A model to define and assess the agility of supply chains: building on humanitarian experience

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Abstract

Purpose – By constantly working in environments with high degree of uncertainty, humanitarian organizations end up becoming specialists in the implementation of agile systems. Their counterparts in profit-making organizations have a lot to learn from them in this domain. Volatility of demand, imbalance between supply and demand and disruptions are all factors that affect commercial supply chains and call for a high level of agility. The aims of this paper are twofold: first, to clearly define the concept of supply chain agility, and second, to build a model for assessing the level of agility of a supply chain.

Design/methodology/approach – Three approaches are used in this research: literature review, case study and symbolic modeling.

Findings – The paper developed first, a framework for defining supply chain agility and second, a model for assessing and improving the capabilities of humanitarian and commercial supply chains in terms of agility, based on an analysis of humanitarian approaches.

Research limitations/implications – The model has been developed thanks to inputs from humanitarian practitioners and feedbacks from academics. The practical application to various humanitarian relief operations and commercial supply chains is yet to be done.

Originality/value – This paper contributes significantly to clarifying the notion of supply chain agility. It also provides a consistent, robust and reproducible method of assessing supply chain agility, which seems appropriate for both humanitarian and business sectors. Finally, it is complementary to existant research on humanitarian logistics. It shows that though humanitarian professionals have a lot to learn from the private sector, the reverse is also true.

Keywords Supply chain management, Aid agencies, Flexible organizations, Modelling

Paper type Research paper

1. Introduction and research questions

One of the particularities of humanitarian logistics is the level of uncertainty they have to cope with. Every day, in many parts of the world, humanitarian workers are confronted

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with various forms of uncertainty. Given that beneficiaries' needs evolve over time and are really difficult to forecast, demand and supply vary on a daily basis. Also, there are many cause-and-effect interactions that affect operations. For example, an earthquake can provoke a flood if a brimming lake is formed by landslides from the earthquake. Local infrastructure may also be damaged to the extent that the supply chain network has to be continuously rethought, along with the reconstruction of roads, airports and other key elements of the network. Humanitarian logisticians have, therefore developed tools and methods to respond quickly to short-term changes, thereby improving the agility of their supply chain.

This high level of agility is more and more required in the private sector (Kleindorfer and Van Wassenhove, 2004). Many examples can be used to illustrate the low responsiveness of most commercial supply chains. After the earthquake in Taiwan in 1999, the prices of global semiconductor were almost doubled, and of the 62 companies based in Asia, only 21 percent had full business contingency plans to protect themselves against business interruption (World Economic Forum, 2008). Demand volatility is also becoming higher in the private sector. Owing to market turbulence, demand in almost every industrial sector seems to be more volatile than it used to be in the past (Christopher and Lee, 2004). Consequently, being able to react quickly to changes is an essential capability for commercial supply chains (Kisperska-Moron and Swierczek, 2009).

Cross-learning opportunities between business and humanitarian sectors have been listed by many authors (Van Wassenhove, 2006; Oloruntoba and Gray, 2006). Recently, disaster relief is becoming a testing ground for many researchers in logistics. More often, they propose methods for implementing in the humanitarian sector the tools that they initially designed for the business sector. Yet, to date, no work seems to have been done the other way round. In other words, no one has explicitly identified the best practices that the business sector can borrow and adapt from humanitarian experts. This paper aims to fill this gap in line with our belief that the business and humanitarian sectors can both learn from each other.

From an academic point of view, supply chain agility is becoming a major field of research. It is highlighted as one of the fundamental characteristics of the best supply chains (Lee, 2004). Given the complexity that is linked to a high level of constraints and uncertainty, the humanitarian sector is an interesting field to study. Moreover, they present a potential added value for both the humanitarian and the private sectors. It is very important for humanitarian organizations to explicitly establish the best practices found in relief chains, and by so doing, they clarify their achievements and facilitate the ramification of these best practices. The business sector could then learn from them in order to improve the agility level of their supply chain. It would enable them to deal with supply, demand and environment uncertainties, and this capability is becoming an order winner for many commercial supply chains.

Many supply chain managers are, therefore in search of methods that would enable them to better assess the level of agility of their supply chain. Unfortunately, in the literature, there is no unanimously accepted framework and consistent system for defining and measuring supply chain agility.

We can therefore formulate two research questions (RQ) as follows:

RQ1. How should supply chain agility be defined?

RQ2. How should supply chain agility be assessed?

Based on the review of literature, we will, in Section 2, address the *RQ1* and present our framework in the form of a house that we will refer to as the "house of supply chain agility". The *RQ2* will be studied in Section 3. By analyzing the capabilities of the major existing approaches, this study evaluates the different ways of assessing supply chain agility. A comparative analysis of the main features of both the humanitarian and the commercial supply chains is done in order to ensure that our assessment is valid for both sectors. An application of the model in the humanitarian sector is used to illustrate the logic of our approach. Finally, in Section 4, we will present our analysis, conclusions, limitations and perspectives for further research. Figure 1 shows a step by step view of our approach.

2. How should supply chain agility be defined?

In the last decade, agility has been one of the key concepts discussed by many authors. We have, therefore reviewed the literature in order to gather its various definitions and dimensions as it applies to supply chains. In this paper, we do not intend to provide an exhaustive literature review but simply a quick scan that is elaborate enough to enable clarify the notion of supply chain agility and to build a consistent assessment model. The conclusions of our literature review are presented in the following paragraph.

