

Assessing the potentialities of Physical Internet for Developing Countries Last Mile deliveries

Sam Ban, Andreea Dan, Félix Guinet, Julien Portanguen, Matthieu Lauras, Sarot Strong

▶ **To cite this version:**

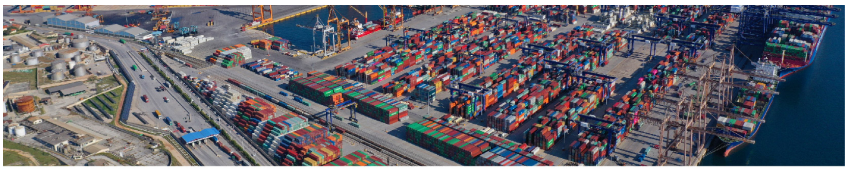
Sam Ban, Andreea Dan, Félix Guinet, Julien Portanguen, Matthieu Lauras, et al.. Assessing the potentialities of Physical Internet for Developing Countries Last Mile deliveries. IPIC 2021 - 8th International Physical Internet Conference, Jun 2021, Online, Greece. 10 p. hal-03395369

HAL Id: hal-03395369
https://hal.science/hal-03395369

Submitted on 22 Oct 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



IPIC 2021 | 8th International Physical Internet Conference

IMT Mines Albi-Carmaux
École Mines-Télécom

Assessing the potentialities of Physical Internet for Developing Countries Last Mile deliveries

Sam BAN[1, 2], Andreea DAN[1], Félix GUINET[1], Julien PORTANGUEN[1], Sarot SRANG[2] and Matthieu LAURAS[1]

[1] Industrial Engineering Department, IMT Mines Albi, Toulouse University, Albi, France
[2] Industrial and Mechanical Engineering Department, Institute of Technology of Cambodia Tuol Kouk, Phnom Penh, Cambodia
Corresponding author: matthieu.lauras@mines-albi.fr

Abstract: *Developing countries are so particular as transports are often saturated, infrastructures are in poor condition and the demand is growing so fast. In such a context, the studied research question is: Does Physical Internet (PI) can improve the Last-Mile delivery performance in developing countries? And if so, how and how-much? To start answering this, the paper develops a quick literature analysis of PI solutions to identify which paradigms could bring added value to developing countries. Then, it presents a dedicated simulation-driven method able to assess the potential benefits and limits of applying PI to this specific situation. A Cambodian field-oriented case is finally presented as a very first ongoing experiment to validate the approach and a set of insights regarding further research able to deliver concrete recommendations for both practitioners and scholars is given.*

Conference Topic(s): *Last mile & City Logistics, PI Modelling and Simulation.*

Keywords: *Physical Internet, Supply Chain, Logistics, Last Mile Delivery, Simulation, Developing Countries, Cambodia.*

1 Introduction

Logistics represent a springboard and a key factor as an efficient supply chain allows for smoother and more competitive cities. This aspect is particularly impacting for developing countries which are mainly based on import-export economies (Tang and Bundhoo, 2017). Developing countries' main cities are designed differently from those of developed countries, in terms of organization and means of transport, which provides an opportunity for flexibility (Reda et al., 2020). Our study intends to apply the principles of the Physical Internet (PI) paradigm to developing countries' supply chains in order to assess its potentiality, notably regarding last-mile deliveries' issues. The research work is developed through an ongoing real application case made in the city of Phnom Penh, Cambodia.

Today, Cambodia's infrastructures, as other developing countries' infrastructures, are in poor condition with little maintenance. There is little to no collaboration between logistics actors as the market is rather competitive (Cervero, 2013). Moreover, there is no strategy or real-time monitoring that aims at consolidating the material flows. All of these factors lead to unoptimized roads where huge traffic jams occur on a regular basis, resulting in expensive logistics and prolonged lead-times (Pucher et al., 2005). There are many issues at stake, and they have a real economic interest because annually important financial loss is due to inefficient-logistics costs (Landschützer et al., 2015). In terms of economic development, in Cambodia, current solutions are the followings: investing in infrastructures, changing current import-export legal background or developing a Logistics Master Plan by the Royal

Government of Cambodia. These objectives are only very long-term solutions while the PI logistics approach of our study makes the bet that a better use of the existing current resources might deliver much more effective results. The PI solutions should have the consequence to reduce lead-times, which should increase customer satisfaction and the country's competitiveness thanks to optimized and fewer journeys (Neeraja et al., 2014). In addition, mitigating traffic leads should imply a reduction in environmental and noise pollution, an increase in the level of health and the quality of life of the inhabitants (Jardas et al., 2016). All of these progresses should support important benefits for developing countries such as the creation of jobs and economic activities. That is what our study intends to demonstrate.

