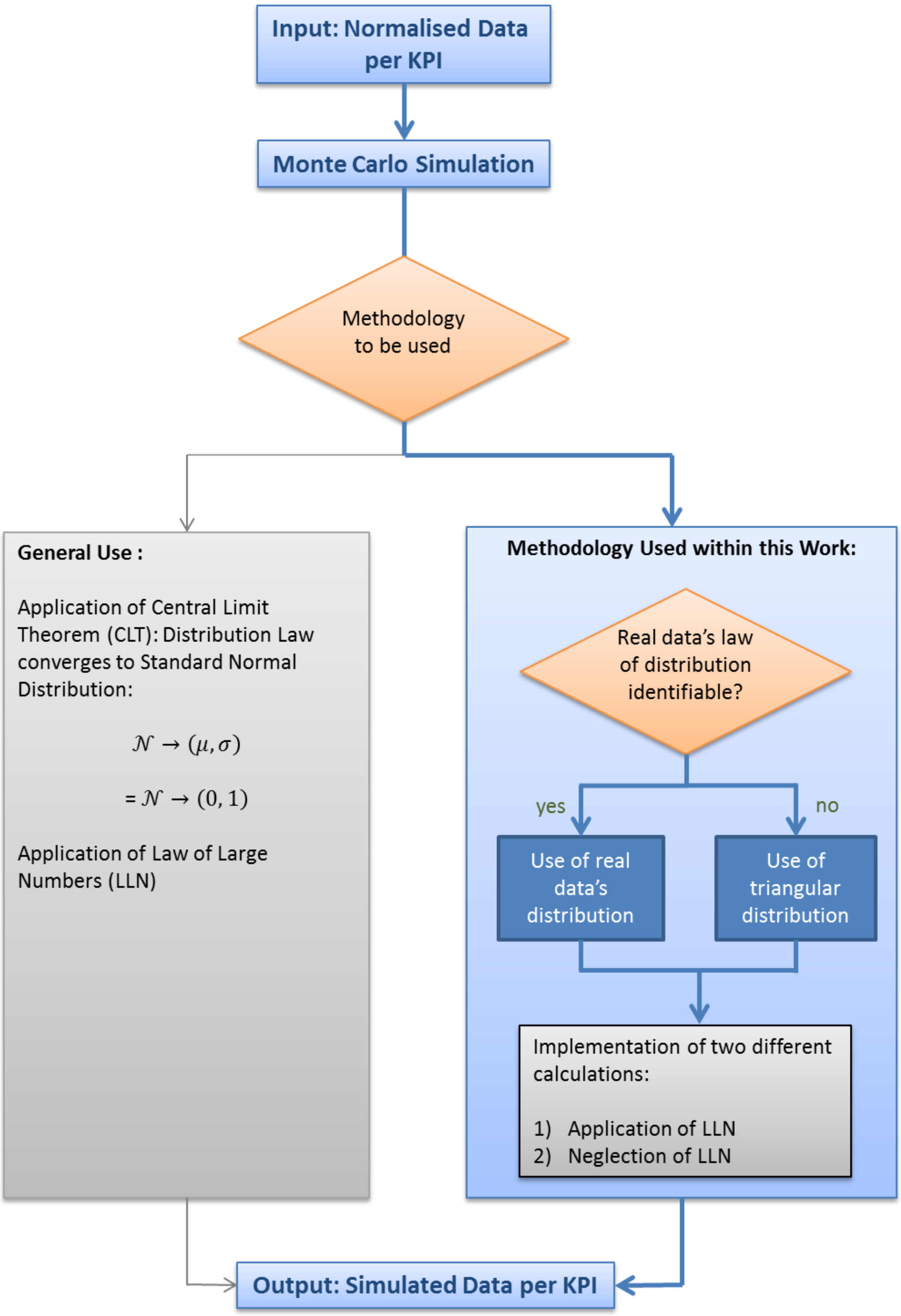


Figure 59 – Risk Quantification: Calculation Methodology Used

Implementing a Monte Carlo Simulation with application of the Laws of Large Numbers

Simulations are usually performed in cases where there are not enough real data to draw a realistic conclusion. The Monte Carlo Simulation, which is of high importance within our model, needs to be based on real data collected in the past. It actually relies on repeated random sampling to assess numerical results. Its main target is to solve issues having a probabilistic interpretation by applying randomness. This kind of simulation is generally implemented to estimate how likely the resulting outcomes are. It might seem paradoxical at first sight, that both real data and randomness provide the base for this kind of simulations. However, while the real data base is needed to simulate the known-knowns and the known–unknowns, the randomness is valuable to illustrate the unknown-knowns and the unknown-unknowns within the simulations. Effectively, unknown-knowns may turn into known-knowns, when analysts ask the right questions. Nevertheless, it is important to be aware that it is not possible to unveil every unknown-known.

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** L**aw of Large Numbers** (LLN) advocates that almost surely $\lim_{n\to\infty} \hat{A}_n = A$. Thus $\hat{A}_n$ converges towards A as the sample's size (n) converges towards infinity (∞). This property is what statisticians call '*consistent'* (Simon & Blume, 1998).

To implement the Monte Carlo Simulation, we will use the Crystal Ball® software. 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. A report of the assumed distribution per KPI is given in Annexe 10.

Crystal Ball attributes the following formula to the triangular distribution (Anandan et al., 2009):

$$f(x) = \begin{cases} \dfrac{h\,(x - Min)}{Likeliest - Min} & if\ Min\ \le x\ \le Likeliest;\ \ Min < Max \\ \dfrac{h\,(Max - x)}{Max - Likeliest} & if\ Likeliest\ \le x\ \le Max;\ \ Min < Max \\ 0 & otherwise \end{cases}$$

where: $h = \frac{2}{Max - Min}$

Crystal Ball is then able to simulate the values per indicator. In Table 31, 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).

Indicator	Mean Value µ	Standard Deviation σ	Min	Max	**Simulated Value**
C	0.147484823	0.074288542	0.0001	0.370870625	**0.724177089**
OTIF	0.98097537	0.010502154	0.916998881	0.990709153	**0.931600607**
Q	0.889766414	0.016777323	0.86	0.92	**0.916918094**
ExM	0.779207142	0.035861142	0.712282267	0.835676292	**0.890366435**
GHG	0.540074261	0.187832529	0.0001	0.722254898	**0.802272534**
RRR	0.980109106	0.010509332	0.950297192	0.997472979	**0.910042984**
EnUs	0.964655901	0.008516988	0.95420348	0.991024763	**0.953209819**
SE	0.83665404	0.031190046	0.8	0.88	**0.798143299**
HSS	0.950623986	0.052827769	0.838068182	0.9999	**0.947688267**
LLL	0.565202189	0.223721013	0.040022762	0.9999	**0.604178601**
GE	0.747847222	0.047781765	0.7	0.82	**0.770336876**
AXD	0.539545455	0.027890725	0.48	0.58	**0.555372516**
EmMo	0.557916667	0.041279451	0.52	0.62	**0.62565581**

Table 31 – Simulation: Defined Distributions per Indicator

To quantify the identified risks, the simulated variables need to be introduced into the evaluation model, elucidated in Chapter II. At this stage, managers need to agree on a specific target, so that the risk of not achieving this target can then be calculated. We opened this section by performing a risk prioritisation, leading to the conclusion that the **environmental related risks need to be assessed first**. We will therefore quantify the **risk of not achieving the ecological degree of sustainability of 0.75** in our case study. This target has been set by Kuehne + Nagel's internal managers since we reached the ecological degree of sustainability of 0.7567 in 2013, as it can be consulted in Table 19 on page 95.

Implementing a Monte Carlo Simulation, neglecting the Laws of Large Numbers

The quantified risks help managers in taking future decisions. Because of the application of the Law of Large Numbers (LLN), the identified risks' interactions as well as their different magnitudes, which have been gathered via the Delphi Method, are neglected within the above explained calculations. In addition, as it can be seen in Annexe 10, the Monte Carlo simulation has been based on real data and has been configured not to go below the value of 0 and not to exceed the 0.98 mark. This was done for simplicity reasons. Nevertheless, we recalculate this same simulation while integrating the different interactions and magnitudes. For consistency reasons, in this second simulation, the sample's size remained the same, i.e.: n = 10 000. This second simulation is calculated by adding the considered indicator's random value with the magnitudes of interacting indicators' variations. Effectively, the interaction have been identified and presented to the experts who answered to the Delphi questionnaire in order to assess the risks' magnitudes. In mathematical terms, this can be expressed as follows:

$$rand.KPI_{i_t} + \Delta KPI_{j_t} \cdot mag_j$$

Where $rand.KPI_{i_t}$ is the considered indicators' random value,
and $\Delta KPI_j = \left(KPI_{j_t} - KPI_{j_{t-1}}\right)$,
and mag_j = magnitude of KPI_j.

As we found out earlier, the potential causes related to the Energy Used (EnUs) indicator is the Trainings per Employees (LLL) indicator. The $EnUs_t$ is calculated as follows:

$$EnUs_{t_{simulated}} = rand.EnUs_t + \Delta LLL_t \cdot mag_{LLL}$$

We found out that some values may become greater than 1 or less than 0. This might be confusing at a first glance, but this is a logical corollary due to the defiance of the boundaries. Effectively, the normalisation has been calculated via the ratio:

$$\frac{Variable}{Variable_{MAX}}$$

While the considered KPI's maximum variable ($Variable_{MAX}$) used for normalising the data has not changed, the new maximum value of this same indicator unveiled through the simulation is greater than the $Variable_{MAX}$ considered for the normalisation. In other words, the baseline has changed through the simulation. Effectively, the indicators presenting negative variables are the ones which have been inverted[43] via the formula:

$$1 - KPI_i$$

In fact, by altering the indicators requiring the data being minimal to be optimal, every indicator is seen being close to excellence when the normalised data approaches to 1. As indicated in Table 12, the considered indicators are thus: C, GHG, RRR; EnUs, and HSS[44].

Introduction of the Simulated Variables into the Evaluation Model

In section 2.5, we calculated the KPI's weightings via the AHP methodology. The sum of each pillar's indicators' weightings equals 1 since every pillar has the same worth within the overall degree of sustainability. The different indicators' weightings ($\varkappa_{KPIi}$) have been reminded in Table 28, on page 158. Since those weightings remain the same for every SC serving the industrial domain, the AHP performed within the evaluation model must be adopted.

As described above, the risk of not achieving the ecological pillar's target is to be assessed first and will be quantified within this case study. For this reason, we need to concentrate our calculations on this pillar's inherent indicators: CO2 equivalent (GHG), Energy Used (EnUs), and Waste Management (RRR). We therefore calculate 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 Figure 60.

[43] In our evaluation model, every indicator is seen being close to excellence when the normalised data approaches to 1. The inverted indicators are C, GHG, RRR, EnUs, and HSS. Please see Chapter II,
able 12 on page 86.
[44] Please see page 86.

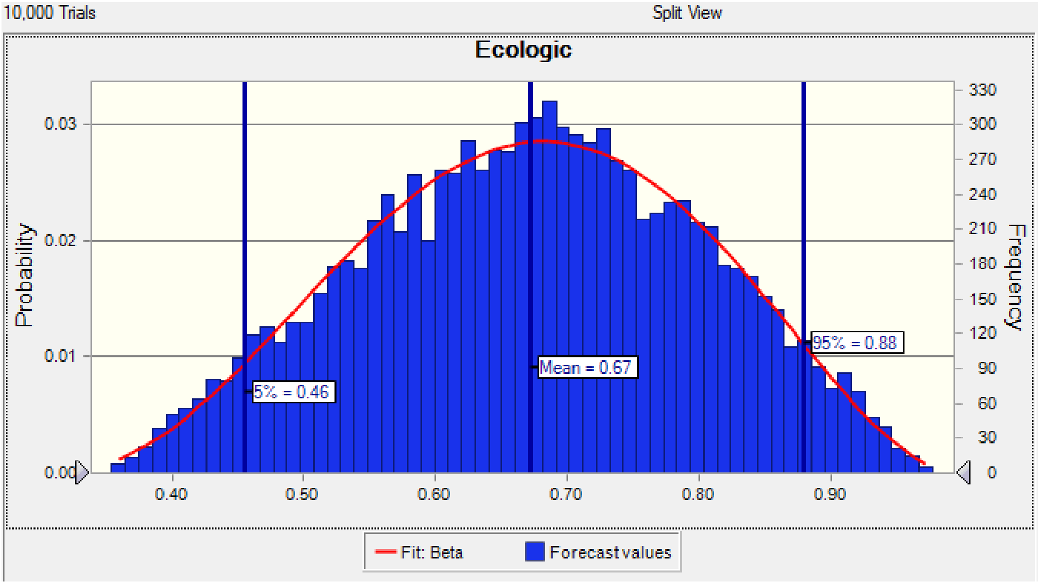


Figure 60 – The Ecological Pillar: Frequencies

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 ∈ [0.75 ; 1]. Crystal Ball[45] allows defining the precision of the calculation, which we set at 95.00%, as it is shown in Figure 61.

