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Introduction to a physics-based theory to manage risks and opportunities in supply chains

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Abstract. Currently, the management of risks and opportunities is highly depending on the ability of managers: to analyze complex situations (with a lack of common vision and decision on the whole supply network), to mobilize their experience and their knowledge. The goal of this article is to introduce a new vision for collaborative network management, especially dedicated to supply chain management. It deals with an innovative and original approach for supply chain management, based on physical principles. With that theory, risks and opportunities can be seen as forces pushing and pulling a system according to its key performance indicators (KPIs).

Keywords: Risk and opportunity management, Supply chain, Physics-based theory.

1 Introduction

Managing a supply chain involves shaping and pursuing objectives. These can be represented by KPIs. Managers tend to like measurable objectives, even though sometimes they are not looking at the “good” data. Within this article, we consider that the majority of objectives can be evaluated through formal KPIs. Managing a supply chain is trying to bring its KPIs to predefined targeted values.

The evolution of the KPIs is due to the occurrence of potentialities, when they become actualities. As defined in [1], a risk is the negative deviation from the expected value of a certain performance measure (a KPI for example), from which result negative consequences for the organization. Symmetrically, an opportunity is a potentiality whose consequences are positive with regard to the target performance indicators.

Besides a supply chain is a collaborative network, dealing with risks and opportunities for the whole network requires a global vision: thus the suggested approach could

contribute to the holistic vision of the supply chain and to interoperability of the network.

This article claims that (i) the identification of objectives and (ii) the support for decision-making are essential to the management of an organization. These decisions provide a chance to seize opportunities or escape risks in order to achieve the target values of the KPIs.

This article answers that following question: “*how to define and control the trajectory of the overall performance of a supply chain with its risks and opportunities represented as forces?*”. This article is structured as follows: Section 2 provides a state of the art regarding risks and opportunities management in supply chain. Section 3 introduces this theory. Section 4 illustrates that theory with a supply chain management use-case. Finally, the last section concludes with some perspectives.

2 State of the art regarding risks and opportunities management in Supply Chain.

Supply chain is earmarked by predictable or unexpected events that threaten the reach its performance objectives [2]. So its management implies to deal with risks and opportunities. As discussed in [3], the concepts of risk and opportunity are in fact very close to each other. These concepts are symmetric: pull or push the considered system in relation to its aims. Indeed, generally speaking, opportunity is the opposite of risk but both impact the location of a system with regards to its KPIs (making it closer or farer to the target values). In the following, the article focuses on the concept of risk, only because the field of risk management and detection is considerably more developed and studied.

In this section, the concept of risk and opportunity will be explored from the literature in order to provide guidelines for characterizing risks and opportunities. First of all, the risk management processes are decomposed in four steps as described in [4]:

- Risk Identification (detection of potentialities by studying an organization and its environment).
- Risk Assessment (evaluation of the impact of risk on the system, it can be divided in two parts: qualification and quantification).
- Risk Mitigation (risks responses strategies such as: acceptance, avoidance, sharing, ...).
- Risk Monitoring (monitor the status of previously identified risks).

In [5], risk is a combination of the impact on the organization and its probability of occurrence. The probability is a way to balance the impact seen as the consequences on the KPIs. This is a very used two dimensions’ framework for risk analysis as presented on Figure 1 (including also opportunity):

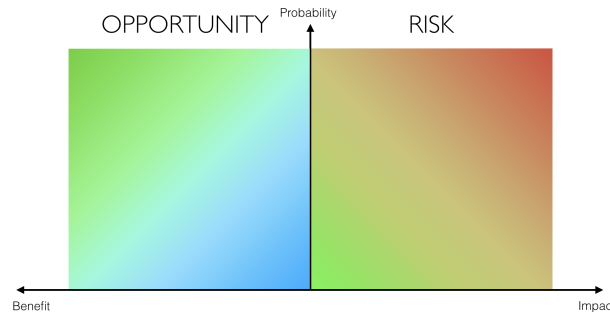


Fig. 1. Two-dimension framework for risk and opportunity analysis (from [8]).