The first section of this paper develops a quick literature analysis of both PI paradigms and developing countries logistics features in order to define and justify the research statement of the project. The second section is dedicated to the presentation of the flow simulation system that is currently developed to compare the current situation with some new PI-driven last-mile delivery options. The third section presents the ongoing application of the proposal to the case of an e-commerce company in Phnom Penh. Finally, the paper concludes on the positive benefits of using PI paradigm to logistics and last-mile delivery in developing countries' context that are beginning to be confirmed and open a set of perspectives for further research.

2 Background and problem statement

2.1 Developing countries' logistics features

The logistics performances in Cambodia, as many other developing countries, are difficult to measure due to the lack of data but approximations made by the World Bank indicate that these countries are systematically below-average of the world Logistics Performance Index (Kraay, 2018). Globally the Logistics Performance Index of a developing country represents something like 50% of a developed country… The lack of logistics data for developing countries also leads to the impossibility of drawing a complete picture with the goal of identifying the problems in the transport's networks. Nevertheless, in developing countries, transport seems to be the highest component in terms of costs followed by inventory carrying (Kraay, 2018). Some studies have shown that the most important factors affecting the logistics processes of some developing countries were in order: limited information centralization, either lack of or poor infrastructures, and some specific risks such as corruption (Yang and Wang, 2019). The World Bank also demonstrates a lack of standard contracts which implies the impossibility of implementing advanced partnerships for managing Supply Chains and Logistics' activities. However, most of the developing countries consider now this issue as a critical point and try to invest in the improvement of their capabilities. For instance, the Royal Government of Cambodia established recently a plan of Industrial Development Policy that is to be implemented between 2015 and 2025 which has the main goal of transforming and modernizing the national industrial structure, and particularly the Supply Chain Management capabilities of the country (Kraay, 2018). However, this kind of initiative is of great interest, it will take decades before achieving effective results. That is why, the aim of the current research work is to assess the potentialities of better using existing assets and means to improve the logistics performance.

On their side, (Reda et al., 2020) studied the features of developed, emerging and developing countries in matter of urban logistics. Based on an extensive literature analysis (more than 300 articles were studied), they demonstrated that the main logistics and supply chain issues for developing countries are urban and city logistics problems. Notably, they remind the key features of these countries, already mentioned in (Guimarães et al. 2020), regarding the last-

mile delivery question: very high traffic congestion and high level of unsafety on roads; high growth of population (i.e., consumers but also drivers); few and poor-quality infrastructures (roads, rails, ports/airports…); expensive, polluting and unreliable vehicles. They also identify those developing countries are working now on some hot topics which are crowd-shipping, urban consolidation centers, e-commerce delivery, loading/unloading areas, alternative transportation modes, and parcel lockers (Reda et al., 2020). Regarding those challenges, Physical Internet (PI) appears as a potential lever able to support the developing countries' logistics performance, particularly in urban areas, and particularly regarding the last-mile delivery issue.

2.2 The PI opportunities

The PI is a recent and innovative concept of interconnected logistics networks capitalizing on the ability to share resources and information (Montreuil et al., 2012). The definition of the PI is a global logistics system built from the interconnection of logistics networks through a standardized set of collaboration protocols, modular containers, and intelligent interfaces for increased efficiency and sustainability (Ballot et al., 2014). As highlighted in this definition, PI proposes a rethinking of the fundamentals of logistics. The term "interconnection" thus refers to the close and intensive connection between actors and network components. The second key aspect of PI is the desire to open up logistics networks and share assets. Today, companies form private and relatively stable networks that own their own warehouses and vehicles in general. PI breaks with this logic and assumes that assets should be shared among all users of this new network and used as needed. Moreover, PI as a "network of networks" seeks to increase visibility and the possibility of new connections between actors.

This concept of PI was born in order to satisfy the increasing requirements in terms of environment and performance of services. Indeed, the current logistics system, particularly in developing countries, presents dysfunctions that are harmful to the environment and tend to compromise the sustainable development objectives (Ballot et al., 2014). Before it is too late, the PI was designed to offer a chance for logistics services to be more resilient, efficient, sustainable, and adaptable for its users by changing the way physical objects transit through the network (Montreuil et al., 2012). In terms of stakes, most of the theoretical advantages of PI usage have been studied and demonstrated in various application domains (Sallez et al., 2016). But almost all instantiations of PI concern developed countries and not really the rest of the world. This remains to be explored.

