TOWARD HYPERCONNECTED HUMANITARIAN LOGISTICS OPERATIONS

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1. PROBLEM AND RESEARCH STATEMENTS
THE PROBLEM STATEMENT
Still has major pains in the humanitarian logistics…

- In recent years, scholars and practitioners have made huge efforts to improve humanitarian logistics performance
- But, strong pains remain…

Should we continue to try to improve the existing or seek to fundamentally rethink beyond the current practices?
The logistics maturity ladder:

1. **Atomistic**: fragmented network and managed through solo operations.
2. **Integrated**: network as an end-to-end channel, in which plants are dedicated.
3. **Collaborative**: network as a whole in which partners are able to share data/activities in peer-to-peer relationships.
4. **Hyperconnected**: network is based on open-hubs and cooperative platforms for both data and material flows.

Should we go through the whole path of logistics maturity ladder or jump directly to the good step?
THE RESEARCH STATEMENT

Toward a sentient immersive response approach of humanitarian logistics…

- A set of new opportunities to make decisions differently…

How to benefit from the new digitalization opportunities to improve efficiency, effectiveness, responsiveness and readiness capabilities?

Sensing  Data-driven  Interconnectivity  Intelligence

How to benefit from the new digitalization opportunities to improve efficiency, effectiveness, responsiveness and readiness capabilities?

SIREN

SENTIENT IMMERSIVE RESPONSE NETWORKS

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THE RESEARCH STATEMENT
A breakthrough innovation for humanitarian logistics operations…

Would it work? That’s the purpose of our research project…

Accelerate & Improve recovery for better alleviate sufferings

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2. THE PHYSICAL INTERNET OPPORTUNITY
THE PHYSICAL INTERNET

Leveraging the Digital Internet metaphor to inspire, guide & steer toward high-performance logistics & supply chains

Goal: To enable improving by an order of magnitude the economical, environmental and societal capability, efficiency, resilience, and sustainability of fulfilling humanity’s needs for physical objects

What: Hyperconnected global logistics system enabling seamless open asset sharing and flow consolidation through standard encapsulation, modularization, protocols and interfaces

Key Building Blocks

- Certified Open Logistics Service Providers
- Smart Data-Driven AI, Analytics, Optimization & Simulation
- Open Digital Logistics Infrastructure
- Global Logistics Monitoring System
- Certified Open Logistics Facilities and Ways
- Standard Logistics Protocols
- Containerized Logistics Equipment and Technology
- Unified Set of Standard Modular Logistics Containers
**THE PHYSICAL INTERNET**

Encapsulating Goods in Standard Modular Containers Flowed Across Facilities Smartly Leveraging Such Containers

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### From handling/ moving goods in custom packages & unit loads

to handling and moving modular containers

protecting & consolidating goods

along their journey from makers to users

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### From dedicated, disconnected, siloed facilities

to open-access, interconnected facilities

designed for modular containerization and

for multi-party/multimodal operations & inter-facility flows

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**Easy to Handle, Store & Transport**

- Robust & reliable
- Snap and interlock
- Load and unload
- Seal and unseal
- Compose & decompose
- Conditioning capable
- Cleanable
- Panel (pub & info)

**Smart & Connected**

- Uniquely identifiable
- Communications capable
- State memory
- Reasoning capabilities

**Eco-friendly**

- Light & thin
- Reusable and/or recyclable
- Minimal off-service footprint
- Distinct structural grades

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**Encapsulating goods in standardized modular containers**

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**Production Fabs**

- Making
- Dis/Assembling
- Recycling
- Processing

**Deployment Centers**

- Ordered objects
- on their way to destination
- Consolidating
- Crossdocking
- Sorting, Swapping
- Transshipping

**Logistics Hubs**

- Factories
- Assembly centers
- Personalization Centers
- 3D Printing Centers
- Recycling Centers

- Warehouses, Depots
- Mixing Centers
- Distribution Centers
- (Micro-) Fulfillment Centers

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**Ordered objects**

- Requested by customer/user, prepositioned for convenient demand fulfilment

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**Transport Containers**

- (Pods)

- Modular fit in vehicles-carriers
- Boxes: 12; 6; 4,8; 3,6; 2,4; 1,2 meters

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**Handling Containers**

- (Totes, Boxes)

- Modular fit in Totes
- Boxes: 1,2; 0,8; 0,6; 0,4; 0,3; 0,2; 0,1
- Totes: 0,6; 0,4; 0,3; 0,2; 0,1 – ε – 6 meters

