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A Proposed Simulation Model for Enhancing the efficiency of Freight Transportation Network in Egypt Based on Physical Internet Tools

Ashrakat Osama
Teacher Assistant
College of international transport and logistics
ashrakatosama7@gmail.com

Dr. Aya Mostafa Elgarhy
Assistant professor
Dean of international transport and logistics institute
aya.elgarhy@aast.edu

Arab Academy for Science Technology and Maritime Transport, Egypt

Abstract

Purpose: Physical internet enhances the efficiency of logistical activities which main aim is to achieve sustainable development especially in lowering the environmental footprint

Design: the paper investigates scientific papers and project reports to define the transportation system especially in Egypt and faced problems, and how the PI-tools can be used to enhance the system

Research methodology: this research conducts a case study to investigate the relationship between applying PI-tools in transportation through conducting interviews with startup companies in transportation fields and applying simulation model to measure the results on largescale and small scale.

Findings: The results revealed a reduction in carbon dioxide emissions and reduction on the cost by 40 %.

Research Limitations: the research paper mainly focused on applying the concept on FMCG industry. Moreover, there are many constraints to apply the concept with its main tools in all countries.

Implications: Applying the physical internet with its main tools will greatly affect the sustainability of transportation systems and will reduce transportation therefore improving the performance of the whole supply chain.

Originality: This paper provides a proposed simulation model for transportation network according to the main principles of the physical internet instead of moving commodities for a long distance from the origin point to the destination, it can move through PI-hubs to the destination to reduce the transportation process

***Keywords**: Freight Transportation, Physical Internet, Road Transportation, Agent-Based Simulation.*

Introduction

Logistics has become an integral part of our way of life, allowing us to consume commodities from all over the world all year long at reasonable costs. It has evolved into the backbone of global trade, owing to the efficiency of container shipping and handling across continents (Montreuil et al., 2013). The present supply chain structure fails to accomplish two objectives: small, frequent, just-in-time shipments and improved environmental performance through the optimal use of heavier, cleaner transportation modes. The future of freight transportation will be different since it is no longer an option but a need. Current transportation, storage, and product handling practices are incompatible with sustainable development principles, resulting in inefficiencies at all levels, from empty trucks to underused distribution facilities. (Serraj et al., 2013) (Matusiewicz 2020).

Freight transportation accounts for 7-8% of global warming emissions, making it one of the most challenging economic sectors to decarbonize. Demand is predicted to skyrocket in the next decades, with fossil

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fuels accounting for the vast majority of it. The physical internet provides an innovative and ecologically sustainable answer to worldwide concerns of how businesses handle, develop, distribute, and consume tangible objects in the actual world (McKinnon, 2018; Montreuil, 2010).

There is a big reliance on road transportation for moving freights, and most of the factories are based in industrial areas far from the cities which make them take long distances to deliver the products to the retailers or customers which has an impact on the increasing rate of the fuel consumption that makes companies pay many costs and at the same time it harms the environment in a bad way. (Sayed and Garhy, 2018) There are other problems resulting from this issue as companies pay fees for car maintenance and toll gates, another aspect includes the drivers especially those who drive across governances for long trips, as they suffer from the lack of social life as they obliged to drive for days to transport the products, sometimes They also take medicines to stay awake, which might result in several mishaps. Therefore, this research seeks to find a solution to reduce the long distances which will reflect the transportation costs and fuel consumption in order to enhance the efficiency of transportation process.

This paper is ordered as follows the first section describes an overview about the fright transportation system and main problem of fuel consumption in road transport, the following section two is about the physical internet and previous studies and case studies of applying the concept. Section three presents the simulation model of the classic model and proposed physical internet model. Finally in section four the results are discussed and limitations for future research.

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Literature Review and theoretical framework

This section presents the main problem of freight transportation in Egypt, and then it reviews the physical internet with its tools and previous studies related to the concept.

Road Transport System

Because of its direct influence on the economy, transportation is the country's cornerstone of economic growth. The establishment of society as a key part in the achievement of economic and social development programs has a significant role in the movement of passengers and liquids, as well as in setting up the desired geographic distribution of population centers to achieve the movement's advancement and development, there must be a link between locations, settlements, and distribution hubs. Internal and external commerce, with its enormous influence on all other sectors of the state, whether service or commodity, contributes significantly to the growth of the state's financial resources and the betterment of its economy. Increasing the availability of transportation services, lowering their costs, and enhancing their performance to contribute the rise in the distribution and degree of settlement, which shows a favorable trend in easing individual and national transportation (Demir et al., 2014).

