Risk Assessment framework for delivery process: a delivery features perspective to optimize efforts in the assessment phase

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Abstract: One of the main issues faced in supply chain risk management is the lack of a tool for evaluating the risk profile and for identifying which risks require mitigation. The complexity of modern supply chains worsens this issue, mostly in delivery and distribution processes, since these significantly vary according to the delivered product, the distribution channel and the target market. Indeed, these features influence so deeply the risk profile of a company that their effect has an impact on each single delivery. This paper proposes a framework aiming to provide risk managers with a tool that can reduce evaluation effort while helping in focusing the efforts on the assessment and mitigation of critical aspects. Starting from a literature review of supply chain risk taxonomies and through mapping the connection between risk classes and features of the supply chain downstream flows, the framework defines which risks are relevant for a given scenario and how to perform an efficient assessment phase. Finally, to validate the framework and to highlight potential gaps between the outcomes and company managers' perception, a real-world scenario is proposed.

Keywords: Delivery, Distribution, Supply Chain Management, Risk Management

1.Introduction

The lack of a holistic vision of the Supply Chain, capable to oversee variability and performance throughout all the stages of the logistic process can lead a company to face great risks. The impact is even amplified when speaking about information coming from market, forecasting and demand management: issues in these areas can bring to severe economic and financial consequences. The fallout of a low development of planning and risk management processes can affect mostly delivery time, product quality and order compliance.

The request for assuring to the customer an appropriate service level often just leads to increase stock levels along the different echelons of the Supply Chain to avoid the impact of delivery risk. Moreover, the increased complexity of downstream supply chain processes, worsened by wider product portfolios and by the globalization of the market served, requires deploying a suitable risk management processes. Nevertheless, if a company offers a wide range of product configurations, it will be affected by continuously increasing distribution and inventory costs: complexity brings high costs with it, and these are even more amplified by the risks involved in product delivery. On top of efficiency, the growth of product portfolios affects also the accuracy of risk assessment process in the delivery phase, since it makes more difficult a punctual assessment of each delivering.

In order to identify a suitable tool for profiling companies in terms of their delivery risks and allow them to plan the appropriate mitigation actions, this paper provides a risk assessment framework that aims to balance efforts in the evaluation phase and the accuracy of the assessment.

2.Supply chain risk management: a literature review

The growing request of risk monitoring and control caught the attention of researchers: considerations on risks, in recent decades, have been applied to a wide range of field, particularly in supply chain management (Heckmann, et al., 2015), (Tang & Musa, 2010) (Wiengarten, et al., 2015), (Wu & Olson, 2008), (Tang & Tomlin, 2008), (Giannakisa & Louis, 2011), (Manuj, et al., 2014), (Curkovic, et al., 2013), (Wieland & Wallenburg, 2012).

Although the topic became important, definitions of supply chain risk (SCR) are often vague, ambiguous and lack quantification. Authors that provide a definition usually assume that SCR is a purely event-oriented concept, related mainly to the probability/ occurrence of disruptive events (Heckmann, et al., 2015). As for SCR meaning, also methods for its identification, assessment and mitigation was not clearly represented in an agreed mathematical decision model (Heckmann, et al., 2015). Indeed, while risk modelling has been studied through and through during centuries for some industries, e.g. finance, SCR modelling is quite new, even if a great research effort has recently been lavished. Hence, SCR needs more investigation particularly in terms of the definition of quantitative measures for the risks assessment and prioritization, as well as the development of proper mitigation plans (Aqlan & Lam, 2015). Modelling approaches for supply chain risks can be distinguished in qualitative, quantitative, and hybrid models. Qualitative techniques are mostly used for risk

identification and risk analysis steps and include techniques such as failure mode and effect analysis (FMEA), empirical analysis, process-performance modelling, multi-criteria modelling methods. Above the latter, the Analytic Hierarchy Process (AHP) seems to be the most quoted, define criteria and methods to effectively select suppliers (Kull & Talluri, 2008), to assess overall (Gaudenzi & Borghesi, 2006) and inbound (Wu & Blackhurst, 2006) supply chain risks.

Quantitative techniques include analytical and simulation models, chance constrained programming, data envelopment analysis, fuzzy and stochastic variables, business scorecard analysis, etc (Aqlan & Lam, 2015).