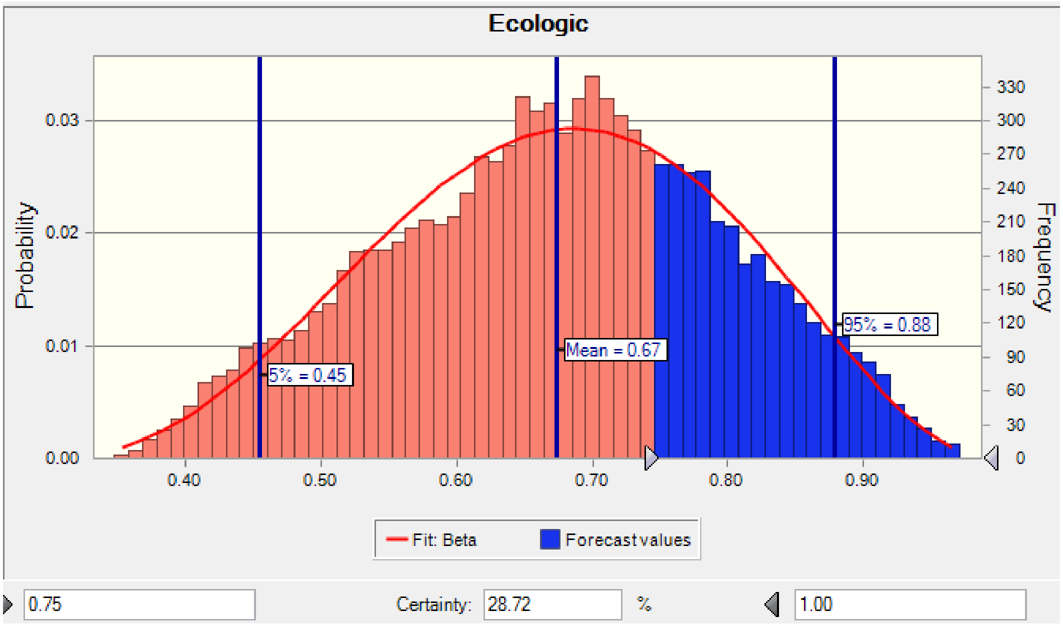


Figure 61 – Ecological Pillar: Risk Quantification

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

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

$$\mathbf{1 - P(Ecol_{sustainability})}$$
$$\mathbf{= 1 - P(0.75)}$$

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

$$\mathbf{= 1 - 0.2872}$$
$$\mathbf{= 0.7128}$$
$$\mathbf{= 71.28\ \%}$$

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**:

$$\mathbf{= 1 - 0.28783}$$
$$\mathbf{= 0.7117}$$
$$\mathbf{= 71.17\ \%}$$

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*.**

Managers often have to choose exclusively one strategy in order to work out a global risk level tolerance (Marmier et al., 2013). This strategy needs to be found through diverse meetings on which SC managers and risk experts participate. The subsequent step of our model consists in agreeing on how to dispose of 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 in that case 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.

3.5 CONCLUSION

We agree with Dittmann (2014), stating that *"In the dynamic global environment, change is a constant. Risks identified and mitigated today become obsolete tomorrow. Risk management must be an ongoing process"*. Effectively, logistics and supply chains are to be considered as dynamic global systems, operating in a steadily changing environment. It is on these grounds that our risk assessment model is to be implemented in an approach of continuous improvement. Even though, the model's last step consists in the risk quantification, this is not to be seen as the last phase of the whole risk management process.

When the potential risks to be considered are identified and classified, the data need to be completed by the endorsed risk mitigation's underlying assumptions. Effectively, the indicators' interactions will remain the same, regardless of the level of detail considered within the calculations. Since those interactions are of crucial matter for quantifying the risks which remain after implementation of the mitigation measures, we suggest performing the Monte Carlo Simulations neglecting the LLN. Although the results provided by the simulations calculated above is not significant, we consider this difference to be important when integrating the risk alleviation procedures into the calculations. De facto, the above case study has been performed under the condition of all other factors being equal *(ceteris paribus)*. This condition is no longer fulfilled when the assumptions provided by the risk mitigation process are taken into consideration. In addition, managers need to be aware that the results provided by the risks' prioritisation may change on a daily basis due to the aforementioned known-unknowns and unknown-unknowns.

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 would result in subsequent frustration due to the defeat in evaluating the results' usability obtained therefrom. However, we agree with Middleton (2003) 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), as it has been described in section 3.3.3. 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.

General Conclusion

4.1 RESEARCH CONTRIBUTION

Even though, end customers and companies became aware of sustainability only a few decades ago, we determined its roots in the XVIII century, when Malthus (1789), under the moniker of J. Johnson, communicated his worries about future generations' livelihood security. It took almost two centuries until the famous Club of Rome met to discuss the ecological collapse they predicted. It became obvious that, at this point in time, sustainability has still been considered under the umbrella of green and ecological thinking. 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 chapter, 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. This is not surprising since those two aspects are of major concern in most of todays' companies. These results have been affirmed during the first meetings within Kuehne + Nagel. 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.

The myriad of authors discussing sustainability could not agree on one common definition; whereby a formal definition can contribute to determine the scope and content to be considered and can explain the essential significance of the subject heading of sustainability. It is important to understand, that the definition itself may not be rigid in the course of time. To guarantee common understanding, we delineated the concept of sustainability, by adapting its definition from the explanations given by Brundtland (1987) and Elkington (1997). Effectively, while the adopted Triple Bottom Line's (TBL) inherent pillars, economic, ecologic, and societal – whereas we consider the latter being divided into two sub-pillars, working environment, and ethical issues – provide the definition's persistence, the included time factor[46] retrieves its resiliency. The first contribution provided by this work consists hence in the clear definition of sustainability.

Managers often deplore that, in their point of view, their endeavours in sustainability matters cannot be compared with their competitors' ones. For this reason, when common understanding was guaranteed, we developed an evaluation model, allowing managers to not only evaluate a certain SC's overall degree of sustainability, but ensuring also the assessment of its degree of sustainability per pillar. It becomes obvious that comparison may be done between companies using the same model, including the same assumptions and calculation methodologies. The aim of this work, from an industrial point of view, was to develop a model which helps Kuehne + Nagel to evaluate their customers' supply chains' degrees of sustainability and to set up a benchmark study per domain served. The evaluation model, whose feasibility has been proved through a case study, constitutes the major contribution provided within the second chapter. We identified a Key Performance Indicator (KPI) dashboard, intended to provide the measurability of a SC's degree of sustainability. This dashboard involves both, quantitative and qualitative indicators, whereas the qualitative ones are mainly subjective. Those subjective indicators' characteristics and interactions are often difficult to be understood by managers, since they are used to handle hard facts, like costs (C) or On Time In Full (OTIF) deliveries. The model *per se* is easy to understand and to be

[46] Considering that the needs may deepen over time

implemented. Howbeit, we admit that the incorporation of subjective factors increases its difficulty and complexity.

The comparability between different companies' supply chain's degrees of sustainability can be assured if the considered enterprises are serving one same domain. Effectively, the indicators' weightings are calculated per domain through the AHP methodology. The pillars' inherent factors are then averaged, resulting in the calculated degrees of sustainability per pillar. Those degrees need to be analysed through the predefined fuzzy sets. In a further step, fuzzy rules need to be defined. The end-results of our evaluation model, i.e. the SC's overall degree of sustainability, are generated through the application of those fuzzy rules. The overall degrees of sustainability can then be depicted in a three-dimensional representation. We proved the hypothesis that the calculation of the mean of the three pillars individual results would falsify the model's final outcome. For this reason, it is important to analyse the three pillars' results provided by the model by applying the previously mentioned fuzzy rules. 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 customer base.

Evaluations are usually performed to determine a specific as-is situation, so that an improvement of the latter can be provided. The definition of the baseline, i.e. the as-is situation, is guaranteed by the above explained evaluation model. Nevertheless, before an improvement can be envisaged, it is important to determine the associated contingent risks. In other words, before a re-design of the considered SC can be implemented, it is important to quantify the potential risks which could derive from this intended re-design. Within Kuehne + Nagel, risks are analysed in a tailored manner. This means that for each risk assessment Kuehne + Nagel performs for its customers, a new model needs to be developed. Effectively, up until now, Kuehne + Nagel has no general risk assessment model in place. The aim of the third chapter is to develop a model which helps managers in taking decisions on future risk assessment measures. Because of the cognitive limits (Simon, 1956), managers cannot handle all information needed to assess every possible risk. For this reason, we suggest managers to identify the risks through the What-If methodology and to classify them afterwards. The classified risks can then be prioritised via the application of the modified FMEA methodology, which has been described in detail in section 3.4. When the risks have been identified, clustered and prioritised, their quantification is provided through a Monte Carlo Simulation (MCS). The latter generates a sample of n simulated variables, based on real data. We suggest that the Central Limit Theorem (CLT) as well as the Laws of Large Numbers (LLN), which are usually applied within the MCS, should be neglected in the simulation phase of the model. Effectively, we accept the external experts' advice not to use the standard normal distribution within those calculations. According to them, the implementation of triangular distributions would provide more realistic results. In addition, we suggest integrating the different indicators' interactions by neglecting the LLN since we assume that those interactions may have major impacts on the results when the model is executed in a deeper level of detail, than presented in our case study. The results provided by the MCS consist of n simulated data per pillar, which need to be re-introduced into the evaluation model, so that n degrees of sustainability as well as their frequencies may be calculated. The analysis of those frequencies provides the quantification of the considered risks. The risk quantification model developed within the third chapter closes thus by a closed loop with the previously developed evaluation model. The major contribution of this chapter consists in the provision of a risk assessment model, which enables managers to quantify the risk of not achieving a particular pillars' required degree of sustainability, *ceteris paribus.* Kuehne + Nagel may use this model as general model which serves as a foundation for its customers' tailored risk management. Effectively, the quantified risks need to be analysed in a subsequent step during which the customer and Kuehne + Nagel's internal SC specialists need to agree on future strategies. The end results provided by our model will help the different stakeholders in taking decisions on whether the considered risks can be taken or whether they need to be mitigated or even avoided.

4.2 LIMITATIONS AND PERSPECTIVES

The evaluation model, presented in the second chapter of this thesis, can be applied to every SC, regardless of its domain served. However, the model presents two major restrictions. On the one hand, to compare different SC's sustainability performances within one same domain, it is important that the maximum value used to normalise the input data is the same for every considered SC. We suggest that this maximum value should be very high i.e. experts need to agree on a value which is high enough so that it is difficult to achieve this value since it is not possible to achieve 100% of sustainability. On the other hand, this value has not to be exaggerated neither. The second restriction lays in the subjectivity of some of the model's data. This subjectivity may be amended if a large number of experts, whose backgrounds and approaches differ widely, are surveyed. Effectively, external experts may not have the necessary insights, to evaluate the subjective indicators in an adequate manner, since most of those KPIs require a deep knowledge of the company's internal culture as well as of the considered SC. In contrast, a group of experts, consisting of a large number of different persons also include a large number of different personalities, whereas some are more optimistic than others. The variables' subjectivity is alleviated ere they are integrated into the model, since we assume that the mean of all answers given should provide a nearly realistic result of the considered surveys. For this reason, it is required that the experts' professional backgrounds and approaches vary widely.