It also should be noted that such a paradigm shift in logistics requires significant transformations at various levels. In other words, the accessibility challenge is consequent. First of all, it is necessary to get adapted information systems using advanced technologies to enable the hyperconnection of actors, allowing increased and standardized information sharing and massive data storage (Montreuil et al., 2010). Then, it will be necessary to make the actors accept to evolve towards this new mode of operation and to engage efforts in this direction. The expected investments will be mainly financial and time related (Grest et al., 2019). In this respect, the ALICE (Alliance for Logistics Innovation through Collaboration in Europe) grouping has recently published a roadmap formulating the important steps and associated prerequisites for the implementation of the PI by 2050 (ALICE-ETP, 2020)… in developed countries. However, we can notice that digitalization of developing countries is quite good, and the key players seem ready to explore innovative solutions instead of duplicating old ones issued from developed countries. As a consequence, it seems reasonable to consider the PI accessibility issues feasible in the context of developing countries.

To sum up, the PI is slowly being implemented almost everywhere in the world, but it needs to be more widely known and especially convincing to be more widely adopted, especially in developing countries. This project therefore aims to show whether or not PI is of interest to the last-mile deliveries in developing countries' urban logistics context. Notably, according to (Ban et al., 2020), the following concrete objectives should be challenged and assessed: (i) reduce transportation lead times; (ii) improve on-time delivery ratio; (iii) avoid useless travelled distance; (iv) limit waste of goods due to bad transportation; (v) improve carriers' profitability; (vi) allow transportation multimodality; (vii) allow real time tracking of goods; (viii) optimize transportation costs; and (ix) reduce carbon footprint impact of transportation.

3 Proposal

Basically, the core contribution of this paper consists in designing both functional and technical architectures able to support the ambition of the whole research project described previously. Obviously, this is only a necessary but not sufficient step towards what will be the major contribution of this research work, i.e., a set of recommendations for significantly improving the logistics performance of developing countries by making better use of existing infrastructure and resources.

3.1 Functional architecture

To reach the goal of the current research, a nine-step methodology has been set up as a functional architecture, as shown in Figure 1. Inspired by the approach developed by (Vernadat, 2004) for supporting enterprise re-engineering and improvement processes, this methodology consists in four main phases which are: Conceptualize, Model, Experiment and Assess.

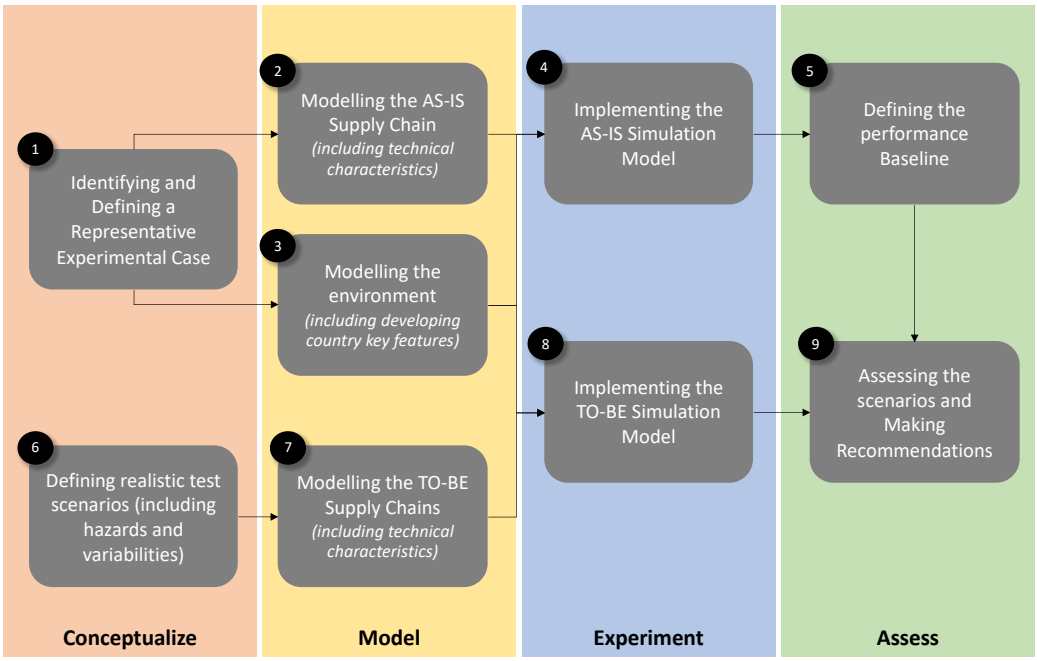


Figure 1: Functional architecture

These phases embedded the following steps:

- Step1: As our approach is field-oriented, this first step consists in selecting a concrete application case which is representative of the studied problem. In our context, the case should be a supply chain located in a developing country and having a high number of urban shipments to manage.