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**Packaging Containers**

- (Packs, Parcels)

- Modular fit in Boxes
- 1,2; 0,8; 0,6; 0,4; 0,3; 0,2; 0,1 – ε – 6 meters

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**Clients**

(Retail shelves, Homes)

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**Products ever better designed for encapsulation**

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**Toward Hyperconnected Humanitarian Logistics Operations**

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**Agile, convenient, efficient, fast, reliable, responsive, smart, sustainable, resilient**

**Adaptable, modular, mobile, scalable**

**Human-centric, automated and/or robotized**

Leveraging, Interconnecting & upgrading multitudes of existing facilities and developing new facility generations
THE PHYSICAL INTERNET
Towards Efficient, Sustainable, and Resilient Hyperconnected Logistics, Transportation and Delivery

From disconnected O/D shipments, long routes, hub-&-spoke networks, and dedicated distribution networks to openly consolidated relay flow through a web of multi-tier mesh networks of logistics hubs, deployment centers, and fabs.

From siloed transport options to concurrently interconnected multi-party omnisource transportation

*Idem for distribution & fulfillment*

From modal clashes & discontinuities to seamless, efficient & reliable multimodality / synchronomodality

Networks of access hubs, local hubs, gateway hubs, regional hubs, global hubs
Networks of fulfillment, distribution, and production centers
Interconnected to enable multimodal, multi-party flow consolidation/routing and distributed near-to-demand product deployment and production

Multiple studies have assessed highly significant improvements in overall induced costs, greenhouse gas emissions, service level, worker quality of life, and resilience.

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Seamless, trustworthy and Ubiquitous Transparency, tracking, traceability, smart contracts, smart predictions & decisions, cybersecurity
THE PHYSICAL INTERNET
Applying the PI paradigm to humanitarian logistics and supply chains

- **Physical Intranet:** Applying PI concepts and principles within a humanitarian organization
  Level 1: Within a country or state, and/or a division, across its multi-tier echelons
  Level 2: Across countries or states, and/or multiple divisions within the organization

- **Physical Internet:** Applying PI concepts and principles beyond a single organization
  Level 1: Across humanitarian organizations and in synergy with suppliers
  Level 2: In synergy with local/regional communities, supply chains & logistics networks
  Level 3: Interconnected with overall global Physical Internet (multi-industry, multi-scale)

Sample of PI features

- Use of standardized modular loading units
- Unilateral network to multi-directional
- Unique supply source to multi-sourcing
- Dedicated fleet to transport consolidation
- Dedicated assets to shared warehouse
- Adjustment of assignments and routings to satisfy changes in demand
- Estimating needs and smartly positioning inventories
- Dynamic capabilities against supply disruptions
3. DEVELOPED APPROACH AND FINDINGS
THE RESEARCH EXPERIMENT

A field oriented approach…

- In partnership with IFRC, Danish Red Cross and Indonesian Red Cross
  - Onsite visits in 2019 + regular workshops in 2019, 2020 and 2021

Focus on sudden onset disasters and relief items only
The testbed...

The experimental bench is made of 3 different interrelated systems:

1. **Scenario**
   - Configures the DSS parameters and the events to be evaluated.

2. **Performance**
   - Continuous monitoring and display of performance indicators.

3. **Virtual humanitarian ecosystem**

   - **(3) Territory Emulator**
     - Represents continuously a territory and its key components that may affect the humanitarian organization.

   - **(4) Disaster Generator**
     - Generates natural disaster events and impacts on people and materials.

   - **(5) Demand Estimator**
     - Estimates the demand in relief items based on victims' number and damages.

   - **(6) Humanitarian Response Simulator**
     - Represents the response for humanitarian organizations from a logistics angle.

   - **(7) Humanitarian Response Optimizer**
     - Support logistics decisions with optimized solutions.

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THE RESEARCH EXPERIMENT

The testbed...