While the main research topic of this thesis comprises the sustainability concept, the risk quantification can be provided for every other domain. We admit that this is not obvious at the first sight. However, the developed risk quantification methodology remains the same, regardless of the risks detected through the identification process. One restriction of the risk quantification model developed within this work is that it incorporates the evaluation model generated within the second chapter, providing hence a closed loop. If managers consider other risks than sustainability related ones, the evaluation model to be incorporated must correspond with the risks taken into consideration. In addition, we suggest that this exchanged model should, for consistency reasons, also be based on normalised data.

Another limitation deals with the fact that the real data used within the simulation process include the indicators' interactions. Those interdependencies may be considered mathematically, depending on whether the Law of Large Numbers (LLN) is applied or not. Even though the difference between the results calculated in our case study do not diverge enormously, we assume that this difference would increase if the model includes the assumptions provided by the risk mitigation processes, which has not been considered within this thesis. The risk assessment processes implemented within Kuehne + Nagel is extremely time-consuming since the inherent approaches and methodologies need to be re-discussed and re-selected for each project. The risk quantification model developed in this thesis is clearly based on sustainability, but may be used for every other risk quantification as well. The model itself would remain the same, even though the identified risks may alter. To further benefit from the risk assessment model developed within this thesis, it should be used as a template within existent projects. Nevertheless, managers need to be aware that the model is not to be seen as a completed risk assessment model. The provided results will not give information about how to handle the considered risks, but will only help managers in taking their decisions of how to further process the risk mitigation strategies. For this reason, we suggest that our model should to be extended by a subsequent model, which is intended to help managers in defining the risk mitigation strategies to be implemented before a re-quantification of the considered risks can be performed. However, the model should not finish with the redesign of the SC, but should be based on the concept of continuous improvement as depicted in Figure 62.

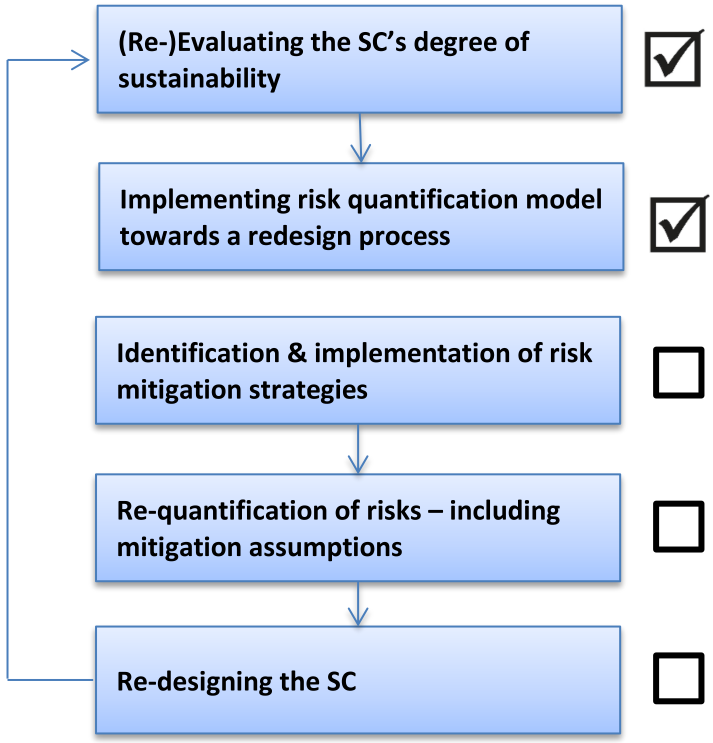


Figure 62 – Risk Assessment Process

From an academic viewpoint, we recommend that further researches should concentrate on the risk magnitudes and on the indicators' interactions. Effectively, the outcomes provided by the models developed within this work would be of higher value if the magnitudes and the interactions were scientifically demonstrated. In addition, as shown in Figure 62, the risk assessment process should conclude with a re-design model. Since this process should be applicable to the operational, tactical, and strategic level and since it should be practicable on any domain served, it is important that its inherent models are developed in a general way, so that they may be used as template.

In an industrial point of view, it would be meaningful for Kuehne + Nagel to offer this work as a 'sustainability project' to their customers. Effectively, the two inherent models should not be separated. To do so, the company will need to set up a team, able to handle both hard facts and subjective data, in order to evaluate the customers' sustainability performance and to help the latter in improving its as-is situation. The team should also be able to apply the risk quantification model in a further step, and to set up the measures to be implemented in order to mitigate the risks. As described before, further researches need to be done so that a risk mitigation model may be set up. The process should then be extended by the implementation of a second risk quantification, including the assumptions provided by the risk mitigation model. Since Kuehne + Nagel is involved in 4PL services, it already helps customers in improving their as-is situations but those improvements do not consider the sustainability issues. The services offered by Kuehne + Nagel could thus be widened by the implementation of a continuous improvement of the customers' sustainability performance.

As stated previously, companies show growing interest in sustainability issues. Their major concern lays in the fact that they cannot compare themselves with their competitors. The evaluation model developed within this work may help Kuehne + Nagel to overcome this problem. By selling the service of evaluating the customers' SC's sustainability performance, Kuehne + Nagel could be involved in investigating and comparing the different degrees of sustainability in an unbiased way, providing a ranking to its customers. Those customers can use this ranking to enhance their customers' trust, and hence, for marketing reasons. Effectively, the ranking should note that the specific customer's SC occupies the X^{th} position out of Y competitors' SCs serving the same market. It is important to keep in mind that it is crucial to use one same calculation basis, if comparison is to be done, no matter if this comparison considers different competitors, or one single SC at different points in time. This needs to be considered when improving the risk assessment process' inherent models.

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Appendix

1. Economic Indicators collected via Literature Review

Economic KPI's / Authors	Financial Performance	ISO 9000 Standards	Order Fill Lead Time	Productivity	Public Reporting of Economic Performance	Technology Infrastructure	Total Quality Management System
Beamon, 1998		x					x
Daniels, 2010a				x		x	
Daniels, 2010b				x		x	
Elkington and Trisoglio, 1996						x	
Gimenez and Tachizawa, 2012		x				x	x
Glenn et al., 2010	x			x			
Lin, 2013	x						
Liyanage et al., 2009	x						
Milne and Gray, 2013					x		
Nikolaou et al., 2013	x						x
Rao and Hold, 2005	x			x			x
Sloan, 2010			x		x		

Table 32 – Literature Review: Economical Pillar

2. Ecologic Indicators collected via Literature Review

Ecologic KPIs Authors	Energy Consumption	Environmental Management Systems	Green Practices	International Regulations (OHSAS 18000; ISO 14000; …)	Public Reporting of Environmental Performance	Toxic Emissions Produced	Waste (Production / Reduction)
Elkington and Trisoglio, 1996				x			
Gimenez and Tachizawa, 2012		x	x	x			
Hoejmose et al., 2012			x				
Kim and Min, 2011	x					x	
Kurien and Qureshi, 2012			x	x		x	x
Li Y., 2011			x		x		x
Lin, 2013		x	x	x			x
Liyanage et al., 2009	x					x	x
Milne and Gray, 2013					x	x	x
Min and Kim, 2012	x					x	
Mtalaa and Aggoune, 2009						x	
Nikolaou et al., 2013	x		x			x	x
Rao and Hold, 2005		x				x	x
Rha, 2010		x	x	x			
Sloan, 2010	x	x		x	x	x	x
Thipparat, 2011		x	x	x			
Towers and Ashford, 2001		x					
Tseng and Chiu, 2013		x	x	x			
Validi et al., 2014						x	
Zhu et al,, 2008		x		x			

Table 33 – Literature Review: Ecologic

3. Social Indicators collected via Literature Review: Work

Societal KPIs: Work Authors	Collective Bargaining Agreements	Net Employment Creation	Occupational Health Hygiene & Safety	Representation by trade union organisations	Safe and Comfortable Workplace	Trainings & Skills Management	Workplace Injuries
Gimenez and Tachizawa, 2012						x	
Glenn et al., 2010							
Hill, 2013						x	
Liyanage et al., 2009			x				
Milne and Gray, 2013							
Nikolaou et al., 2013		x	x	x		x	x
Norman and MacDonald, 2003	x			x	x		x
Porter and Kramer, 2011							
Roberts, 2003							
Sloan, 2010			x			x	

Table 34 – Literature Review: Work

4. Social Indicators collected via Literature Review: Ethics

Societal KPIs: Ethics Authors	Commitment & Confidentiality	CSR	Equal opportunity	National Cultures / Values	Staff: Visible minorities / with disabilities	Trust	Value to greater Community	Well-Being Programmes
Beamon, 1998		x						
Bellizzi and Hasty, 2003			x					
Brink, 2008								
Daniels, 2010a				x				
Daniels, 2010b				x				
Elkington and Trisoglio, 1996				x				
European Commission, 2012			x					
European Commission, 2013			x					
Gimenez and Tachizawa, 2012					x	x		
Glenn et al., 2010	x					x		
Hill, 2013								
Hoejmose et al., 2012								
Keijzers, 2002								
Lenz, 2008								
Liyanage et al., 2009								
Milne and Gray, 2013								
Nikolaou et al., 2013			x				x	
Norman and MacDonald, 2003					x		x	x
Porter and Kramer, 2011								
Roberts, 2003		x						
Sloan, 2010								
Towers and Ashford, 2001						x		
Visser, 2010	x					x		

Table 35 – Literature Review: Ethics

5. FORMULAS PER KPI

5.1 ECONOMIC PILLAR:

5.1.1 Costs (C):

Let LOS_c be the operational costs allocated on customer C.
Let LMS_c be the managerial costs allocated to the customer C.

U_{Cc} : Costs, numerical, real, 0.01, Euro, N = [0 , 1]
$f(U_{Cc}) = \sum \sum LOS_C \, LMS_c$

5.1.2 On Time In Full delivery (OTIF):

Let Df be the freight which was delivered in full and on time, where f = [1 , r].
Let TD be the total freight supposed to be delivered

$U_{OTIF:}$ OTIF, numerical, ordered, 0.01, rate, N = [0 , 1]
$f(U_{OTIF}) = \frac{\sum_{f=1}^{r} Df}{TD}$

5.1.3 Service Quality (Q) :

U_Q : Q , linguistic, ordered, $\mathscr{L}_Q$ = {very poor ; poor ; medium ; good ; excellent}
Where $\mathscr{L}_Q$ = Linguistic set of Q.

5.1.4 Exception Management:

f(ExM) = f(R, F, IS)

$$= \frac{\sum R(x) + \sum F(x) + \sum IS(x)}{ExM_i}$$

- Responsiveness (R):

  Let D_{REQ} be the requests which have been treated in time, where REQ = [1 , Q].
  Let TREQ be the total requests submitted.

  $U_{R:}$ R, numerical, ordered, 0.01, rate, N = [0 , 1]
  $f(U_R) = \frac{\sum_{f=1}^{Q} DREQ}{TREQ}$

- Flexibility (F):

  U_F : F , linguistic, ordered, $\mathscr{L}_F$ = { very poor ; poor ; medium ; good ; excellent }
  Where $\mathscr{L}_F$ = Linguistic set of F.

- Issues Solving (IS):

  U_{IS} : IS, linguistic, ordered, $\mathscr{L}_{IS}$ = { very poor ; poor ; medium ; good ; excellent }
  Where $\mathscr{L}_{IS}$ = Linguistic set of IS.