- Step 2: This step allows building a digital model of the current supply chain which includes the main features of the selected application case. This model would be able to simulate the AS-IS behaviors of the selected case.
- Step 3: This step consists in modelling the environment, and notably the urban characteristics, in which the select supply chain evolves. This model must be able to consider the specific developing countries' features (traffic congestion…).
- Step 4: At this stage, the two previous models are joint in a dynamic way to support simulations of the selected case behavior. Discrete event, multi-agent or systems dynamics models might be used to support this step.
- Step 5: This step consists in measuring objectively the performance of the selected supply chain in order to get a baseline. This baseline will be compared to other organizational alternatives, notably the ones which are based on PI.
- Step 6: From this step, the functional architecture moves to the definition, the modelling and the assessment of possible TO-BE organizations. Particularly, this step consists in designing a set of logistics scenarios likely to improve the overall supply chain performance.
- Step 7: As for step 2, this step supports the modelling part of the potential scenarios previously defined.
- Step 8: As for step 4, this step consists in simulating the scenarios in the context of the environment defined and modelled in step 3.
- Step 9: Finally, this step allows measuring the performance of each scenario defined in step 6 and comparing their results with the baseline calculated in step 5 to make conclusions and deliver some recommendations to practitioners.

3.2 Technical architecture

To the support the previous functional architecture, we have developed the technical architecture presented on Figure 2. First, this architecture supports the gathering of both qualitative and quantitative data from the teams and the legacy systems of the selected company. Additional open data bases are also considered to feed efficiently the step 3 of the functional architecture (particularly regarding the city mapping, the traffic mapping, etc.

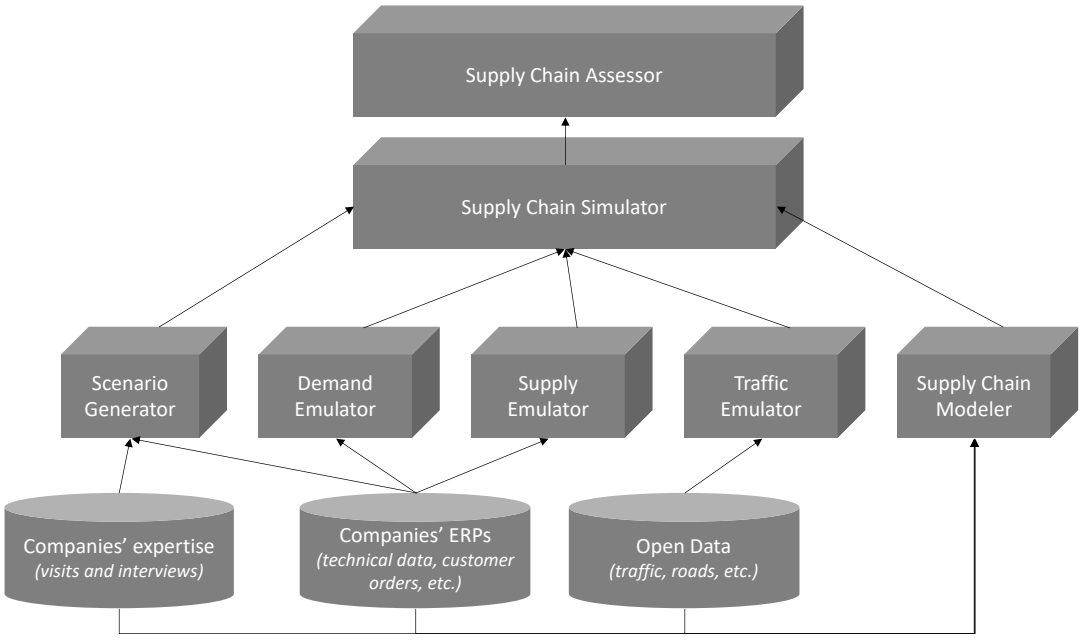


Figure 2: Technical architecture

From those data bases, several technical components have been built based on AnyLogic® simulation software, enriched with some Excel sheets and dedicated Python codes:

- A set of emulators have been set up to feed the simulation model according to the AS-IS and TO-BE scenarios. These emulators allow simulating the behaviors of respectively, the suppliers, the customers and the external traffic in the city.
- A module dedicated to the scenarios' definition has been developed to allow definition in AnyLogic® language of both AS-IS and TO-BE options.
- The core of this architecture is composed of a Supply Chain modeler and a Supply Chain simulator using a hybrid simulation model (multi-agent and discrete event simulation mainly) to support test-runs and assessments of the defined scenarios. This part of the technical architecture is developed on AnyLogic®.
- Last but not least, a dedicated dashboard including Key Performance Indicators such as logistics costs, On-Time delivery In Full, lead times, occupancy rates of used vehicles, carbon footprint, etc. has been set up to compare objectively all the scenarios and to support recommendations.