Notwithstanding that there were many contributions to this topic, still the following research questions are open:

- how to balance efficiency and effectiveness of a given supply chain;
- how to include in the model the risk appetite/aversion of decision makers and of the specific industries;
- how to evaluate responsiveness in case of adverse events, when these occur (Heckmann, Comes, & Nickel, 2015).

3.Risk Identification and Assessment in Delivery

Risk management process typically consist of four basic steps: identification, assessment, management and monitoring (Tuncel & Alpan, 2010). This procedure seems to receive consensus in the literature and is applicable to SCRM as well.

Risk identification and assessment are analytical phase and this is the reason why are crucial for the success of supply chain risk management (Aqlan & Lam, 2015). Risk identification consist in analysing the risk source and effect that may affect the performance of the supply chain. There are several methods to identify risks: the analytical process can start from existent classification, analysing whether a risk is applicable or not, or by contrast analysing process and operation modes. However, both risk categorization and a deep context awareness are required.

The following step is risk assessment, that is the process of assigning values of probability of occurrence and impacts to the identified risk events. Associating probabilities and quantifying potential impacts to risks is not an easy task and requires tedious work, particularly if the risk events to be assessed are several and should be analysed according to different contexts/items/process modes (Tuncel & Alpan, 2010). This issue is worsened when the risk assessment concern delivery phase, since it clearly represents the phase in which most of the risks appears - also the ones coming from previous phases- and the variable to be analysed are multiple. Indeed, delivery risk may arise both from internal issues, originated in production stage or in the planning processes and that leads to shortages of the final products, and from external issues, originated in other supply chain tier (Pinto, Mettler, & Taisch, 2013)

Therefore, delivery risks in a broader sense is a re-interpretation of SC risk, that is widely studied in the past.

Several risk classifications and taxonomies were provided in the past, but most of these models are specific for a given supply chain type. Nevertheless, a certain number of authors developed quite general SCRs classes, which could be applied to several industrial scenarios. The following table lists some of the main risk categories identified by specific contributions in literature.

Table 1: Supply Chain Risks – A compendium

Risk Class	(Tang & Tomlin, 2008)	(Tang C. S., 2006)	(Cavinato, 2004)	(Chopra & Sodhi, 2004)	(Christopher & Peck, 2004)	(Hallikas & Karvonen, 2004)	(Harland & Brenchley, 2003)	(Jüttner & Peck, 2003)	(Jüttner, 2005)	(Rao & Goldsby, 2009)	(Shi, 2004)	(Wu & Blackhurst, 2006)	(Kull & Talluri, 2008)
Asset Impairment							x						
Behavioural	x												
Capacity				x									
Competitive							x						
Control					x				x				
Cost increase											x		x
Culture													
Customer						x	x						
Delays				x									
Delivery			x										x
Demand	x				x	x			x				
Disruption		x		x									
Environmental					x			x	x	x	x		
Financial			x			x	x						
Fiscal							x						
Flexibility						x		x					x
Forecast				x									
Industry										x			
Informational			x	x									x
Intellectual property	x			x									
Inventory				x									
Legal							x						
Market											x		
Operational		x					x				x		
Organizational								x		x			
Political	x												
Process	x				x				x				
Quality													x
Receivables				x							x		
Regulatory							x						
Relational			x					x					
Reputational							x						
Safety													
Strategic							x			x			
Supply	x			x	X		x		x				
Technical			x										

Despite the mentioned contributions belong to the last decade, the proposed classifications can be considered still valid. Indeed, a recent literature review (Rangel, Oliveira, & Leite, 2014) refers to these same classifications as the founders of SCRM.

According to the risks presented in Table 1, a homogeneous reclassification of such risks is proposed.

