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Abstract: The upcoming logistic environment is about to modify deeply the way we supply products. In fact, some new trends are going to require more and more agility between a large number of stakeholders in open and dynamic networks. This should be possible to achieve thanks to new data collection and treatment abilities. Considering this moving technological and logistic environment, it appears necessary to define and categorize more specifically the main disruptive events that can affect a supply chain. In fact, amount of data are collected on the field and must be helpful to make relevant decisions in case of disruption. In order to understand automatically what these data mean, it is necessary to detect and classify the disruptive events in order to find the best adaptation. This paper focuses on the sensitive products' supply chains, that are facing with agility high requirements, based on their ability to detect disruptive events. We take as an example the blood supply chain.

Key words: Disruptive Event, Supply Chain, Sensitive Products, Resilience, Agility.

1. Introduction

In order to organize the vehicles rounds to pick-up and/or deliver products, companies are using scheduling systems, trying to deal with the Vehicle Routing Problem (VRP) problem (Toth and Vigo, 2002). Despite the optimized schedule, a lot of events may affect the on-going process like traffic jam, bad weather conditions, unexpected demand, vehicle failure, etc. These undesirable situations may have negative impacts on the supply chains and transportation performance.

For some years we assist to a supply chain complexification on one hand and to very quick changes on the technological abilities on the other hand. The logistic environment evolves quickly and some new trends are about to modify the way goods are transported. The product customization and the temperature controlled supply chain imply a strict and effective traceability during the transportation steps in order to ensure the delivery of the right product at the right place and moment in the best conditions. Meantime, logistic as a service schemes and responsibilities splitting increase the number of stakeholders involved in the transportation of each box between the sender and the recipient. Finally, the supply chain customization makes the whole network more complex to satisfy the customers' requirements who require anything / anytime / anywhere pick-up and delivery services.

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Thus, in order not to be drawn under the possibilities and demands, it appears necessary to improve agility on the whole supply chain in order to take advantage of the upcoming hyperconnected network and react in case of unexpected events. As an example, we examine in this study the case of sensitive products transportation.

We define a transport as a sensitive one (i) because it is risky for the product itself (fragility, dangerous for the environment, high risk of theft, etc.) or/and (ii) because if a certain quality degree is not reached in the service and/or product (delay in the delivery, product injured). This will have high-impact negative consequences downstream the supply chain. The first category involves products that are expensive (electronics, precious metals, etc.), dangerous for the environment (radioactive, chemicals, etc.), rare (piece of art), fragile (animals, objects sensitive to shocks), and/or vital (organ, drugs). The second one involves any object, even water, blankets or dry food needed during humanitarian crisis for instance. In such a situation, common products are involved in sensitive transportation steps because they are required as a matter of emergency. These two categories are obviously not separated. Indeed, as we explain it hereafter, some transportation combine both aspects when the type of goods transported are related to human health, as there is, besides the economic loss, the potential loss of human lives.

For this reason, it is important to shape an agile supply chain with the main aim to build a resilient one, as agility is one of the key characteristics of the resilience capacity. When working effectively and efficiently, supply chains allow goods to be manufactured and transported in the right quantities, to the right places at the right time and with the right conditions in a cost effective manner (Christopher *et al.,* 2004). Resilient supply chains allow goods to be delivered effectively and efficiently under unstable conditions that is the frequent way of supply chains actual operation.

A resilient supply chain must be adaptable to face up to undesirable situations efficiently and to guarantee the survival (Ruiz-Martin *et al.,* 2018). Resilient processes should be agile to change quickly (Christopher, 2005). Christopher and Peck's (2004) conceptualization of a resilient supply chain includes the agility as a basic characteristic to recover after being disrupted and to provide a more rapid response to changed conditions. Moreover, it is important to highlight that the feature of agility is even more crucial in the case of sensitive products, in order to react to an undesirable situation smartly to minimize the negative impacts.