4 Ongoing application case

4.1 Step 1

The case study of this research is about an e-commerce company (mainly focused on fashion items), located in Phnom Penh city, typical of a developing country import business. Their consumers use a dedicated website to order and are supposed to be delivered within one day at a maximum if the product is in stock, and within few days or weeks if the product is out-stock. The turnover of the company is growing very fast (also typical from a developing country) and according to the CEO, the main challenge of such a company is to manage properly the logistics issues, and particularly the last-mile deliveries. He said that it is very hard to reach the target of logistics services such as same day delivery guarantees, hassle-free delivery and the right products at the right time at the right place and in the exact amount.

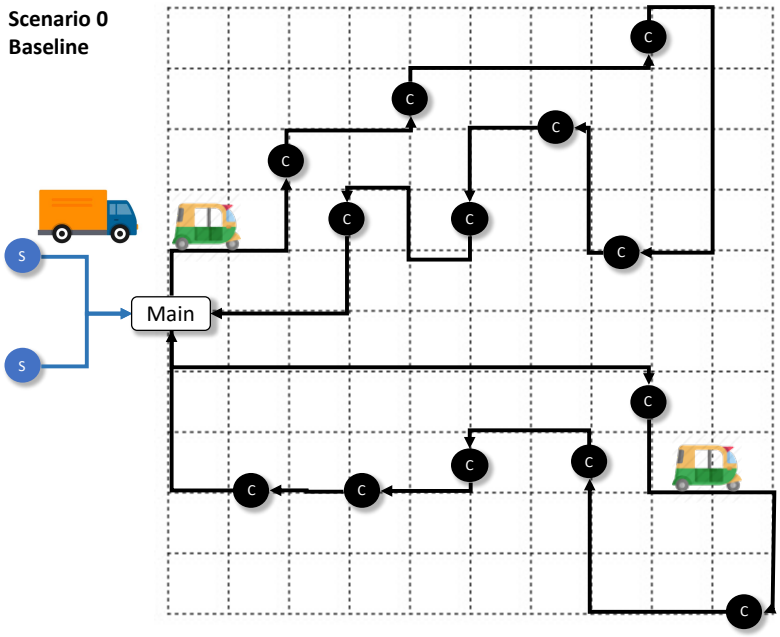


Figure 3: AS-IS Supply Chain scenario

4.2 Step 2

The company manages several thousands of items, both in-stock and out-stock, and its main suppliers are located in China, Thailand and Viet Nam. The company operates through one main warehouse and a small outlying one (not considered in this paper), both located in the city center and ownership of the company. The last-mile delivery is managed through a dedicated fleet (ownership of the company) of vehicles use through basic routings. Although, the company is thinking about a potential evolution of its network, its current supply chain is outlined on Figure 3. If the main activity concerns the management of its own products, the company also offers logistics services to some other companies (particularly regarding transportation). However, this last point is not in the scope of the study yet. The current order fulfillment process is described on Figure 4. We must notice that the IT systems use for managing the information and material flows is quite mature, and a bar-code tracking system is running at each step of the process.