Even if this idea of potentiality (risk and opportunity) being considered as the combination of impact and probability is very well recognized and used, this paper claims that, as discussed in [6], this vision can be refined according to the following three basic components:

- The danger(s) or a driver(s) (induct the risk)
- The event(s) (including the probability of occurrence)
- The consequence(s) (the real impact(s) of the occurrence of the risk)

In [7], a causal vision of the cascading risk chain is based on a very similar structure: *danger – risk – consequence*, so call the DRC chain. Besides, a very interesting aspect of that vision is that it can easily be extended to describe the opportunity by including the notion of favorable condition (*i.e.* the positive version of a *danger*).

Thus, that cascading effect chain can be generalized as illustrated in Figure 2:

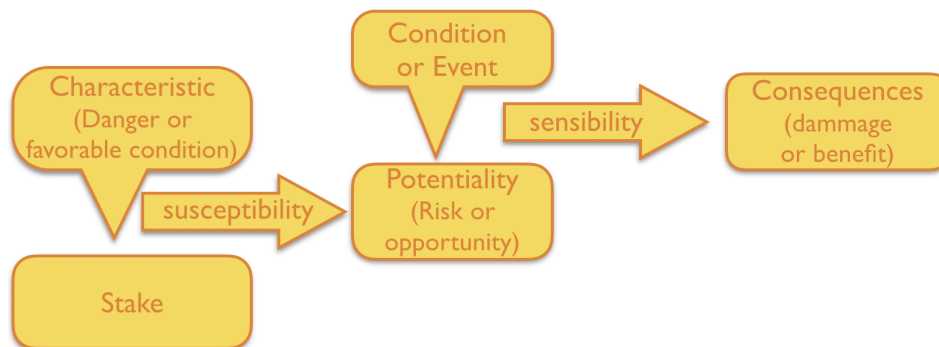


Fig. 2. Causal chain for potentialities (from [8]).

The existing research results on the field of risk management can be symmetrically extended to the question of opportunity management. At the end of the day, both together can be considered as potentiality management. However, the existing approaches on risk identification are essentially based on literature review and other experience-based methods ([9] and [10]). Therefore, it is possible to suggest the following two points:

- The impact/probability model is quite simple and cannot be exploited to model cascading effect.
- There is no automated tool for potentiality identification based on the use of data.

3 A physics-based theory

Now dealing with instability is a norm, as stated by [11] and [12]. But it is a new perspective of management and opens the door to new theories [8]. It is the purpose of this paper to introduce a new and original approach for supply chain management. This approach applies physical principles for supporting decision-making processes to control a supply chain's trajectory.

With that theory, risks and opportunities are modeled by forces pushing or pulling the considered supply chain within its KPI framework (a risk can be seen as a force pushing the supply chain away from its target performance values, while an opportunity would bring it closer to its target performance values). For example, a perspective like "solid mechanics" can be done, especially to study the managed or inflicted deformations of a supply chain due to the faced forces.

In addition to their direction and intensity (given by the KPI framework), the obtained forces are different types which could constitute interesting patterns of impact matrix and vectors [8].