Supply chain agility is usually defined as the ability to respond to unanticipated changes (Sheffi, 2004). The focus on agility from the supply chain perspective emerged in the year 2001 and was first initiated by Van Hoek *et al.* (2001). According to Lee (2004), the main objectives of an agile supply chain are responding quickly to short-term changes in demand (or supply) and handling external disruptions smoothly. Sometimes agility could be mistaken for other similar but different concepts such as adaptability and resilience. While agility is being able to deal with and take advantage of uncertainty and volatility, adaptability is rather used for more profound medium-term changes. Adaptable supply chains adjust their design to meet structural shifts in markets and, modify and adapt the supply network to strategies, products and technologies (Lee, 2004). Figure 2 shows an illustrated difference between agility and adaptability. As for resilience, it aims to mitigate identifiable risks and ensure continuity in the firm's business. Christopher and Peck (2004) defined resilience as the ability of a system to return to its original state or move to a new and more desirable state after being disturbed. Differences between agility and resilience are depicted in Table I.

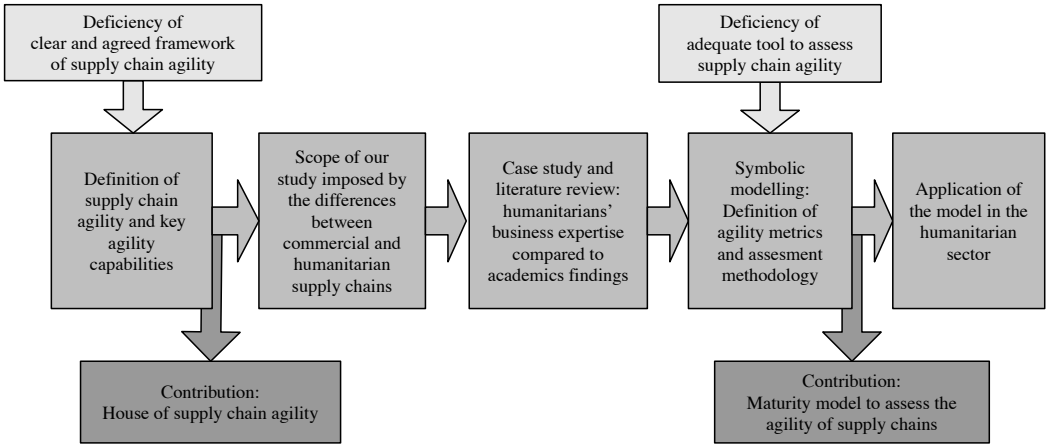
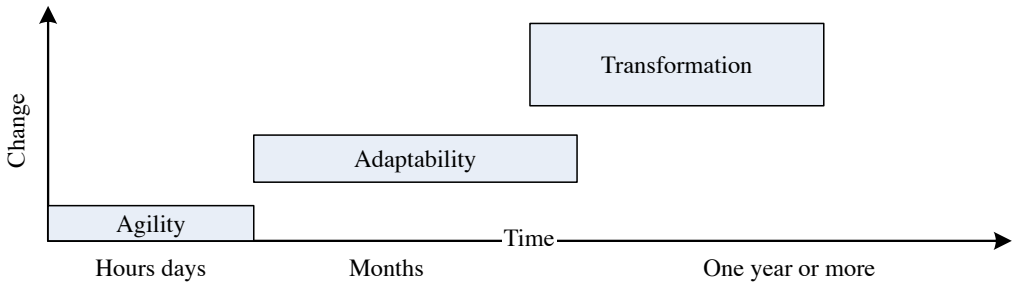


Figure 1.
Our approach step by step

To achieve a high level of agility, a supply chain has to acquire some key capabilities. Many authors have already listed one or more elements associated with agility. Table II shows the definitions and details of these capabilities. The aim of this section is to illustrate all the facets of agility that have to be worked on. The house of supply chain agility (Figure 3) summarizes the main components, which enable the supply chain to be agile. We developed it based on a thorough literature review on agility.

According to Christopher and Towill (2000), a key characteristic of an agile organization is flexibility. In other words, supply chain agility is an externally focused capability that is derived from flexibilities in the supply chain processes (Swafford *et al.*, 2006). They thus assert that "procurement/sourcing flexibility", "manufacturing flexibility" and "distribution/logistics flexibility positively impact supply chain agility". Manufacturing flexibility is broken down into four competences (machine, labor, material handling and routing flexibilities) and two capabilities (volume and mix flexibility) (Zhang *et al.*, 2003). Knowing that internal manufacturing flexibility competencies are neither relevant to our focus on supply chains nor appropriate for service providers such as humanitarians, we will restrict our study to capabilities as pertained to flexibility. We will, therefore adopt and study four flexibility capabilities (product, mix, volume and delivery flexibility) as they are defined and classified by Slack (2005), and summarized in Table II. There is abundant literature on the notion of agile manufacturing (Yusuf *et al.*, 1999; Sharifi and Zhang, 1999; Giachetti *et al.*, 2003).

Consequently, flexibility is a requirement that is necessary to achieve supply chain agility. It is, therefore represented as the foundation of the house of agility. Though a key component, it is not the only capability needed to achieve supply chain agility. Enhanced responsiveness is also a major capability of an agile supply chain (Stevenson and Spring, 2007). Two other key ingredients of agility are visibility and velocity (Christopher and Peck, 2004). A complementary capability is mentioned by Okongwu *et al.* (2008), for whom agility in a supply chain is the combination of effectiveness and responsiveness in a flexible environment. As shown in Table II, our framework will be organized in the following order and manner: flexibility is broken down into four capabilities



Source: McCullen *et al*. (2006)

Figure 2.
Agility vs adaptability

Supply chain ability	Structural properties	Deals with	Aims at
Agility	Flexibility	Volatility and uncertainty	Quick satisfaction of customer
Resilience	Robustness	Identifiable risk of disruption	Business continuity