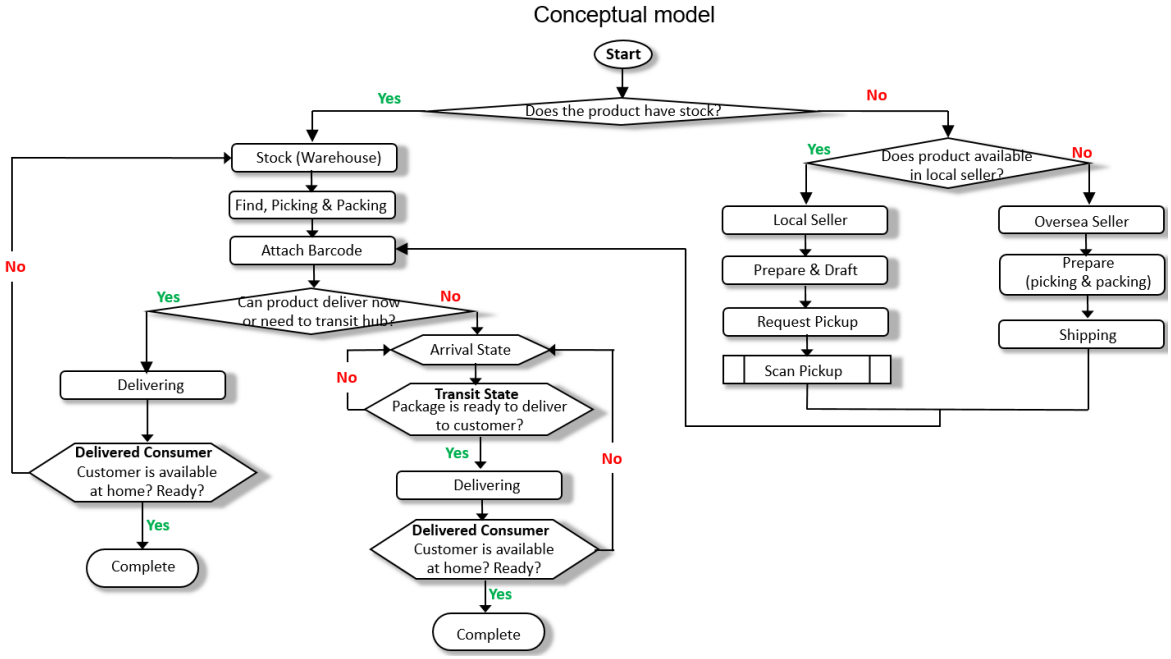


Figure 4: Conceptual model of the order fulfillment process.

4.3 Step 3

A case study by (Seiya Matsuoka, 2018) on traffic management on Phnom Penh clearly stated that traffic congestion and accidents are major issues in Phnom Penh. As a consequence, the speed of vehicles is hazardous and globally slow. Most of the time, companies (like ours) use their own fleet of vehicles for business operations. In addition, there is a huge number of individual transport businesses for passengers and/or goods (motorcycle taxi, tuk-tuk, Remork, Bajaj, etc.) These vehicles are moving randomly in the city to catch up passengers from one place to another. Most of the time, they are moving empty... (Seiya Matsuoka, 2018) also notes that the speed of vehicles is inversely proportional to their capacity, so motorbikes move faster than trucks or tuk-tuks. Basically, these features are the ones which have been implemented in our model by considering different speeds depending on the location, the time and the type of vehicles, by adding variabilities and hazards in the traffic, and by including external vehicles in the model that might be considered as potentialities for the business of the company. A last characteristic has been considered in the model. That's the way of life of Cambodian people who lives outside most of the time during the day. The consequence is a very high number of no-show. This has been also included in the model.

4.4 Step 4

This work has been set up through a simulation model using AnyLogic® package. The model uses both discrete-event and agent-based modelling methodologies for simulating the environment and last-mile delivery process. Mainly, this scenario #0 (baseline) follows the process describes on Figure 4 and is illustrated on the left part of Figure 5.

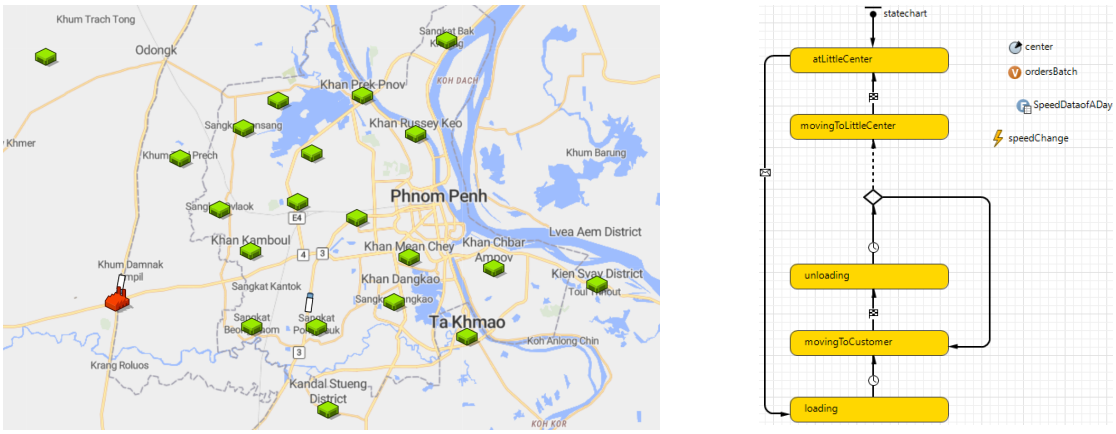


Figure 5: Illustration of simulations made on AnyLogic

In this first instance, in line with the field-reality, last-mile routes are ensured by truck, vans or tuk-tuk as shown on Figure 3. We made the assumption that all products are available in stock as we focused our analysis on the last-mile delivery issue. The transportation capacity is defined as 2 vehicles for 20 customers. All vehicles are attached to the main warehouse.

4.5 Step 5

Resulting from the previous model, we were able to establish a baseline on a set of Key Performance Indicators (KPIs). Mainly, we analyzed the situation regarding the lead-times, costs, no-shows, carbon-footprint and occupancy rate of vehicles. At this stage, as we did not have any reference, it was not possible to say if the KPIs were good enough or not.