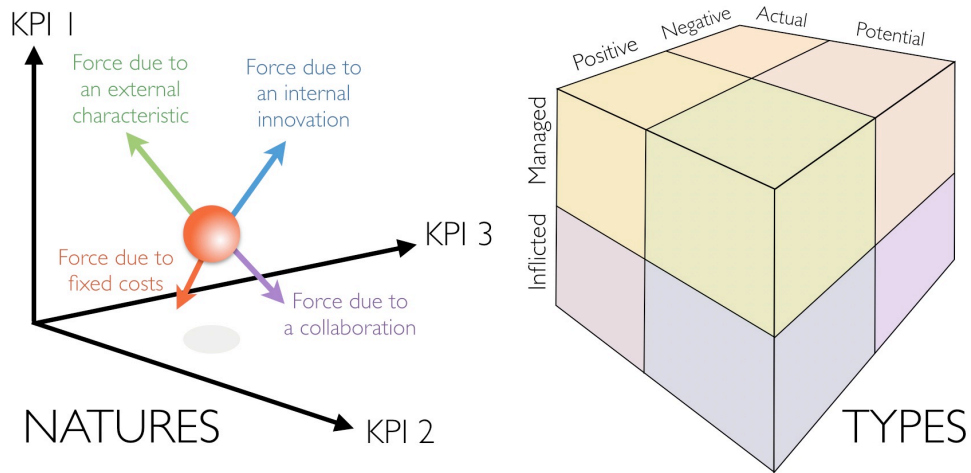


Fig. 3. Complementary characteristics of forces (from [8]).

Indeed, there are two major types of risks and opportunities based on quantifiable and measurable dimensions: external or internal ([13] and [14]). So, we can define four different force natures to model them (the first two for the external part and the last two for the internal part), as explained in [8]:

- External field force: is a force induced by an external characteristic (new taxes, hurricane, etc.).

- Collaboration force: is a force induced by a partnership (a supplier, a subcontractor, etc.).
- Internal force: is a force induced by internal decisions (continuous improvement, buying a new machine, poor forecast, etc.).
- Gravity force: is a force induced by unavoidable internal weights (operating costs, etc.).

These four different types of forces are based on the following criteria as we can see on the Figure 3:

- Is the force real or potential?
- Is the force positive or negative with regards to the considered KPIs, i.e. does it model an opportunity or a risk?
- Is it a force that the considered system is able to manage? Or, is it inflicted on it?

This framework of KPIs (Figure 3) allows to locate the considered supply chain regarding its KPIs and to define its network of forces (each force reflects the probable consequences of each identified risk or opportunity). For a supply chain, the dimensions of the framework could be: cost, quality, time, but also less quantitative dimensions like reactivity, flexibility, robustness, stability, or resilience ([15] key dimensions of today's performance).

This decision-making space can be used to determine the target zone, a part of this space reflecting the target of the considered supply chain in terms of KPIs. By looking intensity of these identified forces, one can study how to select the best combination of potentialities and the required effort to reach the target zone.

4 An illustrative example in the field of supply chain management

Please note that: This use-case is not based on real facts. Its purpose is to illustrate the theory presented in section 3.

The considered system is the supply chain of a spring for truck manufacturer. This plant can catch a big opportunity: to manufacture the further generation of leaf springs for its biggest customer. The plant manager does not want to miss this vital opportunity. It could be the future flagship product for his plant, so he puts a big pressure on the supply chain manager. Some trials are realized and were conclusive. The factory starts to produce the first small series, but a quality problem was detected. This problem is linked to the use of rubber silent blocks. Indeed, during the manufacture process of these leaf springs, rubber bushings must be fit into their eyelets and are tore or weakened in irregular rate. This problem is due to this new eyelet design and it is not possible to change it. Consequently, the supply chain has to make a decision: continue to use rubber silent blocks (i.e. continue to work with the current supplier) or use metal silent blocks (i.e. find another supplier).

In this use-case, the two characteristics studied will be: (i) the raising sales of this product, and (ii) the possible choice of a new supplier which produces metal silent blocks.

The considered performance framework is composed of the following three dimensions: (i) cost, (ii) delay, and (iii) quality. Clearly, management's goal is to minimize these three considered KPIs (note that the concept of time is included in the concept of trajectory):

- Financial rate:

$$\begin{aligned} & \text{Financial rate} \\ &= \frac{\text{Number of parts sold} \cdot (\text{Manufacturing costs} + \text{Investments})}{\text{Sales price}} \end{aligned}$$

- Delay rate:

$$\begin{aligned} & \text{Delay rate} \\ &= \frac{\text{Number of a customer's orders with a delay in delivery bigger than one day}}{\text{Number of its orders}} \end{aligned}$$