- Focus on the disaster generator

Objectives
- Generate disasters with propagation
- Generate impacts

Characteristics
- Disaster
  - Category
  - Type
  - Location
  - Duration
  - Impact

Impact
- Affected districts requiring humanitarian assistance
- People affected, injured or died
- Damage ($)

Real Earthquake

Occurrence of different disasters

Simulation representation

Data visualization - District level

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THE RESEARCH EXPERIMENT

The testbed…

- Focus on the demand estimator

Disaster Intensity Modelling

Affected People Calculation

Relief Item Needs Calculation

Establish Consumption Profile

Generate Demand

Mimicking the real demand estimator system

Developing an ad hoc forecasted demand system

Disaster Location

Daily Requirement

Human Impact

Item

Replenishment Requirement

48h First assessment

Day 1

Day 2

Day 3

Day 4

Day 5

$S_1$

$S_2$

$S_1 + S_2$

$R_1 = S_1$

$W_{S1}$

$W_{S2}$

$W_{S3}$

$W_{S4}$

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THE RESEARCH EXPERIMENT

The testbed…

- Focus on the response simulator

Programming response processes and decision making rules (AS-IS and TO-BE) as an agent-oriented discrete events simulation
Focus on the response optimizer

Example of kits distribution from a regional warehouse to Mobile Storage Units (MSUs)
- Our aim is to serve as much demand as possible while lowering travel and inventory costs

The mathematical model allows determining within a PI perspective:
- Which kits will be delivered to which MSU and from where
- What type of trucks to use
- Which day(s) the truck(s) will leave the warehouse
THE RESEARCH EXPERIMENT

The experiment plan...

- From Physical Intranet to Physical Internet assessments

  **From logistics nodes to PI nodes**
  - Encapsulation system
  - Nodes’ interconnection across network
  - Replenishment method
  - Shared transportation
  - Shared warehouse strategy
  - Optimized transportation
  - Inventory pre-positioning
  - Network assets management

  **From organizational logistics networks to a physical INTRANet network**

  **From the physical INTRANet to the physical INTERnet**

  **Category**

  **HSC levers**

  **Baseline**

  **hyperconnected**

  - Use of standardized modular loading units
  - Unilateral network to multi-directional
  - Unique supply source to multi-sourcing
  - Dedicated fleet to transport consolidation
  - Dedicated assets to shared warehouse
  - Adjustment of assignments and routings to satisfy changes in demand
  - Estimating needs and smartly positioning inventories
  - Dynamic capabilities against supply disruptions
  - Physical intranet to a Physical internet
THE RESEARCH FINDINGS
Promising first results...

- Regarding the time
  - Up to 72% faster response time for PI scenarios

Best scenario are using the matrix sourcing approach with a short replenishment lead time.

Baseline performs less well than the other scenarios which integrate PI concepts.

(SR: Sourcing, RL: Replenishment, SH: Shortage)
THE RESEARCH FINDINGS

Promising first results...

- Regarding the cost
  - Transportation cost is significantly reduced in systems using matrix approach

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Endogenous Factor</th>
<th>Level 0</th>
<th>Level 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR</td>
<td>Sourcing/Replenishment</td>
<td>Hierarchical</td>
<td>Matrix</td>
</tr>
<tr>
<td>RL</td>
<td>Replenishment Lead Time at the RW</td>
<td>15 days</td>
<td>3 days</td>
</tr>
<tr>
<td>SH</td>
<td>Shortage</td>
<td>FIFO</td>
<td>Equity</td>
</tr>
</tbody>
</table>

Cost

Factor influence on the total transportation cost

Scenarios combining hierarchical & equity

(SR: Sourcing, RL: Replenishment, SH: Shortage)
THE RESEARCH FINDINGS

Promising first results…

- Regarding the quality
  - Better demand coverage at 15 days for all the PI scenarios
  - The PI scenarios allow to cover up to 95% more of the total demand than the baseline scenario

![Diagram showing demand coverage distribution at 15 days per scenario based on replications]

(SR: Sourcing, RL: Replenishment, SH: Shortage)
4. AVENUES FOR RESEARCH AND PRACTICE
A PROMISING FUTURE

Conclusions...

- The presented research work is demonstrating the huge potentiality of thinking humanitarian logistics within a hyperconnected and a sentient perspective.

- But the project is still in its infancy…
  - A lot of remaining tasks still have to be done!
A PROMISING FUTURE

Toward a fast and efficient scalability…

- Extending the approach to more favorable fields
  - Slow onset disasters, Logistics Cluster stakeholders…

- From focus to wide research scalability
  - Additional practice-oriented research experiments such as pilot projects, action researches, living labs…

- Opening the project to the instrumentation dimension by moving from concept to reality…
  - Digital Twin decision-support systems
  - PI containers for humanitarian logistics
  - IoT systems for humanitarian logistics
  - AI applications for humanitarian logistics
  - Immersive decision support systems
  - …