Table I.
Agility vs resilience

Table II.
Supply chain agility capabilities: definitions and assessments

	Capabilities	Definitions	CSC	HSC
Flexibility Ability to change or react with little penalty in time, effort, cost or performance (De Toni and Tonchia, 2005)	Volume flexibility	Ability to change the level of aggregated output (Slack, 2005)	++	+++
	Delivery flexibility	Ability to change planned or assumed delivery dates (Slack, 2005)	+	+++
	Mix flexibility	Ability to change the range of products made or delivered within a given time period (Slack, 2005)	++	+++
	Product flexibility	Ability to introduce novel products, or to modify existing ones (Slack, 2005)	++	+
Responsiveness Ability to respond to change within an appropriate time frame (Golden and Powell, 2000)	Reactivity	Ability to evaluate and take needs into account quickly	+	+++
	Velocity	Ability to cover needs quickly	+	+++
	Visibility	Ability to know the identity, location and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/ times for these events (Vernon, 2008)	++	+
Effectiveness Doing all the right things	Reliability (doing the right thing)	Ability to deliver the correct product, to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct user (Supply Chain Council, 2006)	+++	++
	Completeness (doing all)	Ability to realize the goals	++	++

Notes: CSC – assessment for commercial supply chains; HSC – assessment for humanitarian supply chains

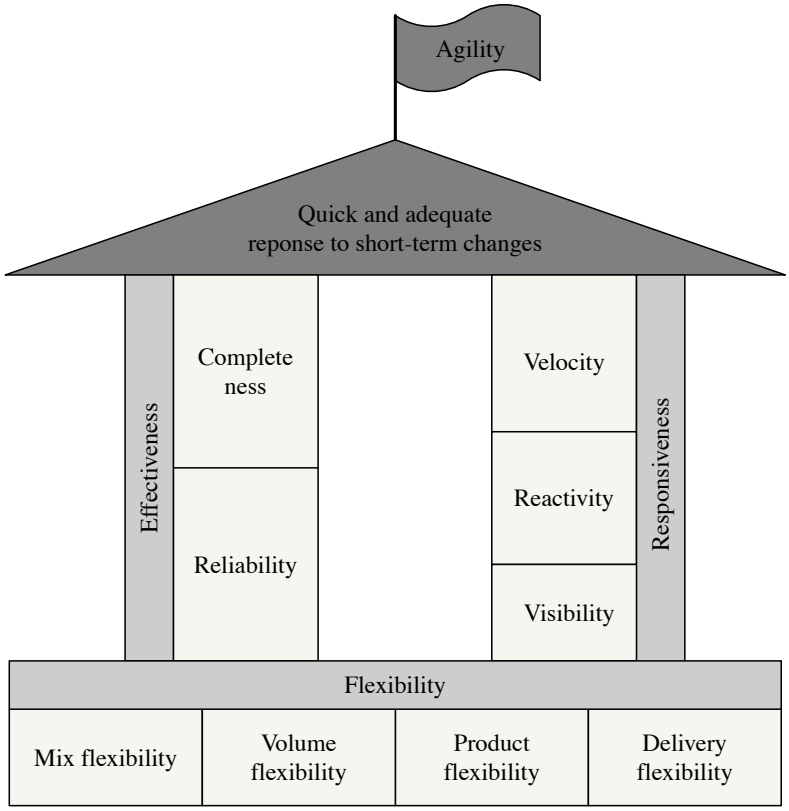


Figure 3.
House of supply chain agility

(volume, delivery, mix and product flexibilities), responsiveness into three capabilities (reactivity, velocity and visibility) and effectiveness is composed of completeness and reliability. All these enable to provide a quick and adequate response to short-term changes. The definitions of these capabilities are given in Table II.

Based on this discussion, we can define supply chain agility as the ability to respond quickly and adequately to short-term changes in demand, supply or the environment. It is derived from the flexibility, responsiveness and effectiveness of the supply chain.

3. How should supply chain agility be assessed?

If we presume that agility is the future business system that will replace the mass production businesses of today (Kidd, 1995), then it will be of prime importance to have a logical, consistent, robust and reproducible model that will be used to assess supply chain agility. This is true for the business, as well as for the humanitarian sector where a high level of agility is needed. The use of a model to assess supply chain agility should:

- emphasize the vital need of humanitarians for preparedness, and this would constitute an additional argument to motivate their donors to increase funds for disaster preparedness actions;
- provide supply chain managers with effective ways of collaborating with other stakeholders in order not only to enhance benchmarking and cross-organizational learning, but also to mutually improve the agility capabilities of their supply chains; and

- enable to measure performance, better manage skills and abilities and facilitate knowledge management, which constitutes a path toward self-improvement.

In this section, we will start by studying existing methods of assessing agility capabilities. Then, we will explain the reasons why we propose a benchmark for humanitarian supply chains and also discuss the consequences of this study of cross-organizational learning on the scope of our work. To carry out this benchmark, we have designed a case study. Indeed:

> [...] the case study method allows investigators to retain the holistic and meaningful characteristics of real life events such as individual life cycles, organizational and managerial processes, changes in the neighborhood, international relations and the maturation of industries (Yin, 2002).

This fits our purpose to assess the agility of supply chains. For this study, we gathered documents, archival records and 12 semi-directive interviews of practitioners working in various regions (Europe, Middle-East or Africa) and at different organizational levels (headquarters, regional logistics centers or field workers). This paper summarizes the evidence collected from the International Federation of the Red Cross (IFRC) and Red Crescent Societies, "Medecins Sans Frontières" (MSF) and the French Red Cross. Other organizations such as Oxfam and the World Food Program (WFP) were also approached but with more informal interviews.

Finally, we will present our model for assessing supply chain agility, its construction and its implementation using a real-life case study. To build the assessment model, we used a symbolic modeling approach. A symbolic model is a representation of the performance measure of a system in terms of its variables. This means that the attributes of the system are linked by an equation (Panneerselvam, 2004). In Section 2, we presented a list of attributes of supply chain agility and in Sections 3.3 we will present a list of metrics associated to these capabilities, as well as a consistent method to evaluate and aggregate them.