For carrying freight along corridors, vehicle transport (trucking) is the most common means of transportation in most locations. Road transport accounts for more than 80% of overland commerce activity, and practically all trade freight is transported by road at some point. For the unhindered flow of freight and people along corridors, efficient delivery of road transport services is important(World Bank Group, 2016).

Problem of Harmful Emissions in Egypt's Transportation Sector

Over the last few decades, there has been widespread agreement that reducing carbon emissions is an unavoidable step in slowing down and mitigating the effects of climate change. As a result, freight transportation is often seen as one of the most challenging economic activities to decarbonize, as fossil fuels are the primary source of energy for most modes of transportation. According to projections, freight's contribution to total carbon emissions would rise from 7% in 2012 to 16% in 2050, as demand for transportation in more linked economies grows (Mckinnon, 2018). From an environmental standpoint, the continuous increase in the use of transportation leads to increased demand for energy, and the expansion in the use of energy inevitably has an impact on the environment, as the resulting emissions harm the surrounding environment, cause pollution, and severely harm all economic and social activities in the country(Riley et al., 2016).

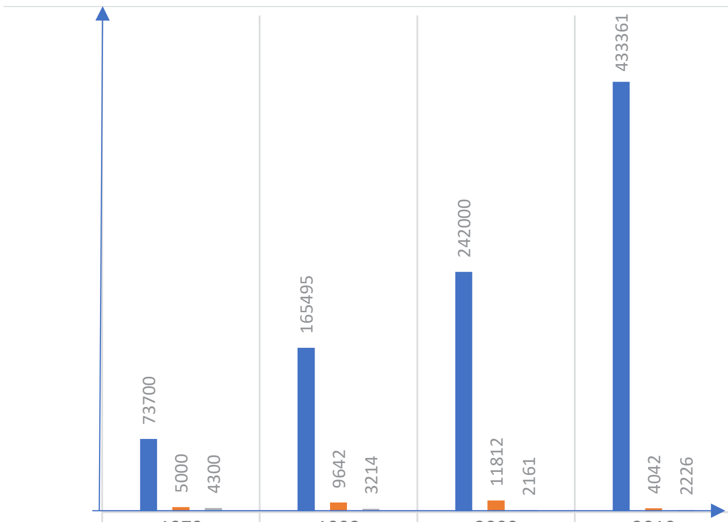
The Egyptian Arab Republic's Ministry of Transport oversees the building, planning, and keeping of transportation networks. Supplying public transportation services to all people and families, as well as controlling the use of public transit. Activities that assure the flow and regularity of movement safely and securely, following transportation demand Each of them, considering adequate levels of service, considering, primarily, the social part without focusing on money return while pursuing the most essential economic objectives of Egypt's transportation system takes advantage of each mode's unique characteristics (Yehia et al., 2019).

As shown in figure 1 transportation in Egypt over the last decades rely heavily on roads, according to (JICA, 2012) from 1979 modal share was more than 88% while railways were about 6%and the inland waterway was 5%, and the reliance on roads kept increasing till in 2010 it reached 98.6% for the road only, while 0.5% for the inland waterway and 0.9% for the railway. As said by (Yehia et al., 2019) As a result of boosting economic and social growth, the total demand for goods transportation has been steadily increasing. In the

Arab Republic of Egypt, the total weight of movables in 2010 was around 171 percent of the total weight of movables in 2000. This reflects an increase in the demand for road transportation services.

Demand for rail and water transportation has decreased and as expected (JICA, 2012) in 2027 total size of transportable products will reach be increased to 232% from 2010 and about 96% will also rely on the roads.

