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Risk Management Approach for Lean, Agile, Resilient and Green Supply Chain

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***Abstract*—**Implementation of LARG (Lean, Agile, Resilient, Green) practices in the supply chain management is a complex task mainly because ecological, economical and operational goals are usually in conflict. To implement these LARG practices successfully, companies' need relevant decision making tools allowing processes performance control and improvement strategies visibility. To contribute to this issue, this work tries to answer the following research question: How to master performance and anticipate problems in supply chain LARG practices implementation? To answer this question, a risk management approach (RMA) is adopted. Indeed, the proposed RMA aims basically to assess the ability of a supply chain, guided by "Lean, Green and Achievement" performance goals, to face "agility and resilience risk" factors. To proof its relevance, a logistics academic case study based on simulation is used to illustrate all its stages. It shows particularly how to build the "LARG risk map" which is the main output of this approach.

***Keywords*—**Risk approach, lean supply chain, agile supply chain, green supply chain, resilient supply chain.

I. Introduction

GENERALLY, supply chains (SC) operate in a more and more complex context. Indeed, SC managers are continuously asked to manage different constraints, which are sometimes conflicting due to the markets opening, increasing competition, products diversity, customer's costs, quality, delay, and new environmental and social requirements. To address these constraints, researchers defined several concepts and approaches for managing the SC, the most predominant of which today are Lean, Agility, Resilience and Green (LARG) SC concepts.

Literature shows that performance based on a single criterion is not always relevant. Managers seek a multidimensional performance incorporating several LARG aspects. For example, according to [5], for many companies, the implementation of lean manufacturing contributes to reduce waste and generate profit. However, companies should achieve efficiency not only by implementing practices such as lean manufacturing, but also in improving their environmental impact.

Several research studies on LARG practices were carried out. Some practical works show sometimes contradictory effects between LARG goals, especially between Lean and Green. For [1] Lean manufacturing and sustainable development are often considered compatible because of their common focus on reducing waste. Reference [1] affirms also that been ecological can reduce costs and add value. According to the same reference, just-in-time application requiring products delivery in small batches can be harmful to the environment in terms of increased transport, packaging and handling.

Scientific studies aiming at addressing the relationship of Lean manufacturing with sustainable development focus on Lean manufacturing and its ability to reduce the use of raw material and energy resources and the generation of pollution [3]. Several scientists were interested at the correlation between the application of Lean manufacturing and GWRT (Green Waste Reduction Total) [3]. Applying GWRT is significantly correlated with the improvement of cost performance and Lean global results [28]. Reference [28] confirmed that there are companies that have managed to reduce environmental waste generation through Lean manufacturing application. However, there is no evidence that if a company is Lean, it is automatically Green [28].

Other studies have attempted to integrate LARG concepts to build new approaches. In Lean manufacturing and its relationship to sustainable development, the concept of Lean Green appears. Lean Green is devoted to the understanding of the values and needs of society and then defines the system that can deliver them while minimizing environmental waste [25]. Lean Green considers eight types of waste: excessive use of water, excessive energy consumption, excessive use of resources, pollution, garbage, greenhouse, and poor health and safety [25]. For [5], Lean Green could provide a method for companies to develop a tool to measure both productivity and environmental performance based on qualitative and quantitative analysis.

Literature review shows that the relationship between LARG practices do not follow a clear guideline and switches between convergence and antagonism. It also shows that the integrated implementation of these practices is a topic of great interest for companies. However, few studies have attempted to address the integrated implementation of the four LARG practices in the supply chain. This implementation appears to be a complex task mainly because ecological, economic and business goals are often in conflict. To implement these LARG practices, companies need new decision making approaches and tools allowing better performance control and visibility.

To contribute to this problem, this work tries to answer the main research question: How to implement the LARG practices in the supply chain in an integrated way? To answer this question, we make the hypothesis that a risk management

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approach (RMA) could be a relevant solution. Indeed, according to several authors, RMA is a relevant general approach to master and manage organization's processes. Many companies have chosen to get involved in the international standard ISO 9001 V 2015 [6] that requires this approach. In order to comply with the requirements of the new version of the standard, an organization must plan and implement actions to face risks and opportunities. Taking into account both risk and opportunity is the basis for improving the effectiveness of the quality management system, have best results and prevent negative effects. LARG practices actually engender risks and opportunities that's why we think that this approach fit well their implementation. In this context, several secondary research questions are also addressed: What conceptual relationship does exist between the four LARG aspects? How to introduce the concept of risk in LARG practices? How to identify, assess and prioritize these risks? To validate this hypothesis, we adopted a qualitative approach that adapt a general RMA in LARG practices implementation context and use as validity proof an academic case study based on simulation. This work is structured as follows. Section II presents a literature review about RMA in a general context first and then in the supply chain context. Section III presents the RMA adapted to LARG practices implementation context. Section IV presents the application of this approach to an academic logistics case study based on simulation that allows the building of the risk map and shows the relevance of this approach. The conclusion discusses the results and presents some extensions for further work.