The objective of this paper is to categorize the main disruptive events that can affect the normal operation of a sensitive product supply chain focusing on the transportation step. This is a starting point to focus on agile aspects and the disruptive events detection to build a resilient supply chain. The agility detection step, put forward by Barthe-Delanoë *et al.,* (2013) is a key element in order to automatically identify that something is going wrong. The identification of the main disruptive events that negatively affect a sensitive product supply chain has been performed based on the categorisation framework of disruptions developed by Sanchis and Poler (2014) and on the exhaustive study and analysis of the blood transportation supply chain in France. This has been performed through the historical data provided by the Etablissement Français du Sang (French Blood Establishment: EFS) of a whole region with 25 sites, representative of the other one in France. Figure 1 shows the relationship between the different elements of the scope of this research (grey ones) whose main aim is focused on the categorisation of the main disruptive events in the transport of the sensitive products supply chains.

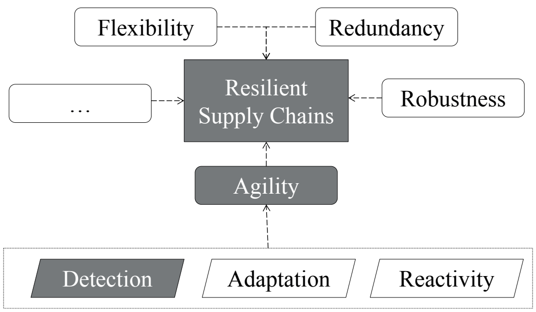

Figure 1. Conceptualization of the research scope to build a resilient supply chain.

The paper is organized as follows. Section 2 describes the literature review related to the upcoming logistic environment and how it will increase the need of resilience and agility. A former categorisation framework of disruptions is studied. Section 3 focus on our proposal consisting of an extended version of the categorisation framework of disruptions and its use in the sensitive products supply chain during transportation steps. Finally, section 4 uses the EFS use case to discuss this proposition.

2. Literature Review

2.1. The Upcoming Logistic Environment

The logistic environment evolves quickly regarding the technologies and trends. This study considers some upcoming technologies that would allow improvement in our ability to collect and treat data automatically and in real time. This should be useful to take up the challenges of being resilient in the future logistic environment.

First, thanks to new mobile devices able to collect and transmit data on the Internet (IoT: Internet of Things), the data collection in real time should not be a problem in a near future. These new technologies, linked with the cloud computing is creating a hyper-connected network of devices affordable by anyone (Harris *et al.,* 2015). Big Data aspects, described by Wamba *et al*. (2015) as a combination of data Volume, Velocity, Variety, Veracity and Value were a limitation to extract added value from these data-collection. Considering how important and relevant must be considered the ability to use these data to support the decision making process in real time, we can expect in a near future that this kind of technologies, accessible through Software as a Service model will spread in the whole supply chain. Harris *et al.,* (2015) explain that the Small and Medium Sized Enterprises (SMEs) should also take advantage of these technologies.

On a network aspect, we are usually considering pre-determined and fixed network. The multimodality, defined by the United Nations (1980), may represent a risk for the products to be transported because it is no longer possible to consider the vehicle as a black box between the sender and the recipient. Currently, the transshipments may endanger the products (storage conditions, forgotten container, theft, etc.) whereas they may increase the effectiveness combining the advantages of each transportation mean used (Harris *et al.,* 2015). In light of the new data collection and treatment abilities, it should be easier to control these steps and less hazardous to organize them. Moreover, as it is the case for softwares from several years, logistics activities are split between different companies like 3-4-5PL (Party Logistics) firms subcontracting a increasingly larger perimeter. This "service" trend, visible and used by the consumers (Uber, AirBnB, Deliveroo, etc.) should spread in logistics activities with companies responsible of just one part of the whole supply chain. The last mile delivery is one of these potential perimeters. The distribution customization based on "anytime, anywhere delivery model" (DHL, 2016) complexifies the network between the sender and the recipient, requiring more agility and ability to pick up and deliver the products the closest to the sender and recipients. Finally, automation inside hubs and Automated Vehicles themselves (Van Meldert *et al.,* 2016) should provide more transportation possibilities and contribute to build an open and agile network.

