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Towards Physical Internet Enabled Interconnected Humanitarian Logistics

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Abstract: *Based on core pillars of the Physical Internet (PI), this paper proposes a global interconnected humanitarian logistics system. By removing physical boundaries between the various actors, it aims to enable efficient interconnectivity of individuals, donors, contractors, suppliers, NGOs, international institutions, governments and beneficiaries. Moreover, it suggests a global humanitarian logistics web that is materialized in the evolution from the current private and limited logistics networks toward a more economically, socially, and environmentally sustainable and efficient global logistics system composed of multiple interconnected and open supply chains. As a result, access to global logistics networks becomes open to all actors in the humanitarian sector while allowing an endless variety of collaboration forms.*

The paper starts by an introductory perspective that explains the idea of completely revolutionizing humanitarian logistics. It then presents a broad literature review on the concept of PI and its core principles. It summarizes the current main humanitarian logistics practices and challenges, and repositions them through a PI conceptual framework. Expected results are underlined with a proposition of creating an interconnected humanitarian logistics system based on a PI conceptualization, suggesting the key components for its operationalization, including protocols, humanitarian informational platforms, and monitoring approaches while exposing scenarios of operating such humanitarian global logistics network.

Keywords: *Humanitarian logistics, Physical Internet, supply chain, disaster, crisis management, earthquake, NGO, relief network, green logistics, interconnected systems, Sustainability.*

1 Introduction

In regard to the challenging context of humanitarian crises, this paper explores the idea of using the Physical Internet (PI) to radically change the way humanitarian operations are conducted at the global level. PI stems from the general assertion that the way physical objects are currently transported, handled, stored, realized, supplied and used throughout the world is unsustainable

both economically, environmentally and socially (Montreuil, 2011). PI's premise applies both to private, public, for-profit and not-for-profit businesses.

This paper explores the perspective of PI in the context of the humanitarian relief, particularly with the goal of harmoniously and efficiently interconnecting all actors, already involved or potential, in addressing humanitarian needs, and notably crisis emergencies, at the global level. Accordingly, referring to the fundamental assertion underlying the need for PI, the current research adopts the following statement: The way the coordination of activities to design, produce, handle, transport, store, supply and use physical objects in the humanitarian field is neither efficient nor sustainable both economically, socially, and environmentally.

In the current humanitarian context, actors are mainly comprised of not-for-profit organizations, namely NGOs and international institutions (De Torrenté, 2013; Yao-Jen et al., 2010), such as the United Nations and its sub-entities, which are not fully taking advantage of all opportunities to collaborate with actors in the private sector for various reasons ranging from a lack of openness in the system to issues of ethics and conflicts of interest.

This paper explores the perspective of using Physical Internet as a means to achieve globally more efficient humanitarian logistics while ensuring sustainability. Thus, it aims at making more efficient and sustainable the conception, design, production, movement, storage, supply, construction, and use of physical objects in the humanitarian sector by proposing a global Humanitarian Logistics Web based on PI's dynamic framework. It presents a proposition of using the PI framework as a way out for the humanitarian sector's recurrent challenges and inefficiencies.

How this work began lies deeply to a scientific desire and curiosity to discover the various potentials of the Physical Internet vision to transform the way business activities are being conducted. In fact, from the start, this idea of exploring the humanitarian sector based on a PI approach was suggested by Professor Benoit Montreuil who came out with a project during the course "GSO-8008, Paradigms of Value Creation Network Management" in the winter semester of 2011. Accordingly, the work stared in January 2011 and continued though the year and until now with the main results being exposed through the current paper. The project required weekly meetings of nine researchers that were discussing every dimension of, on one hand, the humanitarian sector and the way it operates and, on the other hand, the concept of Physical Internet and how it could be translated into an operational tool for better coordinated and effective humanitarian assistance, rescuing or relief operations on a global and systemic perspective. So, after several meetings during which broad and deep discussions on the two key parts of the project's idea, namely the humanitarian and PI, in-depth literature reviews where conducted to better understand the current practices in the humanitarian sectors by identifying its strengths, weaknesses and challenges ahead while paying attention to the potential zone where a PI approach may bring radical improvements. The main objective is to transpose the generic model of Physical Internet to the field of humanitarian logistics.

The paper is divided into four parts. The first section starts by an introductory perspective that explains the idea of completely revolutionizing the humanitarian logistics. The second section presents a broad literature review on the concept of PI and its core principles. The third section then summarizes the current main humanitarian logistics practices and challenges and finally repositions them through a PI conceptual framework. Fourth is introduced the proposition of

creating an interconnected humanitarian logistics system based on a PI conceptualization while suggesting the key components for its operationalization, including protocols, humanitarian informational platforms, and monitoring approaches, and then exposing the scenarios of operating such humanitarian global logistics network. Fifth are synthesized conclusive remarks and avenues for further research.

2 Physical Internet

Montreuil et al. (2013) defined the Physical Internet (PI, π) as an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols. The Physical Internet aims to enable the global efficiency and sustainability of physical object mobility (transportation, handling), storage, realization (production, assembly, finishing, refurbishing and recycling), supply and usage (Montreuil, 2011). Economically, the Physical Internet aims to unlock highly significant gains in global logistics, production, transportation and business productivity. Environmentally, it is to create a more sustainable global environment with significant reduction in energy and pollution induced by logistics, production and transportation. Along the societal dimension, it aims to significantly lead towards the improvement of the quality of life of the logistic, production and transportation actors, and of the overall population by increasing the accessibility to objects and their functionality across the world. Accordingly, the vision of this new paradigm shift is to evolve, through a metaphor of Digital Internet, towards a PI momentum to address the grand challenge towards global logistics sustainability that the world is currently facing. These underlined core principles and potentials of PI can be transposed into various economic and social sectors such as the humanitarian domain.

Three key types of physical elements enabling the Physical Internet are the containers, the nodes and the movers (which are respectively named π-containers, π-nodes and π-movers to emphasize that they are designed for the Physical Internet), as described in Figure 1 sourced from Montreuil et al. (2010).

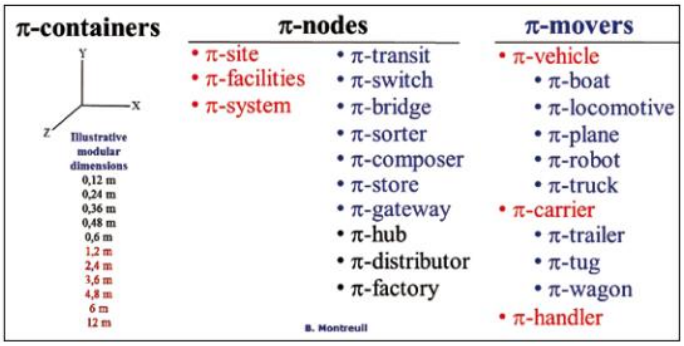

Figure 1: Key types of Physical Internet elements,
by Montreuil et al. (2012)

Containers are the fundamental unit loads that are moved, handled and stored in the Physical Internet. Physical Internet Containers come in modular dimensions. The nodes correspond to the sites, facilities, and physical systems of the Physical Internet. The movers transport convey or

handle containers within and between nodes of the Physical Internet. They also come in a variety of types, as highlighted in the figure above.

Based on its interconnectivity principle, the Physical Internet, as suggested by Montreuil et al. (2013), encapsulates physical objects in physical packets or containers named π-containers so as to differentiate them from current containers. In the context of humanitarian logistics, containers are hereafter fully named as humanitarian π-containers and nicknamed as *blue containers*. They are world-standard, smart, green and modular containers which in the perspective of this paper are seen as smart containers that are modularized and standardized worldwide in terms of dimensions, functions and fixtures and adapted to all humanitarian purposes such as being easily transformed and used as tents, dormitories or beds. In fact, currently the idea of smart containers is completely absent in humanitarian logistics.

Based on the core vision of the Physical Internet, this new humanitarian perspective states the need for fundamental changes towards better humanitarian logistics amongst which the encapsulation of donations in world-standard humanitarian smart green modular π-containers. Thus, the humanitarian Physical Internet (called hereafter HPI) perspective underlines the necessity to adapt key functional characteristics of blue containers by unitizing humanitarian donations as their content so that this content is not dealt with explicitly by the Physical Internet. Also, blue containers have to be designed in various modular sizes, from the cargo container sizes down to tiny sizes while ensuring the easiness to flow through various humanitarian transport, handling and storage modes and means.

Table 1: Key enabling changes towards Interconnected Humanitarian Logistics

Interconnected Humanitarian Logistics **Key enabling changes aligned with the Physical Internet**
Pursuing universal humanitarian interconnectivity
Embracing a unified humanitarian multi-tier conceptual framework
Activating and exploit an open global Humanitarian Logistics Web
Exploiting smart networked humanitarian containers embedding smart objects
Designing products fitting humanitarian containers with minimal space waste
Evolving from material to humanitarian π-container handling and storage systems
Evolving from point-to-point hub-and-spoke transport to distributed humanitarian multi-segment intermodal transport
Minimizing physical moves and storages by digitally transmitting knowledge and materializing objects as locally as possible
Deploying open performance monitoring and capability humanitarian certifications
Prioritizing webbed reliability and resilience of networks in humanitarian operations
Stimulating humanitarian business model innovation
Enabling open infrastructural innovation in the humanitarian sector

Moreover, the proposed humanitarian, smart, green and modular π-containers will be easy to handle, store, transport, seal, clench, interlock, load, unload, construct, dismantle, panel, compose and decompose and are tag-enabled with sensors to allow their proper humanitarian identification, routing and maintaining. This proposition considers that the blue containers be made of environmentally friendly materials, with minimal off-service footprint by minimizing packaging materials requirements through the enabling of fixture-based protection and stabilization of their embedded humanitarian products. Containers may also come in various usage-adapted structural grades with safe conditioning capabilities and in sealable structures for safety purposes.

Beside all these technical changes, to enable interconnected humanitarian logistics, there are several crucial innovations needed and which are essential for establishing PI-inspired interconnected humanitarian logistics. The most important are presented in Table 1. Section 4 is to elaborate on multiple facets of the evolution towards the interconnected humanitarian vision.

Now that the key components and premises of Physical Internet have been exposed, the next section presents current challenges of the humanitarian sector in line with its potentials towards enabled interconnected humanitarian logistics.