3.1 Existing approaches for assessing the capability level of a system

There are two main approaches for assessing the capability level of a system: maturity assessment and performance evaluation. We have looked at the capability maturity model (CMMI®) used for assessing the maturity level of organizations, the European Quality Award of the European Foundation for Quality Management (EFQM) used for auditing the quality competencies of companies and the supply chain operations reference (SCOR) model used for measuring the performance of supply chains. The EFQM model is not suitable for humanitarian organizations or for industrial sectors that are faced with frequent short-term changes. In both cases, the emphasis on strict procedures and their documentation may particularly go against agility. For these reasons, EFQM cannot be used in our specific case.

CMMI® cannot readily be used either. The design of a specific model for agility capabilities is necessary as CMMI® has more than 500 pages. This leaves little room for interpretation and makes it a time-consuming process, and therefore not usable in humanitarian organizations. Moreover, the emphasis on strict procedures and their documentation could lead to a bureaucratic behaviour. It also aims to have stabilized processes, which is not a fundamental characteristic of agile processes.

Supply chain performance measurement systems, such as the SCOR model, use a language of common metrics with associated benchmarks and provide a platform for best-in-class comparison and inspiration (Huan *et al.*, 2004). Some of the performance dimensions in the SCOR model are required to achieve supply chain agility but the model cannot be used to assess agility either, for it focuses on transactional efficiency rather than on the relationship with customers and suppliers (Lambert *et al.*, 2005).

Finally, we believe that our quest to define a specific model for assessing agility represents a real need that neither quality awards nor actual maturity models (or performance measurement systems) can satisfy. Our proposition follows a similar approach as maturity models but the assessment is done on performance dimensions rather than on the completeness of the process implementation. This is because first, stabilized processes are not a fundamental characteristic of agile processes and second, processes are only one of the various areas to work on. People, products and partners are also elements that impact the capability levels (Figure 4). Actually, to be able to react quickly and adequately to short-term changes, specific processes are needed, but these processes should be able to move quickly from one stabilized state to another. Having them stabilized may help, for example, in terms of visibility, but it is not enough to achieve agility.

3.2 Humanitarian supply chains: the experience of uncertainties

The notions of change and uncertainty that we have previously discussed are closely connected to that of agility. There are four sources of uncertainty: foreseeable uncertainties, residual risks ("what is left over after planning for foreseeable uncertainty"), complexities and unknown unknowns:

> [...] those that do not have a definite formulation, have no stopping rule that allows one to determine when the problem is solved, where solutions cannot be fully tested and the problem cannot be generalized, and where there is ambiguity on the causes of the problem (Loch *et al.*, 2006).

Agility would then mean to be able to respond quickly when confronted with any of these uncertainties. All these sources exist in the humanitarian world. There are many occasions where humanitarian supply chains have to develop their agility capabilities and they often do that successfully. One has to pay close attention to the elements that distinguish humanitarian supply chains from commercial supply chains in order to transfer the best practices of the former to the latter. Because of the differences, studies of the agility capabilities of humanitarian supply chains need to be filtered and adapted before they can be used in the business sector (Table III). First, our study will focus on the whole supply chain, except the manufacturing part, since it is irrelevant both from a humanitarian point of view and from an academic perspective (see Section 2).

The choice of adequate semantics also needs to be considered. Within humanitarian organizations, there is actually no consensus on the acceptance and the definition of the notion of customer. In a commercial supply chain, a customer pays for the product or service he uses. In the humanitarian world, the end-user (or beneficiary) is an entity different from the buyer or donor. Similar comments can be made upstream of the supply chain, where there are two kinds of suppliers: those who give products or money (donors), and those who are paid by the organization for the supply of the necessary items. Given these elements, we can, therefore say that the notion of supply chain (and hence the notion of supply chain agility) varies slightly from one sector to another.

Figure 4.
List of metrics

Metrics	Capabilities	Reference
Extent to which supplier lead time can be expedited/changed	Volume flexibility	Narasimhan and Das (1999)
Extent of exibility (options) within supplier contracts	Volume flexibility	Narasimhan and Das (1999)
Number of suppliers selected per component on a global basis	Volume flexibility	Kekre *et al*. (1995)
Number of components purchased per supplier	Volume flexibility	Kekre *et al*. (1995)
Range of possible order sizes from suppliers	Volume flexibility	Sethi and Sethi (1990)
Number of end users supported by each distribution facility, on average	Volume flexibility	Sethi and Sethi (1990)
Adequacy between world wide storage capacity and needs	Volume flexibility	Sethi and Sethi (1990)
Adequacy between global delivery capacity and needs	Volume flexibility	Sethi and Sethi (1990)
Number of items handled by each distribution facility, on average	Mix flexibility	Sethi and Sethi (1990)
Number of items per order handled by each distribution facility, on average	Mix flexibility	Sethi and Sethi (1990)
Number of world wide storage/distribution facilities	Delivery flexibility	Sethi and Sethi (1990)
Percentage of user orders filled from alternate global facilities	Delivery flexibility	Sethi and Sethi (1990)
Number of adequate available delivery modes	Delivery flexibility	Sethi and Sethi (1990)
Number of carriers used for each type of delivery mode, on average	Delivery flexibility	Sethi and Sethi (1990)
Delivery lead times	Delivery flexibility	Van Hoek *et al*. (2001)
Level of customization	Product flexibility	Van Hoek *et al*. (2001)
Intermediate user [and end user] involvement in writing products specifications	Reliability	Van Hoek *et al*. (2001)
Percentage of the demand fullled within acceptable time frame	Completeness	Okongwu *et al*. (2008)
Percentage of workforce in self-directed teams	Velocity	Van Hoek *et al*. (2001)
Number of organizational levels	Velocity	Van Hoek *et al*. (2001)
Authority level at which risks can be taken and decisions are made	Velocity	Van Hoek *et al*. (2001)
Presence/exhaustiveness of contingency plans	Velocity	
Number of emergency response teams	Velocity	
Frequency of intermediate [and end user] needs assessment	Reactivity	Kisperska-Moron *et al*. (2009)
Availability and diffusion of information regarding identity, location and status of entities transiting the supply chain (people, items, etc.)	Visibility	Van Hoek *et al*. (2001)