From the product point of view , we are currently tracking in real time the vehicles when containers are loaded inside. In this evolving network, more stakeholders involved in the supply chain and more transshipment may be settled. In this situation, with numerous stakeholders in charge of each container, instead of tracking the vehicles, it must be valuable to track directly each box. This idea is a part of the Physical Internet philosophy, making a parallel between the box on the supply chain network and the packets on the internet network (Montreuil, 2011). This point of view appears relevant in the expected network and even more in a product customization trend. In fact, this "batch size one production" (DHL, 2016) prevents the possibility of replacing a container damaged by another one in the same storage area, because each product is different. A supply chain issue on a container may require to manufacture again the products inside. Thus, the sensitivity of each of them increases as the traceability needs. Moreover, the climate-controlled supply chain demand increases and (Bogataj *et al.,* 2005) the laws that control it are very strict. This sensitive supply chain also involves anomaly detection in real time to be resilient.

Figure 2 illustrates these evolutions, putting forward the increasingly more complex logistic environment. In this hyperconnected and open network where the containers are tracked independently in real time, resilience is a key element.

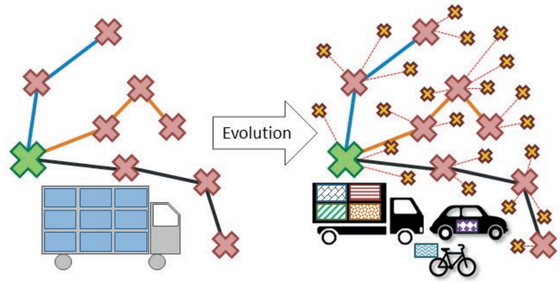

Figure 2. Expected supply chain environment.

2.2. Resilience and Agility

Resilient supply chains allow to detect the potential and/or the real disruptive event occurrence and increase agility. Resilience was firstly coined by Holling (1973), as a system that persists in a state of equilibrium (stability) and how dynamic systems behave when they are stressed and move from this equilibrium.

Gallopin (2006) explains that the capacity of resilience is the enabler for enterprises and supply chains to decrease the level of vulnerability to expected and unexpected risks, to determine how agile it is in reorganizing itself despite its changing environment, and assess how effective it may be in recovering in the least possible time and at the least possible expense.

Morales Allende *et al.,* (2017) explain that there is not entire consensus about the definition of the term resilience. There is a high amount of definitions in the literature. Table 1 shows some of these literature review's definitions of resilience but, in this case, applied to supply chains to understand the importance of being resilient to face potential disruptive events but also to identify the different elements that are related to this essential supply chains' ability.

Sanchis and Poler (2013) state that the ability of resilience in an enterprise or its supply chain is function of (i) the vulnerability; (ii) the adaptative capacity (adaptation) and (iii) the recovery ability. Moreover the authors propose a framework with the main research areas related to the study of resilience that will serve as the foundation for further research. This framework relates the adaptation to aspects such as flexibility, agility, robustness, redundancy, … among others. One of the main remarkable features of the supply chain to be able to adapt to the new situation provoked by a disruptive event is the agility with which the supply chain is able to manage this new undesirable situation. It is conceptualised as the ability to better deal with unexpected events, to overcome unforeseen situations of business environment as to take benefits and opportunities of changes (Swafford *et al.,* 2008). Therefore, agility is a prerequisite for building resilient supply chains.