II. Supply Chain Risk Management

A. Risk Management in General Context

1. Risk Definition

Risk concept goes back to the 1950s. At that time risk management consisted mainly of mathematical, probabilistic models which aimed at helping the company to cope with the uncertainties created by its environment. In 1956, an article in the Harvard Business Review magazine offered the first definition of "risk management". According to this definition, "manage risk is to live in the possibility that a future event causes a harm". From that moment, some companies considered relevant to employ someone full time to care for managing risks and minimizing losses from these letter [3], [4].

Another definition, produced by Canada Government assumes that "the risk relates to the uncertainty that surrounds future events and results. It is the expression of the likelihood and the impact of an event likely to influence the achievement of the objectives of the organization". According to [6], risk is the effect of uncertainty and this uncertainty can have positive or negative effects. A positive deviation generated by a risk can provide an opportunity, but the positive effects of a risk do not always become opportunities. It should be noted that, in these definitions, the basic overlapping elements of the concept of risk, are the terms "objective" or "forecasts", "likelihood" and "consequences". Indeed, "the risk combines the probability of an event and its consequences. In some cases, risk is away from what was expected" [6].

2. Risk Typology

Several types of risks have been identified in the literature. According to [7] operation function concerns "design activities, creation and delivery of goods and services of a company" It therefore includes manufacturing-related activities and those related to logistics, which constitute microeconomic sources of risks. However, adding to these microeconomic sources, operational risk also comes from macroeconomic factors, external to the company, which includes the risks associated with exchange rates and the political risk. Moreover, as the risk and the variability are key elements in value creation, it is necessary for companies to find ways to apprehend and minimize their effects.

Reference [8] considers three basic sources of strategic risk: operational risk, the risk of damage of assets and the risk of competition. Operational risk arises from the consequences of a breakdown in the heart of the operating capacity, manufacturing or process. Each firm that creates value through manufacturing or services activities faces operational risk to varying degrees. For example, some defective products can be shipped and harm the consumer, maintenance activities can be neglected causing outages, customer contracts may be lost, transactions can be processed with errors. Any operational error that hinders the realization of products and high quality services has the potential to expose the company to losses.

3. Risk Management Approach (RMA)

According to [6], RMA allows an organization to determine the factors that may cause deviation of its processes and its quality management system regarding to expected results, to set up preventive control in order to limit the negative effects and exploit the opportunities when they arise. The risks and opportunities that may affect the conformity of products and services and the ability to improve customer satisfaction are determined and taken into account. The options to deal with risks may include: avoid risk, take the risk to profit from an opportunity, eliminate the source of risk, change the risk appearance probability or consequences, share or keep the risk on the basis of an informed decision, evaluate the effectiveness of actions taken against risks and opportunities.

Based on an extensive literature review, [9] propose a strategic risk management tool called "manager's guide to strategic risks". It includes five steps:

- Step 1: Identify and assess risks
- Step 2: Mapping risks
- Step 3: Quantify risks
- Step 4: Identify the potential benefit of each risk
- Step 5: Develop risk mitigation action plans

The quantitative treatment of risk is an important phase in any method of risk management. It concerns the determination of risk occurrence probabilities. To model the different probabilities of occurrences, [10] affirms that there are three methods. The first is to integrate the different scenarios in probability trees. The second is a simulation method known as

"Monte Carlo" and the third called "neural networks" consists in emitting scenarios based on experience and learning.

B. Logistics Risk Management

1. Supply Chain Definition

Supply Chain (SC) includes all the tasks and actors acting on the flow to help transform a good from the state of raw material to marketed finished product. The challenges of Supply Chain Management (SCM) are numerous. The most important include improved customer service, reduced working capital (inventory reduction ...) and improving the profitability of resources and operating resources.