5.2 ECOLOGIC PILLAR

5.2.1 CO_2(e) (GHG):

U_{GHG}: GHG Emissions Produced, numerical, ordered, 0.01, TKM, N = [0,1]
Where TKM means 'Ton – Kilometers'.
$f(U_{GHG}) = \sum_{l=1}^{v} \mathrm{TKM}_l$

5.2.2 Waste Management (RRR):

U_{RRR} : Waste Management, numerical, ordered, 0.01, average, N = [0,1]

$$f(U_{RRR}) = \frac{\sum_{d=1}^{p}(RRR)\ \alpha_{FTE}}{\mathrm{TRRR}}$$

where TRRR = Company's Total Waste
and RRR = Recycled waste
and α_{FTE} = Percentage of FTEs dedicated to the considered SC
where FTE =[1 , p]

5.2.3 Energy Used (EnUs):

U_{EnUs} : Energy Used, numerical, ordered, 0.01, kWh, N = [0,1]
$f(U_{EnUs}) = \mathrm{TNRG} \cdot \alpha_{FTE}$

Where NRG = Kilowatt hours of energy used
and α_{FTE} = Percentage of FTEs assigned to the considered SC,
and FTE =[1 , p]

5.3 SOCIETAL PILLAR: WORK

5.3.1 Trainings per Employee to Improve Skills (LLL)

U_{LLL} : LLL, numerical, ordered, 0.01, hours, N = [0,1]

$$f(U_{LLL}) = \frac{\sum_{i=1}^{n}\sum_{d=1}^{p} LLLid}{\sum_{i=1}^{n} LLLi} \cdot \alpha_{FTE}$$

where i = considered employee; i = [1,n]
and d = considered department; d = [1,p]

and α_{FTE} = Percentage of FTEs assigned to the considered SC
where FTE =[1 , p]

5.3.2 Security of Employment (SE)

U_{SE} : SE, linguistic, ordered, $\mathscr{L}_{SE}$ = { very poor ; poor ; medium ; good ; excellent }
Where $\mathscr{L}_{SE}$ = Linguistic set of SE.

5.3.3 Health, Security, and Safety (HSS)

U_{HSS} : HSS, linguistic, ordered, $\mathscr{L}_{HSS}$ = { very poor ; poor ; medium ; good ; excellent }
Where $\mathscr{L}_{HSS}$ = Linguistic set of HSS.

5.4 SOCIETAL PILLAR: ETHICS

5.4.1 Gender Equality (GE)

f(GE) = f(DifSalary, FeQuo, SubGE)

- U_{Salary} : Salaries, numerical, ordered, 0.01, average salary, N = [0,1]
  f(U_{Salary}) = $\frac{1}{iw}\sum_{i=1}^{n} Salary_{iw\beta} - \frac{1}{im}\sum_{i=1}^{n} Salary_{im\beta}$

- $U_{DifSalary}$: Differences in Salaries, linguistic, ordered, $\mathscr{L}_{HSS}$ = { very poor ; poor ; medium ; good ; excellent }
  Where $\mathscr{L}_{DifSalary}$ = Linguistic set of DifSalary

- U_{FeQuo} : Abidance concerning the Female Quota, linguistic, ordered,
  $\mathscr{L}_{FeQuo}$ = { very poor ; poor ; medium ; good ; excellent }
  Where $\mathscr{L}_{FeQuo}$= Linguistic set of FeQuo,

- U_{SubGE} : Subjective opinion about Gender Equality (SubGE), linguistic, ordered,
  $\mathscr{L}_{SubGE}$ = { very poor ; poor ; medium ; good ; excellent }
  Where $\mathscr{L}_{SubGE}$= Linguistic set of SubGE,

U_{GE} : Gender Equality, linguistic, ordered, $\mathscr{L}_{GE}$ = { very poor ; poor ; medium ; good ; excellent }
Where $\mathscr{L}_{GE}$= Linguistic set of GE.

5.4.2 Actions Taken Against Xenophobia and Discrimination (AXD)

U_{AXD} : AXD, linguistic, ordered, $\mathscr{L}_{AXD}$ = { very poor ; poor ; medium ; good ; excellent}
Where $\mathscr{L}_{AXD}$ = Linguistic set of AXD.

5.4.3 Actions Taken to Increase Employees' Motivation (EmMo)

$U_{EmMo:}$ EmMo, linguistic, ordered, $\mathscr{L}_{EMO}$ = {very poor ; poor ; medium ; good ; excellent }

Where $\mathscr{L}_{EmMo}$ = Linguistic set of EmMo.

6. Quantitative KPIs: Results

6.1 Costs

Year	Month	C Normalised
2010	January	0.8417
2010	February	0.8568
2010	March	0.8849
2010	April	0.8712
2010	May	0.8737
2010	June	0.9363
2010	July	0.9545
2010	August	0.7916
2010	September	0.9312
2010	October	0.9127
2010	November	0.9062
2010	December	0.7477

Year	Month	C Normalised
2011	January	0.8865
2011	February	0.8832
2011	March	0.9494
2011	April	0.8891
2011	May	1.0000
2011	June	0.8973
2011	July	0.9398
2011	August	0.8400
2011	September	0.8091
2011	October	0.8450
2011	November	0.9039
2011	December	0.7296

Table 36 – Normalised Costs: 2010 and 2011

Year	Month	C Normalised
2012	January	0.8639
2012	February	0.8215
2012	March	0.8851
2012	April	0.7752
2012	May	0.8162
2012	June	0.8853
2012	July	0.8910
2012	August	0.7713
2012	September	0.8672
2012	October	0.9386
2012	November	0.8998
2012	December	0.6458

Year	Month	C Normalised
2013	January	0.8649
2013	February	0.8267
2013	March	0.8135
2013	April	0.8485
2013	May	0.8117
2013	June	0.8279
2013	July	0.9158
2013	August	0.7096
2013	September	0.8357
2013	October	0.8900
2013	November	0.8352
2013	December	0.6291

Table 37 – Normalised Costs: 2012 and 2013

6.2 On Time In Full delivery

Year	Month	OTIF Normalised
2010	January	0.9672
2010	February	0.9809
2010	March	0.9797
2010	April	0.9765
2010	Mai	0.9773
2010	June	0.9804
2010	July	0.9779
2010	August	0.9858
2010	September	0.9764
2010	October	0.9869
2010	November	0.9782
2010	December	0.9170

Year	Month	OTIF Normalised
2011	January	0.9865
2011	February	0.9837
2011	March	0.9812
2011	April	0.9866
2011	Mai	0.9818
2011	June	0.9770
2011	July	0.9759
2011	August	0.9881
2011	September	0.9879
2011	October	0.9864
2011	November	0.9829
2011	December	0.9836

Table 38 – Normalised On Time In Full delivery: 2010 and 2011

Year	Month	OTIF Normalised
2012	January	0.9868
2012	February	0.9836
2012	March	0.9865
2012	April	0.9749
2012	Mai	0.9836
2012	June	0.9879
2012	July	0.9840
2012	August	0.9781
2012	September	0.9862
2012	October	0.9822
2012	November	0.9858
2012	December	0.9707

Year	Month	OTIF Normalised
2013	January	0.9813
2013	February	0.9782
2013	March	0.9823
2013	April	0.9822
2013	Mai	0.9823
2013	June	0.9884
2013	July	0.9866
2013	August	0.9907
2013	September	0.9830
2013	October	0.9828
2013	November	0.9855
2013	December	0.9647

Table 39 – Normalised On Time In Full delivery: 2012 and 2013

6.3 Exception Management – Responsiveness

Year	Month	Responsiveness
2010	January	0.8435
2010	February	0.7314
2010	March	0.8098
2010	April	0.7821
2010	Mai	0.6934
2010	June	0.7326
2010	July	0.7340
2010	August	0.7117
2010	September	0.7137
2010	October	0.6993
2010	November	0.7704
2010	December	0.8342

Year	Month	Responsiveness
2011	January	0.7343
2011	February	0.7444
2011	March	0.7673
2011	April	0.7134
2011	Mai	0.8061
2011	June	0.7926
2011	July	0.7740
2011	August	0.6536
2011	September	0.7146
2011	October	0.7088
2011	November	0.7752
2011	December	0.7406

Table 40 – Normalised Responsiveness: 2010 and 2011

Year	Month	Responsiveness
2012	January	0.8608
2012	February	0.8430
2012	March	0.8756
2012	April	0.7861
2012	Mai	0.8265
2012	June	0.8335
2012	July	0.7865
2012	August	0.7539
2012	September	0.8094
2012	October	0.7522
2012	November	0.7684
2012	December	0.7626

Year	Month	Responsiveness
2013	January	0.8426
2013	February	0.8140
2013	March	0.8530
2013	April	0.8820
2013	Mai	0.7643
2013	June	0.8484
2013	July	0.7843
2013	August	0.7822
2013	September	0.7849
2013	October	0.8046
2013	November	0.7757
2013	December	0.7914

Table 41 – Normalised Responsiveness: 2010 and 2011

6.4 CO_2E EMISSIONS

Year	Month	GHG Normalised
2010	January	0.3140
2010	February	0.3138
2010	March	0.3396
2010	April	0.3275
2010	Mai	0.3175
2010	June	0.3453
2010	July	0.9840
2010	August	0.8076
2010	September	1.0000
2010	October	0.9661
2010	November	0.9841
2010	December	0.7963

Year	Month	GHG Normalised
2011	January	0.4589
2011	February	0.4369
2011	March	0.4953
2011	April	0.4316
2011	Mai	0.4882
2011	June	0.4767
2011	July	0.4675
2011	August	0.4123
2011	September	0.4849
2011	October	0.4439
2011	November	0.4710
2011	December	0.3786

Table 42 – Normalised CO2e Emissions: 2010 and 2011

Year	Month	GHG Normalised
2012	January	0.3347
2012	February	0.3437
2012	March	0.3678
2012	April	0.3201
2012	Mai	0.3492
2012	June	0.3629
2012	July	0.3361
2012	August	0.3097
2012	September	0.3397
2012	October	0.3929
2012	November	0.3831
2012	December	0.2777

Year	Month	GHG Normalised
2013	January	0.3945
2013	February	0.3736
2013	March	0.3580
2013	April	0.3888
2013	Mai	0.3676
2013	June	0.3803
2013	July	0.4172
2013	August	0.3295
2013	September	0.3890
2013	October	0.4355
2013	November	0.4016
2013	December	0.2932

Table 43 – Normalised CO2e Emissions: 2012 and 2013

6.5 Waste Management per Assigned FTE

Year	Month	RRR Normalised per Assigned FTE
2010	January	0.0316
2010	February	0.0156
2010	March	0.0479
2010	April	0.0392
2010	Mai	0.0259
2010	June	0.0382
2010	July	0.0436
2010	August	0.0248
2010	September	0.0304
2010	October	0.0166
2010	November	0.0345
2010	December	0.0382

Year	Month	RRR Normalised per Assigned FTE
2011	January	0.0233
2011	February	0.0178
2011	March	0.0388
2011	April	0.0138
2011	Mai	0.0195
2011	June	0.0184
2011	July	0.0098
2011	August	0.0274
2011	September	0.0149
2011	October	0.0079
2011	November	0.0217
2011	December	0.0181

Table 44 – Normalised 'Waste' Indicator per Assigned Full Time Equivalent: 2010 and 2011

Year	Month	RRR Normalised per Assigned FTE
2012	January	0.0189
2012	February	0.0187
2012	March	0.0247
2012	April	0.0160
2012	Mai	0.0193
2012	June	0.0245
2012	July	0.0062
2012	August	0.0209
2012	September	0.0194
2012	October	0.0497
2012	November	0.0140
2012	December	0.0071

Year	Month	RRR Normalised per Assigned FTE
2013	January	0.0261
2013	February	0.0070
2013	March	0.0146
2013	April	0.0197
2013	Mai	0.0225
2013	June	0.0159
2013	July	0.0153
2013	August	0.0137
2013	September	0.0031
2013	October	0.0025
2013	November	0.0039
2013	December	0.0045

Table 45 – Normalised 'Waste' Indicator per Assigned Full Time Equivalent: 2012 and 2013

6.6 ENERGY USED PER FTE

Year	Month	EnUs per assigned FTE
2010	January	0.0351
2010	February	0.0351
2010	March	0.0399
2010	April	0.0344
2010	Mai	0.0326
2010	June	0.0308
2010	July	0.0305
2010	August	0.0319
2010	September	0.0352
2010	October	0.0371
2010	November	0.0379
2010	December	0.0405

Year	Month	EnUs per assigned FTE
2011	January	0.0440
2011	February	0.0423
2011	March	0.0441
2011	April	0.0372
2011	Mai	0.0367
2011	June	0.0341
2011	July	0.0371
2011	August	0.0396
2011	September	0.0397
2011	October	0.0400
2011	November	0.0393
2011	December	0.0381

Table 46 – Normalised Energy Used per Assigned Full Time Equivalent: 2010 and 2011

Year	Month	EnUs per assigned FTE
2012	January	0.0414
2012	February	0.0390
2012	March	0.0382
2012	April	0.0345
2012	Mai	0.0341
2012	June	0.0340
2012	July	0.0353
2012	August	0.0364
2012	September	0.0337
2012	October	0.0382
2012	November	0.0388
2012	December	0.0362