Moreover, Barthe-Delanoë *et al.,* (2013) explains that agility is a function of detection, adaptation and reactivity as follows:

$$\text{Agility} = (\text{Detection} + \text{Adaptation}) \times \text{Reactivity} \quad (1)$$

Starting with the first element, detection is very important as the supply chain is not aware about the

Table 1. Supply Chains Resilience Definitions

Authors	Definition
Ponomarov and Holcomb (2009)	The adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function.
Barroso *et al*., /2011)	Ability to react to the negative effects caused by disturbances that occur at a given moment in order to maintain the supply chain's objectives.
Berle *et al*., (2011)	Ability of the supply chain to handle a disruption without significant impact on the ability to serve the supply chain mission
Ponis and Koronis, (2012)	The ability to proactively plan and design the Supply Chain network for anticipating unexpected disruptive (negative) events, respond adaptively to disruptions while maintaining control over structure and function and transcending to a post-event robust state of operations, if possible, more favourable than the one prior to the event, thus gaining competitive advantage
Wieland and Marcus-Wallenburg, (2013)	The ability of a supply chain to deal with change either proactively or reactively.
Brandon-Jones *et al*., (2014)	The ability of a supply chain to return to normal operating performance, within an acceptable period of time, after being disturbed.

disruptive event happening and most important, it is crucial to detect it as soon as possible, preferably in “real time”, in order to be able to take the most appropriate decisions and implement the most adequate actions to reduce and minimize the undesirable consequences of the disruptive event occurrence. Adaptation is the following element and tries to modify the current conditions of the supply chain to make them compliant with the new supply chain circumstances. The last element is the reactivity which is in charge of altering supply chain behaviour when a disruptive event occurrence has been detected and the supply chain is adapting to this new context.

Agility allows on one hand to detect if the ongoing processes meet the requirements of the current situation, on the other hand to adapt the ongoing processes if necessary (Barthe-Delanoë *et al.,* 2013).

Therefore, to build resilient supply chains, it is necessary to be as agile as possible. This also depends on the detection element to be able to discover that the current situation is not the expected one. For this reason, having deep knowledge about the potential disruptive events is not enough as it is also desirable to have the appropriate means to monitor and detect what causes the lack of supply chain resilience, i.e. to categorize the most relevant and probable disruptive events.

2.3. Categorisation Framework of Disruptions

The identified disruptive events have been classified based on the already defined categorisation framework of disruptions developed by Sanchis and Poler (2014). This framework was applied to typical manufacturing supply chains and the authors did not consider its application to other types as the sensitive products transportation supply chains. In this paper, we will confirm if the categorisation framework of disruptions presents enough generality to be applied to any singular supply chain, even though to any logistic environment, or on the contrary it needs to be updated.

When developing the categorisation framework of disruptions, Sanchis and Poler (2014) pointed out that there is a high degree of confusion both in terms of disruption and in its constituent elements. For example a forest fire during summer nearby a road is a disruptive event whose source might be a cigarette. The consequences are the roads nearby cut off and the forest destruction. Focusing here on the forest, it is easy to identify the source, the disruptive event and the consequences. However, considering the road, the cut off is the triggering event, the source is the fire and the consequences are deviations and traffic jam. Next, considering a truck which contains sensitive products, the disruptive event is the traffic jam, the source is the road cut off and the consequences are still to be defined, depending on the products, their sensitivity (related to their characteristics or the context/demand), etc. However, we could consider that the source of traffic jam is the forest fire, setting apart the road cut off.

This short example put forward the difficulty to clearly define the system considered and the disruption elements among all the events included in a butterfly effect.

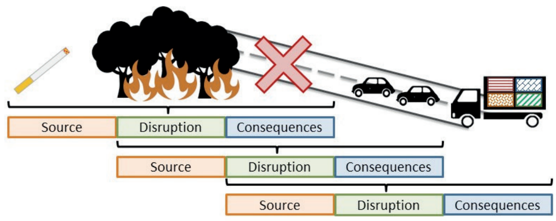

Figure 3. Butterfly effect showing the difficulty to define clearly the nature of each event.