2. Supply Chain Risks

At the industrial level, different types of risks appeared, which are still imperfectly identified and taken into account: risks related to cooperation protocols in the SC, specificities of each partner in the SC environment, arrangements for the exchange of information, etc. [2].

A first definition of risk in the field of supply chain management was given by [11]. They define risk as "a variation in the distribution of possible supply chain outcomes, their likelihood, and their subjective values". A risk is therefore a break in flow between the components of the supply chain. This potential variability can thus affect the flow of information, materials, products; and it may modify the use of resources (human and equipment).

To continue on risk related to procurement, [12] define it as "the transpiration of significant and/or disappointing failures with inbound goods and services". A few years later, [13], in a study on the aerospace sector, offers the following definition: "supply risk is defined as the probability of an incident associated with inbound supply from individual supplier failure or the supply market occurring, in which its outcomes result in the inability of the purchasing firm to meet customer demand or cause threats to customer life and safety". This definition highlights an important criterion: risk probability occurrence.

References [12], [16]-[18] tried to identify and understand the sources of risk in the supply chain. Five categories of risk sources are usually highlighted: environment, demand, supply, and process control. The vulnerability of the supply chain can also be a factor aggravating the risk; it can be 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" [18]. Some works on risk in the context of logistics / supply show that the risks exist because of the complexity of the supply market, characterized by the following: the shortage of providers, product renewal and technology, barriers entrance, logistics costs, complexity and market conditions for suppliers (monopoly or oligopoly) [19].

3. Logistics Risk Management Approach

The purpose of logistics risk management methodologies is to provide guidelines or procedures. Most of the works about logistics risk management methodologies (statements include [20]-[23]) reach similar methodologies which can be summarized by five key phases, which are actually quite conventional in management: identification, assessment, control, monitoring and treatment of residual risks. Each of these steps can be characterized by the issues and questions that are always asked by managers.

- Risks identification: does a risk exist? What damage can the risks cause on the company and its partners? What are their impacts: on customers, the organization, etc.?
- Risk assessment: how serious are the negative effects when the risk occurs (the effects can then be evaluated and measured through financial consequences, production or commercial)? What is the probability of occurrence of the risk? And what will be the extent of the loss?
- Risk management by planning short, medium and long term actions: how to control and contain the risk? By implementing techniques and measures of prevention and protection, company staff training, risk financing or its sharing with partners?
- Control: Following the example of seismograph, what indicators, should be implemented to monitor the evolution of risk and the effectiveness of a particular action that was deployed?
- The treatment of residual risk: despite all measures and precautions to reduce the risk, what consequences would its occurrence cause? And, is there any solution, to reduce them, since they are not removable?

C. SC LARG Risk Management

1. Lean Supply Chain

In its simplest form, Lean consists in eliminating all kinds of waste and increase the flow of the supply chain. Each inventory or stock-in-progress, which is not required to support operations and meet the customer's immediate needs, is to be considered as waste to be treated with priority. These elimination actions have a reducing effect on the cycle time and logistics costs, thereby increasing the speed and responsiveness of the supply chain.

2. Green Supply Chain

Several definitions for green logistics are presented in the literature. We retain the following [24]: "Integration of the environmental dimension in the SCM, including product design, procurement and material selection, manufacturing process, product delivery to final consumers and end of life management of the product after its useful life".

3. Agile Supply Chain

Several definitions are presented in the literature for the logistics agility. We retain the following [26]: "Agility applied to supply chains is the ability to respond quickly and adequately to short-term changes on applications, supply or the environment. It comes from the flexibility, response capacity and efficiency of supply chains".

4. Resilient Supply Chain

Several definitions are presented in the literature for the logistics resilience [27], [29], [30]. Resilience is the ability to return to a stable state after a disturbance. In the field of SCM, it is to analyze the continuity of flow after a break in a supply chain, regardless of its nature. Resilience is considered as an organizational capability of adapting and continuously adjusting the supply chain organization to events that threaten the balance of activities [27].

III.RMA FOR LARG SC

Literature shows that the various methods of risk management include common and generic phases. It's their adaptation to a particular context that constitutes their originality. It also shows that the crucial step aiming at setting performance goals was omitted. Indeed, given the multitude of risks that can happen, their importance depends on the priority performance goals defined by the company. During their identification, risks and their importance should be classified and prioritized according to performance goals. The adopted approach in this paper as RMA consists of five phases: identification of performance goals, risk identification, risk measurement, risk assessment and risk treatment. In the following sections, we apply this logic in the context of LARG supply chain.