3 Humanitarian Logistics Challenges

The humanitarian sector encounters several challenges among which the lack of coordination among stakeholders (Stephenson, 2005), the difficulty of access for new players (Macalister-Smith, 1991), the lack of strategic location and the under-utilization of potential storage (Duran et al., 2011), the inefficient transport of products to crisis areas (Saetti and Cauët, 2008), the limited supply network (Balcik et al., 2010), the inadequate identification, management and delivery of donations to beneficiaries (Stapleton et al. 2010), and finally the neglect of environmental impact in humanitarian actions (Eng-Larsson and Vega, 2010).

All these challenges make humanitarian operations often inefficient in terms of response time and resource consumption, thus resulting in fundamental logistics problems when addressing humanitarian crises. This paper is based on the fact that currently, the way that the design, production, handling, transportation, storage, supply and use of physical objects in the humanitarian field is neither efficient nor socially, economically, and environmentally sustainable. Many humanitarian areas need improvement as well as a rethought approach to tackle major challenges.

3.1 Inefficient Transportation and Delivery of Products to Crisis Areas

Amongst the various humanitarian transportation problems, many appear to be very common in emergency operations, such as impracticable roads. In fact, regarding humanitarian logistical planning, organizations such as the United Nations stated, at the time of the Haiti earthquake crisis for instance, that a major issue to be immediately solved would certainly be transportation and roads. Indeed, most of the problems that existed before and after the earthquake are largely due to poor roads and ineffective transportation as illustrated by the image of Figure 2.

Figure 2: Haitian road after the earthquake
Source: http://interactive.wxxi.org/files/images/highlights/nou_bouke.jpg

In fact, often, crisis areas are not accessible and vehicles have difficulty to access rural areas during humanitarian emergencies. Thus, it is a good idea to create customized transport systems and vehicles dedicated to humanitarian aid in delicate areas. Moreover, the state of receiving zones is critical in emergency operations. It is necessary to perform a quick check of sites where the goods are received to identify all scenarios that may affect their arrival and receiving.

For example, in Indonesia, to manage the December 26, 2004 tsunami around Banda Aceh, some NGOs used satellite images to administer first aid logistics, which helped to better assess the state of accessibility of different areas (Saetti and Cau ët, 2008). An illustration of such cases is clearly visible in the map of Figure 3 that shows the damaged areas in and around Port-au-Prince after the Haitian earthquake disaster. Such problems could compromise any logistical humanitarian aid effort. For instance, in the case of the 2010 Haiti earthquake, aircrafts could not land at the airport in Port-au-Prince due to damaged airstrip. The map of Figure 3 says it all, through its high number of red points symbolizing difficult or even inaccessible crisis areas at the time.

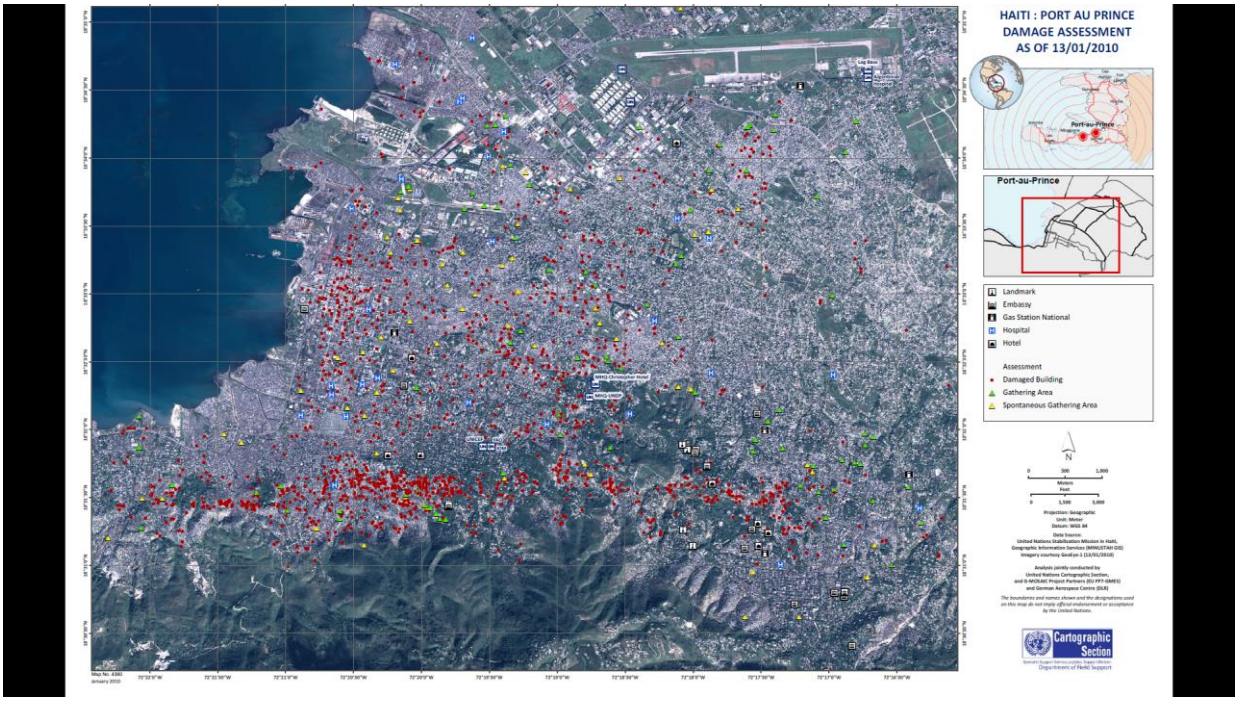

Figure 3: View of Port-au-Prince after the earthquake disaster
Source: UN Department of Field Support, Cartographic Section, 2010

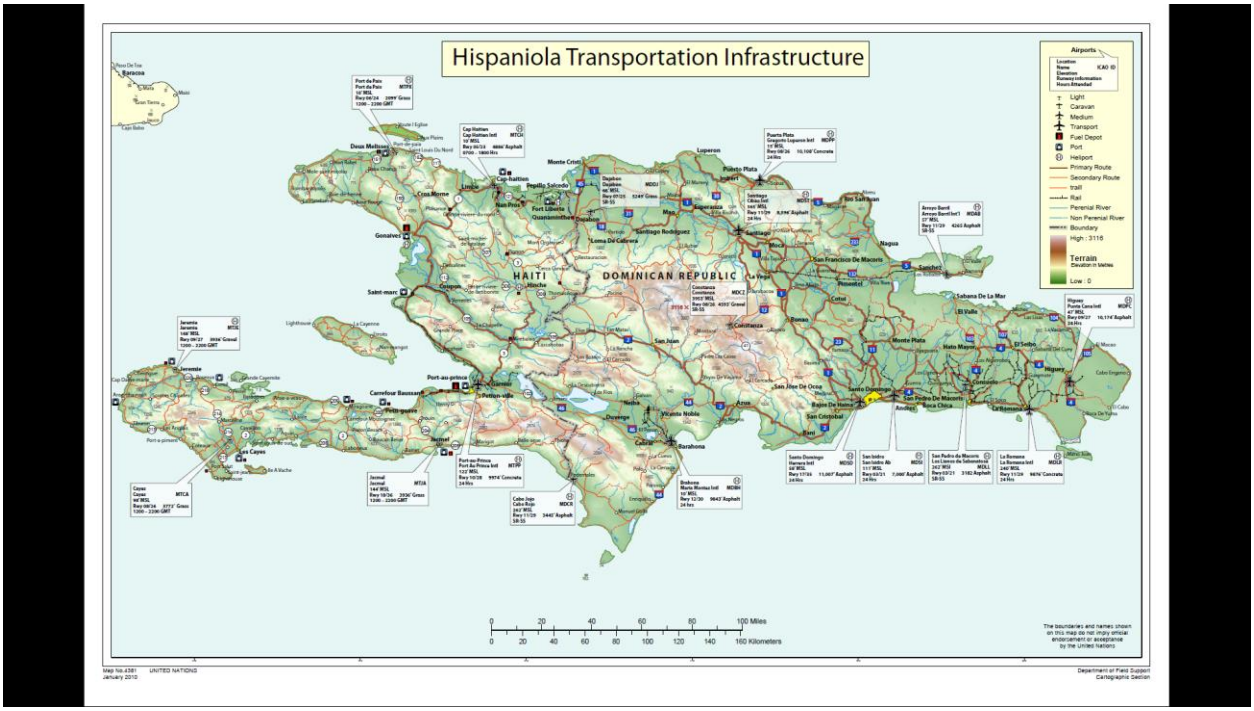

Figure 4: Dominican Republic and Haitian maps
Source: UN Department of Field Support, Cartographic Section, 2010

Other significant challenges include the unavailability of transportation while large quantity of products needs to be transported. Also, according to Thomas and William (2002), disaster response time is crucial for the arrival of donations on site. Thus, it has to be extremely quick in order to send humanitarian goods on time by identifying the most convenient roads. Finally, the choice of route and mode of transport is crucial for effective humanitarian operations. Indeed, the choice of mode of transport (air, water, rail or road) depends on a number of parameters such as needs and opportunities. For instance, in the case of the Haiti earthquake, the first days after the disaster, large aircrafts could not land on the runway. It was therefore necessary that their content be transferred to smaller aircrafts from the Dominican Republic airport to the Haitian airport (see the map of Figure 4). In fact, during the following weeks, the saturation of the airport caused subsequent major problems leading the European Commission Unit of Civil Protection to state that, on January 25, there were 7-day delay for arriving flights and 1,000 aircraft awaiting.

Amongst many other challenges, there is the recurrent weakness related to an incorrect estimation of transportation when sending humanitarian products, caused by poor demand estimation of humanitarian goods in crisis areas. Besides, there is the problem of mismanagement during the transport of humanitarian goods because even if means of transport are widely available, humanitarian goods fail to reach crisis areas on time. Also, the high cost of transportation and resource management a big issue due to the non-optimality of moved products via roads. Finally, the distribution of humanitarian goods is neither egalitarian nor controlled, thus creating the need to ensure that humanitarian donations are in good hands. In fact, humanitarian products are always expected to end up meeting the needs of affected zones and their people. The image of Figure 5 shows an operation of humanitarian donations distribution in a Haitian crisis area.