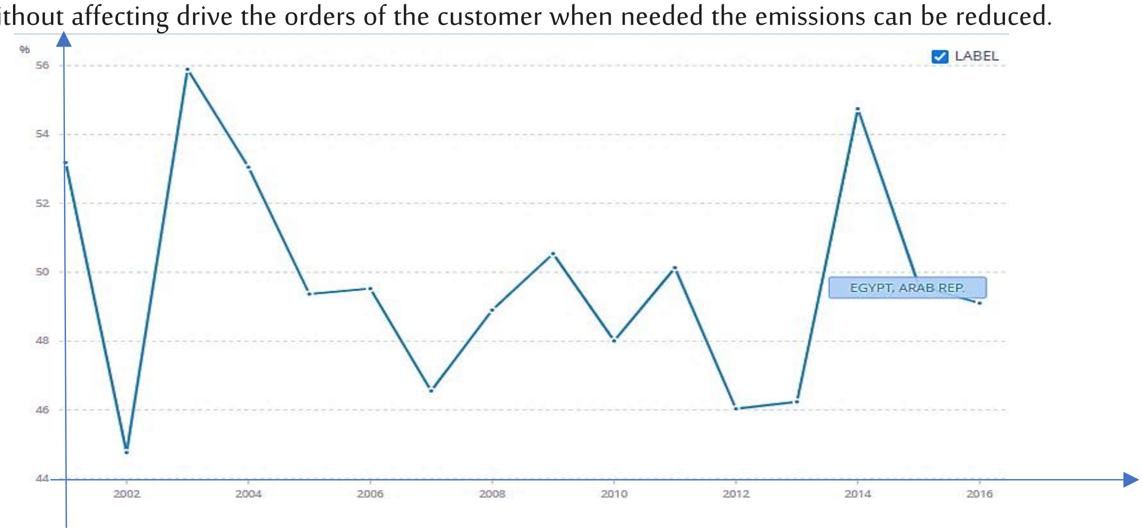
The fuel consumed during the journey of delivering the products and the percentage of co2 emissions that can harm the environment should be considered as shown in figure 2 the emissions of co2 from liquid fuel consumption in Egypt till 2016. Most trucks in Egypt are diesel-fueled vehicles. Trucks oversee more than 97% of freight transport in Egypt with 204,377, 200ton-kilometers per day(JICA, 2012) which means that there are many trips for long distances moreover in some cases the return journey for the truck can be empty which causes waste of time, effort, costs and may also harm the environment with more co2 emissions. So, if there is any way to avoid empty journeys without affecting drive the orders of the customer when needed the emissions can be reduced.



	1979	1992	2000	2010
Road	73700	165495	242000	433361
Railway	5000	9642	11812	4042
IWT	4300	3214	2161	2226

(JICA, 2012)

Figure 1:Annual cargo volume per ton for three modes of transport from1979 to 2010



(The world bank, 2016)

Figure 2:CO2 emissions from liquid fuel consumption (kt) - Egypt, Arab Rep

Physical Internet in Logistics

The Physical Internet paradigm was created to address the big issue of aging logistics systems. A corresponding ecosystem is renovated and reinvented to reach the aim. The physical internet is a network of logistics networks enabled by interconnection and interoperation of nodes and standard protocols for handling, transporting, and storing containers using matching movers, using the Digital Internet as a metaphor. (Tran-Dang et al., 2020). Physical Internet pushes research and practice frontiers, to improve logistical operations to build more efficient and sustainable supply chains. Physical Internet is a worldwide logistics system in which items are moved in standardized, modular containers across continents as efficiently and smoothly as information is sent between servers on the Digital Internet. It is a game-changing idea that is already causing consternation in the logistics business and attracting investment.

The way the Internet transports data across the world by subdividing it into information packets with the essential information that shows how divided packets are to be linked again is one of the most fundamental aspects of how it works. TCP/IP protocols are used to do this. If the protocols are set up, the process is platform-agnostic, so it makes no difference whether people get information on a Mac, Linux, or Windows PC or an iOS or Android phone, tablet, or wristwatch. As an example, if someone transmits a 25MB photo from Gdansk to New York, the file is broken into packets and sent over the most efficient way (Matusiewicz, 2020b)

As explained by (Ballot, 2019)an example that illustrates the physical internet concept is Consumer goods are shipped to warehouses in significant geographic locations by a consumer goods maker. From there, all its brands' items are sent to each retailer's distribution center. The merchandise is then shipped to each retailer's location. This is the traditional supply chain structure. There is no need to own or rent warehouses for years on the Physical Internet. The items are sent to various open hubs near the marketplaces and are refilled regularly based on demand. Products contained in containers are transported to markets using shared transportation methods. When a store needs a product, it is obtained from the most dependable supplier. Depending on the product and distribution channel, the supply chain border between the supplier and the merchant may change.

A decentralized and intelligent logistics network can help the effective transfer of multiple and small batches/consignments of items. Parallel to the expanding containerization in the transportation business, the physical internet, an innovative concept initially proposed by Benoit Montreuil, is a positive response from the logistics sector to the Internet of Things being implemented in service sectors. A physical internet, rather than dedicated and specialized networks, is an open global logistics system based on physical, digital, and operational interconnection (Montreuil, 2011). The promising concept of the Physical Internet was started based on these rules and needs. The Physical Internet is a project that enhances the logistics network as it aims to provide an innovative and long-term solution to global issues about travel, handling, storing, creating, delivering, and using physical items in the real world. The lack of economic, environmental, and social sustainability of the freight business, as physical goods are processed, carried, and stored, is one of the fundamental difficulties with how freight is now managed between continents as introduced (Montreuil, 2010).