Svensson (2000) and Kleindorfer and Saad (2005) define disruption as an unexpected event that interrupts the normal flow of products and materials in a supply chain. This definition does not consider the ability to foresee this event and to reduce the risk of occurrence. Barroso *et al.* (2008) takes it into account and define disruption as a foreseeable or unforeseeable event, which affects directly the usual operation and stability of an enterprise or its supply chain. In this research work we add to this last definition the fact that this disruptive event is potentially damaging for the considered supply chain and its components if some parameters are forgotten in the analysis step. For instance, during its round, a carrier receives the instruction to deviate from this initial plan in order to deliver a customer who have ordered a product unexpectedly. Inside the vehicle, if the containers/products state and their constraints are not checked before making the decision of deviation, the adaptation solution found may be more damaging than other solutions. In fact, the delay this deviation implies for the following deliveries may not be allowed or could injure the products. We consider here that all the parameters require to make an adapted decision are detected by sensors on the field or indirectly.

The categorisation framework of disruptions (Sanchis and Poler, 2014) considers that a disruption is composed by 3 elements as it is shown in Figure 4:

- Source: the trigger that causes and originates the disruption.
- Disruptive event: incident that causes an expected or unexpected disturbance that alters the normal operation of the supply chain.
- Consequence: Impact of the disruptive event in form of negative effects on the supply chain.

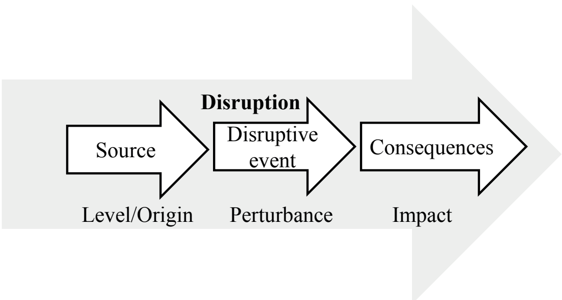

Figure 4. Elements of the categorisation framework (source: based on Sanchis and Poler, 2014).

The authors divide the source element into the level in which the disruption have its origin: (i) within an enterprise of the supply chain, (ii) outside an enterprise but internal to the supply chain and (iii) external to the supply chain; and into the origin that causes the disruptive event, considering accidental, customer, energetic, equipment, financial, Information and Communications Technologies (ICT), infrastructure, man-made, natural, political, product, regulatory, supplier and terrorism.

The consequences element is also divided into the following ones: (i) business interruption; (ii) damage to reputation/brand; (iii) delays and failure of due dates; (iv) failure to attract or retain top talent; (v) failure to meet customer needs; (vi) high inventories; (vii) impossibility to pay personnel, suppliers, taxes; (viii) increase of final products price; (ix) increase of production costs; (x) injury to end customers; (xi) injury to workers; (xii) loss of intellectual property/ data; (xiii) loss of networked communication; (xiv) physical damage; (xv) sales decrease; (xvi) understaffing; (xvii) unfulfilled orders. Moreover, the authors differentiate the initial impact, the quickest negative signals of the disruptive event occurrence and the long-term consequences as the lasting ones.

Table 2 shows an example of the original categorisation framework of disruptions. As it could be observed, the examples are more related to a typical manufacturing supply chain. However, in this paper, we would evaluate if the categorisation framework of disruptions is as generic as necessary to be able to be applied to any type of supply chain.

3. Proposal: Extended Categorisation Framework and Disruptive Events

3.1. Taking the Detection into Account

Based on the French Blood Establishment (EFS) experience and the historical data about the main disruptive events that affect the blood transportation supply chain, the identification of the core disruptive events has been performed. Moreover, for each of the disruptive events identified, the source where the disruptive event is originated and the consequences, as the negative outcome of the disruptive event occurrence have been analysed in detail accordingly

Table 2. Small fragment of the categorisation framework of disruptions of Sanchis and Poler (2014).