Figure 5: Residents at a Haiti camp for displaced persons getting bleach and water purification tablets from a helicopter
Source: UN MINUSTAH, Logan Abassi, 2010

Challenges of transporting humanitarian aid also lie in deciding the right modes of transportation and in optimizing routes based on the existing infrastructure and the state of the crisis areas. So, in order to ensure a better coordinated humanitarian logistical system, many improvements are needed in the transportation of products, gifts and services to areas of humanitarian crises in order to meet as quickly as possible the needs of victims. Also, innovation in transportation and delivery of humanitarian supplies to crisis areas has to be rethought. Finally, innovation in blue containers used to store humanitarian goods needs equally to be greatly improved by drawing on industrial logistics (refer to section 2), and in this sense, the use of Less-Than-Truckload transport systems could be effective.

3.2 Inadequate Product Deployment and Under-Utilization of Potential Storage Centers

Many challenges related to humanitarian logistics are related to the lack of strategic locations and the under-utilization of potential warehouses, preventing the rapid deployment of humanitarian aid (Duran et al., 2011).

In situations of humanitarian crises, the main issue is the urgency to save victims of natural, technological/industrial disaster or armed conflict or other natural/anthropogenic events that affect a given population. Often, victims live in poverty and have various urgent basic needs including water, food, clothing, health care, pharmaceuticals, blankets, tents, and lighting. Under these circumstances of extreme urgency, humanitarian organizations and non-governmental organizations use all necessary means to assist affected populations through structured logistics (procurement, transport, storage, and distribution of products/goods). Besides, warehouse inventories are additional key elements. There is an insufficiency of warehouse diversity with regards to humanitarian needs, yet addressing it is weakened by the under-utilization of warehouses (Natsios, 1995). There is a need of more suitable warehouses in order to protect humanitarian products until their distribution. In the current state of humanitarian logistics, there are three categories of warehouses that are often grouped into a single warehouse often due to a lack of space.

- General shipping warehouses: Goods are stored for an indefinite period of time, or awaiting to be sent to the field or in a secondary warehouse. These warehouses are usually located in the capitals or central points called centroids;
- Slow-rotation warehouses: Occasionally used; where non-urgent items such as spare parts, equipment or tools are stored;
- Fast-turnover warehouses: shipping warehouses where daily or frequent shipping of products are stored.

Though little choices are available to NGOs about the storage places during emergencies, the following factors should also be considered:

- Type of stored products: it takes, for example, fresh, dry and ventilated warehouses for drugs and foods, while taking into consideration that some types of products cannot be mixed;
- Convenience of location: while ensuring sufficient space for storage, warehouses have to be easily accessible for transport;
- Adequate safety rules: the right security of the warehouse has to be considered while insuring its good functional condition and its standards of external security. The natural

and social environments (opportunities, floods, landslides, armed militias based nearby, etc.) should also be considered.

Furthermore, the time constraint is an important factor in storing the products as it could be a major obstacle for NGOs. Furthermore, given the urgency of victims' needs and the pressure of public opinion, vigilance about the expiry date of the products is crucial to avoid waste. Additionally, improper storage, too many gauges or inadequate transportation could degrade humanitarian products (Saetti and Cau et, 2008).

Thus, the main challenge remains to adequately meet the needs induced by various humanitarian crises. Accordingly, advantages in using the warehouses of private companies around the world are real. The Physical Internet perspective of interconnected humanitarian logistics takes into account the location of any warehouse that may contribute to the rapid deployment of humanitarian aid. A decentralized and fluid humanitarian supply chain is fundamental for the effective and timely delivery of products (Gatignon et al., 2010). Also, in case of insufficient structures, the possibility to create temporary warehouses for rapid deployment of humanitarian aid is appropriate and should be considered.

3.3 Limited Supply Networks for Humanitarian Products

Van and Martinez (2012) showed that by using operational research to adapt supply chain best practices to humanitarian logistics, significant improvements can be achieved in addressing crises.

The main issue is that humanitarian products fail to reach destinations in a timely manner, while available products nearby are not taken as an advantage to quickly and efficiently reach the victim's needs (Balcik et al., 2010). In the current context, the international humanitarian system is based on the idea of providing goods and services to people and communities affected by disasters and conflicts across all sectors of humanitarian assistance, including health, water and sanitation, shelter and camp management, food and nutrition, agriculture, logistics, and telecommunications.

Various products have been introduced to improve humanitarian responses in situation of disaster-affected populations. For instance, in the 80s the "famine biscuit" was developed by Oxfam in collaboration with a candy company. As challenges are diverse, if the organization decides to purchase, it can create local constraints as quality and quantity are not always guaranteed. This can create a competition between organizations for the purchase of a product, making sure that the products are not available in the local market. This can cause price inflation, which can further impoverish local communities. Also the purchase of products by local NGOs can lead to a lack of supply of the normal local market. Conversely, if NGOs decide to import the product, it may cause an increase in delivery times and transportation costs, and demonstrates a lack of support for the local economy. In addition, foreign products may not be adapted to local needs.

Companies do not always have to think of physical assets when looking for ways to provide assistance during humanitarian relief efforts. There are a range of trade logistics processes and products that can be used to make a significant difference on the ground often, by simply adapting existing tools. For instance, UPS has developed its profit track pad technology, a

system commonly used to track packages in offices, to contribute to organizational relief efforts during Hurricane Katrina, the Haiti earthquake, and the oil spill in the Gulf. In Haiti, the technology has been used to manage the distribution of food to families in need. Replacing paper forms used by the Army by hi-tech barcodes to confirm what each family has received, the number of families, their location in the camp and their needs. This system has helped to ensure that all families receive supplies at the right time, and to reduce theft and fraud, while freeing up volunteers for other tasks.

Product innovations derived directly from the R & D specialist sectors allow aid workers access to new approaches which then influences the way work is undertaken. However, there may be a tendency to focus on basic product innovation, which in some cases may be harmful. In the area of management of camps, NGOs have a multitude of tent styles. Many of them are based on the idea that a single product can operate in all environments. Aid agencies have tended to focus on the delivery of tents with incremental innovations. This product-based view can lead to inappropriate innovations. A different approach to innovation can be a part of the answer to address the problems of supply. Bringing local knowledge in selecting products for a crisis may be crucial in contextualizing the delivery of aid.

Following the development context of the problem of supply and services in humanitarian crisis networks, these key issues are therefore identified: the existence of a range of trade logistics processes and products that can be used to make a significant difference on the ground; the necessity not to focus only on basic incremental innovations; and the urgency to leverage local knowledge and networks in the products choice and supply.

3.4 Inadequate Identification, Management and Delivery of Donations

Humanitarian product management is a bottleneck that can have serious impact on the effectiveness of aid delivery. To illustrate the negative impact of inappropriate donations, consider the case of the World Food Programme (WFP) in response to the food crisis in Eastern Africa in 2002. This case illustrates the complexities in humanitarian supply chain that can be caused by donations. When donations reached the area in response to food shortages, corns delivered in Zambia had traces of genetically modified organisms (GMOs). The Zambian government immediately denied the corn. Thus, WFP had to purchase local corn. This example demonstrates the cost, time and resources that can be mobilized in the event of mismanagement of donations.

Although essential, donations are often poorly managed and can impede the proper functioning of a humanitarian intervention. For example, donations occur frequently without request, and often do not meet the needs. If they are under-used or not used at all, it translates into waste of time and resources. In addition, from an ethical point of view and the image of the organization, the donations are often difficult to refuse. Finally, the response of individuals and businesses during a crisis with respect to donations cannot be guaranteed. In 2005, donations to the tsunami were funded at 475 % while the crisis in Djibouti was funded at only 39% (International Federation of Red Cross, 2006).

Partnerships, volunteerism, product, and cash are the four major categories of donations identified:

1. Donations in nature may meet the specific requirements provided by humanitarian organizations through public calls. Donors should consider the costs associated with shipping and handling. To ensure the highest level of effectiveness, donors should ensure that the goods are delivered to the recipient in a timely manner and in the right place so they can be easily used as intended by humanitarian agencies. During the 2004 tsunami, given the large amount of donations in nature from the private sector, NGOs were overwhelmed and were unable to take advantage of non-monetary gifts because they do not have the appropriate staff.
2. Donations in cash: Here the presence or absence of media determines humanitarian organizations' ability to raise funds for the less publicized disasters.
3. Resources in the form of volunteering are also possible forms of corporate contributions for disaster relief operations. They can provide technical assistance to support local knowledge. However, unless well managed, they can be detrimental to the operation.
4. Partnerships, as a donation, require a long-term commitment of both parties. Considering all the work needed to create partnerships, it is necessary to do it before the disaster arises. According to a report from the United Nations (2005), humanitarian partnership takes 12 to 18 months in general to be achieved.

3.5 Lack of Coordination among Humanitarian Stakeholders

Coordination appears to be the biggest issue slowing down the effectiveness of humanitarian actions (Stephenson, 2005). Coordination refers to the sum of various relationships and interactions between different actors operating in the framework of a joint action (Balcik et al., 2010). Here, coordination takes place in humanitarian activities. The literature in the humanitarian field uses the idea of horizontal and vertical coordination to define the concept of coordination, which is perceived to be interchangeable with the notion of collaboration (Russell, 2005). On one hand, vertical coordination is reflected in the sum of relationships and interactions between, for example, traditional NGOs and a transportation company. On the other hand, the same amount of interactions between various NGOs involved in the same humanitarian crisis is seen as a horizontal coordination.

Three levels of commitment in humanitarian actions can be specified: (a) strategic or long-term commitment, (b) tactical or medium term commitment and (c) operational or short term commitment. Here, coordination is considered as the sum of interactions at all levels of commitment. According to a finding from Stephenson (2005), humanitarian actors operate in an environment that does not globally emphasize coordination. Several factors were identified as determinant of successful planning and coordination. Table 2 highlights key influential dimensions.

Moreover, the nature of donations, expectations of donors and the availability of information are additional factors that may increase difficulties in the coordination of humanitarian actions. Above all, there is no regulation in the coordination of activities between various actors in the sector of humanitarian aid. This major weakness results in undefined specific roles of actors leading to uncoordinated actions that are causing serious problems such as resources waste or misuse, delays in the humanitarian chain, inefficient and ineffective actions when addressing humanitarian crises.