Year	Month	EnUs per assigned FTE
2013	January	0.0413
2013	February	0.0374
2013	March	0.0386
2013	April	0.0385
2013	Mai	0.0416
2013	June	0.0439
2013	July	0.0458
2013	August	0.0414
2013	September	0.0090
2013	October	0.0102
2013	November	0.0099
2013	December	0.0094

Table 47 – Normalised Energy Used per Assigned Full Time Equivalent: 2012 and 2013

6.7 TRAININGS TO IMPROVE SKILLS PER ASSIGNED FTE

Year	Month	Normalised LLL per Assigned FTE's
2010	January	0.5296
2010	February	0.4830
2010	March	0.9859
2010	April	0.6104
2010	Mai	0.5299
2010	June	0.4401
2010	July	0.6135
2010	August	0.5878
2010	September	0.8046
2010	October	0.8550
2010	November	0.7123
2010	December	0.6396

Year	Month	Normalised LLL per Assigned FTE's
2011	January	0.6294
2011	February	1.0000
2011	March	0.6143
2011	April	0.6432
2011	Mai	0.8827
2011	June	0.5820
2011	July	0.7136
2011	August	0.5738
2011	September	0.9961
2011	October	0.7859
2011	November	0.7295
2011	December	0.5316

Table 48 – Normalised Trainings per Assigned Full Time Equivalent: 2010 and 2011

Year	Month	Normalised LLL per Assigned FTE's
2012	January	0.6334
2012	February	0.7342
2012	March	0.6902
2012	April	0.5594
2012	Mai	0.5462
2012	June	0.5403
2012	July	0.5918
2012	August	0.5081
2012	September	0.6168
2012	October	0.9615
2012	November	0.5969
2012	December	0.5021

Year	Month	Normalised LLL per Assigned FTE's
2013	January	0.3742
2013	February	0.3387
2013	March	0.6408
2013	April	0.4543
2013	Mai	0.3800
2013	June	0.4850
2013	July	0.3145
2013	August	0.1905
2013	September	0.0400
2013	October	0.0813
2013	November	0.1255
2013	December	0.0707

Table 49 – Normalised Trainings per Assigned Full Time Equivalent: 2012 and 2013

6.8 Health Security and Safety per Assigned FTE

Year	Month	HSS per Assigned FTE
2010	January	0.0000
2010	February	0.0000
2010	March	0.0041
2010	April	0.0020
2010	Mai	0.0000
2010	June	0.0019
2010	July	0.0019
2010	August	0.0000
2010	September	0.0000
2010	October	0.0038
2010	November	0.0019
2010	December	0.0000

Year	Month	HSS per Assigned FTE
2011	January	0.0019
2011	February	0.0057
2011	March	0.0000
2011	April	0.0000
2011	Mai	0.0037
2011	June	0.0000
2011	July	0.0000
2011	August	0.0056
2011	September	0.0000
2011	October	0.0000
2011	November	0.0019
2011	December	0.0040

Table 50 – Normalised Health, Security, and Safety per Assigned Full Time Equivalent: 2010 and 2011

Year	Month	HSS per Assigned FTE
2012	January	0.0000
2012	February	0.0059
2012	March	0.0020
2012	April	0.0020
2012	Mai	0.0020
2012	June	0.0000
2012	July	0.0021
2012	August	0.0000
2012	September	0.0041
2012	October	0.0000
2012	November	0.0062
2012	December	0.0042

Year	Month	HSS per Assigned FTE
2013	January	0.0021
2013	February	0.0063
2013	March	0.0021
2013	April	0.0000
2013	Mai	0.0000
2013	June	0.0042
2013	July	0.0062
2013	August	0.0000
2013	September	0.0061
2013	October	0.0000
2013	November	0.0020
2013	December	0.0000

Table 51 – Normalised Health, Security, and Safety per Assigned Full Time Equivalent: 2012 and 2013

7. Qualitative KPIs: Results

7.1 Exception Management: Flexibility and Issues Solving

Year	Month	F normalised	IS normalised
2010	January	0.775	0.7875
2010	February	0.775	0.7875
2010	March	0.775	0.7875
2010	April	0.775	0.7875
2010	Mai	0.775	0.7875
2010	June	0.775	0.7875
2010	July	0.7625	0.75
2010	August	0.7375	0.725
2010	September	0.7375	0.725
2010	October	0.7125	0.725
2010	November	0.7375	0.725
2010	December	0.7375	0.725

Year	Month	F normalised	IS normalised
2011	January	0.7375	0.7
2011	February	0.7375	0.7
2011	March	0.7375	0.7
2011	April	0.7375	0.725
2011	Mai	0.7625	0.7375
2011	June	0.7625	0.7375
2011	July	0.775	0.7375
2011	August	0.775	0.7375
2011	September	0.775	0.7375
2011	October	0.775	0.7375
2011	November	0.775	0.7375
2011	December	0.775	0.7375

Table 52 – Normalised Flexibility & Issues Solving: 2010 and 2011

Year	Month	F normalised	IS normalised
2012	January	0.8	0.8
2012	February	0.8125	0.8125
2012	March	0.8125	0.8125
2012	April	0.8125	0.8125
2012	Mai	0.8125	0.8125
2012	June	0.8125	0.8125
2012	July	0.8125	0.8125
2012	August	0.8125	0.8125
2012	September	0.8	0.8
2012	October	0.8	0.8
2012	November	0.8	0.8
2012	December	0.8	0.8

Year	Month	F normalised	IS normalised
2013	January	0.8	0.8125
2013	February	0.8	0.8125
2013	March	0.8125	0.8125
2013	April	0.8125	0.8125
2013	Mai	0.8125	0.8125
2013	June	0.8125	0.8125
2013	July	0.8125	0.8125
2013	August	0.8125	0.8125
2013	September	0.8125	0.8125
2013	October	0.8125	0.8125
2013	November	0.8125	0.825
2013	December	0.8125	0.825

Table 53 – Normalised Flexibility & Issues Solving: 2012 and 2013

7.2 Service Quality

Year	Month	Q normalised
2010	January	0.86
2010	February	0.86
2010	March	0.86
2010	April	0.86
2010	Mai	0.86
2010	June	0.86
2010	July	0.86
2010	August	0.86
2010	September	0.88
2010	October	0.88
2010	November	0.88
2010	December	0.88

Year	Month	Q normalised
2011	January	0.88
2011	February	0.88
2011	March	0.88
2011	April	0.88
2011	Mai	0.88
2011	June	0.88
2011	July	0.88
2011	August	0.88
2011	September	0.88
2011	October	0.88
2011	November	0.88
2011	December	0.88

Table 54 – Normalised Quality: 2010 and 2011

Year	Month	Q normalised
2012	January	0.88
2012	February	0.88
2012	March	0.88
2012	April	0.88
2012	Mai	0.9
2012	June	0.9
2012	July	0.9
2012	August	0.9
2012	September	0.9
2012	October	0.9
2012	November	0.9
2012	December	0.9

Year	Month	Q normalised
2013	January	0.9
2013	February	0.9
2013	March	0.9
2013	April	0.9
2013	Mai	0.9
2013	June	0.9
2013	July	0.92
2013	August	0.92
2013	September	0.92
2013	October	0.92
2013	November	0.92
2013	December	0.92

Table 55 – Normalised Quality: 2012 and 2013

7.3 Security Of Employment

Year	Month	SE normalised
2010	January	0.8200
2010	February	0.8200
2010	March	0.8000
2010	April	0.8000
2010	Mai	0.8200
2010	June	0.8200
2010	July	0.8200
2010	August	0.8200
2010	September	0.8000
2010	October	0.8200
2010	November	0.8000
2010	December	0.8000

Year	Month	SE normalised
2011	January	0.8000
2011	February	0.8000
2011	March	0.8000
2011	April	0.8000
2011	Mai	0.8000
2011	June	0.8000
2011	July	0.8000
2011	August	0.8000
2011	September	0.8000
2011	October	0.8000
2011	November	0.8000
2011	December	0.8000

Table 56 – Normalised Security of Employment: 2010 and 2011

Year	Month	SE normalised
2012	January	0.8400
2012	February	0.8400
2012	March	0.8400
2012	April	0.8400
2012	Mai	0.8600
2012	June	0.8600
2012	July	0.8600
2012	August	0.8600
2012	September	0.8600
2012	October	0.8600
2012	November	0.8600
2012	December	0.8600

Year	Month	SE normalised
2013	January	0.8600
2013	February	0.8600
2013	March	0.8600
2013	April	0.8600
2013	Mai	0.8800
2013	June	0.8800
2013	July	0.8800
2013	August	0.8800
2013	September	0.8800
2013	October	0.8800
2013	November	0.8800
2013	December	0.8800

Table 57 – Normalised Security of Employment: 2012 and 2013

7.4 Actions Taken against Xenophobia and Discrimination

Year	Month	AXD Normalised
2010	January	0.4800
2010	February	0.4800
2010	March	0.4800
2010	April	0.4800
2010	Mai	0.4800
2010	June	0.4800
2010	July	0.5200
2010	August	0.5200
2010	September	0.5200
2010	October	0.5200
2010	November	0.5200
2010	December	0.5200

Year	Month	AXD Normalised
2011	January	0.5200
2011	February	0.5200
2011	March	0.5200
2011	April	0.5200
2011	Mai	0.5200
2011	June	0.5200
2011	July	0.5200
2011	August	0.5200
2011	September	0.5200
2011	October	0.5200
2011	November	0.5200
2011	December	0.5200

Table 58 – Normalised Actions taken against Xenophobia and Discrimination: 2010 and 2011

Year	Month	AXD Normalised
2012	January	0.5400
2012	February	0.5400
2012	March	0.5400
2012	April	0.5400
2012	Mai	0.5400
2012	June	0.5400
2012	July	0.5400
2012	August	0.5400
2012	September	0.5400
2012	October	0.5400
2012	November	0.5400
2012	December	0.5400

Year	Month	AXD Normalised
2013	January	0.5800
2013	February	0.5800
2013	March	0.5800
2013	April	0.5800
2013	Mai	0.5800
2013	June	0.5800
2013	July	0.5800
2013	August	0.5800
2013	September	0.5800
2013	October	0.5800
2013	November	0.5800
2013	December	0.5800

Table 59 – Normalised Actions taken against Xenophobia and Discrimination: 2012 and 2013

7.5 ACTIONS TAKEN TO INCREASE EMPLOYEES' MOTIVATION

Year	Month	EmMo Normalised
2010	January	0.5200
2010	February	0.5200
2010	March	0.5200
2010	April	0.5200
2010	Mai	0.5200
2010	June	0.5200
2010	July	0.5200
2010	August	0.5200
2010	September	0.5200
2010	October	0.5200
2010	November	0.5200
2010	December	0.5200

Year	Month	EmMo Normalised
2011	January	0.5200
2011	February	0.5200
2011	March	0.5200
2011	April	0.5200
2011	Mai	0.5200
2011	June	0.5200
2011	July	0.5200
2011	August	0.5200
2011	September	0.5200
2011	October	0.5200
2011	November	0.5200
2011	December	0.5200

Table 60 – Normalised Actions taken to increase Employees' Motivation: 2010 and 2011

Year	Month	EmMo Normalised
2012	January	0.5600
2012	February	0.5600
2012	March	0.5600
2012	April	0.5600
2012	Mai	0.5600
2012	June	0.5600
2012	July	0.5600
2012	August	0.5600
2012	September	0.5600
2012	October	0.5600
2012	November	0.5600
2012	December	0.5600

Year	Month	EmMo Normalised
2013	January	0.5800
2013	February	0.6200
2013	March	0.6200
2013	April	0.6200
2013	Mai	0.6200
2013	June	0.6200
2013	July	0.6200
2013	August	0.6200
2013	September	0.6200
2013	October	0.6200
2013	November	0.6200
2013	December	0.6200

Table 61 – Normalised Actions taken to increase Employees' Motivation: 2012 and 2013

7.6 Gender Equality

Year	Month	GE Normalised
2010	January	0.7000
2010	February	0.7000
2010	March	0.7000
2010	April	0.7000
2010	Mai	0.7000
2010	June	0.7000
2010	July	0.7000
2010	August	0.7000
2010	September	0.7000
2010	October	0.7000
2010	November	0.7000
2010	December	0.7000