Sources			Consequences	
Level	**Primary origin**	**Disruptive event**	**Initial impact**	**Long-term consequences**
in-, inter-, extra-	Accidental	Fire, gas leak, explosions…	Injury to workers	i, iii, v, xi, xii, xiii, xiv, xvii
in-, inter-	Customer	Unanticipated or very volatile demand	High inventories / Delays and failure of due dates	v, ix, xv, xvii
in-, inter-, extra-	Energetic	Energy/water interruption (electricity, gas…)	Business interruption	ii, iii, viii, ix, xvi
in-, inter-, extra-	Equipments	Breakdown of machinery	Delays and failure of due dates	i, ii
in-, inter-, extra-	Financial	Economic slowdown	Sales decrease	i, iv, vii
in-, inter-, extra-	ICT	Lack of technology infrastructure to support business needs	Failure to meet customer needs	xiii
in-, inter-, extra-	Infrastructure	Transportation infraestructure failure (e.g.rail disruptions)	Delays and failure of due dates	ii
in-, inter-, extra-	Man-made	Crime/Theft/Fraud/Employee Dishonesty	Loss of intellectual property/data	ii, iii, v, xvi
in-, inter-, extra-	Natural	Natural disasters (e.g. earthquake, flooding, tsunami, tornados…)	Business interruption	iii, v, xi, xiii, xiv, xvi
in-, inter-, extra-	Political	Political instability or other socio-political crises		i, iii, v, x, xi, xiii, xiv, xvi, xvii
in-, inter-, extra-	Product	Nocive substances in products	Damage to reputation/brand / Injury to end customers	ii, v, x, xv
in-, inter-, extra-	Regulatory	Regulatory and legislative changes	Injury to end customers	v, viii, ix, xv
in-, inter-	Supplier	Natural resource scarcity/unavailability of raw materials	Delays and failure of due dates	i, ii, v, viii, xvii
in-, inter-, extra-	Terrorism	International terror attacks	Business interruption	ii, iii, v, xi, xii, xiii, xiv, xv, xvi, xvii
…	…	…	…	…

to the categorisation framework of disruptions presented.

However, to apply this framework to the real and current situation of the sensitive products' supply chains and considering the expected one, it has been recognized the necessity to add another element that put forward the detection that a disruptive event is happening or potentially will happen (deviation from the expected situation). For this reason, the existing framework (Figure 4) has been extended (Figure 5) including the detection element, that can be defined as the signal that allows the identification and perception of a disruptive event occurring or potentially occurring.

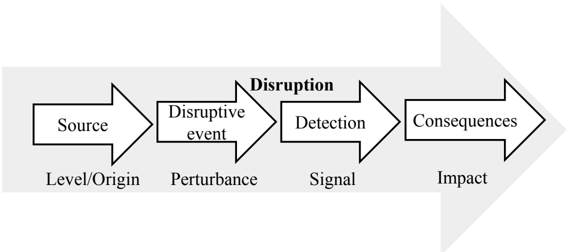

Figure 5. Elements of the extended version of the categorisation framework of disruptions.

In fact, in sensitive supply chains, if the products are transported through hundreds of kilometres, the detection step of a disruptive event is not as easy as it can be in a manufacturing factory where almost everything is under control or at least, delimited. During transportation processes, some parameters are not under control (traffic, weather…) and may affect others already difficult to monitor because of detection issues or data broadcast (truck compartment load and state, container state, vehicle location/speed/state, client demand).

This surveillance aspect needs to be continuously reviewed and monitored in order to detect "in real time" or after few minutes the disruptive events. Sensitive products, like the blood ones, may be damaged after few minutes and in case of urgent delivery, the receiver may not be able to wait for few more minutes.

Even if it may be easy for the driver to detect it through embedded sensors, in order to react correctly and in accordance to all the other containers transported and vehicles deployed, the information sharing and processing among the whole agents involved is essential. In fact, it is necessary to analyse correctly the whole situation to preview the consequences and make an adapted decision based on all the available means, considering the context (traffic, weather, distances, time, etc.) and current needs.