Table 2: Factors affecting the success of planning and coordination in humanitarian logistics

Number and diversity of actors	*The high number of players and diversity in cultural, geographical and procedural terms tend to create additional barriers in terms of communication. Furthermore, the operational environment of a humanitarian crisis does not have a strict regulation which ensures that roles of each stakeholder are clearly defined (Seaman, 1999);*
Competition for money and the effects of media	*The competition for money is at the highest level in the first two phases of the humanitarian crisis where the donations given to players as well as the attention of the global media are at their peak. This leads participants not to share strategic competitive information thus creating problems in terms of coordination (Stephenson, 2005);*
Use of different methods of coordination due to iterative phases of operation	*The way preparation, immediate response and rehabilitation activities are coordinated in deploying humanitarian aid is different at each step. Amongst others, the problem lies in the lock during the preparation phase which leads to a subsequent lock through all the logistic chain (Seaman, 1999). This is why the vision of coordination in delivering humanitarian aid needs to be configured in a unique, systemic, efficient, and sustainable design;*
Volatile shortages and surpluses of resources	*Scarcity and surplus of resources can consume efforts and various logistical resources that affect coordination (Gatignon et al., 2010). The case of the 2004 Tsunami where a third of the containers remained blocked at customs airports five months after the event was illustrative;*
Costs of coordination	*Coordination activity involves costs such as staff salaries, mission fees, and travel expenses. For smaller players in humanitarian aid, reduced financial capacity does not allow them to neither allocate sufficient working force nor undertake effective actions during the deployment of humanitarian aid (McCoy and Brandeau, 2011);*
Unpredictability of humanitarian crises and scenarios	*Usually, neither humanitarian crises nor their intensity, location or time are known in advance. Moreover, forecasting the state of infrastructure regarding transport or communications in a potential humanitarian area is challenging (Charles and Lauras, 2011). This makes coordination mechanisms difficult to determine in advance thus affecting the efficiency of humanitarian actions;*
Lack of standardization of products and supply chains	*The characteristics of supply chains are always associated with the type of humanitarian crisis and the actors involved (Heigh and Jahre, 2010). Accordingly, organizational and situational differences from the preparation phase to the rehabilitation phase make coordination difficult particularly regarding the supply chain especially when the concept differs from one organization to another;*

Taking the example of Haiti where the government has been overwhelmed by the scale of the humanitarian crisis and where the role of coordination was assigned to the United Nations, a major challenge resulted in the presence of several operating modes that were overlapping during the deployment of the humanitarian aid both at international and national levels.

This humanitarian cacophony causes coordination difficulties as each organization considers its own mode of operation as the best (Balcik et al., 2010) and thus tries to impose it. Also, the specific characteristics of each humanitarian crisis increase the difficulty of coordination due to operating conditions and scenarios' unpredictability. The adaptability of the response to each specific humanitarian crisis remains a challenge for all organizations.

3.6 Difficult Integration of new Players in the Humanitarian System

An analysis of NGOs' activities and structures shows limited access to the humanitarian sector for several actors. Among entry barriers is the problem of obtaining NGO status recognition both at national and international levels. These barriers revolve around bureaucratic constraints and practices amongst countries, international institutions, and beyond.

According to the international guidelines for humanitarian assistance operations (Macalister-Smith, 1991), acting effectively in the humanitarian field requires a status allowing players to practice globally in line with the assertion that the successful provision of humanitarian assistance depends on a speedy, efficient, and coordinated response based in turn on suitable legal and administrative foundations, provided that humanitarian actions are needed.

Another barrier lies in the access to government subsidies because some countries, especially African, are reluctant to massive recognition of new humanitarian organizations because such a move implies significant government expenditures.

The heavy process of decision making amongst humanitarian giants including the United Nations and its sub-entities is another issue. Due to the small number of actors in the humanitarian field, decision-making power is often detained by big organizations and NGOs that decide who should be allowed to join the network and who should be dismissed without giving sufficient objective reasons for the exclusion (Peltonen, 2010).

These types of disqualification prevent universal access to actors during humanitarian operations and reduce diversity of players while underexploiting potentials for open partnerships. Amongst key entry barriers in the humanitarian workflow, there is also the limited capacity of some NGOs vis-à-vis local conditions and specific characteristics of the humanitarian crisis such as the accessibility of the site making many NGOs with small capacities and limited resources completely disqualified and needless.

All of these barriers result in a monopoly of the NGOs cluster over the humanitarian sector where actions are not necessarily coordinated (Dworken, 1995) and at the same time compromising the ability to use additional external partners, thus weakening the potential for globally well-coordinated actions during humanitarian emergencies.

3.7 Neglect of Environmental Impact in Humanitarian Actions

How humanitarian products and services are provided is not environmentally sustainable and this is characterized by the fact that at various stages (preparedness, response, rehabilitation), humanitarian aid appears to have short-term goals (Eng-Larsson and Vega, 2011). In fact, the objectives of a humanitarian deployment are expected to be achieved in a very short time in respect with the organizations' missions. During the response phase, the long-term considerations are often ignored.

At the very first moment of the disaster, the procedures seem to prioritize immediate action thus, often making humanitarian operations following the disaster cause more environmental damage than the catastrophe itself (Eng-Larsson and Vega, 2011).

Indeed, it is rare that a product or service, in the case of humanitarian aid is designed in a sustainable manner. The emergency response and loss of human lives are often at the basis of plans prioritizing immediate action that marginalizes environmental and long-term considerations.

The approach to green logistics is quite the opposite. In a context where every action is studied in order to understand its environmental significance and sustainability, long-term considerations are paramount. So it seems that "green" temporary activity, as in the case of humanitarian logistics, is a paradox. The question to ask is: How green logistics can be integrated into organizations' temporary measures without compromising the achievement of short-term goals?

Humanitarian operations generate significant movement of materials and information. Studies exploring the management of these movements through the supply are limited, especially regarding environmental impact. However, there is an increasing awareness in the literature on this problem and its current state. Indeed, actions frequently updated and denounced show all the weaknesses while questioning the practices of various humanitarian actors.

The mismatch between institutional donations sent and actual demand can cause greenhouse gas emissions resulting from unnecessary energy waste. For instance, Bosnia and Herzegovina received more than 17,000 tons of expired drugs in humanitarian aid. This required the construction of an incinerator, mobilizing unnecessary monetary resources for transportation and storage.

Indeed, in the context of humanitarian logistics, all decisions and activities during the phases of preparedness, response and rehabilitation will impact the amount of transport used to meet needs. In addition, the distribution of products and services involves the consumption of large amounts of fossil fuels, often gaseous emissions, waste oils, and fuels. For example, in order to perform their daily tasks and their humanitarian work, members of the Fleet Forum, which includes the International Federation of Red Cross and World Food Programme, had to mobilize nearly 80,000 vehicles. Meanwhile, the organization of the United Nations peacekeeping had nearly 17,000 vehicles, most of which were trucks, SUVs and armored vehicles to meet the needs in its operations. In addition to the number of vehicles involved, the lack of communication between the different actors and their poor coordination often lead to duplication and redundancy, creating unjustified overuse of resources.

In addition, inventory management is often another problem cited in the literature as the source of large amounts of greenhouse gas emissions. Although many organizations try to preposition their inventories in strategic locations in order to minimize response time following a natural disaster, they still have to travel long distances before reaching their destination, thus generating more greenhouse gas emissions.

Therefore, in the local and global supply storage system, there is place to reduce energy waste. Finally, the exploitation of natural resources is also criticized in the literature. For example,

between 1994 and 1996, 36 million trees of Virunga National Park, in The Democratic Republic of Congo, have been used for heating and construction to meet the needs of Rwandan refugees.

Following the problems of neglecting environmental impact during humanitarian crises, key issues include the need to improve coordination to optimize transport, the use of biofuels, "green procurement" and the modification of materials used in humanitarian products to make them more environmentally sustainable. There are a variety of methods of environmental management, such as life cycle analysis that can be used in order to make a significant difference on the ground. Another challenge is the need to improve innovation in the management and recycling of waste in order to benefit from the processing and reuse. Moreover, the issue of limited access to green technologies due to high cost and low availability needs to be addressed through, for example, more electric vehicles, biofuels or biodegradable plastic products.

Finally, organizations should moderate their tendency to focus on the urgency of the response without evaluating the environmental consequences vis-à-vis their actions.

The potential solutions that the Physical Internet could bring address the sum of problems described above. Every solution identified thanks to a potential implementation of the Physical Internet covers sometimes two or several problems in different domains. It leads us to the conclusion centered on a unique vision and integrated by this idea of enabled interconnected humanitarian logistics which intend to make the deployment of the humanitarian aid efficient and sustainable.

Without claiming completeness, section 4 is hereafter describing the elaboration of an interconnected humanitarian logistics system. It also presents scenarios stemming from proposed solutions which are described in a top–down logic through the vision of the concept of the Physical Internet in all its dimensions and with particular emphasis on transport, distribution, and supply.

4 Building a Humanitarian Interconnected Logistics System Introduction

The proposed humanitarian interconnected logistics system targets the objectives of (1) creating a Humanitarian Logistics Web enabling interconnected humanitarian (a) transport, (b) distribution, and (c) supply; and (2) offering the key components for operating a humanitarian PI through (a) standardized, modular and smart humanitarian π-containers from box and case sizes to cargo container sizes, (b) adapted and appropriate humanitarian means of transport, handling, and storage and logistics facilities, and finally (c) humanitarian protocols and informational platforms.

4.1 Towards Interconnected Humanitarian Logistics

Global interconnectivity of the humanitarian logistics is to allow breaking the isolation induced by the physical borders between the various actors by enabling the interconnectivity of individuals, donors, companies, suppliers, NGOs, international institutions, governments and beneficiaries. The global Humanitarian Logistic Web is to evolve from a private logistic network or from a limited partnership towards a global logistic network of interconnected humanitarian

supply networks. The access to the global web thus becomes open by allowing the implication of all the actors of the humanitarian aid under any form of collaboration.

Interconnected humanitarian transport, as one of three key elements of interconnected humanitarian logistics, must evolve towards distributed multi-segment and multimodal transportation by using open hubs and warehouses across the world and the certified blue containers in order to exploit carriers' global networks. Interconnected humanitarian distribution means to network and to enable access to all warehouses and distribution centers of NGOs and other organizations and businesses, airports, ports, etc., allowing a better, openly pooled, storage of products before a crisis as well as a better response to crises, notably through a further distribution of the help to a disaster. Finally, interconnected humanitarian supply must evolve towards a global web of suppliers and donators, displaying in a dynamic way products and services needed and available, while involving the global certified PI networks. This mode assures an efficient adaptability to a variable demand.

As a key constituent of a humanitarian Physical Internet, the modular, intelligent and standardized humanitarian π-containers are to allow efficient transport, handling and storage of products towards disaster areas, but also to be used in other purposes on the ground such as a blue container which can become a mobile tent, etc. Adapted humanitarian means of transportation, handling and storage are indispensable to incite innovation in the conception of logistics means adapted to humanitarian crises, thus allowing the access to difficult grounds while taking into account eco-design. Finally, humanitarian protocols and informational platforms are important to building an open distributed networked infrastructure that will connect all actors in humanitarian logistics.