Notes: Process Partner People Product

	Commercial supply chain	Humanitarian supply chain	So what?
Supply chain range	From suppliers' supplier to customers' customer	From donors and suppliers to beneficiaries	Production of goods does not apply for humanitarians
Customer definition	End user = buyer	End user (beneficiary) ≠ buyer (donor)	Focus in this thesis is on end-users, not donors
Shelf life	Some years, but tends to shorten	Some weeks to some months in total, mounting and dismantling included Project oriented	Best practice transfer needs validation of relevance per business case, but it fits with the trend toward shorter life cycles of products
Information flow	Generally well structured	High importance of the media; means of communication often reduced (no internet access on field, etc.)	Visibility is more difficult to achieve for HSC
Human flows		People flows + knowledge transfer	
Financial flows	Bilateral and known	Unilateral (from donor to beneficiary) and uncertain	
Supplier	Only, known in advance generally, 2 or 3 on average	Supplier and/or donor uncertain and multiple	
Actors	Known, with aligned incentives	Multiplicity in nature, but scarcity in numbers + misaligned incentives	High level of uncertainty for HSC, so higher level of agility required. Best practice transfer needs validation of relevance per business case
Demand	Usually forecasted/known	Uncertainties	
Environment	More and more volatile	Highly volatile and unstable	

Table III.
Main differences between humanitarian and commercial supply chains

As a result, a clear statement on the scope of the study is required in order to clarify the other areas. In this paper, we focused on suppliers and end-users, but not on donors. We also did not consider the manufacturing part, thereby focusing on the elements that are common to most supply chains.

Another major difference lies in the lifecycle of each supply chain. Relief chains are project oriented. They have a short lifecycle and are set up in specific conditions, thus facing more uncertainties. They, therefore require a high level of agility. Not all commercial supply chains require such agility capabilities. Consequently, a preliminary assessment of the most appropriate level of agility for a given commercial supply chain is needed prior to any cross-learning implementation. Such a study may be inspired from Weber, who proposes a tool for measuring an organization's need for agility (Weber, 2002).

A last comparative element is the nature and size of flows in each supply chain. Regarding information flows, the role played by the media is incredibly high in humanitarian supply chains. It directly impacts the size and the complexity of the relief operations. With no media coverage, the number and commitment of donors,

and, therefore the number of items transiting the supply chain, tends to diminish. On the contrary, over exposition leads to over reaction of donors and this creates some imbalance between the amount of items received and the amount of resources available to manage them. Also, it often leads to a higher number of unsolicited items that get in the way of relief operations and hinder the actual delivery of aid. Moreover, local means of communication are often reduced at the end of a disaster; scarce internet access is an example. Visibility is, therefore much more difficult to achieve for humanitarian supply chains.

The next step in the development of our assessment model entails creating explicit humanitarian methods that enable to achieve supply chain agility. David Kaatrud, former Chief of Logistics for the United Nations WFP, explains that in comparison to the business sector, their:

> [...] operational settings are typically very different and difficult, and to get supplies to the most remote areas, we may have to resort to a range of imaginative and unconventional delivery systems, from air-dropping to using elephants for transport (Tomasini and Van Wassenhove, 2009).

They also developed specific tools to better monitor their supply chains and enable a quicker response to changes. The humanitarian logistics software (HLS), for example, enables the IFRC to increase its supply chain visibility. Similar logistics software, such as HELIOS, the second generation of HLS or SUpply MAnagement (SUMA) is in use or under deployment in other agencies, namely Oxfam and World Vision International for HELIOS and the World Health Organization for SUMA. Specific platforms for sharing information have also been developed. ReliefWeb, the web site of United Nations Joint Logistics Center or Humanitarian Information Centers allow various stakeholders to use the information given to build their knowledge of the situation and, with it, take effective action in the field (Tomasini and Van Wassenhove, 2005).

Short-term changes are thus humanitarians' daily routine. To cope with uncertainties, they have developed quite a good number of methods. Whereas most of them are widespread in many organizations, others are not so commonly used. To help humanitarians formalize those practices and enable the business sector to draw from them, we have designed and conducted a case study research as earlier explained. The methods used by the IFRC to quickly respond to changes are shown in the Appendix. A reference to the corresponding methods that are listed in the literature is added. It is inspired from Lee (2004), Van Hoek *et al.* (2001), Swafford *et al.* (2006) and Lin *et al.* (2006). Surprisingly (or perhaps not), majority of the methods found in the literature are applied in the humanitarian sector. Those that cannot be found have no application for humanitarian supply chains since they concern agile manufacturing.

3.3 Supply chain agility assessment model

As we mentioned earlier, humanitarian and commercial supply chains differ on many points. Therefore, for the transfer of best practices to be relevant, we need to focus on the agility metrics that are relevant for both supply chains. This leads to a fundamental question: how can agility capabilities be assessed in a consistent manner?

With reference to Section 2, the agility capability of a supply chain is measured by its reactivity to changes. Some agility metrics can be found in the literature (Van Hoek *et al.*, 2001; Slack, 2005; Okongwu *et al.*, 2008; Kekre *et al.*, 1995; Narasimhan and Das, 1999; Sethi and Sethi, 1990; Kisperska-Moron and Swierczek, 2009). Unfortunately, most of

the metrics listed are not relevant for humanitarians since they usually deal with the production of goods. We have thus refined the tables such as to list only agility indicators that are relevant for both sectors, hence dropping the metrics that are used to assess manufacturing agility (Figure 4).