A. Performance Goals Identification

1. Achievement Goals Identification

The main objective of a system in general and a SC in particular is to satisfy its customers. The performance achievement aims at this satisfaction following the classical triangle of cost, delay, quality. The performance achievement can be measured through various performance indicators; the most used of which are the service rate, the average time of delivery, the claim rate. For instance, the case study presented in Section IV uses the average waiting time for delivery of an order.

2. Lean Goals Identification

Lean aims at eliminating all kinds of wastes which are not required to support operations and to increase the SC flow. Lean goals are represented by these wastes. Table I shows lean logistics performance goals by transposition from lean manufacturing goals.

TABLE I
PERFORMANCE LEAN LOGISTICS BY TRANSPOSITION FROM LEAN MANUFACTURING [15]

Goal / Muda	Definition in Manufacturing	Transposition in logistics
Over production	Produce more than needed and often too early regarding the request.	disproportionate handling, movement / trips of larger quantities than needed
Waiting	Waiting of equipment, end of a machine cycle, a decision	Waiting of truck operators, drivers, ...
Transport	Transport information or materials from one place to another	Vacuum Transport
Unnecessary operations	Any operation in the production process that is not required to satisfy the customer's need	Travel / transport unnecessary and / or redundant, repacking ...
Stock	Keep more of materials and components that the minimum necessary to carry out the work	idem
Unnecessary movement	Concern any movement that does not directly contributes to adding value to the finished product: a rotation piece, operator moves...	unnecessary human movement and displacement
Correction / rework	Non-quality generates defective parts, requiring further actions (control, rework, scrap) that the end customer does not pay	Goods deterioration, picking palletizing seizure errors, ...

TABLE II
SD 21000 SUSTAINABLE DEVELOPMENT CHALLENGES

Challenge	Definition
Product / eco-design	Concern the integration of environmental aspects into product design. It considers the environmental requirements on the product and the environmental impact throughout the life cycle of the product including end of life.
Purchasing policy	Refers to the relationship with subcontractors and suppliers. Sustainable purchasing ensure within its procedures, its contracts (or other means) that its suppliers and subcontractors have the same objectives as those advocated by its SD strategy
Transport and logistics	Concern the transport of primary and finished products. Some transport modes affect directly or indirectly the environment and quality of life, air pollution, energy consumption, …
Water consumption	The "blue gold" main factor of subsistence whose consumption should be rationalized. Consumption may occur in different uses: production, sanitation, cooling systems, irrigation, etc …
Air pollution	The aquatic resource heritage is so diffuse and superficial then weak in quality and quantity. It is important to preserve the aquatic heritage in quality and quantity while sustaining economic uses.
Energy consumption	The control of energy supplies is a major economic issue. Manage energy in a rational way allows costs reduction and contributes to the preservation of the environment and resources for future generations
Air pollution	Means the pollutant emissions in the atmosphere: drainage pipes, heating systems, exhaust pipes, solvent vapors, other pollutants, greenhouse gas emissions
Waste	Means any residue of a production process, processing or use, any substance, material, product or more generally any good discarded or the holder intends to discard
Soil pollution	A contaminated site is a site that may have been contaminated by former waste deposits or infiltration of substances. Polluted soil can cause a large number of perennial nuisance for all soil ecosystems and for the surrounding population
…	…

1. Green Goals Identification

Green SC aims at considering the environmental challenges of all the product life cycle stages. These challenges constitute performance green goals. Table II shows green logistics performance goals inspired from SD21000 guide [31].

B. Risk Factors Identification

1. Agility Risk

Agility is the ability to respond quickly and adequately to short-term changes on demand, supply or the environment. We define "agility risk" as logistics risk due to changes in the external environment of SC. They do not cause the breakdown of flows but generate disturbances. Agility is measured by "agility risks" impact on the SC performance goal. For example, in the case study below, demand variation and changes in customs procedures are adopted.

2. Resilience Risk

Resilience is the ability to return to a stable state after a disturbance that affects the continuity of SC flow. We define "resilience risk" as logistics risk due to changes in the internal environment of SC. Unlike "agility risks", they can cause the breakdown of flows. Resilience is measured by "resilience risks" impact on the SC performance goal. For example, in the case study below, conveyer and transporter availability are adopted.