Scenarios that take into account the complexity of the deployment of humanitarian assistance associated with the involvement of several actors are presented subsequently in section 5, in a design that applies the principles of Physical Internet while considering the very specific nature of humanitarian intervention challenges at the global level.

Before exposing the scenarios, we hereafter present the operational characteristics and the structure of the traditional relief chain which depend of the type of disaster and the types of relief actors involved and some issues in terms of supply acquisition/procurement, pre-positioning /warehousing, transportation and coordination mechanisms. The typical flow of supplies (Blacik et al., 2010) is illustrated in Figure 6.

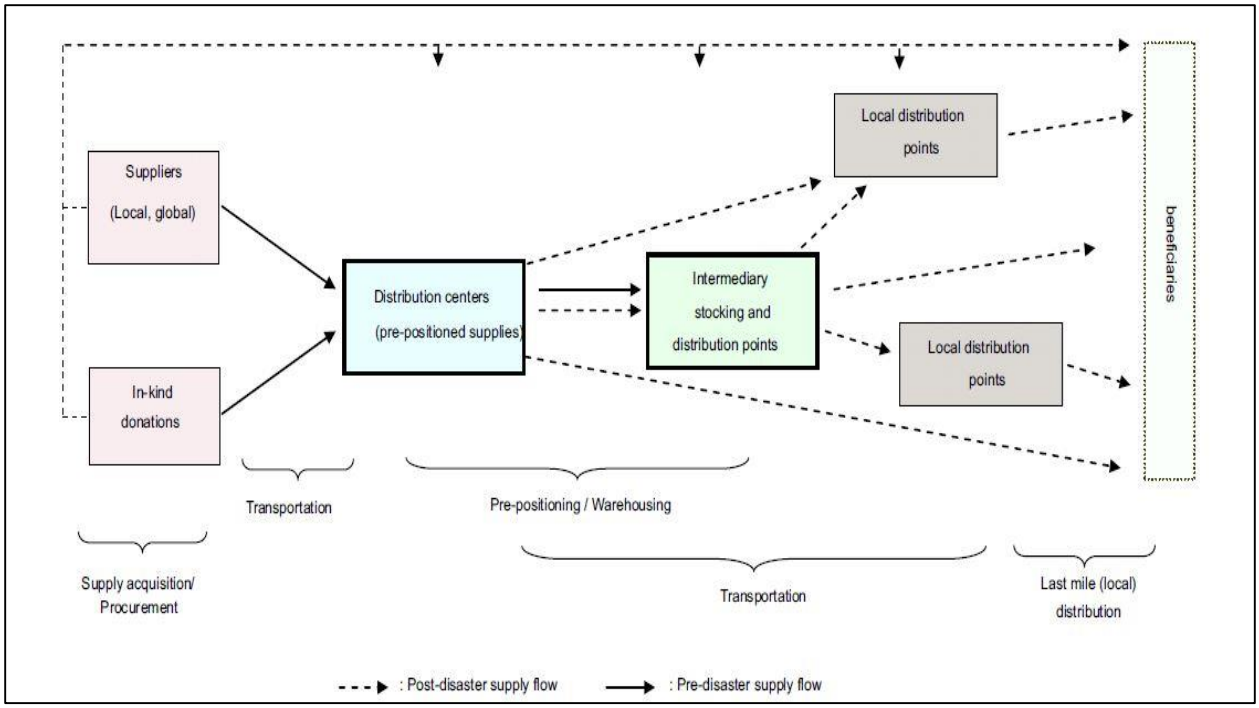

Figure 6: Relief chain structure
Adapted from Blacik et al. (2010)

In terms of supply acquisition and procurement, the NGOs, for example, can procure supplies locally and/or globally. Each of these options has advantages and disadvantages which are concentrated around the costs, the lead-times and the availability of products and/or services. If we analyse for example the costs of logistics, there is generally an important difference between the local supply versus the global one with an important cost advantage on the first one (Balcik and Beamon, 2008). It is aimed that interconnected humanitarian distribution and interconnected humanitarian supply can mitigate the risks in regard to product availability. It also could bring economies of scale and a better cost distribution in the humanitarian logistic ecosystem.

At the level of pre-positioning and warehousing, in the traditional logistic chain as shown in the Figure 6, the NGOs may hold pre-positioned stock at multiple levels (global, regional, in-country) to make sure of the availability of products. It may also hold storage facilities at airports and seaports for the same purpose. According to the proposed approach in this paper, translated in the scenarios of forthcoming section 5, the presence of a unique counter (single window) which gives the possibility to all humanitarian actors to analyze correctly the offers and demands and to take the best decisions, brings potentially important savings in terms of logistic costs, a better distribution of products and services and better resources management.

Transportation is also a key problem in the traditional humanitarian supply chain. The lack of global connectivity between carriers, the low adaptability of transport, the limiting and often (partially) destroyed infrastructure, as well as the lack of coordination are among the elements that now characterize transport in humanitarian aid. As shown in the key physical constituents of Humanitarian PI, modular, intelligent and standardized humanitarian π-containers and innovation in the design of transportation means could bring added value to the efforts of humanitarian actors to attenuate and eventually eliminate these problems.

Coordination has an extremely important and sometimes expensive role relative to participating organizations. Each actor in humanitarian aid has its specificity, resulting in coordination mechanisms becoming very heavy as multiple types of organizations are allowed to participate in humanitarian actions without standardization. The proposed approach, based on single entry point or a single window, ensures that stakeholders are brought together in a single coordination mode with added value for all stakeholders. The openly protocoled Physical Internet (PI) coordination could move humanitarian actors toward a seamless horizontal coordination.

4.2 Towards Interconnected Humanitarian Logistics

The *Humanitarian Physical Internet* (*HPI*) corresponds to the application of the Physical Internet principles to the humanitarian field in order to relieve the problems and inefficiencies of the field. It enables a global Humanitarian Logistics Web based on PI's dynamic framework and aims at making the conception, design, production, movement, storage, supply, construction, and use of physical objects in the humanitarian sector more efficient and sustainable. Operationalization of *HPI* is divided into the following three phases.

4.2.1 Upstream Phase

a) Digital Platform

The *HPI* platform digitally supports the interconnection of all stakeholders (individuals, donors, companies, suppliers, NGO, international institutions, governments and beneficiaries) and has to ensure the connection of these stakeholders with actors in the crisis zone. This platform presents the interface between the *HPI system* and each stakeholder. The latter may connect with his account, see the latest news about humanitarian crises, some statistics on the performance of the system, some forecasts of what will happen in the near future related to humanitarian crisis, information about partners (donors who want to be published, etc.), progress in operations in crisis situations, and so on. Each stakeholder has his own interface. For example, a donator has interface for funds transfer, a supplier has an interface for registering his/her products to be supplied, beneficiaries have interfaces for registering their needs, etc.

The HPI platform is to evolve with technological innovations. For example, videoconferencing with crisis zones is an application that can elevate the degree of live interconnectivity. At the present time, in such a context, it may be difficult to ensure a connection with personal computer whereas, it may be easier to connect with a smart phone. The HPI platform is to ease seamless high-performance interconnectivity.

b) Donations

Donations can be in different forms: money (cash or price reduction), services, goods, food, medicines, equipment (transport, handling, etc.), space (volume and weight) in transport means or in warehouses, back-haul movement, innovative ideas for equipment, etc.

Donations are to be received through the digital platform. As soon as there is a donation anywhere in the world, it is registered on the digital platform. Then, donations are properly labeled and the donor can give utilization tags. In fact, donors can state their restrictions and preferences in the nature of use of their donations. For example, a donor can require that his/her

donations be used for crises in Africa or only for humanitarian organizations such as the Red Cross, or yet any natural disaster except those that are war induced. This is the donor's choice. The donations are registered as humanitarian assets and are prepared and deployed in preparation and/or in response to the occurrence of a humanitarian crisis. Finally, when necessary, donated goods must be stored and moved as needed, given the scope of potential use as bounded by restrictions form donors and according to the preferences of their donors.

c) Monitoring of Worldwide Requirements

It is proposed that *HPI* embeds extensive monitoring and dashboard capabilities. In fact, good learning from, and good preparation to humanitarian crises can improve the quality of the reaction and response times to humanitarian crises. The HPI dashboard can:

(1) Examine the current situation on the world based on multiple sources of information such as satellites, news, actors in crises zones, etc.;
(2) Learn about actual situation in the world: people, demographic changes, climate changes, conflict inert-countries, people's revolutions, geographical phenomena\transformation, etc.;
(3) Learn also about occurred crises: have a history of crises, indicators of crises, the evolution of crisis, triggers of crisis as floods, wars, problems and challenges of each type of humanitarian crisis causes inefficiency in logistics operations, intervention strategies, intervention steps, key success;
(4) Forecast future humanitarian crises, assess the needs of potential crisis areas depending on the type of crisis and the crisis area expected requirements (electricity, clothing, tents, food, water, helicopter, etc.), estimate the gap between what these crisis zones need and what is available from donations;
(5) Establish tactical deployment of humanitarian assets before crisis occurrence.

d) Tactical Deployment before Crisis Occurrence

After predicting the crisis and the estimated needs of these crisis areas, *HPI* system should ensure that assets to satisfy these needs be located near predicted areas of crisis.

For this, the location of warehouses and transportation means according to available quantities is established as in the generic PI system. It is paramount that the HPI system exploits and benefits from PI-transportation means, PI-Hubs as well as PI-containers which are already in service for all kinds of other sectors.

In fact, Montreuil et al. (2013) report that trucks and containers are often half empty at departure, with a large chunk of the non-emptiness being filled by packaging. Indeed, 56.8% of containers and trucks are full but not empty, and the average of utilization of trucks and containers is 42.6%. Also, vehicles and containers often return empty, or travel extra routes to find return shipments (25% of travel) and loaded vehicles get emptier and emptier as their route unfolds from delivery point to delivery point. In this context, HPI is to exploit the empty movements and the empty volume in trucks and containers to package and transport humanitarian goods, as often as possible at humanitarian discounts or even better as donations.

To achieve these goals, *HPI* should (1) contact the related stakeholders and call for help and awareness among the different actors (suppliers, drivers, warehouses owners, donators,

volunteers, etc.) on a continuous year-round basis; (2) solve optimization problems for locating and selecting warehouses, for planning transport and for dynamic asset distribution; and after that (3) determine intervention strategies and establish an interim plan in order to be efficient when a humanitarian crisis occurs.