From these metrics, an assessment of the agility capabilities of the supply chain has to be deduced. For this specific purpose, we used a symbolic modeling approach. The idea is to use the above metrics to measure each capability. They will enable to qualify the supply chain to a given level for each capability, using evaluation grids such as the one shown in Figure 5. As we can see in figure, supply chain agility metrics are linked by equations in order to enable a consistent assessment of each capability. Supply chain agility can then be deduced from the previous scores on the basis of the model shown in Figure 6. The method used to build these equations is similar to the one used to build the CMMI® maturity model: brainstorming and validation by practitioners. To conduct an overall assessment of supply chain agility, each capability (flexibility, responsiveness and effectiveness) has to be evaluated through its evaluation grid. Special care has been taken to keep it as robust and reproducible as possible.

To illustrate how to use the model, we conducted an assessment of the agility of IFRC's relief chain during its response to the 2006 Yogyakarta earthquake. The detailed scores of the responsiveness of IFRC's supply chain correspond to the darker cells in Figure 5. The overall assessment is summarized in the radar graph, as shown in Figure 7. On the 0-3 scale for the capability levels, we can see that IFRC scored 3 on velocity, 2 on reactivity and 1 on visibility. Indonesia being used to natural disasters, its National Society has developed contingency plans and the local delegation fosters a Regional Disaster Response Team, a trained team of experts with pre-prepared field equipment, including computers and telecommunications. These teams are deployed from the region and are, therefore more likely to point out local specificities and adequately evaluate the needs of beneficiaries. They helped increase reactivity. IFRC has also developed units to respond to specific needs, for example, IT and telecommunications, and referral hospital or logistics. Dispatching these units definitively contributed to increasing velocity and reactivity levels. Consequently, IFRC's velocity and reactivity levels are quite high. Regarding visibility, IFRC scored only 1 for this specific operation. Actually, following their decentralization process, they had a system in place to track the location and status of goods at the regional level. Since it was their first operation with such an organization, the information flow was not optimal. During the first days of the operation, there was no tracking system in place. They had parallel pipelines, which hindered visibility and reporting lines were not clearly defined.

3.4 Proceeding method of our model for assessing supply chain agility

The aim of the evaluation grid shown in Figure 5 is to assess the responsiveness of supply chains. Other similar tables have been built to assess the overall agility level. To make the best out of it, it should not be used without a method that should provide organizations with instructions on how to use it, as well as improvement paths that would enable to achieve higher levels in the grid. The assessment of supply chain agility starts with the preparation phase, where the person in charge of the audit selects the participants to be interviewed, selects and prepares the assessment team and develops the assessment plan. The second phase consists in conducting the assessment. To do this, interviews, records and documentation are used to gather relevant information and

Figure 5.
Utilization of the metrics to assess capabilities — supply chain responsiveness evaluation grid

		Score = 0	Score = 1	Score = 2	Score = 3
Velocity, 5 metrics	Percentage of work force in self directed teams	Less than 20% of workers are organized in teams	Between 20% and 60% of workers are organized in teams	Between 60 and 80 percent of workers are organized in teams	More than 80% of workers are organized in teams
	Number of organizational levels	More than 6 organizational levels	5 or 6 organizational levels	3 or 4 organizational levels	Less than 3 organizational levels
	Authority level at which risks can be taken and decisions are made	No authority at field level	Field workers have to wait for the person in charge of them to approve before acting	Signicant changes need approval from hierarchy	Worker can act if necessity is there
	Presence/exhaustiveness of contingency plans	No contingency plan exists	Presence of a contingency plan, but rough	Presence of a contingency plan, but not sufficiently detailed	Presence of an exhaustive contingency plan
	Number of emergency response teams	No emergency teams	Some emergency teams, but just enough to cope with less than 50% of uncertainties	Some emergency teams, but just enough to cope with 50 to 90% uncertainties	Enough emergency teams to cope with uncertainties
Assessment of supply chain velocity		$\left(\sum \begin{pmatrix} Scores \\ of\ above \\ metrics \end{pmatrix}\right) < 5$	$5 \leq \left(\sum \begin{pmatrix} Scores \\ of\ above \\ metrics \end{pmatrix}\right) < 10$	$10 \leq \left(\sum \begin{pmatrix} Scores \\ of\ above \\ metrics \end{pmatrix}\right) < 14$	$\left(\sum \begin{pmatrix} Scores \\ of\ above \\ metrics \end{pmatrix}\right) \geq 14$

		Score = 0	Score = 1	Score = 2	Score = 3
Velocity	Overall assessment of supply chain velocity, from previous table	Workers are individuals, having no authority to take risks	Atleast 20% of workers operate in self directed teams having mandate to deal with small size risks	Atleast 60% of workers operate in self directed teams having mandate to deal with medium size risks	Supply chain management is responsibility of teams
Reactivity	Frequency of intermediate and end user needs assessment	Neither intermediate nor end use needs are assessed	Intermediate user's need are assessed on a yearly basis. No assessment of end user needs	Intermediate user's need are assessed on a monthly basis. End user needs atleast once a year	Evaluation and assessment of all user needs is done on a weekly or daily basis
Visibility	Availability and diffusion of information on entities transiting the supply chain	No systematic capture of information	Information about people and products is captured, but not circulated	Information about people and products is captured, but only partially circulated	Supply chain is structured around information flow
Responsiveness	Overall assessment of supply chain responsiveness	$\sum \begin{pmatrix} Scores\ of \\ Velocity \\ Reactivity \\ Visibility \end{pmatrix} < 3$	$\sum \begin{pmatrix} Scores\ of \\ Velocity \\ Reactivity \\ Visibility \end{pmatrix} \geq 3$	$\begin{cases} Velocity\ level \geq 2 \\ Reactivity\ level \geq 2 \\ Visibility\ level \geq 1 \end{cases}$	$\begin{cases} Velocity\ level = 3 \\ Reactivity\ level = 3 \\ Visibility\ level \geq 2 \end{cases}$
		Supply chain is not able to respond to change with in an appropriate time frame	Supply chain is able to respond to some changes but not within an acceptable time frame	Supply chain is able to respond to most changes, usually within an acceptable time frame	Supply chain is able to respond to any change within an appropriate time frame