C. Risk Measurement

Agility and resilience measurement requires exposing the SC to changes to estimate its ability to face their effects. We consider three levels for each agility and resilience risk. The first level expresses the actual value of the risk. The second and the third levels indicate a positive or negative degree of variability, respectively.

In this paper, experimental approach is the preferred way to measure risk. According to the Tagushi approach [14], the full factorial design is theoretically perfect, but the time and costs of experimentation in the industrial context becomes prohibitive as soon as three or four factors are exceeded. A fractional factorial design greatly reduces the number of experiments to be performed at the expense of accuracy.

When experimentation is not relevant in reel context regarding implementation costs and/or lack of operation historical data, simulation may be used. Simulation experimentation generates no cost or time as soon as the simulation program is built, especially if the simulation software enables automation of experiments. Using a full factorial design involving risks identified above, each having three levels becomes relevant.

In the case study below, two agility and two resilience risk factors are selected and a total of 81 experiments based on simulation with ARENA simulator are then operated.

To estimate the agility and resilience of a risk factor, we adapt the terms of the mean response and the average effect from experiment design [14]. For example, the agility of the risk factor Fj for Green Goal performance (GG) is given by the ratio between the GG performance indicator responses average when the factor Fj is at level (2), (3) and the GG performance indicator responses average when the factor F is at level 1, refer to (1):

$$A_{GG/Fj} = \frac{GG\left|F_j = i\right.}{GG\left|F_j = 1\right.} \quad (1)$$

where F_j: The considered "risk agility" factor, $OG\left|F_j = i\right.$: Average of the Green performance indicator (OG) responses when the factor F_j is at level I, i index of variability level, j: factor order.

According to experiments design vocabulary, $A_{GG/Fj}$ is the overall effect of F_j which we have made here in the form of a ratio (instead of a difference) to have an estimation without unit. This effect represents the agility of the SC regarding the risk factor F_j as it provides information on the gap between the SC performance when this risk factor is in variability i level and when it's in its actual level (level 1). The other risk factors are equally taken into all the possible levels to undo their effects. The closer the ratio $A_{GG/Fj}$ is to 1, the more agile is the SC for F_j.

Resilience is calculated similarly to agility. Equation (2) gives resilience of the risk factor Fj for Lean Goal performance (GG).

$$R_{LG/Fj} = \frac{LG\left|F_j = i\right.}{LG\left|F_j = 1\right.} \quad (2)$$

Agility/resilience estimations of different risk factors for different goals can be aggregated using the weighted average to estimate the agility/resilience Lean and Green for each goal. Agility/resilience for the various performance goals can also be aggregated to SC global Agility/resilience. Equations (3) and (4) present these estimations:

$$A_{XG} = \frac{\sum_j \alpha_j A_{XG/Fj}}{\sum_j \alpha_j} \quad R_{XG} = \frac{\sum_j \alpha_j R_{XG/Fj}}{\sum_j \alpha_j} \quad (3)$$

$$A_{global} = \frac{\sum_{X:Ac,L,G} \alpha_X A_{XG}}{\sum_{X:Ac,L,G} \alpha_X} \quad R_{global} = \frac{\sum_{X:Ac,L,G} \alpha_X R_{XG}}{\sum_{X:Ac,L,G} \alpha_X} \quad (4)$$

A: Agility, R: Resilience, *XG*: Goal performance, X can be: Ac as Achievement, L as Lean or G as Green.

The coefficients α_j and α_x are set based on the relative importance that the Working Group attaches to each risk factor and each performance goal.

D. Risk Assessment and Treatment

Risk assessment aims at building the "LARG risk map", which is the main output of this approach. Risk assessment aim at analyzing supply chain performance in a LARG context based on calculated elements (Achieving agility, Lean agility, Green agility, Achieving resilience, Lean resilience, and Green resilience). For this reason, three-dimensional risks map is useful to prepare the next step aiming at risks treatment (Fig. 2). This risk map can highlight four areas of influence:

1. Critical risks area: includes agility and resilience risks that have a strong influence on the three performance goals “Achievement, Lean and Green”.
2. Medium risks area: includes agility and resilience risks that have a strong influence on two of the three goals of performance "Achievement, Lean and Green".
3. Low risks area: includes agility and resilience risks that have a strong influence on one goal among the three performance goals "Achievement, Lean and Green".
4. Non influential risks area: includes agility and resilience risks that have very low influence on the three performance goals "Achievement, Lean and Green".