4.2.2 Operationalization of Interconnected Humanitarian Logistics

4.2.2.1 Containerization of Humanitarian Food, Goods and Equipment

For efficient and secure humanitarian goods transportation, handling and storage, it is proposed that blue containers be used. These are π-containers designed for humanitarian logistics. They are modular, standardized and intelligent π-containers. As blue containers, they are also designed for taking various roles, to be used for purposes besides packaging humanitarian goods. In fact, it is suggested that blue containers be transformable for reuse as tents, tables, medical offices, kitchens, etc. It should also be possible to integrate cameras in these *HPI-containers* in order to film situations in crisis areas, interventions of actors implicated there for help, people reactions, etc., and ideally to be able to transmit the movies live to humanitarian stakeholders. These films would serve to collect as much information as possible and situations about each type of humanitarian crises. On one hand, it can fulfill some function of the press, and act as a feed, if it is not possible for press members to join the crisis emplacement, and, on the other hand, it can be a knowledge base that should be analyzed later in order to draw conclusions from the past operations and plan efficiently for future interventions.

4.2.2.2 Humanitarian Interconnected Transport

As displayed in Figure 1 for the generic PI, beyond the blue containers, the other two key types of humanitarian physical elements enabling the HPI are the *HPI-nodes* and the *HPI-movers*. The HPI-nodes correspond to the sites, facilities, and physical systems of the Humanitarian Physical Internet. The HPI-movers transport, convey or handle containers within and between nodes of the Humanitarian Physical Internet.

a) Humanitarian Interconnected Transport (HPI Transport)

When a humanitarian crisis occurs, HPI system will connect to its databases, to find and repair empty volumes placed at the disposal for HPI. Volumes on containers, warehouses and means of transport owned by donators can be used to ensure efficiency of humanitarian aid interventions.

b) Humanitarian Hubs (HPI Hubs)

Humanitarian PI-hubs are a subset of π-Hubs. In fact, when a humanitarian crisis occurs, and based on location of the crisis area, a decisional problem of locating HPI-hubs should be solved. The objective is to place them near intersections with other π-hubs in a way that it contributes to the global objective which is an efficient and sustainable humanitarian PI.

c) Humanitarian Warehouses (HPI Warehouses)

Humanitarian PI-Warehouses are warehouses certified for the Physical Internet and for interconnected humanitarian purposes. There exist two basic types of actions relative to humanitarian warehouses: (1) Exploit empty space of a π-warehouse dedicated to blue containers as a donation (free or discount), (2) Create humanitarian π-warehouses, devoted for warehousing

equipment and goods for humanitarian aid, these π-warehouses can be stationary, transient or even mobile.

d) Humanitarian Supply Network

The HPI system should ensure the interconnection of service/goods providers and beneficiaries. It should integrate suppliers, the type of service they offer to the humanitarian aid and then contact them when necessary.

In the HPI conception, it is proposed that donations can take the form of a promise. For example, suppliers can donate information about the volume, the quantities, and the types of goods that they may offer in case of humanitarian crisis. In such a case, the physical goods are transferred to HPI warehouses only when a real humanitarian crisis occurs. Also, suppliers can offer discounts on goods and these goods are transferred to HPI warehouses only when a real humanitarian crisis occurs.

4.2.3 Downstream Phase

Once the crisis has ended, the HPI system should retrieve all recovered material, obsolete equipment, waste, remains, etc., that is not needed anymore in the zone. In fact, from an economic perspective, all the equipment or remaining goods can be reused in other humanitarian crises. The way that they are recovered and transported to HPI-warehouses is the same as before or in the case of humanitarian crises. Empty movements, empty means of transport and empty warehouses can be used also for delivering them to other HPI warehouses for serving other possible humanitarian crises.

From an environmental aspect, the affected areas need to be fixed and garbage that are not recycled there may be harmful. Thus, expired products must be transported to storage locations in order to be recycled afterward.

The next section proposes realistic scenarios that take into account the complexity of the deployment of humanitarian assistance coupled with the involvement of several actors, all presented in a design that applies the principles of the Physical Internet while globally considering the very specific nature of humanitarian intervention challenges.

5 Scenarios

Indeed, following the presentation of the key elements for humanitarian Physical Internet and its operationalization, all the issues raised previously conduct, this time in humanitarian logistics, towards the same conclusion as that of Montreuil (2011, 2013): the way physical objects are moved, handled, stored, realised, supplied and used through the world is not sustainable economically, environmentally et socially. Thus, concrete solutions are to be set up to building an interconnected humanitarian logistics system which will assure the global sustainability.

In this section, some scenarios are generated to present some of the possibilities provided by humanitarian Physical Internet to three types of participants in humanitarian logistics: NGO, the company and the individual. The first three scenarios concern essentially the use of the single entry point by the users, the categorization of the donations and the possible avenues of decisions

for the stakeholders. The final fourth one creates a hypothetical crisis and focuses on the value added by PI-enabled interconnected humanitarian logistics.

Scenario 1 uses a single entry point to mitigate problems presented in the section about typical relief chain structure. The scenario is triggered by a request coming from an NGO concerning goods and/or services. Figure 7 highlights the options associated with the NGO request. Table 3 presents the step-by-step process associated with this scenario.

As highlighted in Figure 8, scenario 2 is in the same context yet focuses on an offer from an individual person about donating funds, goods or services. Figure 9 highlights scenario 3 that focuses on an offer form a company. Tables 4 and 5 present the step-by-step processes associated with these scenarios.

Finally, the scenario 4 represents the case of an emergency that may arise, as happened in Haiti**.** Following consultation between the various humanitarian actors that form the cluster taking decisions on intervention in coordination with the government, Figure 10 presents the sequence of decisions that an NGO can take in an emergency using the Humanitarian Physical Internet. The associated step-by-step process is synthesized in Table 6.

These are four scenarios which demonstrate the added value of a humanitarian interconnected logistics system based on Physical Internet. Other scenarios must be analysed and tested in order to transpose all the PI characteristics as described by Montreuil (2011, 2013) and Montreuil et al. (2013) and sketched in Table 1.