Table 2: Risk reclassification, related risks in literature

Risk class	Related risks
Loss of value of the stocked products	Asset Impairment
Inability to cope with fluctuating demand	Capacity
	Customer
	Demand
	Flexibility
Forecasting error	Forecast
Uncompliant conditions of transport	Industry
	Quality
Safety risks for human health and environment	Safety

Loss of delivery visibility	Behavioural Control Strategic
Growth of delivery costs	Competitive Cost Increase
Goods missing in the storage points	Inventory
Operational delays in deliveries	Capacity Delays Delivery Supply
Malfunction of information systems	Informational
Inadequate organization and processes	Operational Organizational Process Relational
Issues related to socio-cultural differences	Culture
Obstacles in delivery due to natural disasters	Disruption
Context-based risks (political and economic)	Environmental Political
Legal/Regulatory risks	Legal Regulatory
Fiscal risks	Financial Fiscal

However, different supply chains lead to heterogeneous risks in delivery process, e.g. delivering goods directly to the consumer is significantly different from distributing through a point of sale, in terms of storage point, stock, service level, etc.

In order to evaluate the main variables of the delivery process and identify applicable risks, an in-depth analysis of delivery process configuration was performed. The baseline for the analysis is SCOR model (Supply Chain Council, 2010), that provides a conceptual framework of processes and components of the integrated supply chain and that is often used as the landmark for SCRM models (Samaranayake & Laosirihongthong, 2016). SCOR identifies four main categories of delivery process:

1. *Deliver stocked products*, that is the process of delivering product that is previously manufactured basing on expected and aggregated customer orders.
2. *Deliver make-to-stock product*, that is the process of delivering products that are made and sourced in response to a specific order in retail (most commonly known as make-to-order in production systems).
3. *Deliver engineer-to-order product*, that is the process of delivering a product in response to an order that has unique requirements or specifications.
4. *Deliver Retail Products* that is the process used to acquire, merchandise, and sell finished goods at a retail store, that sells products direct to the consumer (Supply Chain Council, 2010)

Table 3 shows for each SC Delivery model introduced by SCOR the most critical and non-applicable SC risks, following the reclassification proposed in table 2.

Table 3: Most critical and non-applicable risk in SC models

SC Model	Most critical risk class	Non-applicable risk class
1	• Forecasting errors • Goods missing in the storage point • Loss of value of stocked product	-
2	• Inability to cope with fluctuating demand	• Loss of value of the stocked products • Forecasting error • Goods missing in the storage points
3		• Loss of value of the stocked products • Forecasting error • Goods missing in the storage points
4	• Forecasting errors • Goods missing in the storage point • Loss of value of stocked product	-

Identification, classification and assessment of risk classes according to different potential scenarios represent an input for an assessment framework. The analysis performed to summarize and reinterpret the existing classifications on SC risk in a delivery-centric sense allowed to define a potential baseline for the risk assessment. Hence, in the following paragraphs, delivery risk classes analysed in table 2 and 3 will be used as the baseline of the proposed framework, in terms of risk categories to be assessed.

4.A framework proposal

4.1 Framework objectives

In order to address the open issues described above, and to develop a framework that allows to identify most critical deliveries, some specific objectives were defined:

- The framework should be practical in being applied, to allow its use also in business environments where the maturity level of SCR management is not high. It should include metrics and ready-to-use lists that help risk managers in defining the appropriate level for each identified risk, even if non-quantitative aspects need to be assessed and ranked. In addition, considering practical implications, risk assessment should avoid the excess of evaluation and comparisons, to identify the expected value of the risk. In this regard, the framework starts from a short - but nevertheless quite complete - list of delivery risk and a clear way to evaluate them and get the final risk scoring.
- The framework should be applicable to all industrial business contexts, taking into account the peculiarities of the context and the risk appetite of the decision maker in the same time. According to this purpose, a list of generic risks and a set of criteria to remove the unnecessary ones and define the most critical is provided within the framework.
- The framework should balance both effectiveness and efficiency aspects. Indeed, only few authors consider effectiveness-based aspects, like service level. Even fewer authors combine both concepts for effectively balancing supply chain efficiency and supply chain effectiveness. Therefore, the real goal will be not to try to reduce indiscriminately all risks,

but to adopt specific mitigation actions to address only risks that entail too heavy aftermaths. In this regard, the framework was developed to focus efforts and resources on the most critical deliveries, while reducing efforts for risk assessment.

4.2 Framework hypothesis

The proposed framework aims at providing a criticality ranking of the deliveries. The model univocally identifies a delivery using three features: the product ordered, the target market of the delivery and the distribution channel used. The definition used in the framework for these features is the following:

- *Delivered product* means a class of goods characterized by a set of homogeneous attributes,
- *Target market* means a group of customers located in a geographic area that is characterized by a homogeneous environment (culture, laws, economic and political system)
- *Distribution channel* means the different ways in which the company make the product available to the end customers (e.g. retailers, mass merchandisers, etc.).