For each risk area, the working group will design a specific action plan. According to [6], the options to deal with risks may include: avoid risk, take the risk to profit from an opportunity, eliminate the source of risk, change the risk appearance probability or consequences, share or keep the risk on the basis of an informed decision, evaluate the effectiveness of actions taken against risks and opportunities

IV. Case Study

A. Presentation

A supplier based in Europe sells its products in Morocco. He set up a distribution center in Casablanca.

Supply process: The distribution center is supplied every month at Casablanca port by a 100 unit full container capacity. The container passes five days in administrative proceedings before the items become available in the “Port Zone”. The center's trucks transport the goods to the center “Reception Zone” to be stored.

Demand Management process: it’s assumed that the supplier has a single customer in Casablanca. Customer delivery is made according to its order (10 units every three days; the first order is initiated on day three). When the stock is insufficient the order waits for the stock recovery otherwise the items are picked from the store and placed in a conveyor. Once discharged from the conveyor, they are placed in the shipping area ready to be transported.

In this case study, the implementation phase is carried out using ARENA simulator. The main design and operation data used in the simulation are:

Data Supply:

- Each truck has a capacity of 20 units. To reduce costs, a full truck policy is adopted. Traffic speed is 60 km/h.
- Distance between the port and the distribution center is 10 km
- For simplicity, it is assumed that the times of loading and unloading are negligible.

Order data:

- Getting out items from stock in the store: the delay of this operation follows a Triangular (0.5, 1, 1.5) mn distribution.
- Conveyor discharge: the delay of this operation follows a Triangular (0.5, 1, 1.5) mn distribution.
- Full truck load policy is adopted. Traffic speed is 100 km/h
- The conveyor covers a distance of 100 m
- Other distances between zones are presented in Table III.

TABLE III
DISTANCES BETWEEN ZONES

Port	Reception	10 Km
Reception	Expedition	0 Km
Expedition	Customer	30 Km
Customer	Port	25 Km

B. Selected Risk Factors

Risk factors selected for the simulation and their variability levels are presented in Table IV.

TABLE IV
RISK FACTORS AND THEIR VARIABILITY

Factor ↓/ Level→		Actual value (1)	Negative variability (2)	Positive variability (3)	Comments
Agility risks					
F1	Demand variability	10	15	5	Order in unit. One order every 3 days
F2	Customs’ procedures	5	10	2	In days
Resilience risks					
F3	Conveyor’s availability	30	15	45	Performance degradation expressed in terms of speed in m/mn
F4	Transporter’s availability	3	2	4	Number of trucks. Reflects breakdown

Selected performance goals for agility and resilience measurement are presented in Table V.

TABLE V
PERFORMANCE GOALS

	Indicator	Comments
Lean goal	Stock	Measured by the average stock
Green goal	CO_2 Emission	Measured by the distance covered by trucks multiplied by the quantity emitted by diesel per km

C. Experiment Design

TABLE VI
EXPERIMENT DESIGN

Experiment number	Factor levels F1	F2	F3	F4	Goal Lean: Stock (LG)	Goal Green: Emission CO2 (GG)	Goal Achievement: waiting time delivery (AcG)
1	1	1	1	1	LG1	GG1	AcG1
2 à 27	1	…	…	…	…	…	…
28	2	1	1	1	…	…	…
29 to 54	2	…	…	…	…	…	…
55	3	1	1	1			
56 to 80	3	…	…	…	…	…	…
81	3	3	3	3	LG81	GG81	AcG81

Case study considers that the four probable risk factors of the parameters of the simulation. The experiment design for agility and resilience measurement is presented in Table VI.

D. Results

Experiment design realization with ARENA simulator yielded several results. For example, the different measures that can be deduced for Lean agility are presented as follows:

- Lean Agility for the risk factor "Demand variability" with negative variation (index 2) measures the negative aspect of the risk factor. It is calculated as:

$$A_{LG/F1-} = \frac{LG|F1=2}{LG|F1=1} = \frac{average\ (LG28,..,LG54)}{average\ (LG1,...,LG27)} = 0{,}16$$

- Green Agility regarding the risk factor "Demand variability" with positive variation (index 3) measures the opportunity aspect of the risk factor. It is calculated as:

$$A_{LG/F1+} = \frac{LG|F1=2}{LG|F1=1} = \frac{average\ (LG55,..,GG81)}{average\ (LG1,...,GG27)} = 1{,}80$$