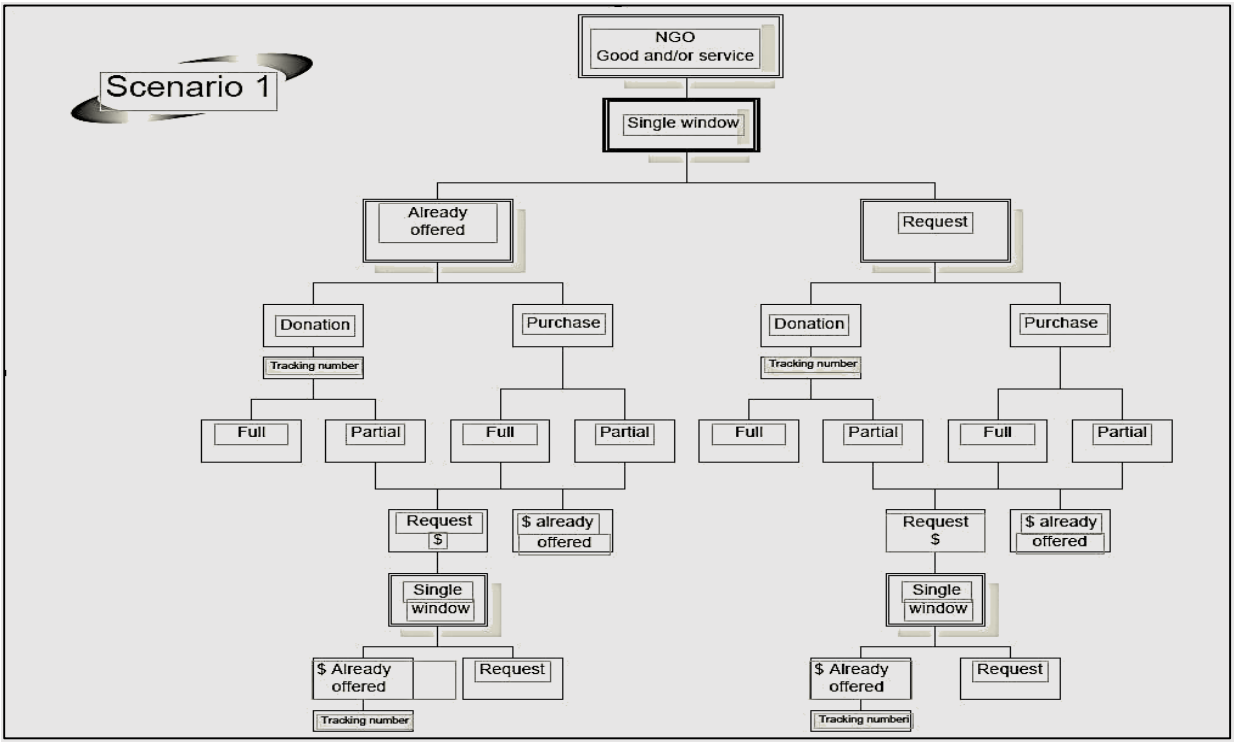

Figure 7: Scenario 1 - Request coming from an NGO

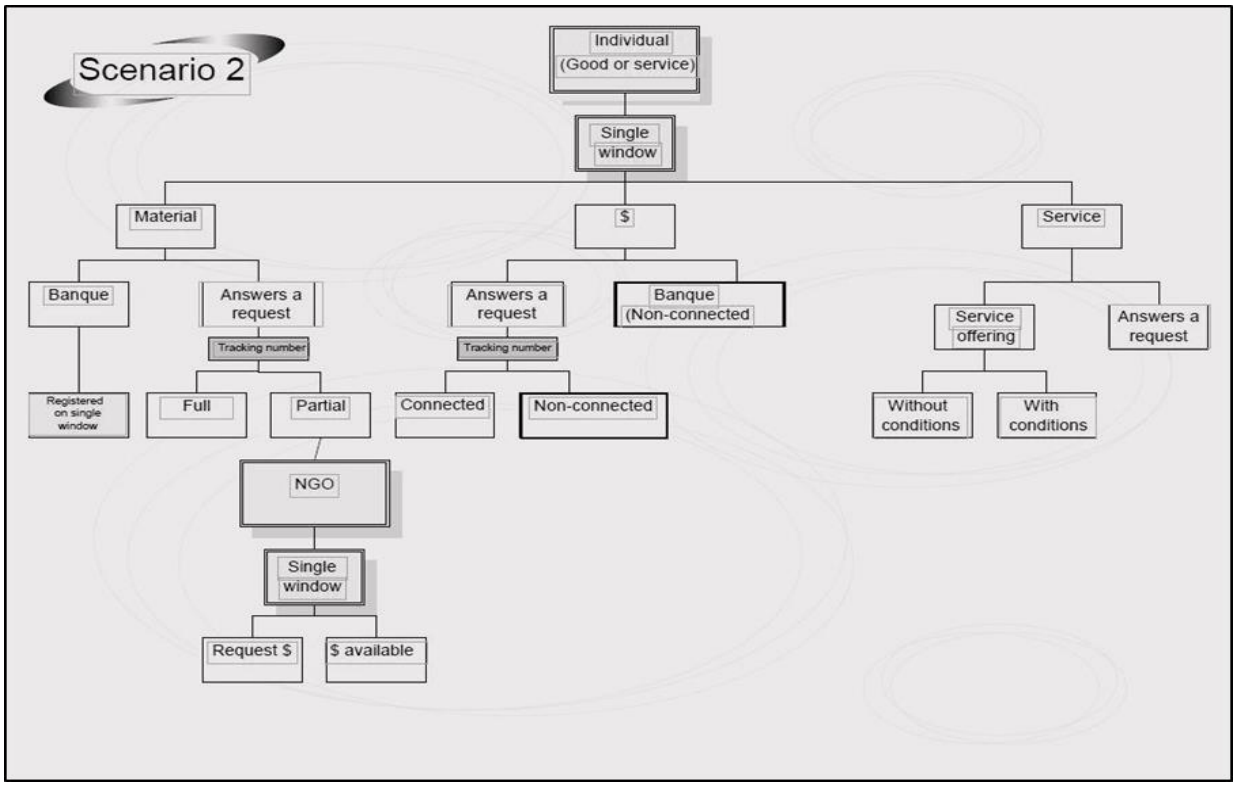

Figure 8: Scenario 2 – Donation offer from an individual

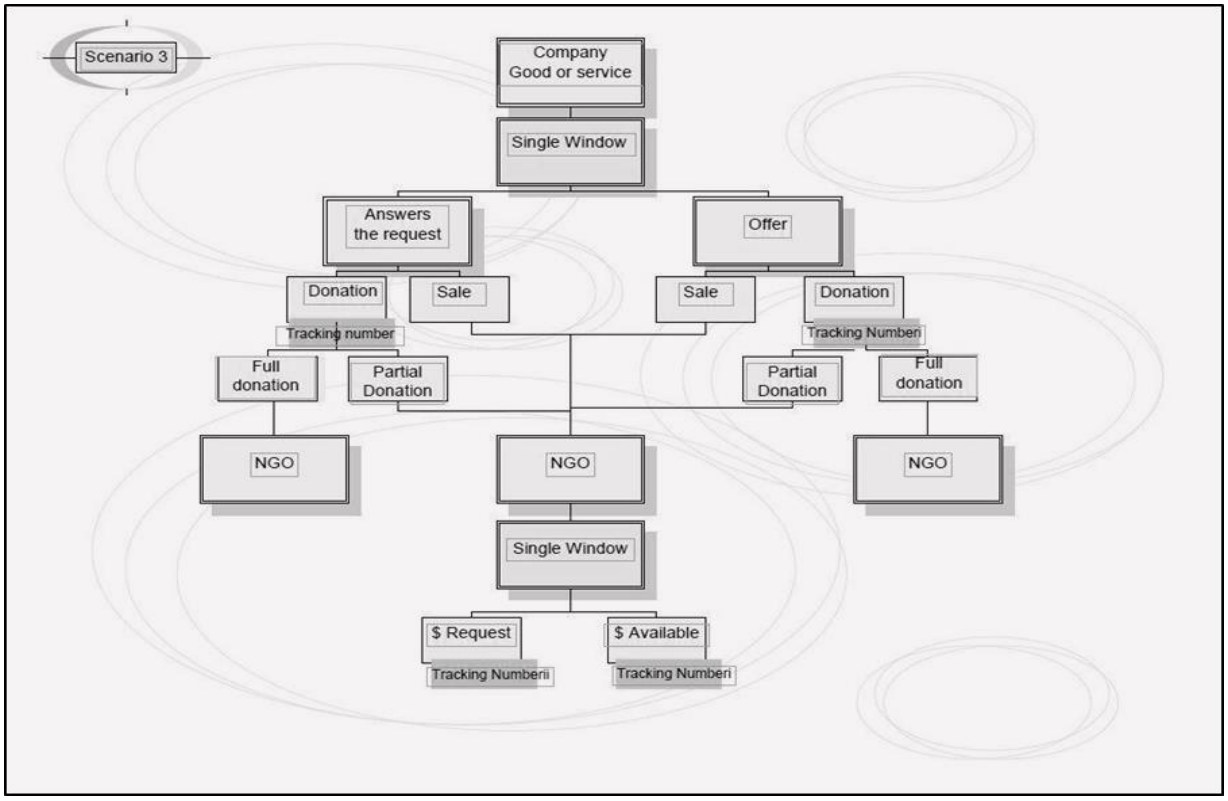

Figure 9: Scenario 3 – Offer coming from a company

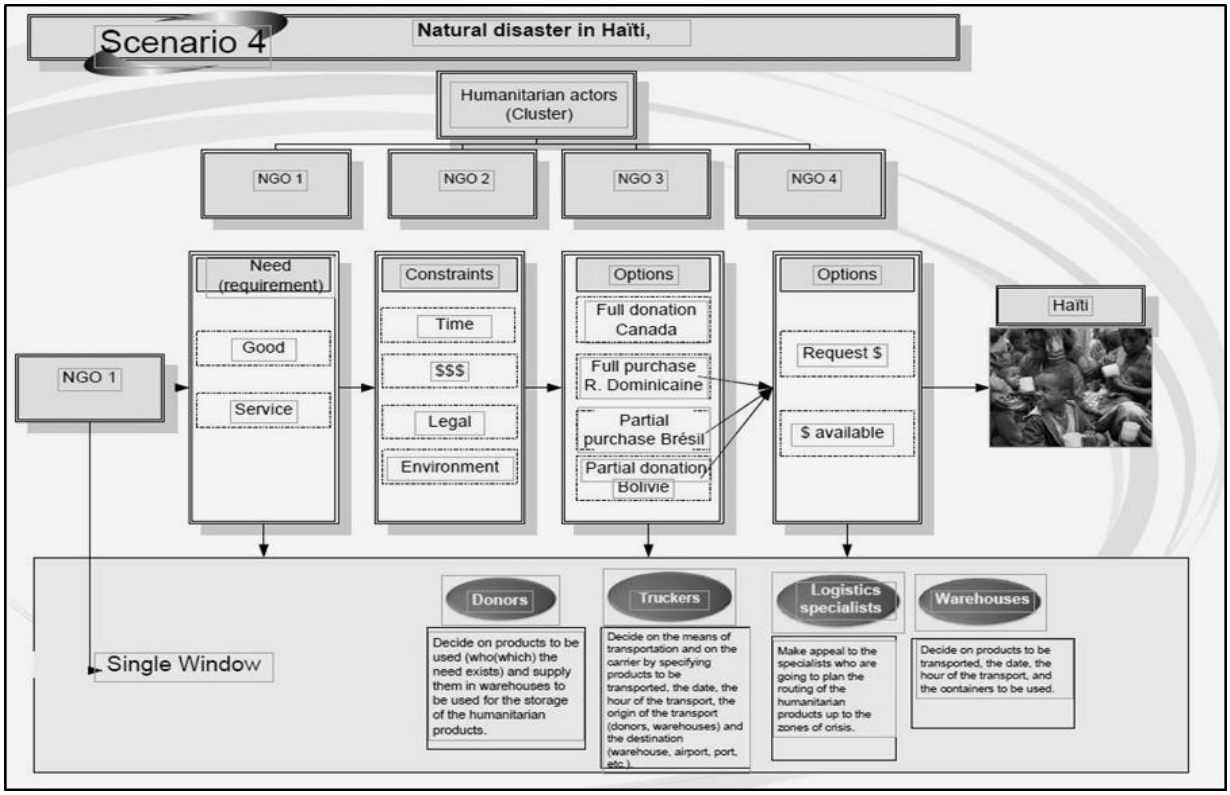

Figure 10: Scenario 4 - The sequence of decisions that an NGO can take in an emergency using the humanitarian Physical Internet

Table 3: Scenario 1 – Step-by-step process for a request coming from an NGO

Step-by-step	Action
1	Having estimated its need, the NGO consults the single window to fill it.
2	From the single window, the NGO can fill its need, by considering the already registered offers or it can create a specific request.
3	In the case of an offer already registered on the single window: a. If it is about a complete donation, a tracking number is sent to the donor. The good and/or the service is dispatched in the requested zone at the expense of the donor; b. If a partial donation occurs, the NGO can support non-covered expenses by its financial resources. If the NGO does not possess the necessary financial resources, she can consult again the single window to consider the monetary offers already registered on the single window or make a request. Once again, when a donation is incurred, a tracking number is sent to the concerned actor. c. If it is about a partial or complete purchase, the procedure of the point *b* applies.
4	In the case of a request on behalf of the NGO on the single window, the procedures illustrated to stage 3 are the same. Actually, when an actor answers at the request of the NGO, the same processes can apply.

Table 4: Scenario 2 – Step-by-step process for a donation offer coming from an individual

Step-by-step	Action
1	The individual reaches the single window to propose a material donation, a monetary donation or a service.
2	In case the individual proposes a material donation: a. If there is no request registered in the single window for the proposed item, the offer is registered in the system for future use; b. If the individual proposes a material donation to answer a request already made in the single window, two avenues are possible: b1. If it is about a complete donation, a tracking number is sent to the individual. The good or service is dispatched in the request zone at the expense of this one; b2. If it is about a partial donation, the NGO can cover non-covered expenses by its financial resources. If the NGO does not possess the necessary financial resources, she can consult again the single window to consider the monetary offers already registered on the single window or make a request. Once again, when a donation is incurred, a tracking number is sent to the concerned actor.
3	In case the individual proposes a monetary donation: a. If there is no request registered in the single window for the proposed sum, the offer is registered in the system for future use and a tracking number is sent to the individual when used; b. If the individual proposes a sum to answer a request already made in the single window, two avenues are possible: b1. The sum can be precisely connected to a specific group. For example, the request is for the humanitarian aid in Japan, but the individual can wish that the sum which he gives is for health care. A tracking number is sent; b2. The sum can be non-connected and be used according to the will of the applicant. A tracking number is sent.
4	In case the individual proposes a service: a. If there is no request registered recorded in the single window for the proposed service, the offer is registered in the system. The offer can be with or without conditions; b. If the individual proposes a service to answer a request already made in the single window, the conditions of the request will apply.