The framework structure is based on the possibility to assign each risk class, as defined in paragraph 0, to just one of the three delivery features, considering that each risk belonging to a feature be independent of the other two features. The approach for allocating risks to the delivery features considers the nature of the risk.

The following figure shows the assignment of each risk class to one of the delivery feature.

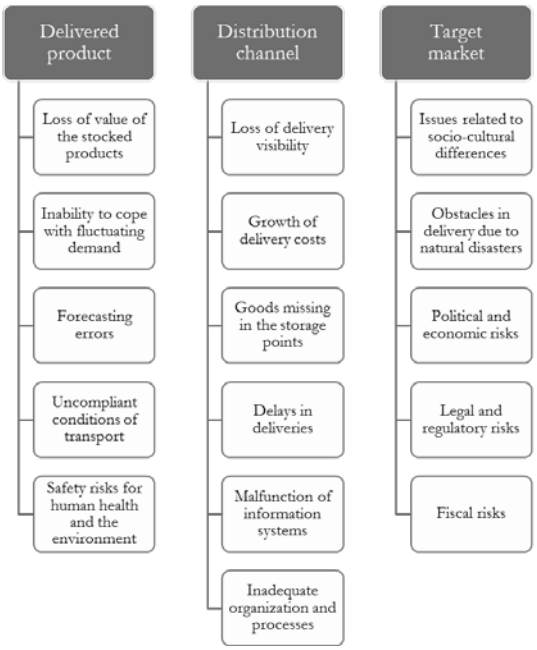

Figure 1: Clusters for risk classes

Considering the whole distribution chain as a set of triads product-market-channel, the possibility to assign a risk to just one of the delivery feature simplifies the process of assessing the whole set, since a risk is evaluated just once per feature, instead of once per element: for example, the risk value for *fiscal risk* will be assessed only once for a given market, and the result will be valid for all the product delivered and the distribution channel deployed in the specific geographical market. That value will be then combined with the others, specific for the distribution channel and the product, to evaluate the risk criticality for the element of the distribution chain set.

Indeed, the allocation of a risk class to a delivery feature does not ensure the complete independence from other aspects in all supply chains. Hence the framework includes a preliminary step for the evaluation inter-dependencies of each risk from other clusters.

4.3 Framework structure

Considering the aforementioned aspects, the framework was structured in three different phases:

1. *Risk Independence* - Identification of risks that could not have been evaluated separately, since their value is affected by more than a delivery feature.
2. *Risk Evaluation* - Assessment of applicable risks in terms of occurrence, severity and detectability
3. *Risk Synthesis* – Combination of evaluations for occurrence and severity in the expected value at risk, weighting of risk classes and synthesis of delivery criticality

1. Risk independence evaluation phase

This preliminary step allows to ensure that the risk classes are actually independent from the other characteristic elements of the supply chain, except the one to which they belong.

This analysis should be carried out at a strategic level, using an adjacency matrix of the risk classes, evaluating whether a risk class is dependent on the others, considering the business environment in which the company operates.

If a risk class depends on at least one risk not belonging to the same delivery feature, the two should be treated separately in the next stage of analysis. This paper only addresses the case in which no dependency appears in the risk matrix.

2. Risk evaluation phase

The evaluation phase aims at evaluating independent risk class identified in previous phase. Each risk class should be evaluated for each alternative of the clusters:

- risk classes belonging to product must be evaluated for each product of the portfolio, at the appropriate level;
- risk class belonging to distribution channel cluster must be evaluated for each sales and distribution approaches followed by the organization;
- risk classes belonging to market must be evaluated for each different competitive environment in which the organization operates, according to the definition given above;

Hence, first step of the risk evaluation phase consists in identifying the products that the company delivers, the distribution channel used by the company to make products available, and each single geographical market. Then, for each of them, all risk belonging to the specific delivery feature should be evaluated separately, assigning a score, that could be structured according to a 5-points Likert scale. At the end of this phase, the output should consist in 3 sets of vectors:

- r_{ip}, that are the risk score for each risk of the product cluster (i), evaluated for each product delivered by the company (p)
- r_{jd}, that are the risk score for each risk of the distribution channel cluster (j), evaluated for each distribution channel used by the company (d)
- r_{km}, that are the risk score for each risk of the market cluster (k), evaluated for each target market in which the company operates (m)

The vectors could vary in length, according to those risks eliminated in the independence phase. If no risk has been eliminated in the previous phase, the length of such vectors is respectively equal to 5, 6 and 5. Instead, the size of the three sets depends respectively by the number of products, distribution channels and the markets treated by the company.