- Agility Lean for the risk factor "Demand variability" for both variations (2 and 3 index) measures the overall impact of the risk factor. It is calculated as:

$$A_{LG/F1} = \frac{LG|F1=2{,}3}{LG|F1=1} = \frac{average\ (LG28,..,LG81)}{average\ (LG1,...,LG27)} = 0{,}98$$

The other agility and resilience measures for risk factors are calculated similarly. We can deduce from the calculations above, agility and resilience for each performance goal considering that the risk factors have a weighted importance. For example, in the case study, considering that the risk factors have the same importance, the Lean agility is given by:

$$A_{LG} = \frac{\sum_{j:1,2} \alpha_j A_{LG/Fj}}{\sum_{j:1,2} \alpha_j} = average\ (A_{LG/F1}, A_{LG/F2}) = 0{,}99$$

We can also deduce the integrated agility and resilience weighted from the goal performance agility and resilience. Tables VII and VIII and Fig. 1 summarize the different results obtained in the case study.

The analysis of Tables VII and VIII data allowed mapping the risk presented in Fig. 2. This card argues that:

- The supply chain is globally agile and resilient regarding the Achievement, Lean and Green goals for all risk factors except for F1 regarding the Achieving goal. It is because of the data used in the case study. Indeed, in most cases, negative impact of the risk is completely offset by its positive one.
- The supply chain is not agile for factor F1 «Demand variability" regarding Lean goal. A degradation of this factor of 42% causes a decrease in performance of 84%, while an opportunity for improvement of this factor of 42% increases performance of 80%.
- The supply chain is not agile for factor F1 "demand variability" regarding the Green goal. A degradation of this factor of 42% causes a decrease in performance of 30%, while an opportunity for improvement of this factor of 42% increases also performance of 30%.
- The supply chain is not agile for factor F1 "demand variability" regarding the achievement goal. A degradation of this factor of 42% causes a decrease in performance of 1,100%, while an opportunity for improvement of this factor of 42% increases performance of 0%.
- The supply chain is not agile for factor F2 "customs procedure" regarding the achievement goal. A degradation of this factor of 100% causes a decrease in performance of 395%, while an opportunity for improvement of this factor of 60% increases performance of 99%.
- For all the other factors, the supply chain is perfectly agile and resilient regarding the Achievement, Lean and Green goals.

We can conclude that only the risk factor F1 "demand variability" is critical for both Lean and Green goals. It therefore requires an action plan to mitigate or even eliminate its effect. Risk map showing these results is presented in Fig. 2.

TABLE VII
AGILITY MEASURES REGARDING LEAN, GREEN AND ACHIEVEMENT PERFORMANCE GOALS

	Performance Lean							Performance Green							Performance Achievement						
	F1-	F1+	F1	F2-	F2+	F2	Mean (F)	F1-	F1+	F1	F2-	F2+	F2	Mean (F)	F1-	F1+	F1	F2-	F2+	F2	Mean (F)
Agility	0,16	1,80	0,98	0,95	1,05	1,00	0,99	1,30	0,70	1	1	1,00	1	1	12,03	1,00	6,51	4,95	0,01	1,00	1,00

TABLE VIII
RESILIENCE MEASURES REGARDING LEAN, GREEN AND ACHIEVEMENT PERFORMANCE GOALS

	Performance Lean							Performance Green							Performance Achievement						
	F3-	F3+	F3	F4-	F4+	F4	Mean (F)	F3-	F3+	F3	F4-	F4+	F4	Mean (F)	F3-	F3+	F3	F4-	F4+	F4	Mean (F)
Resilience	1,09	1	1	1	1	1	1	0,97	1	1	1	1	1	1	0,97	1,00	1,00	1,00	1,00	1,00	1,00