Therefore, on the detection step depends our ability to detect the disruptive event as soon as possible after it appears with enough relevant and reliable data. Gathering them, it allows to draw a relevant picture of the situation in real time and to anticipate the consequences. The objective of detecting these events and being able to react with agility is to reduce as much as possible the negative impact of the consequences on the supply chain and the products.

Based on this, Figure 5 shows the extended version of the categorisation framework of disruptions to be applied in the current sensitive products supply chain and broadly in the expected logistic environment.

3.2. Extended Categorisation Framework of Disruptions Applied to Sensitive Products Supply Chain

The identification of the main elements that shape the extended version of the categorisation framework of disruptions has been mainly performed through the analysis of the historical data provided by the EFS, due to, our best knowledge, the lack of information in the literature. This supply chain, described more specifically in section 4 deals with very sensitive products through thousands of kilometres everyday and allow us to describe in Table 3 the extended categorisation framework of disruptions to sensitive supply chain in general. The source element has been simplified as it has been only categorized the origin in which the disruptive event is happening. It is already preconceived that for the analysed disruptive events (Table 3), the level in which the disruptive event occurs is external to the sensitive product transportation supply chains as it is related to the traffic, natural conditions, man-made disruptions, among others.

The main disruptive events identified are eight. The number is not very high but the consequences if these disruptive events occur, could be, in some cases, disastrous. In fact, considering the both aspects that lead to define a supply chain as sensitive (cf. Introduction) either the products themselves may be injured or the receiver stuck in a damaging situation.

Finally, the detection element has been included as it is difficult to notice a disruptive event happening, mainly in real time. For this reason, it is so crucial to monitor continuously this element to be able to respond in an agile way. One of the challenging issue here is not just to detect and transmit these data to the monitoring system but to treat them in real time in order to understand what is happening globally on the field and find adapted solutions.

As it appears in Table 3, the categorisation is adapted to the upcoming environment described above, focusing on the container and not just on the vehicles. Knowing the high number of stakeholders potentially involved in container transportation steps between a sender and a receiver, the detection must be as technically standardized as possible regardless of the disruption or the sensors used.

We discuss in the last section the relevancy of this categorisation, considering the sensitive blood supply chain.

4. Blood Supply Chain Discussion

We develop here aspects of the blood supply chain in order to study the extent to which the categorisation presented may be implemented.

The blood transportation supply chain is considered as a sensitive one because of its own structure and the products sensitivity the EFS deals with. In fact, in order to provide to the hospital enough blood products, the EFS has to collect around 10.000 blood bags everyday through the country. Each year, 2 millions of blood bags (2/3) are collected in "one-day collection sites" settled in public spaces, universities and firms. Two major constraints imply to organize collection sites everywhere in France in thousands of different sites.

Firstly, donors have to wait at least 2 months between two blood donations, and several weeks between two platelets of plasma donation. As a consequence, the

Table 3. Extended version of the categorisation framework of disruptions applied to sensitive products supply chains during transportation steps.

Source (Origin)	Disruptive event	Detection	Consequences
Transport	Traffic Jam	Current vehicle or container position is different from the expected position	• Disorganization (delay/cancellation of product delivery)
Natural	Bad weather conditions		• Increasing the risk of accident • Product damage risks growth (delay, constraints respect, etc.)
Human	Theft	Either a position sensor on the container or a door sensor and detection by the driver or the recipient	• Malicious/dangerous use of the product
	Forgotten or lost container	Either a position sensor on the container, the Transport Management System, the sender or the recipient	• Product damage risks growth (delay, constraints respect, etc.) • Undelivered package
Vehicle	Truck compartment or container physical parameter failure	Physical parameter (temperature, humidity, etc.) out of limit during x minutes	• Disorganization (delay/cancellation of product delivery)
	Vehicle breakdown	Current vehicle or container position is different from the expected position	• Product damage risks growth (delay, constraints respect, etc.)
Demand	Unexpected product order	Order received by phone call or directly on the transport management system	• Disorganization (delay/cancellation of product delivery) because of the verification of re-routing possibilities if a valid product is in the truck
	Unexpected and urgent product order		

EFS must not collect blood at the same place too often because potential donors will not be able to give their blood again.