3. Risk synthesis phase

This step provides information for the appropriate combination of the values obtained in the evaluation phase. This phase consists of two main steps:

3.1 the synthesis of the risk values for each possible configuration of the delivery features
3.2 the combination of the values of the elements that characterize each delivery

Step 3.1 allows the aggregation of vectors defined in risk evaluation phase, according to the following formulas, respectively for products, distribution channels and target markets:

- $r_p = \sum_{i=1}^{I} r_{ip}$, for each identified product p
- $r_d = \sum_{j=1}^{J} r_{jd}$, for each identified channel d
- $r_m = \sum_{k=1}^{K} r_{km}$, for each identified target market m

In this way, each product, distribution channel and target market is characterized by a risk value which results as the aggregation of all the risk related to the same cluster.

Once that all risk values (r_p, r_d, and r_m) have been computed, the overall criticality of each delivery element can be obtained according to the following formula:

$$r_{p,d,m} = r_p \cdot r_d \cdot r_m$$

Where $r_{p,d,m}$ represents the overall criticality of a given delivery, that considers the risk value of the product, distribution channel and target market;

This approach avoids repeating the evaluation of the risks for each delivery, thus reducing the efforts for risk assessment according to the following expression, describing the percentage of saved evaluation steps when adopting the proposed approach with respect to a traditional risk assessment procedure:

$$\Delta\% = \frac{(i \cdot P + j \cdot D + k \cdot M) - (P \cdot D \cdot M) \cdot (i + j + k)}{(P + D + M) \cdot (i \cdot j \cdot k)}$$

Where:

- P is the overall number of products
- D is the overall number of distribution channels
- M is the overall number of markets

5.Validation of the framework

The proposed framework was validated in order to verify that the reduction in the risk assessment complexity does not lead to an alteration in the results of the assessment itself. It was defined an acceptance ratio of 10% in the mean absolute deviation between the framework results and those from a traditional approach; this value should be valid for each delivery feature results. Validation was performed through the assessment of a delivery, that means one product, delivered through a specific distribution channel, in one market.

The validation was performed through a questionnaire divided in two phases:

1. The first phase consisted in independently assessing the risks related to the specific product, the specific market and the specific distribution channel. All evaluations were made considering the individual delivery feature, highlighting the eventual interactions with other delivery features, when applicable.
2. The second phase consisted in repeating the assessment of the same risks through the traditional risk assessment approach, thus jointly considering product, market and distribution channel characteristics.

The assessment concerned the delivery of a confectionary product of a primary multinational company operating in the food industry. The product under analysis is distributed through a central warehouse and other distribution centre to different points of sale (that represent the final customers for the manufacturing company) and the target market is the North America region.

For each delivery feature it was required to the product manager to estimate the occurrence and severity values of each risk class on a 5-points Likert scale (very low, low, average, high, very high). The results in terms of risk classes (on a 1-25 scale) are summarized in the following graphs.