Note: Grey cells indicate IFRC level for the response to the 2006 Yogyakarta earthquake

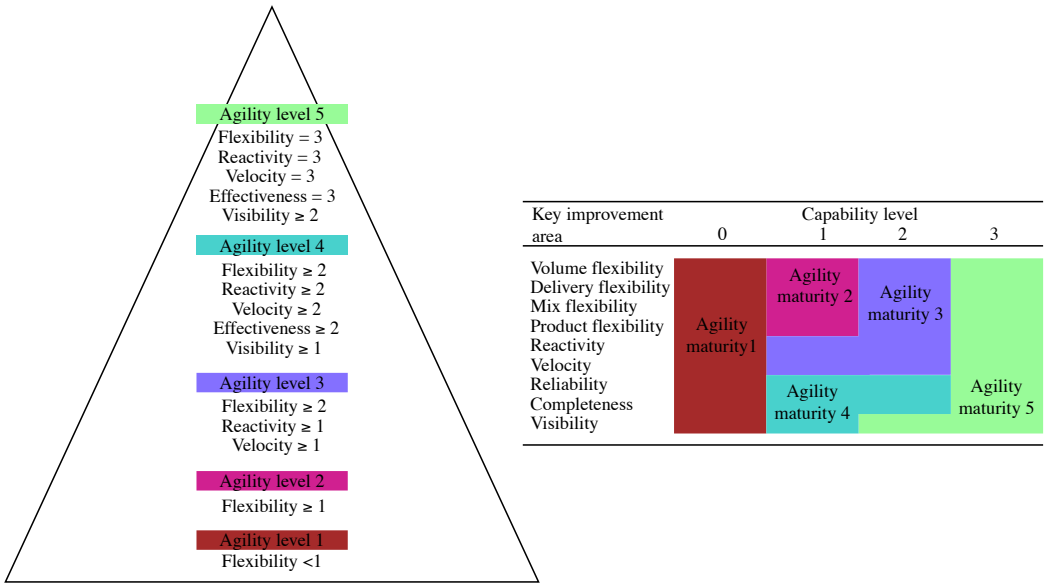


Figure 6.
Proceeding method and evaluation grid for supply chain agility

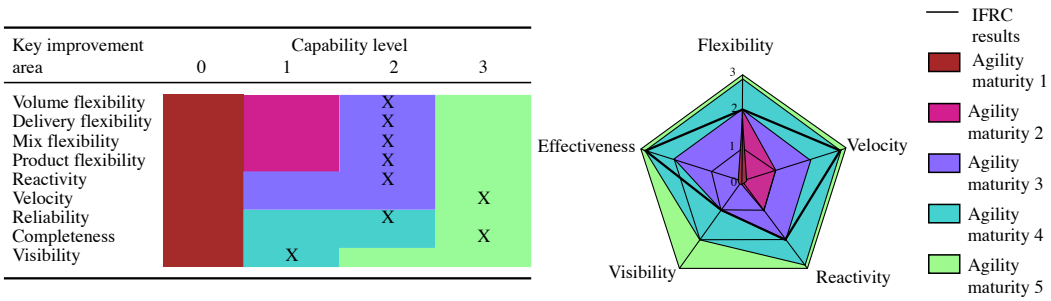


Figure 7.
Summarized results for IFRC supply chain in Yogyakarta in 2006

generate results. Once the results are validated, the final report can be delivered and documented. The final step consists then in developing the improvement plan, with the aim of achieving the desired levels for all capabilities.

To design the improvement plan, two options are open to the organization. Either it focuses on the capabilities with the lowest score or it focuses on sets of pre-defined capabilities depending on its current and desired agility level. The first option enables an organization to implement process improvement in different process areas at different rates. The capabilities that the organization want to focus on are evaluated independently using their specific evaluation grid, for example, Figure 5 for the assessment of responsiveness. The second option is shown in Figure 6. To use it, each capability has to be assessed with its evaluation grid. The results are then aggregated to qualify the supply chain to a given level of agility. There are five levels of overall agility (*ad hoc*, repeatable, defined, managed and optimized) and four levels for each capability that can be assessed thanks to the metrics defined in the previous section. A rough correspondence between agility maturity and capability levels is shown in Figure 6. The improvement path may be either increasing a given capability (depending on the organization's strategy) or increasing the overall agility level by targeting a given profile.

For example, an organization that has achieved a capability level of 2 on all dimensions (flexibility, reactivity and velocity) may want to increase its agility level by working on its reliability and completeness.

Let us now go back to our previous application – the IFRC solution to the 2006 Yogyakarta earthquake. Figure 7 shows the summarized results of this example.

As we can see in the figure, IFRC achieved capability levels of 2 for flexibility, reactivity and reliability, 3 for velocity and completeness and 1 for visibility. Consequently, its agility level is ranked 4 (managed) for this relief operation. A realistic improvement plan should first be discussed with the IFRC management team in order to validate the desired level. One recommendation that ensues from these results could be to start by improving the flexibility of the supply chain before improving reliability and finally visibility.

This is the first application of our model. Further research is underway to use this tool in other situations. In the case of project-oriented supply chains, as is the case for the humanitarian and some industrial sectors, the study can be carried out in two ways:

(1) For a single organization, assess the agility of the supply chain in multiple projects in order to evaluate the consistency, evolution, min, max and average level of their supply chain agility.

(2) For a given type of project, assess the agility of the supply chain of various organizations. For example, how well did various organizations perform during the 2009 hurricane season in the Caribbean?

Such a study will enable to identify best practices and gaps, first steps toward self-improvement and opportunities for the transfer of best practices.