Year	Month	GE Normalised
2011	January	0.7000
2011	February	0.7000
2011	March	0.7000
2011	April	0.7000
2011	Mai	0.7000
2011	June	0.7000
2011	July	0.7000
2011	August	0.7000
2011	September	0.7000
2011	October	0.7000
2011	November	0.7000
2011	December	0.7000

Table 62 – Normalised Gender Equality: 2010 and 2011

Year	Month	GE Normalised
2012	January	0.7400
2012	February	0.7400
2012	March	0.7400
2012	April	0.7800
2012	Mai	0.7800
2012	June	0.7800
2012	July	0.7800
2012	August	0.7800
2012	September	0.7800
2012	October	0.7800
2012	November	0.7800
2012	December	0.7800

Year	Month	GE Normalised
2013	January	0.7800
2013	February	0.7800
2013	March	0.7800
2013	April	0.7800
2013	Mai	0.8200
2013	June	0.8200
2013	July	0.8200
2013	August	0.8200
2013	September	0.8200
2013	October	0.8200
2013	November	0.8200
2013	December	0.8200

Table 63 – Normalised Gender Equality: 2012 and 2013

8. Normalised Results of Exception Management

Year	Month	R Normalised	F normalised	IS normalised	ExM
2010	January	0.8435	0.7750	0.7875	0.8020
2010	February	0.7314	0.7750	0.7875	0.7646
2010	March	0.8098	0.7750	0.7875	0.7908
2010	April	0.7821	0.7750	0.7875	0.7815
2010	Mai	0.6934	0.7750	0.7875	0.7520
2010	June	0.7326	0.7750	0.7875	0.7650
2010	July	0.7340	0.7625	0.7500	0.7488
2010	August	0.7117	0.7375	0.7250	0.7247
2010	September	0.7137	0.7375	0.7250	0.7254
2010	October	0.6993	0.7125	0.7250	0.7123
2010	November	0.7704	0.7375	0.7250	0.7443
2010	December	0.8342	0.7375	0.7250	0.7656

Table 64 – Normalised Exception Management: 2010

Year	Month	R Normalised	F normalised	IS normalised	ExM
2011	January	0.7343	0.7375	0.7000	0.7239
2011	February	0.7444	0.7375	0.7000	0.7273
2011	March	0.7673	0.7375	0.7000	0.7349
2011	April	0.7134	0.7375	0.7250	0.7253
2011	Mai	0.8061	0.7625	0.7375	0.7687
2011	June	0.7926	0.7625	0.7375	0.7642
2011	July	0.7740	0.7750	0.7375	0.7622
2011	August	0.6536	0.7750	0.7375	0.7220
2011	September	0.7146	0.7750	0.7375	0.7424
2011	October	0.7088	0.7750	0.7375	0.7404
2011	November	0.7752	0.7750	0.7375	0.7626
2011	December	0.7406	0.7750	0.7375	0.7510

Table 65 – Normalised Exception Management: 2011

Year	Month	R Normalised	F normalised	IS normalised	ExM
2012	January	0.8608	0.8000	0.8000	0.8203
2012	February	0.8430	0.8125	0.8125	0.8227
2012	March	0.8756	0.8125	0.8125	0.8335
2012	April	0.7861	0.8125	0.8125	0.8037
2012	Mai	0.8265	0.8125	0.8125	0.8172
2012	June	0.8335	0.8125	0.8125	0.8195
2012	July	0.7865	0.8125	0.8125	0.8038
2012	August	0.7539	0.8125	0.8125	0.7930
2012	September	0.8094	0.8000	0.8000	0.8031
2012	October	0.7522	0.8000	0.8000	0.7841
2012	November	0.7684	0.8000	0.8000	0.7895
2012	December	0.7626	0.8000	0.8000	0.7875

Table 66 – Normalised Exception Management: 2012

Year	Month	R Normalised	F normalised	IS normalised	ExM
2013	January	0.8426	0.8000	0.8125	0.8184
2013	February	0.8140	0.8000	0.8125	0.8088
2013	March	0.8530	0.8125	0.8125	0.8260
2013	April	0.8820	0.8125	0.8125	0.8357
2013	Mai	0.7643	0.8125	0.8125	0.7964
2013	June	0.8484	0.8125	0.8125	0.8245
2013	July	0.7843	0.8125	0.8125	0.8031
2013	August	0.7822	0.8125	0.8125	0.8024
2013	September	0.7849	0.8125	0.8125	0.8033
2013	October	0.8046	0.8125	0.8125	0.8099
2013	November	0.7757	0.8125	0.8250	0.8044
2013	December	0.7914	0.8125	0.8250	0.8096

Table 67 – Normalised Exception Management: 2013

9. Sustainability Performance – per Pillar

9.1 The Economical Pillar

The economic pillar's sustainability performance is calculated as follows:

$$\text{Weight}_i \cdot \text{KPI}_i + \text{Weight}_j \cdot \text{KPI}_j + \ldots + \text{Weight}_n \cdot \text{KPI}_n$$

Year	Month	1 - C	OTIF Normalised	Q Normalised	ExM Normalised	The Economical Pillar's Sustainability Performance
2010	January	0.1583	0.9672	0.8600	0.8020	0.69770
2010	February	0.1432	0.9809	0.8600	0.7646	0.69626
2010	March	0.1151	0.9797	0.8600	0.7908	0.68959
2010	April	0.1288	0.9765	0.8600	0.7815	0.69153
2010	May	0.1263	0.9773	0.8600	0.7520	0.68894
2010	June	0.0637	0.9804	0.8600	0.7650	0.67317
2010	July	0.0455	0.9779	0.8600	0.7488	0.66568
2010	August	0.2084	0.9858	0.8600	0.7247	0.71412
2010	September	0.0688	0.9764	0.8800	0.7254	0.67445
2010	October	0.0873	0.9869	0.8800	0.7123	0.68318
2010	November	0.0938	0.9782	0.8800	0.7443	0.68381
2010	December	0.2523	0.9170	0.8800	0.7656	0.70580
2010	**Total**	**0.1127**	**0.9788**	**0.8655**	**0.7564**	**0.6887**
2011	January	0.1135	0.9865	0.8800	0.7239	0.69145
2011	February	0.1168	0.9837	0.8800	0.7273	0.69147
2011	March	0.0506	0.9812	0.8800	0.7349	0.67194
2011	April	0.1109	0.9866	0.8800	0.7253	0.69083
2011	May	0.0000	0.9818	0.8800	0.7687	0.66008
2011	June	0.1027	0.9770	0.8800	0.7642	0.68741
2011	July	0.0602	0.9759	0.8800	0.7622	0.67453
2011	August	0.1600	0.9881	0.8800	0.7220	0.70537
2011	September	0.1909	0.9879	0.8800	0.7424	0.71573
2011	October	0.1550	0.9864	0.8800	0.7404	0.70456
2011	November	0.0961	0.9829	0.8800	0.7626	0.68781
2011	December	0.2704	0.9836	0.8800	0.7510	0.73748
2011	**Total**	**0.1189**	**0.9835**	**0.8800**	**0.7437**	**0.6932**

Table 68 – Sustainability Performance: Economic Pillar 2010 & 2011

Year	Month	1 - C	OTIF Normalised	Q Normalised	ExM Normalised	The Economical Pillar's Sustainability Performance
2012	January	0.1361	0.9868	0.8800	0.8203	0.70525
2012	February	0.1785	0.9836	0.8800	0.8227	0.71634
2012	March	0.1149	0.9865	0.8800	0.8335	0.70000
2012	April	0.2248	0.9749	0.8800	0.8037	0.72465
2012	May	0.1838	0.9836	0.9000	0.8172	0.72191
2012	June	0.1147	0.9879	0.9000	0.8195	0.70392
2012	July	0.1090	0.9840	0.9000	0.8038	0.69950
2012	August	0.2287	0.9781	0.9000	0.7930	0.73079
2012	September	0.1328	0.9862	0.9000	0.8031	0.70722
2012	October	0.0614	0.9822	0.9000	0.7841	0.68356
2012	November	0.1002	0.9858	0.9000	0.7895	0.69663
2012	December	0.3542	0.9707	0.9000	0.7875	0.76352
2012	**Total**	**0.1616**	**0.9825**	**0.8933**	**0.8065**	**0.7128**
2013	January	0.1351	0.9813	0.9000	0.8184	0.70699
2013	February	0.1733	0.9782	0.9000	0.8088	0.71600
2013	March	0.1865	0.9823	0.9000	0.8260	0.72278
2013	April	0.1515	0.9822	0.9000	0.8357	0.71340
2013	May	0.1883	0.9823	0.9000	0.7964	0.72111
2013	June	0.1721	0.9884	0.9000	0.8245	0.72104
2013	July	0.0842	0.9866	0.9200	0.8031	0.69782
2013	August	0.2904	0.9907	0.9200	0.8024	0.75895
2013	September	0.1643	0.9830	0.9200	0.8033	0.71947
2013	October	0.1100	0.9828	0.9200	0.8099	0.70423
2013	November	0.1648	0.9855	0.9200	0.8044	0.72074
2013	December	0.3709	0.9647	0.9200	0.8096	0.77192
2013	**Total**	**0.1826**	**0.9823**	**0.9100**	**0.8119**	**0.7229**

Table 69 – Sustainability Performance: Economic Pillar 2012 & 2013

9.2 THE ECOLOGICAL PILLAR

The ecologic pillar's sustainability performance is calculated as follows:

$\text{Weight}_i \cdot \text{KPI}_i + \text{Weight}_j \cdot \text{KPI}_j + \ldots + \text{Weight}_n \cdot \text{KPI}_n$

Year	Month	1 - GHG	1 - RRR	1 - α EnUs	The Ecological Pillar's Sustainability Performance
2010	January	0.6860	0.9684	0.9649	0.79135
2010	February	0.6862	0.9844	0.9649	0.79500
2010	March	0.6604	0.9521	0.9601	0.77100
2010	April	0.6725	0.9608	0.9656	0.78134
2010	May	0.6825	0.9741	0.9674	0.79082
2010	June	0.6547	0.9618	0.9692	0.77102
2010	July	0.0160	0.9564	0.9695	0.37068
2010	August	0.1924	0.9752	0.9681	0.48489
2010	September	0.0000	0.9696	0.9648	0.36286
2010	October	0.0339	0.9834	0.9629	0.38682
2010	November	0.0159	0.9655	0.9621	0.37151
2010	December	0.2037	0.9618	0.9595	0.48765
2010	**Total**	**0.3910**	**0.9683**	**0.9654**	**0.5971**
2011	January	0.5411	0.9767	0.9560	0.70124
2011	February	0.5631	0.9822	0.9577	0.71648
2011	March	0.5047	0.9612	0.9559	0.67507
2011	April	0.5684	0.9862	0.9628	0.72150
2011	May	0.5118	0.9805	0.9633	0.68490
2011	June	0.5233	0.9816	0.9659	0.69277
2011	July	0.5325	0.9902	0.9629	0.69994
2011	August	0.5877	0.9726	0.9604	0.73014
2011	September	0.5151	0.9851	0.9603	0.68752
2011	October	0.5561	0.9921	0.9600	0.71463
2011	November	0.5290	0.9783	0.9607	0.69474
2011	December	0.6214	0.9819	0.9619	0.75353
2011	**Total**	**0.5462**	**0.9807**	**0.9607**	**0.7060**