4.6 Step 6

From this step, we defined a set of simple but PI-oriented scenarios in order to assess the potential improvements we can expect in such a context. The scenario #1 includes 4 PI-hubs in addition to the main warehouse (see Figure 6 on the left). Each PI-hub is located at the border of a part of the city and is used to manage all the customer orders of this area. Smaller vehicles (motorbikes) are now attached to these PI-hubs and trucks and tuk-tuks are only used to send massive group of orders from the main warehouse to the PI-hubs. Nothing is changed regarding the supply, the customers' and traffic behaviors.

A scenario #2 (see Figure 6 on the right) is then defined which is almost the same than the scenario #1, except that here we do not consider an own fleet of vehicles for the company. Vehicles are not attached to the PI-hubs, they are chartered "on demand" depending on opportunities around the PI-hub when there is a need (like Uber).

A scenario #3 (not illustrated in this paper) consists in considering that two companies having two different main hubs but sharing the PI-hubs previously defined. Although these companies are on different businesses, have different products and different customers, they share facilities and process regarding the last-mile delivery.

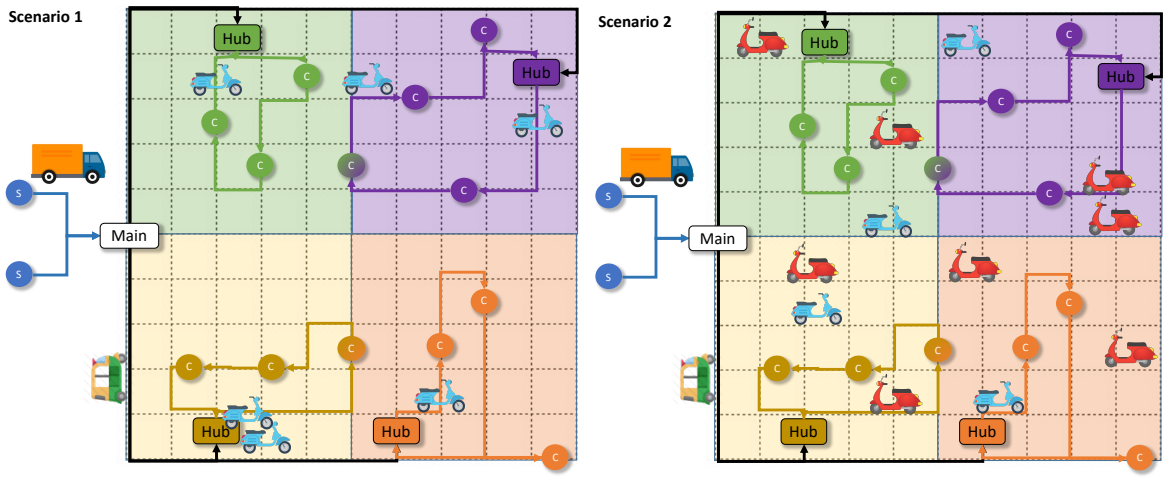


Figure 6: PI-oriented scenario #1 and #2

4.7 Step 7

In this step, the same modelling techniques than the ones discussed in Step 2 have been used.

4.8 Step 8

In this step, the same modelling techniques than the ones discussed in Step 4 have been used.

4.9 Step 9

Even if the experiments are still ongoing, first results start to appear thanks to the proposed methodology and simulation tools. Figure 7 for instance shows first results in matter of lead-time between scenarios #0 (baseline) and #1. It appears, that the introduction of PI-hubs in the context of the studied company, in Phnom Penh city speed up drastically the deliveries. Our experiments seem to indicate the same trend (i.e., better results with the PI scenario compared to the baseline) in matter of logistics costs, carbon footprint and vehicle occupancy rate. Obviously, additional studies remain necessary to analyze these very first results, particularly regarding the validity of the assumptions, the size of the model (coverage) and the sensitivity of the model.

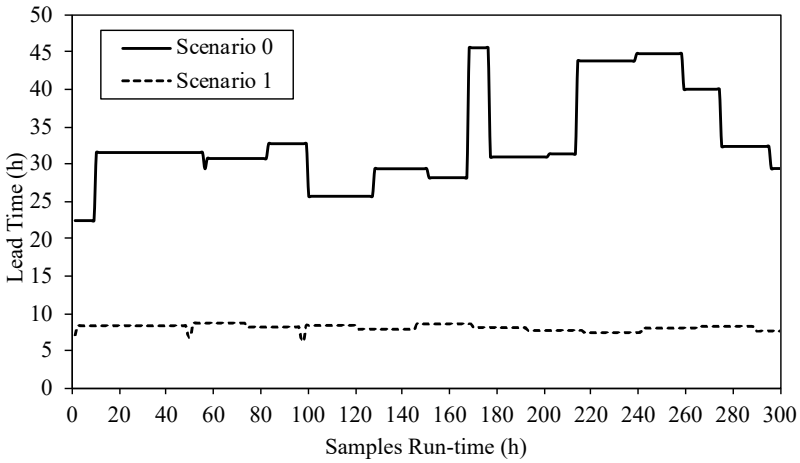


Figure 7: Lead-time comparison of scenarios #0 (baseline) and #1

5 Conclusions and further research

In this study, we addressed the question of the relevance of using the PI approach in a developing country context. In particular, we studied the question of how to improve the