Table 5: Scenario 3 – Step-by-step process for an offer coming from a company

Step-by-step	Action
1	The company reaches the single window to provide a good or service.
2	In the case of an offer which meets a request as a donation: a. If it is a complete gift, a tracking number is sent to the donor. The good or service is supplied to the zone request on the donor's expenses. The NGO provide management in the case of a service; b. If it is a partial donation, NGO can pay the costs not covered by using its financial resources. If the NGO does not have the necessary financial resources, it can consult again the single window to consider monetary offers already recorded on the single window or make a request. Again, when a donation is incurred, a tracking number is sent to the concerned actor; c. If it is a sale, the procedure of paragraph *b* applies.
3	In the case of an offer for which there is no request registered, the procedures in sections 2 apply when the company offer is accepted.

Table 6: Scenario 4 – Step-by-step process for an NGO in an emergency using the humanitarian Physical Internet

Step-by-step	Action
1	NGO accesses the single window to find a good or service.
2	NGO analyses its needs to face constraints they may have. These constraints can be : a. Time: Does the NGO need the products or services immediately or can it wait? a. Money: Is the money available immediately? c. Legal: Are there legal constraints facing products or services? (Ex: products manufactured in the United States supplied to Cuba, etc.); d. Environment: What are the environmental constraints faced by NGOs? (Ex: chemical or biological emergencies, etc.).
3	NGO analyzes its options via the single window. For example, in our scenario we have a complete gift from Canada, a partial donation from Bolivia, a full purchase from the Dominican Republic and a partial purchase from Brazil. Comparing the constraints options, the NGO can make the best choice and make the best decision in a mix.
4.	Depending on its decisions, NGO can make a request on the single window to fund her project.

6 Conclusion

This paper has contributed towards establishing a foundation for Physical Internet enabled interconnected humanitarian logistics. Its major contributions lie on the systemic approach based on the Physical Internet perspective to bring fundamental changes to the way humanitarian logistics is currently being thought and run. Overall, the paper concludes that the Humanitarian Physical Internet has emerged as a natural and credible, effective and sustainable solution to many problems plaguing the emergency humanitarian supply chain and its management. It is part of a promising perspective and foresight to explore through scientific research by taking HPI's key components, tools, and scenarios exposed hereby to the crucial stage of full implementation.

Research avenues include the exploration of more coordinated humanitarian actions that consider the potential of the Physical Internet concept. In fact, the humanitarian emergency aid presents many challenges for organizations attempting to manage data, information and knowledge on various situations or events. Humanitarian organizations must be able to identify the critical information they need, where to find it, and the best way to share, present and disseminate it. These challenges can be addressed in part by using humanitarian PI through knowledge management to deal with its determinants and the mechanisms to be put in place to ensure sustainability.

In any humanitarian intervention, success is often determined by reference to the cost, time and quality of the intervention. Budgetary constraints are often too large and some missions are underfunded while others are over-funded. In this regard, humanitarian PI is a way to promote better financial distribution and optimization. Also, during humanitarian intervention, the lack of regulation in the humanitarian field makes stakeholders' roles not clearly defined. Given that and under current conditions, the State acting as a main coordinating actor, the following research question has to be explored: To what extent the transition to the Physical Internet will influence the role of the State and other stakeholders in terms of coordination and regulation at the level of participants, especially in the situation where the State does not have the capacity to carry out this coordination activity, as was the case of Haiti?

The proposed interconnected humanitarian framework offers one single Internet window sharing centralized and comprehensive information. Lots of information and opportunities provided by the system should allow humanitarian actors to make decisions economically, environmentally and socially optimal with a broad portfolio of solution options. In practice, the amount of information to be processed by the optimization tools is often the source of long periods of resolution. Therefore the following question has to be answered: What will be the impact of the integration of the Physical Internet to decision support tools of NGOs?

The humanitarian sector is now made into a kind of oligopoly whose main actors are the NGOs. This structure of the humanitarian field does not deal with external actors, reducing the opportunities for greater involvement of actors with the potential to contribute to the strength of humanitarian interventions. It is suggested to explore the facilitation of the entry of new actors in the humanitarian field to improve synergies between all stakeholders towards more collaborative and coordinated humanitarian actions. Accordingly, an avenue of research could be: How to facilitate the access and integration of new actors in the humanitarian field for an operationalization of the HPI?

Innovative means of transport adapted to humanitarian aid would be very useful to reach difficult places and to improve the speed of transport of humanitarian goods. For example, this could involve small land based or aerial drone based vehicles for transporting smart containers to remote villages. Thus, another avenue is to look at the potential contribution of the Physical Internet in innovating new ways to get to inaccessible areas.

In humanitarian crises, time management is fundamental to save lives. Thus, the time constraint plays a lot in storing donations. Indeed, it is a major challenge for NGOs. Given the urgency and the pressure of public opinion, they must be vigilant about the expiry date of the products to avoid waste. In addition, improper storage and inadequate transportation can degrade the products. It is therefore important to investigate further how HPI can enable to better manage the physical storage time, the storage and distribution of humanitarian aid to beneficiaries. The HPI, if globally implemented, may contribute to overcome the constraints of storage time towards a better time management.

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References

Balcik B., B.M. Beamon, C.C. Krejci, K.M. Muramatsu, M. Ramirez (2010): *Coordination in humanitarian relief chains: Practices, challenges and opportunities*, International Journal of Production Economics, v126, no1, 22-34.

Charles A., M. Lauras (2011): *An enterprise modelling approach for better optimisation modelling: application to the humanitarian relief chain coordination problem*, OR Spectrum, v33, no3, 815-841.

De Torrenté N. (2013): *The Relevance and Effectiveness of Humanitarian Aid: Reflections about the Relationship between Providers and Recipients*, Social Research, v80, no2, 607-634.

Duran S., M.A. Gutierrez, P. Keskinocak (2011): *Pre-Positioning of Emergency Items for CARE International*, INTERFACES, v41, no3, 223-237.

Eng-Larsson F., D. Vega (2010): *Green logistics in temporary organizations: A paradox? Learnings from the humanitarian context*, RIRL 2010 , The 8th International Conference on Logistics and SCM Research, BEM Bordeaux Management School, Sept. 29-30 and Oct.1st 2010.

Eng-Larsson, F., D. Vega (2011): *Green Logistics in Temporary Organizations: A Paradox? Learnings from the Humanitarian Context*, Supply Chain Forum: An International Journal v2, no12, 128–39.

Gatignon A., L.N. VanWassenhove, A. Charles (2010): *The Yogyakarta earthquake: Humanitarian relief through IFRC's decentralized supply chain*, International Journal of Production Economics, v126, no1, 102–110.

Heigh I., M. Jahre (2010): *Humanitarian Supply Chains*, Supply Chain Forum: International Journal, v11, no3, 2-3.

International Federation of Red Cross and Red Crescent Societies (2006): *World Disaster Report: Focus on neglected crises*, ATAR Roto Presse, Satigny/Vernier, Switzerland, 255p.

Macalister-Smith, (1991): *International Guidelines for Humanitarian Assistance Operations,* Max Planck Institute for Comparative Law and International LAWHEIDELBERG 1991, http://www.ifrc.org/Docs/idrl/I356EN.pdf, accessed on March 3rd, 2014.

McCoy J., M. Brandeau (2011): *Efficient stockpiling and shipping policies for humanitarian relief: UNHCR's inventory challenge*, OR Spectrum, v33, no3, 673-698.

Montreuil B. (2011): *Towards a Physical Internet: Meeting the Global Logistics Sustainability Grand Challenge,* Canada Research Chair in Enterprise Engineering, CIRRELT Interuniversity Research Center on Enterprise Networks, Logistics and Transportation Université Laval, Québec, Qc, Canada.

Montreuil B. (2013): *"Physical Internet Manifesto: Transforming the way physical objects are moved, stored, realized, supplied and used, aiming towards greater efficiency and sustainability",* Version 1.11.1, (Original v1.0, 2009), www.physicalinternetinitiative.org, 2014/02/20.

Montreuil, B., R. D. Meller & E. Ballot (2010): *Towards a Physical Internet: the impact on logistics facilities and material handling systems design and innovation*, in Progress in Material Handling Research 2010, Edited by K. Gue et al., Material Handling Industry of America, p. 305-328.

Montreuil B., Meller, R.D. and Ballot, E. (2013): *Physical Internet Foundations*, in Service Orientation in Holonic and Multi Agent Manufacturing and Robotics, ed. T. Borangiu, A. Thomas and D. Trentesaux, Springer, p. 151-166.Natsios A.S. (1995): *NGOs and the UN system in complex humanitarian emergencies: conflict or cooperation?*, Third World Quarterly, v16, no3, 405-419.

Peltonen H. (2010): *Modelling international collective responsibility: The case of grave humanitarian crises*, Review of International Studies, v36, no2, 239-255.

Saetti A., O. Cauët (2008): *La Logistique Humanitaire : Besoins, Enjeux, Moyens, Cadre Règlementaire*, étude de cas, Expression Communication.

Seaman J. (1999): *Malnutrition in emergencies: how can we do better and where do the responsibilities lie*? Disasters v23, no4, 306–315.

Stapleton O., L. Van Wassenhove, R. Tomasini (2010): *The Challenges of Matching Corporate Donations to Humanitarian Needs and the Role of Brokers,* Supply Chain Forum: International Journal, v11, no3, 42-53.

Stephenson M. (2005): *Making humanitarian relief networks more effective: operational coordination, trust and sense making*, Disasters, v29, no4, 337-350.

Thomas N., T.T. William (2002): *The Utility of Human Security: Sovereignty and Humanitarian Intervention*, Security Dialogue, v33, no2, 177–192.

United Nations (2005): *Humanitarian Response Review; An independent report commissioned by the United Nations Emergency Relief Coordinator & Under-Secretary-General for Humanitarian Affairs, Office for the Coordination of Humanitarian Affairs (OCHA),* August 2005, New York and Geneva.