Secondly, in order to store the highest diversity of blood types, the EFS has to collect blood everywhere in the country in order to be close to the broadest diversity of people.

However, the blood bags have to be processed in order to separate their components (plasma, platelets, and red blood cells) and tested to check the innocuousness of each donation. These steps require laboratory professionals and expensive equipment. Thus, 12 EFS centres process every day the 10000 donations and 4 qualification laboratories test everyday all the samples associated with the blood bags (more than 50000 samples). Then, the blood products are stored in 130 distribution centres, the nearest to the hospitals where they are used to care receivers.

As it can be observed, this supply chain has an X structure with a lot of suppliers sending raw materials to few processing centres that send end products to a lot of distribution centres. This implies transportation steps over around 20 million kilometres every year, dealing with around 2 million containers. The main difficulty is to reconcile this aspect with the sensitivity of each product in terms of storage temperature and lifecycle as described in Table 4.

Table 4. Labile blood products storage conditions.

Products	Lifetime	Temperature
Whole blood	Less than 48 h	18-24°C
Blood samples	Less than 48 h	2-10°C
Platelets	5 days	20-24°C shaken
Red blood cells	42 days	2-10°C
Plasma	1 year	< –25°C

Finally, because it is not possible to store each type of product everywhere and some of them are required as a matter of emergency, a few dozens of urgent and unexpected transports are settled everyday on demand.

As it can be viewed, the blood transportation supply chain presents high complexity due to the product characteristics and the usage of this singular product. For this reason, the categorisation framework of disruptions has been applied to this unusual case as an initial attempt to illustrate the main characteristics of the blood transportation supply chains and as a starting point to address all the efforts to detect as soon as possible the disruptive events categorised and adapt efficiently to the new situation to shape a resilient supply chain. The disruptive events presented in Table 3 are coherent with the blood supply chain. Unexpected demand coming from hospital may appear anytime while the trucks full of blood products are proceeding their round and it may be useful to deviate one of them. Moreover, because of temperature sensitivity, being able to detect a temperature issue in a compartment is essential in order to find an adapted way of recovery.

This framework should contribute to develop methods and tools to assess, analyse and propose actions to improve the resilience capacity in the sensitive products transportation and, in turn, the blood transportation supply chain.

5. Conclusions

The application of the extended version of the categorisation framework of disruptions establishes the starting point to study and analyse the proper actions to be implemented with regards to the current blood supply chain focusing on the transportation steps and the upcoming logistic environment. The special features of the blood transportation make this categorisation more critical if possible, as, besides the economic losses; we are talking about potential human lives losses.

It is very important to know which disruptive events are the most serious (either per frequency or per criticality) to focus all the efforts on these ones to minimize the negative impact of its consequences. Moreover, it is also very important to define the detection elements as they allow the discovery that the real situation is not the expected one. This element will provide reliable and real-time information that will permit to take decisions quicker and more efficient.

The categorisation framework of disruptions provides a useful first direction to address the research towards the most appropriate actions to respond in an agile way and shape resilient supply chains.

Further research will be focused on defining the appropriate and specific detection means to be able to receive the relevant information when necessary and to define the appropriate actions to be implemented in each of the disruptive events identified based on the information received from an agile perspective to achieve a resilient sensitive products supply chain. A machine learning perspective could be used in order to deduce for each case the best adaptation solution to implement. Finally, these detection events may come from any device, internal (our own sensors) or external (weather, traffic jam, container/vehicle position, etc.) to the company. Thus it is necessary to be able to collect and understand them. An adapted disruptive events metamodel must be necessary and this represents an interesting research topic to work on.

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