performance of last-mile delivery in such a context. Our ambition is to demonstrate that PI might be a great alternative for developing countries allowing them to have good logistics performance despite of poor infrastructures and means. For the moment, the proposal only consists in a concrete methodology composed of functional and technical architectures dedicated to this issue on one hand, and on a real ongoing illustrative case on the other hand. While the research work is in its infancy, first promising results appear and seem to demonstrate the relevance of using PI in developing countries logistics problems. Obviously, significative additional works remain to do to confirm these first conclusions and finally produce concrete recommendations for both scholars and practitioners. Rapidly expanding the proposed models to match much better the complexity of the field seems a necessity (more customers, more products, etc.). Also, including other dimensions of the studied supply chains such as supply is a room for improvement. Last but not least, enriching the environment simulation to better consider developing countries' features (as risks or opportunities) seem to be an essential perspective.

References

Cervero, R. (2013). Linking urban transport and land use in developing countries. *Journal of transport and land use*, *6*(1), 7-24.

Neeraja, B., Mehta, M., & Chandani, A. (2014). Supply chain and logistics for the present day business. *Procedia economics and finance*, *11*, 665-675.

Jardas, M., Dundović, Č., & Badurina-Tomić, P. (2016). Supply chain–a key factor of the sustainable development of city centers. Pomorstvo, 30(1), 45-50.

Montreuil, B., Rougès, J. F., Cimon, Y., & Poulin, D. (2012). The physical internet and business model innovation. *Technology Innovation Management Review*, *2*(6).

Montreuil, B., Meller, R. D., & Ballot, E. (2010). Towards a Physical Internet: the impact on logistics facilities and material handling systems design and innovation.

Sallez, Y., Pan, S., Montreuil, B., Berger, T., & Ballot, E. (2016). On the activeness of intelligent Physical Internet containers. *Computers in Industry*, *81*, 96-104.

Ballot, E., Montreuil, B., & Meller, R. (2014). *The physical internet*. La Documentation Française.

Grest, M., Lauras, M., & Montreuil, B. (2019, September). Toward Humanitarian Supply Chains Enhancement by using Physical Internet Principles. In *2019 International Conference on Industrial Engineering and Systems Management (IESM)* (pp. 1-6). IEEE.

Ban, S., Lauras, M., & Srang, S. (2020, November). Toward Physical Internet-Enabled Supply Chain and Logistics Networks in Developing Countries. In *Working Conference on Virtual Enterprises* (pp. 379-389). Springer, Cham.

Vernadat, F. B. (2004, June). Enterprise Modelling: Objectives, Constructs and Ontologies. In *CAiSE Workshops (3)* (p. 99).

Guimarães, Vanessa de Almeida, Gustav Carl Skroder, Glaydston Mattos Ribeiro, and Pedro Henrique González-Silva (2020). « Strategic planning of freight transportation to support smart cities design: The Brazilian soybean case ». Revista Facultad de Ingeniería Universidad de Antioquia.

Reda, A. K., Gebresenbet, G., Tavasszy, L., & Ljungberg, D. (2020). Identification of the regional and economic contexts of sustainable urban logistics policies. *Sustainability*, *12*(20), 8322.

Kraay, A. (2018). Methodology for a World Bank human capital index. *World Bank Policy Research Working Paper*, (8593).

Landschützer, C., Ehrentraut, F., & Jodin, D. (2015). Containers for the Physical Internet: requirements and engineering design related to FMCG logistics. *Logistics Research*, *8*(1), 1-22.

Tang, K. B., & Bundhoo, D. (2017). Foreign aid and economic growth in developing countries: Evidence from Sub-Saharan Africa. *Theoretical Economics Letters*, *7*(05), 1473.

Pucher, J., Korattyswaropam, N., Mittal, N., & Ittyerah, N. (2005). Urban transport crisis in India. *Transport Policy*, *12*(3), 185-198

Yang, N., & Wang, Y. (2019). Identify silent data corruption vulnerable instructions using SVM. *IEEE Access*, *7*, 40210-40219.