Table 70 – Sustainability Performance: Ecologic Pillar 2010 & 2011

Year	Month	1 - GHG	1 - RRR	1 - α EnUs	The Ecological Pillar's Sustainability Performance
2012	January	0.6653	0.9811	0.9586	0.78025
2012	February	0.6563	0.9813	0.9610	0.77505
2012	March	0.6322	0.9753	0.9618	0.75876
2012	April	0.6799	0.9840	0.9655	0.79108
2012	May	0.6508	0.9807	0.9659	0.77224
2012	June	0.6371	0.9755	0.9660	0.76250
2012	July	0.6639	0.9938	0.9647	0.78309
2012	August	0.6903	0.9791	0.9636	0.79623
2012	September	0.6603	0.9806	0.9663	0.77823
2012	October	0.6071	0.9503	0.9618	0.73757
2012	November	0.6169	0.9860	0.9612	0.75151
2012	December	0.7223	0.9929	0.9638	0.81926
2012	**Total**	**0.6569**	**0.9801**	**0.9634**	**0.7755**
2013	January	0.6055	0.9739	0.9587	0.74128
2013	February	0.6264	0.9930	0.9626	0.75915
2013	March	0.6420	0.9854	0.9614	0.76706
2013	April	0.6112	0.9803	0.9615	0.74672
2013	May	0.6324	0.9775	0.9584	0.75888
2013	June	0.6197	0.9841	0.9561	0.75205
2013	July	0.5828	0.9847	0.9542	0.72882
2013	August	0.6705	0.9863	0.9586	0.78464
2013	September	0.6110	0.9969	0.9910	0.75483
2013	October	0.5645	0.9975	0.9898	0.72566
2013	November	0.5984	0.9961	0.9901	0.74659
2013	December	0.7068	0.9955	0.9906	0.81428
2013	**Total**	**0.6226**	**0.9876**	**0.9694**	**0.7567**

Table 71 – Sustainability Performance: Ecologic Pillar 2012 & 2013

9.3 The Sub-Pillar Work

The sub pillar Work's sustainability performance is calculated as follows:

$Weight_i \cdot KPI_i + Weight_j \cdot KPI_j + \ldots + Weight_n \cdot KPI_n$

Year	Month	SE Normalised	1 - α HSS	αLLL	Sub - Pillar Work
2010	January	0.8200	1.0000	0.5296	0.83140
2010	February	0.8200	1.0000	0.4830	0.82133
2010	March	0.8000	0.8812	0.9859	0.87367
2010	April	0.8000	0.9417	0.6104	0.81741
2010	May	0.8200	1.0000	0.5299	0.83147
2010	June	0.8200	0.9455	0.4401	0.78957
2010	July	0.8200	0.9463	0.6135	0.82742
2010	August	0.8200	1.0000	0.5878	0.84399
2010	September	0.8000	1.0000	0.8046	0.88343
2010	October	0.8200	0.8910	0.8550	0.85684
2010	November	0.8000	0.9457	0.7123	0.84110
2010	December	0.8000	1.0000	0.6396	0.84774
2010	**Total**	**0.8127**	**0.9592**	**0.6502**	**0.8388**
2011	January	0.8000	0.9456	0.6294	0.82314
2011	February	0.8000	0.8381	1.0000	0.85893
2011	March	0.8000	1.0000	0.6143	0.84229
2011	April	0.8000	1.0000	0.6432	0.84853
2011	May	0.8000	0.8936	0.8827	0.85644
2011	June	0.8000	1.0000	0.5820	0.83529
2011	July	0.8000	1.0000	0.7136	0.86376
2011	August	0.8000	0.8392	0.5738	0.76727
2011	September	0.8000	1.0000	0.9961	0.92483
2011	October	0.8000	1.0000	0.7859	0.87939
2011	November	0.8000	0.9469	0.7295	0.84529
2011	December	0.8000	0.9001	0.5316	0.78320
2011	**Total**	**0.8000**	**0.9470**	**0.7235**	**0.8440**

Table 72 – Sustainability Performance: Sub – Pillar Work 2010 & 2011

Year	Month	SE Normalised	1 - α HSS	αLLL	Sub-Pillar Work
2012	January	0.8400	1.0000	0.6334	0.86127
2012	February	0.8400	0.8499	0.7342	0.82119
2012	March	0.8400	0.9490	0.6902	0.85255
2012	April	0.8400	0.9495	0.5594	0.82448
2012	May	0.8600	0.9499	0.5462	0.82921
2012	June	0.8600	1.0000	0.5403	0.84858
2012	July	0.8600	0.9488	0.5918	0.83862
2012	August	0.8600	1.0000	0.5081	0.84161
2012	September	0.8600	0.8995	0.6168	0.82370
2012	October	0.8600	1.0000	0.9615	0.93965
2012	November	0.8600	0.8464	0.5969	0.79750
2012	December	0.8600	0.8971	0.5021	0.79791
2012	**Total**	**0.8533**	**0.9408**	**0.6234**	**0.8397**
2013	January	0.8600	0.9478	0.3742	0.79116
2013	February	0.8600	0.8449	0.3387	0.74105
2013	March	0.8600	0.9490	0.6408	0.84930
2013	April	0.8600	1.0000	0.4543	0.82998
2013	May	0.8800	1.0000	0.3800	0.82134
2013	June	0.8800	0.8968	0.4850	0.80153
2013	July	0.8800	0.8487	0.3145	0.74483
2013	August	0.8800	1.0000	0.1905	0.78039
2013	September	0.8800	0.9697	0.0400	0.73535
2013	October	0.8800	1.0000	0.0813	0.75676
2013	November	0.8800	0.9899	0.1255	0.76218
2013	December	0.8800	1.0000	0.0707	0.75447
2013	**Total**	**0.8733**	**0.9539**	**0.2913**	**0.7807**

Table 73 – Sustainability Performance: Sub – Pillar Work 2012 & 2013

9.4 THE SUB-PILLAR ETHICS

The sub pillar Ethics' sustainability performance is calculated as follows:

$Weight_i \cdot KPI_i + Weight_j \cdot KPI_j + \ldots + Weight_n \cdot KPI_n$

Year	Month	GE Normalised	AXD Normalised	EmMo Normalised	Sub-Pillar Ethics
2010	January	0.7000	0.4800	0.5200	0.54239
2010	February	0.7000	0.4800	0.5200	0.54239
2010	March	0.7000	0.4800	0.5200	0.54239
2010	April	0.7000	0.4800	0.5200	0.54239
2010	May	0.7000	0.4800	0.5200	0.54239
2010	June	0.7000	0.4800	0.5200	0.54239
2010	July	0.7000	0.5200	0.5200	0.54717
2010	August	0.7000	0.5200	0.5200	0.54717
2010	September	0.7000	0.5200	0.5200	0.54717
2010	October	0.7000	0.5200	0.5200	0.54717
2010	November	0.7000	0.5200	0.5200	0.54717
2010	December	0.7000	0.5200	0.5200	0.54717
2010	**Total**	**0.7000**	**0.4982**	**0.5200**	**0.5448**
2011	January	0.7000	0.5200	0.5200	0.54717
2011	February	0.7000	0.5200	0.5200	0.54717
2011	March	0.7000	0.5200	0.5200	0.54717
2011	April	0.7000	0.5200	0.5200	0.54717
2011	May	0.7000	0.5200	0.5200	0.54717
2011	June	0.7000	0.5200	0.5200	0.54717
2011	July	0.7000	0.5200	0.5200	0.54717
2011	August	0.7000	0.5200	0.5200	0.54717
2011	September	0.7000	0.5200	0.5200	0.54717
2011	October	0.7000	0.5200	0.5200	0.54717
2011	November	0.7000	0.5200	0.5200	0.54717
2011	December	0.7000	0.5200	0.5200	0.54717
2011	**Total**	**0.7000**	**0.5200**	**0.5200**	**0.5472**

Table 74 – Sustainability Performance: Sub – Pillar Ethics 2011 & 2012

Year	Month	GE Normalised	AXD Normalised	EmMo Normalised	Sub-Pillar Ethics
2012	January	0.7400	0.5400	0.5600	0.58478
2012	February	0.7400	0.5400	0.5600	0.58478
2012	March	0.7400	0.5400	0.5600	0.58478
2012	April	0.7800	0.5400	0.5600	0.59082
2012	May	0.7800	0.5400	0.5600	0.59082
2012	June	0.7800	0.5400	0.5600	0.59082
2012	July	0.7800	0.5400	0.5600	0.59082
2012	August	0.7800	0.5400	0.5600	0.59082
2012	September	0.7800	0.5400	0.5600	0.59082
2012	October	0.7800	0.5400	0.5600	0.59082
2012	November	0.7800	0.5400	0.5600	0.59082
2012	December	0.7800	0.5400	0.5600	0.59082
2012	**Total**	**0.7700**	**0.5400**	**0.5600**	**0.5893**
2013	January	0.7800	0.5800	0.6200	0.63937
2013	February	0.7800	0.5800	0.6200	0.63937
2013	March	0.7800	0.5800	0.6200	0.63937
2013	April	0.7800	0.5800	0.6200	0.63937
2013	May	0.8200	0.5800	0.6200	0.64541
2013	June	0.8200	0.5800	0.6200	0.64541
2013	July	0.8200	0.5800	0.6200	0.64541
2013	August	0.8200	0.5800	0.6200	0.64541
2013	September	0.8200	0.5800	0.6200	0.64541
2013	October	0.8200	0.5800	0.6200	0.64541
2013	November	0.8200	0.5800	0.6200	0.64541
2013	December	0.8200	0.5800	0.6200	0.64541
2013	**Total**	**0.8067**	**0.5800**	**0.6200**	**0.6434**

Table 75 – Sustainability Performance: Sub – Pillar Ethics 2012 & 2013

9.5 The Societal Pillar

The societal pillar's sustainability performance is calculated as follows:

$Weight_i \cdot$ intermediate $result_i$ + $Weight_j \cdot$ intermediate $result_j$ ¸whereas the intermediate results are the results given in Annexe 9.3 and 9.4.

Year	Month	Societal Pillar	Year	Month	Societal Pillar
2010	January	0.68689	2011	January	0.68515
2010	February	0.68186	2011	February	0.70305
2010	March	0.70803	2011	March	0.69473
2010	April	0.67990	2011	April	0.69785
2010	May	0.68693	2011	May	0.70181
2010	June	0.66598	2011	June	0.69123
2010	July	0.68729	2011	July	0.70546
2010	August	0.69558	2011	August	0.65722
2010	September	0.71530	2011	September	0.73600
2010	October	0.70201	2011	October	0.71328
2010	November	0.69413	2011	November	0.69623
2010	December	0.69746	2011	December	0.66518
2010	**Total**	**0.6918**	**2011**	**Total**	**0.6956**
2012	January	0.72303	2013	January	0.71526
2012	February	0.70299	2013	February	0.69021
2012	March	0.71866	2013	March	0.74434
2012	April	0.70765	2013	April	0.73468
2012	May	0.71001	2013	May	0.73338
2012	June	0.71970	2013	June	0.72347
2012	July	0.71472	2013	July	0.69512
2012	August	0.71622	2013	August	0.71290
2012	September	0.70726	2013	September	0.69038
2012	October	0.76523	2013	October	0.70108
2012	November	0.69416	2013	November	0.70380
2012	December	0.69437	2013	December	0.69994
2012	**Total**	**0.7145**	**2013**	**Total**	**0.7120**

Table 76 – Sustainability Performance: Societal Pillar 2011 – 2013

10. The Fuzzy Rules Set

Economic	Ecologic	Societal	Result
Very Poor	Very Poor	Very Poor	**Very poor**
Very Poor	Very Poor	Poor	**Very poor**
Very Poor	Very Poor	Medium	**Very poor**
Very Poor	Very Poor	Good	**Poor**
Very Poor	Very Poor	Excellent	**Poor**
Very Poor	Poor	Very Poor	**Very poor**
Very Poor	Poor	Poor	**Very poor**
Very Poor	Poor	Medium	**Poor**
Very Poor	Poor	Good	**Poor**
Very Poor	Poor	Excellent	**Poor**
Very Poor	Medium	Very Poor	**Very poor**
Very Poor	Medium	Poor	**Poor**
Very Poor	Medium	Medium	**Poor**
Very Poor	Medium	Good	**Poor**
Very Poor	Medium	Excellent	**Medium**
Very Poor	Good	Very Poor	**Poor**
Very Poor	Good	Poor	**Poor**
Very Poor	Good	Medium	**Poor**
Very Poor	Good	Good	**Medium**
Very Poor	Good	Excellent	**Medium**
Very Poor	Excellent	Very Poor	**Poor**
Very Poor	Excellent	Poor	**Poor**
Very Poor	Excellent	Medium	**Medium**
Very Poor	Excellent	Good	**Medium**
Very Poor	Excellent	Excellent	**Good**
Poor	Very Poor	Very Poor	**Very poor**
Poor	Very Poor	Poor	**Very poor**
Poor	Very Poor	Medium	**Poor**
Poor	Very Poor	Good	**Poor**
Poor	Very Poor	Excellent	**Poor**
Poor	Poor	Very Poor	**Very poor**