- Scrap rate:

$$\text{Scrap rate} = \frac{\text{Number of scraps}}{\text{Number of used silent blocks}}$$

At the end of the first production orders, this is the position of our supply chain in its framework of KPIs. A potentiality is to choose a new supplier, modeled by these initial matrix and vectors:

$$F_{\text{new supplier}} = \begin{bmatrix} 1.5 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0.9 \end{bmatrix} \cdot E + \begin{bmatrix} 2 \\ 0 \\ -0.5 \end{bmatrix} \text{ with } E = \begin{bmatrix} E_{\$} \\ E_{\text{Delay}} \\ E_{\text{Quality}} \end{bmatrix}$$

The trends observed by this expression of this potential force can be explained by:

- 1.5: metal silent blocks are more expensive
- 1: any change on the process time
- 0.9: new silent blocks improve the quality of each spring
- 2: the plant invests in an adapted machine for these news bushings
- 0: any change on the delivery time
- -0.5: new silent blocks reduce the number of scraps

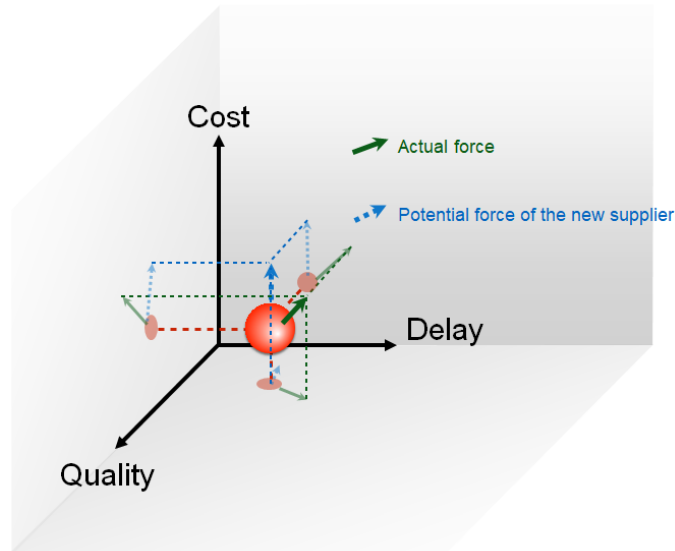


Fig. 4. Initial situation and forces.

The scales are normalized for clarity reason. As illustrated in figure 4, the same supplier forces (i.e. the force which represents the raising sales of this new product with a rubber bushing) and the new supplier force (i.e. the force which represents the raising sales of this new product with a metal bushing) are not pushing the supply chain in the same direction. The new supplier force is a potential collaborative force. If the manager chooses to continue with the current supplier, the supply chain may move in the framework and new forces will be associated to that new position (see figure). The following matrix and vectors are those of this new position:

$$F_{same\ supplier} = \begin{bmatrix} 2 & 0 & 0 \\ 0 & 1.5 & 0 \\ 0 & 0 & 4 \end{bmatrix} \cdot E + \begin{bmatrix} 2 \\ 1 \\ 3 \end{bmatrix}$$

The trends observed by this expression of this force can be explained by:

- 2: the manufacturing costs increase due these high rate of scrap
- 1.5: the process time increases sharply with all these scraps
- 4: the scraps increase
- 2: the plant invests to improve the accuracy of the machine
- 1: as the process time and quantities ordered increase, there is a risk of delay
- 3: the overall quality of the products decreases, risks tarnishing its image