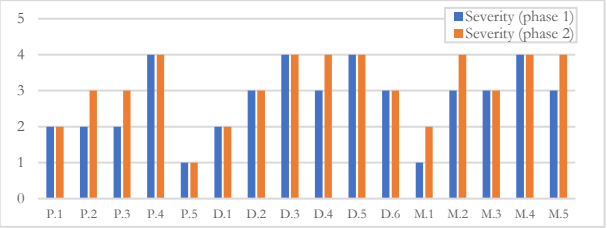

Figure 2: Severity values for each risk class

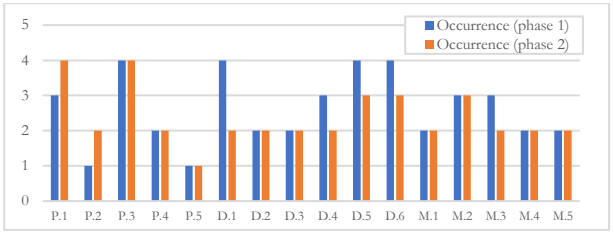

Figure 3: Probability values for each risk class

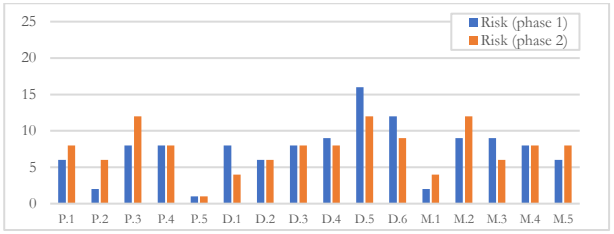

Figure 4: Risk values for each risk class

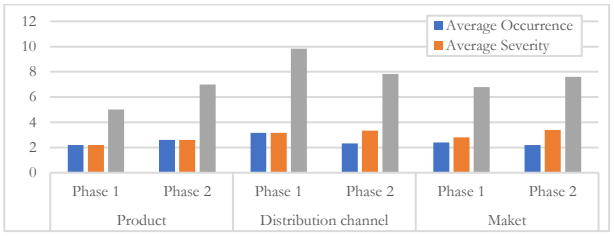

Figure 5: Aggregated results for delivery feature

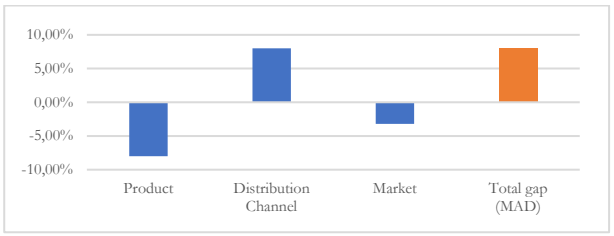

Figure 6: deviation (%) between phase 1 and phase 2 results

Figure 2 and figure 3 show respectively the results of probability and severity, comparing the values estimated by the product manager in phase 1 and phase 2. Values are often the same, and when results of phase 1 and phase 2 are different the gap is almost always a level of the scale. Figure 4 shows the same comparison for resulting risk value: the combination of the probability and severity values does not entail any compensation effect, which is a necessary condition for carrying out analysis of the overall deviation level on the delivery features.

Figure 6 shows that the mean absolute deviation (MAD) of the total risk score at an aggregated level: considering all the risk features, results coming from phase 1 and phase 2 differs 8% on average and the deviation for each delivery feature is lower than 10%, that is the acceptance value. This means that the information loss for a risk evaluation using the proposed framework instead of a classical approach is acceptable. In this specific case, given that great size of the company along with the complexity of the distribution function and the high number of products, being able to contain the survey complexity without any severe impact on the analysis is definitely critical.

6.Conclusion and next steps

Risk mitigation in supply chain management is becoming a greater issue, due to the market globalization and the appearance of new risks. Deliveries with service level constraints that just ten years ago were deemed to be impossible to be respected are now included in the standard agreements.

Analytical phases of the risk assessment process are often complex since several esteems are required and often it is not easy to quantify them. This aspect is even worse if risk management is applied to delivery phase, since most of the risks that originate in one of the SC tier affect this process; additionally, the variables to be analysed to perform an accurate assessment of this phase are multiple. Following this practical issue, also literature agrees that SCRM need to focus on reducing evaluation efforts, balancing efficiency and effectiveness of the risk management.

This paper proposed a new framework for risk assessment that aims to the efficiency without affecting the assessment itself. The results of the application are an overall criticality index ($r_{p,d,m}$) for the deliveries managed by the company, that could be ranked in a Pareto diagram to better understand risks affecting supply chain and deploying a mitigation strategy. The framework was validated in a real-world case, verifying that alteration of the criticality index brought by the new framework is contained in 10% of the classical results. Nevertheless, to obtain a complete risk assessment framework much work must be still performed. This proposal only represents a first step. Future research should focus on:

- including the assessment of those risks classes that are dependent from other delivery features;
- validating the results with different industries, different company sizes and different markets;
- Connecting the framework results to a risk mitigation strategy and validating it on a company-wide case.

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