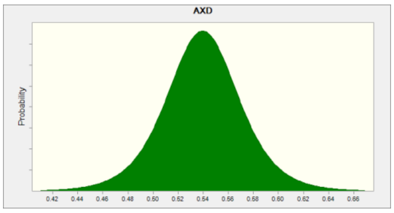
Economic	Ecologic	Societal	Result
Poor	Medium	Good	**Medium**
Poor	Medium	Excellent	**Medium**
Poor	Good	Very Poor	**Poor**
Poor	Good	Poor	**Poor**
Poor	Good	Medium	**Medium**
Poor	Good	Good	**Medium**
Poor	Good	Excellent	**Good**
Poor	Excellent	Very Poor	**Poor**
Poor	Excellent	Poor	**Medium**
Poor	Excellent	Medium	**Medium**
Poor	Excellent	Good	**Good**
Poor	Excellent	Excellent	**Good**
Medium	Very Poor	Very Poor	**Very poor**
Medium	Very Poor	Poor	**Poor**
Medium	Very Poor	Medium	**Poor**
Medium	Very Poor	Good	**Poor**
Medium	Very Poor	Excellent	**Medium**
Medium	Poor	Very Poor	**Poor**
Medium	Poor	Poor	**Poor**
Medium	Poor	Medium	**Medium**
Medium	Poor	Good	**Medium**
Medium	Poor	Excellent	**Medium**
Medium	Medium	Very Poor	**Poor**
Medium	Medium	Poor	**Medium**
Medium	Medium	Medium	**Medium**
Medium	Medium	Good	**Medium**
Medium	Medium	Excellent	**Good**
Medium	Good	Very Poor	**Poor**
Medium	Good	Poor	**Medium**
Medium	Good	Medium	**Medium**
Medium	Good	Good	**Good**

Economic	Ecologic	Societal	Result
Poor	Poor	Poor	**Poor**
Poor	Poor	Medium	**Poor**
Poor	Poor	Good	**Poor**
Poor	Poor	Excellent	**Medium**
Poor	Medium	Very Poor	**Poor**
Poor	Medium	Poor	**Poor**
Poor	Medium	Medium	**Medium**
Good	Poor	Very Poor	**Poor**
Good	Poor	Poor	**Poor**
Good	Poor	Medium	**Medium**
Good	Poor	Good	**Medium**
Good	Poor	Excellent	**Good**
Good	Medium	Very Poor	**Poor**
Good	Medium	Poor	**Medium**
Good	Medium	Medium	**Medium**
Good	Medium	Good	**Medium**
Good	Medium	Excellent	**Good**
Good	Good	Very Poor	**Medium**
Good	Good	Poor	**Medium**
Good	Good	Medium	**Good**
Good	Good	Good	**Good**
Good	Good	Excellent	**Good**
Good	Excellent	Very Poor	**Medium**
Good	Excellent	Poor	**Good**
Good	Excellent	Medium	**Good**
Good	Excellent	Good	**Good**
Good	Excellent	Excellent	**Excellent**
Excellent	Very Poor	Very Poor	**Poor**
Excellent	Very Poor	Poor	**Poor**
Excellent	Very Poor	Medium	**Medium**
Medium	Good	Excellent	**Good**
Medium	Excellent	Very Poor	**Medium**
Medium	Excellent	Poor	**Medium**
Medium	Excellent	Medium	**Good**
Medium	Excellent	Good	**Good**
Medium	Excellent	Excellent	**Good**
Good	Very Poor	Very Poor	**Poor**
Excellent	Very Poor	Good	**Medium**
Excellent	Very Poor	Excellent	**Good**
Excellent	Poor	Very Poor	**Poor**
Excellent	Poor	Poor	**Medium**
Excellent	Poor	Medium	**Medium**
Excellent	Poor	Good	**Good**
Excellent	Poor	Excellent	**Good**
Excellent	Medium	Very Poor	**Medium**
Excellent	Medium	Poor	**Medium**
Excellent	Medium	Medium	**Good**
Excellent	Medium	Good	**Good**
Excellent	Medium	Excellent	**Good**
Excellent	Good	Very Poor	**Medium**
Excellent	Good	Poor	**Good**
Excellent	Good	Medium	**Good**
Excellent	Good	Good	**Good**
Excellent	Good	Excellent	**Excellent**
Excellent	Excellent	Very Poor	**Good**
Excellent	Excellent	Poor	**Good**
Excellent	Excellent	Medium	**Good**
Excellent	Excellent	Good	**Excellent**
Excellent	Excellent	Excellent	**Excellent**

Table 77 – The Fuzzy Rules Set

11. INDICATORS' SIMULATED DISTRIBUTIONS

Assumption: AXD

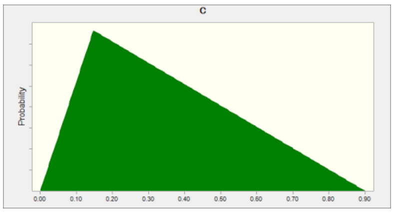


Logistic distribution with parameters:

Mean	0.54
Scale	0.02

Selected range is from 0.00 to 0.98

Assumption: C

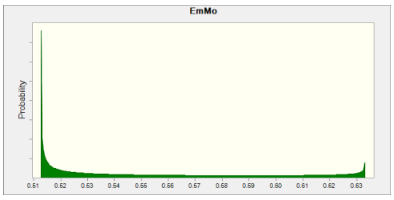


Triangular distribution with parameters:

Minimum	0.00
Likeliest	0.15
Maximum	0.90

Selected range is from 0.00 to 0.98

Assumption: EmMo

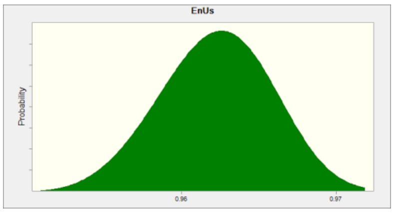


Beta distribution with parameters:

Minimum	0.51
Maximum	0.63
Alpha	0.345752817
Beta	0.636618412

Selected range is from 0.00 to 0.98

Assumption: EnUs

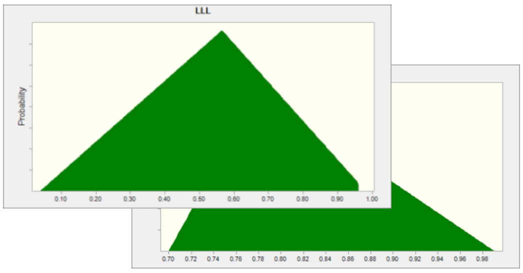


Weibull distribution with parameters:

Location	0.95
Scale	0.01
Shape	0.952128672

Selected range is from 0.00 to 0.98

Assumption: ExM

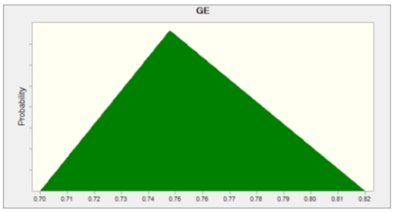


Triangular distribution with parameters:

Minimum	0.70
Likeliest	0.78
Maximum	0.98

Selected range is from 0.00 to 0.98

Assumption: GE

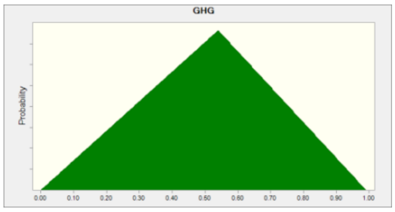


Triangular distribution with parameters:

Minimum	0.70
Likeliest	0.75
Maximum	0.82

Selected range is from 0.00 to 0.98

Assumption: GHG

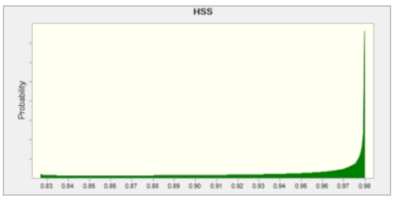


Triangular distribution with parameters:

Minimum	0.00
Likeliest	0.54
Maximum	0.98

Selected range is from 0.00 to 0.98

Assumption: HSS

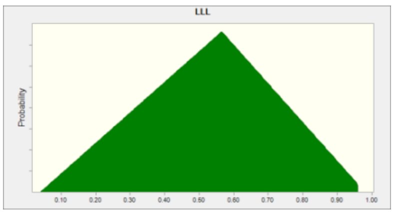


Beta distribution with parameters:

Minimum	0.83
Maximum	0.98
Alpha	0.881927767
Beta	0.387730904

Selected range is from 0.00 to 0.98

Assumption: LLL

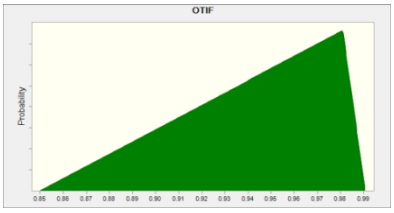


Triangular distribution with parameters:

Minimum	0.04
Likeliest	0.57
Maximum	0.98

Selected range is from 0.00 to 0.98

Assumption: OTIF

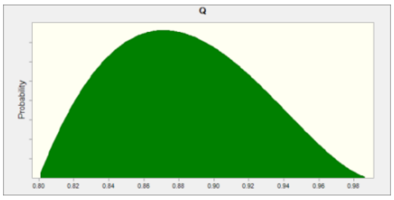


Triangular distribution with parameters:

Minimum	0.85
Likeliest	0.98
Maximum	0.99

Selected range is from 0.00 to 0.99

Assumption: Q

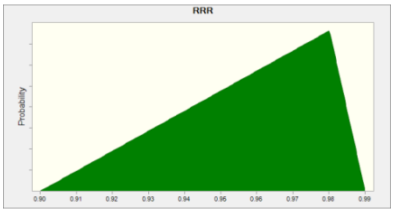


Beta distribution with parameters:

Minimum	0.80
Maximum	0.99
Alpha	2.002739568
Beta	2.670142374

Selected range is from 0.00 to 0.99

Assumption: RRR

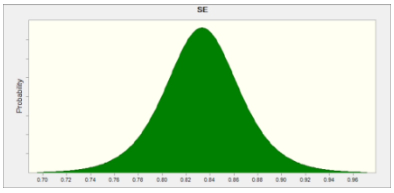


Triangular distribution with parameters:

Minimum	0.90
Likeliest	0.98
Maximum	0.99

Selected range is from 0.00 to 0.99

Assumption: SE



Logistic distribution with parameters:

Mean	0.83
Scale	0.02

Selected range is from 0.00 to 0.98

Anne WINTER

Evaluation Model of a Supply Chain's Sustainability Performance and Risk Assessment Model Towards a Redesign Process. Case Study at Kuehne + Nagel Luxembourg

Dans le présent travail, le concept de durabilité a été redéfini pour que la compréhension commune puisse être garantie. Un modèle d'évaluation du degré de durabilité d'une chaîne logistique existante a été conçu par la suite. Ce modèle a été testé de façon empirique à travers une étude de cas. En appliquant l'amélioration continue, il faut que cette évaluation soit suivie d'un processus de reconception de la chaîne logistique en question. Cependant, il est important qu'une évaluation des risques soit réalisée auparavant. Pour cette raison, un modèle de quantification des risques a été développé. Le modèle peut considérer soit les risques débouchant sur une reconception, soit les risques dus à une reconception. Une étude de cas basée sur les risques débouchant sur une reconception de la chaîne logistique a été mise en place pour prouver l'applicabilité du modèle dans un environnement réel. Les résultats qui découlent du modèle doivent être considérés comme étant une aide à la decision.

In the present work, the sustainability concept has been redefined so that common understanding can be guaranteed. Subsequently, a model intended to evaluate an existent supply chain's overall degree of sustainability has been developed and empirically tested through a case study. Considering the approach of continuous improvement, this evaluation should be followed by a redesign of the considered supply chain. However, a risk assessment needs to be done ex-ante. For this reason, a risk identification and quantification model has been evolved. This model may consider both, the risks leading to the redesign process and the risks resulting from the redesign phase. A case study, which considers the risks leading to a redesign phase, has been implemented so that the model's feasibility in a real business' environment can be proved. The model's outcomes must not be mistaken for ultimate results but need to be considered being a decision support for managers.