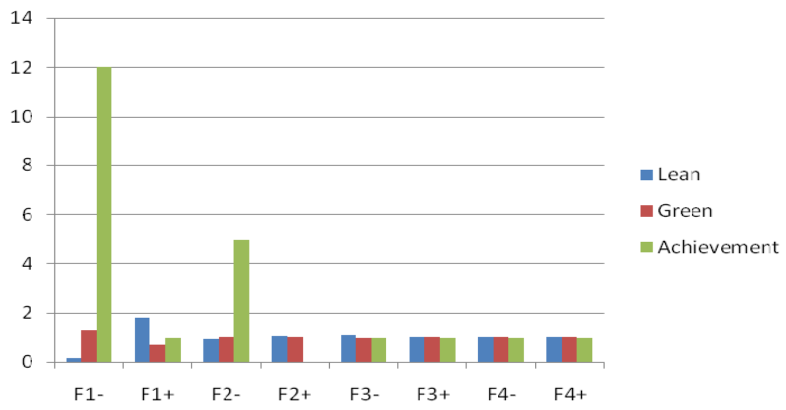

Fig. 1 Histogram of results

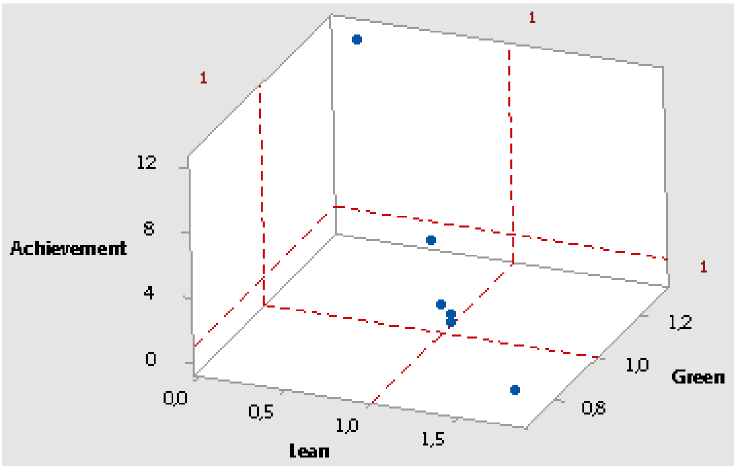

Fig. 2 LARG Risk Map

V. Conclusion

To implement LARG practices in the supply chain in an integrated way, this work has proposed an approach based on risk management. It consists in adapting a general RMA to introduce, identify, assess and prioritize risk in LARG practices. The logistics academic case study based on experimental simulation show the relevance of this approach as it allowed all stages unfold without blocking or ambiguity.

This work presents several contributions compared to existing methods. The proposed approach is an adaptation of the RMA in a context of great importance for companies mixing the four performance concepts widely used in logistics i.e. Lean, Green, Agility and Resilience (LARG). Integrated RMA application in LARG context was not addressed in the literature. Compared to conventional RMA methods, the proposed approach includes a step of identifying performance goals. This is of a great importance because of the number of risks that a system may face with. To classify and prioritize them, their importance is measured in terms of impact on performance. However, the performance itself has many faces. The impact of risk should then be measured according to company performance goals priority.

This work presents also a new classification of logistics risks. Indeed, the literature identifies operational risks in logistics according to their physical occurrence levels (supply, transport, handling …) in the supply chain or in connection with a particular partner in this chain (supplier, customer, staff …). The proposed classification divides in addition these risks according to their contribution to agility or resilience. Risks are qualified then as "agility risk" or "resilience risk".

Through this work, we could also respond to several secondary research questions. Regarding the conceptual relationship between the four LARG aspects, this work confirms first the antagonist character that may connect Lean and Green goals as announced in the literature (see factor F1- in Table VIII). It also shows that the impact of risk on performance is relevant to be calculated according to agility or resilience and that this performance could be Lean or Green. It finally proves that for a given system, Lean and Green goals can be directly compared because they concern production means performance. However, unlike what is believed, agility (vs. resilience) and Lean (vs. green) cannot be directly compared because they are related through the risks that the system can undergo.

This work is original because it introduces the concept of "LARG risk map". This map can be considered as a scoreboard for managers allowing them to drive the performance of their system. It classifies agility and resilience risk according to Lean, Green and Achievement goals. It identifies whether a risk can cause an impact on agility or resilience and in what magnitude in terms of Lean, Green and Achievement goals. Managers could then have visibility on the progress actions to drive according to their strategies mixing Lean, Agile, Resilient and Green (LARG) goals.

At the end, this work started a research topic which has the distinction of addressing the SC in a LARG context. It answered a number of questions such as the introduction of risk in this context, its classification and its experimental calculation, the relationship between Lean, Green, Agility and Resilience. Other research issues can be addressed in perspective including:

- Are the risks agility (vs. resilience) in relation with each other?
- Are the risks agility in relation with the risk resilience?
- Can we innovate through resolution of risk and performance goals contradictions?

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