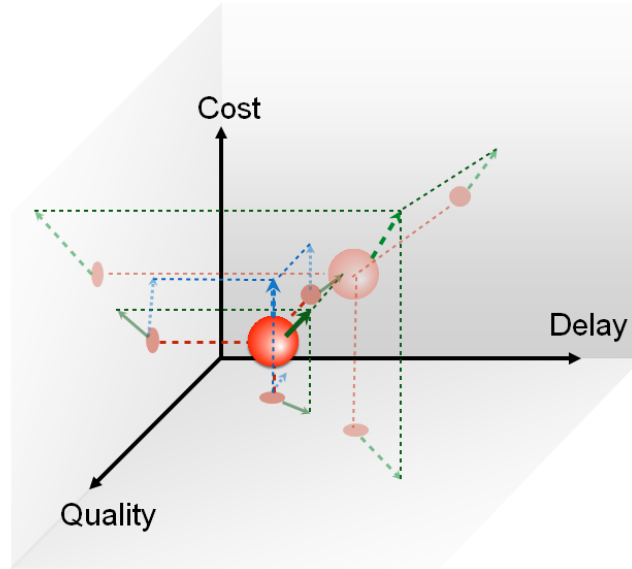


Fig. 5. Possible position and forces of the supply chain if the company maintains the current supplier.

On figure 5, the light red sphere shows the further possible position of our supply chain, pushed only the raising sales of this product with the current supplier force. As a consequence of that new position and the previous force, a potential force has been calculated (green vectors). It is important to note that the new vector associated to the choice of the new supplier has not been calculated.

If the decision to choose a new supplier is taken, the supply chain may move in the framework and new forces will be associated to that new position modeled by these new matrix and vectors (see figure 6):

$$F_{new\ supplier} = \begin{bmatrix} 3 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0.7 \end{bmatrix} \cdot E + \begin{bmatrix} 2 \\ 0 \\ -1 \end{bmatrix}$$

The trends observed by this expression of this force can be explained by:

- 3: metal silent blocks are more expensive and sales volumes increase
- 1: any change on the process time
- 0.7: the parts are more robust
- 2: the plant invests to improve the accuracy of the machine
- 0: any change on the delivery time
- -1: the recent machine is more accurate and the scraps go down

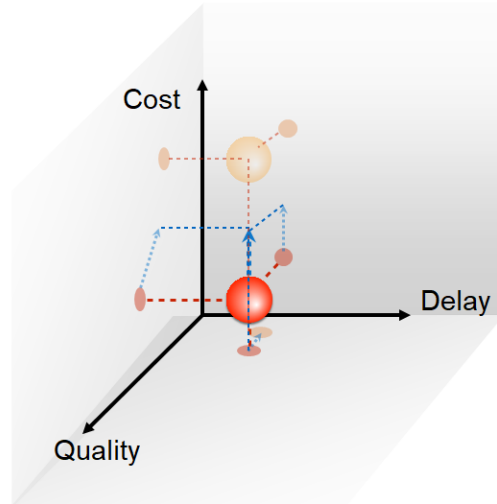


Fig. 6. Possible position and forces of the supply chain if the company takes the new supplier.

On figure 6, the new supplier force pushes the supply chain to a possible position represented by the orange sphere.

Finally, the best decision for the supply chain manager would be to choose a new supplier. For this use-case, this decision is relatively simple. The Figure 5 allows to easily understanding that if the manager does not change anything, the forces acting on its supply chain will push it to very bad results.

5 Conclusion and perspectives

Dealing with instability is a new management perspective [8]. In order to adapt to the forces in presence, the mechanics of solids will be taken into consideration, especially to study the chosen or inflicted deformations of an organization. The theory presented in this paper opens the door to an innovative vision for management and decision-making. The aim being to develop an intuitive decision tool to support inter-enterprise collaboration. With that tool managers could see the impacts of each potentiality on the collaboration performance and help interoperability. In return, interoperability contributes to one type of forces (collaboration force) by favouring the exchange of information and thus helping to improve the quality of the relationship.

The following points are a set of identified tasks to make this theory operational:

- The real-time calculation of trajectories.
- The study of accessible KPI space areas and efforts to join these areas.
- The visualization, being able to observe the supply chain within the framework of its KPIs. This last aspect is very important, because frameworks usually include more than three dimensions and are already hard to manage. Virtual Reality is considered a potent way for supporting such visualization.

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