4. Conclusion and perspectives

As we have shown is this paper, humanitarians have developed tools and methods to quickly respond to changes. Yet, especially in the humanitarian context, it is hard, if not impossible, to extensively develop some of the agility capabilities enumerated in Section 2. Total visibility, for example, is not easily achievable by humanitarians, for not only there is usually no single entity responsible for the whole supply chain, but also there are few systems in place to share information between all the actors of the end-to-end supply chain. On the other side, given the highly competitive and uncertain business environments in which they operate, commercial supply chains constantly search for new ways of developing their agility capabilities in order to improve their competitiveness and profitability. Thus, supply chain agility is a strategically important capability in many sectors, including the humanitarian.

The contributions of this paper are twofold. First, it provides a framework (represented in the form of a house of supply chain agility) that enables to understand the notion of supply chain agility. Second, it develops a model for assessing the agility of a supply chain. The expertise of humanitarians in the field of supply chain agility is used to suggest some systematic methods used to achieve a high level of agility. We also propose some metrics and a proceeding method that can be used to evaluate supply chain agility. All this will constitute a basis for future field research, with the aim of identifying and transferring best practices in supply chain agility. Further work to finalize the maturity model is in progress. This will be followed by field applications for various humanitarian relief operations as well as for some commercial supply chains.

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(The Appendix follows overleaf.)

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Aurelie Charles is a PhD student since 2007. Her research focus in on supply chain agility, and on the design of supply chains under high level of uncertainties regarding demand, supply and environment. She also has an industrial engineering background and worked in the chemical industry before joining both INSEAD as Visiting Researcher and the Université de Toulouse – Mines Albi as a PhD student. Aurelie Charles is the corresponding author and can be contacted at: aurelie.charles@mines-albi.fr

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Appendix

Table AI.
Capabilities of IFRC's supply chain, enabling them to develop their agility

Capability	Why	How	Corresponding methods found in literature
Volume flexibility	The amount of relief items/people sent in the field depends on donations, often unforeseeable. It also depends on needs, which are only known after the crisis and assessed in parallel with the setting up of the supply chain	Creation of the disaster response emergency fund and other buffer funds allowing to start responding before receiving donations Pre-training of teams of experts sent to field within 24 hour to assess needs Presence of regional stocks, with capacity to provide relief items within 48 hour to 40,000 families in total (stock capacity is adjusted per region)	Organize work force in self-directed teams (Van Hoek *et al.*, 2001) Adjust worldwide storage capacity (Swafford *et al.*, 2006)
Delivery flexibility	Little or no visibility on delivery planning, depending on the arrival of unsolicited in kind donations, etc.	Development of clear systems and procedures, job descriptions, etc. Creation of tailor-made software enabling pipeline time reduction and pipeline reports editions Assessment of all available delivery modes made by logistician team in the field	Alter delivery schedules to meet changing customer requirements (Swafford *et al.*, 2006) Change delivery modes when necessary (Swafford *et al.*, 2006)
Mix flexibility	Depending on the affected area and the nature of the crisis, many different products have to be handled	Standardization of as many emergency items as possible: emergency item catalog with specifications and references of all items, that might be of use (around 7,000 ref. for the IFRC) Creation of tailor-made software enabling the edition of mobilization tables, etc. for every crisis	Increase level of customization (Swafford *et al.*, 2006) Promote flow of information with suppliers and customers (Lee, 2004; Lin *et al.*, 2006)
Product flexibility	In kind donations may not correspond exactly to the specifications. New needs may arise, that require specific items to be delivered	Continuous work on an emergency item catalog to make sure specifications and references of all items are known in advance and up to date Experts trained at assessing the quality of products received by suppliers	Fast introduction of new products (Lin *et al.*, 2006)

(*continued*)

Capability	Why	How	Corresponding methods found in literature
Reactivity	Needs of beneficiaries evolve constantly	Experts in need identification and evaluation are present in many regions Pre-trained teams in field assessment are ready to deploy in case of emergency	Organize work force in self-directed teams (Van Hoek *et al.*, 2001) Draw up contingency plans and develop crisis management teams (Lee, 2004) Virtual integration (instantaneous demand capture, interpretation and response) (Van Hoek *et al.*, 2001) Facilitate rapid decision making (Lin *et al.*, 2006)
Velocity	Many tools and methods have been developed to accelerate the setting up of the supply chain and allow it to evolve with needs	Pre-positioning of emergency relief items Framework agreements with suppliers Development of tools enabling faster response in the field (mobile warehouses, teams of pre-trained experts with their specific materials (logistics, water and sanitation, telecoms, etc.))	Adjust worldwide storage capacity (Swafford *et al.*, 2006) Have a dependable logistics system or partner (Lee, 2004) Develop collaborative relationships with supplier (Lee, 2004; Lin *et al.*, 2006) Organize work force in self-directed teams (Van Hoek *et al.*, 2001) Facilitate rapid decision making (Lin *et al.*, 2006)
Visibility	The complexity of the environment makes it really difficult to have a clear vision of what stakeholders are doing	Creation of a tailor made software enabling a better monitoring of the response (HLS/HELIOS), a software to manage stocks (LOGIC), some balanced scorecards, etc.	Information accessible supply chain wide (Lin *et al.*, 2006)
Reliability	Delivering the adequate aid may be a question of life or death for the beneficiaries	Use of an emergency item catalog to make sure specifications and references of all items are known and validated by potential beneficiaries Products and kits are modified depending on the areas. (winter tents or just mosquito nets for shelter; medicines and clothes in agreement with local customs and laws, etc.)	Customer sensitivity (customer centered logistic policy) (Van Hoek *et al.*, 2001) Design for postponement (Lee, 2004)
Completeness	Basic needs not fulfilled may result in deaths	Keep track of number of families being assisted	Measurement (Van Hoek *et al.*, 2001)

Table AI.

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