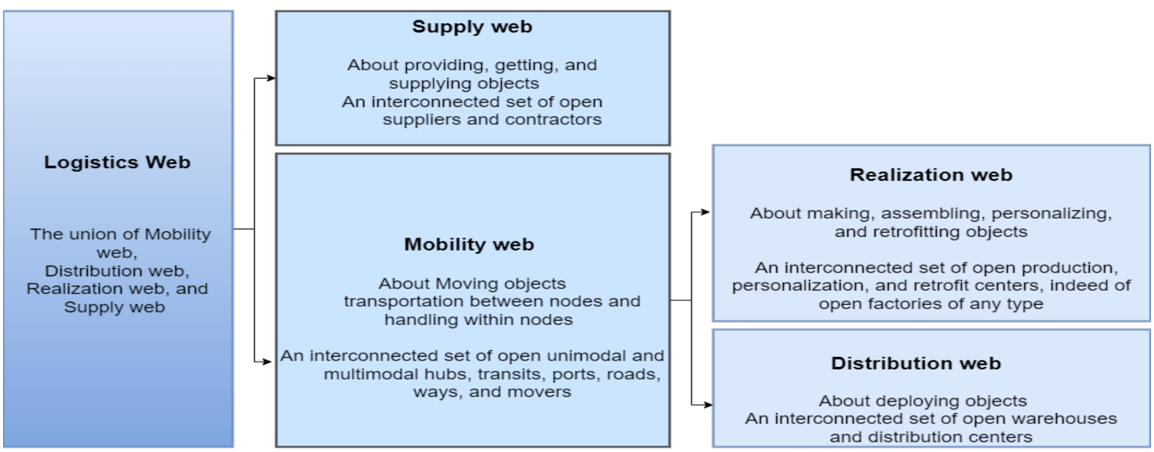
The main tools of the physical internet with the implementation

In the beginning, the physical internet concept was introduced, and its standardized tools and basic guidelines were discussed on the Physical Internet was first presented. The basis and core principles of the physical internet address the existing global logistics lack of economic, environmental, and social sustainability, and are based on the rapid evolution of the digital world, owing to different standardizations that have helped reshape digital communications in networks, as well as how the Internet metaphor relates, were discussed (Montreuil, 2011; Montreuil et al., 2010)..

From a conceptual standpoint, the essential component of the system includes four main elements Pi-containers, Pi-nodes, Pi-movers, and Protocols PI-containers: In the same way, data packets moved through the digital internet network to move information the PI-container is a standardized modular container are modified, stored, and routed across the Physical Internet's systems and infrastructures. They must be logistical modules with different dimensions that are globally standardized and established following open standards. They must be built to allow for easy handling and storage in the Physical Internet's physical nodes, as well as transportation between these nodes and, of course, protection of commodities. move the products through a logistics network. PI-movers are tools that will transport, convey, or handle PI-containers including PI- vehicles that will transport the PI-container, PI lift trucks that will handle the PI-container or PI-conveyor that will be used to handle PI-containers automatically and the last part is PI-node. PI-nodes are sites that are linked to the logistical processes dedicated to working with PI-containers. There is a range of PI-nodes that provide services ranging from basic carrier transfer between PI-vehicles to extensive multimodal multiplexing of PI-containers(Montreuil, 2011; Montreuil et al., 2010).

(Hakimi et al., 2012a; Montreuil, 2011) provide a framework for the logistics web as shown in figure 3 The Logistic Web is a global network of physical, digital, human, organizational, and social actors and networks that serve the dynamic and evolving logistics demands of the world. The Physical Internet intends to enable the Logistics Web to be more open and global while being dependable, resilient, and adaptable in the pursuit of efficiency and sustainability. The Mobility Web, the Distribution Web, the Realization Web, and the Supply Web are four interconnected webs that make up the Logistics Web.

Mobility Web is concerned with the movement of physical things across a global network of open unimodal and multimodal hubs, transits, ports, highways, and paths. The Delivery Web is concerned with the distribution of things throughout a global network of open warehouses, distribution hubs, and storage places. Making, assembling, personalizing, and retrofitting products as best fits inside the worldwide interconnected set of open factories of all types is what the Realization Web is all about. The Supply Web is a global interconnected network of open suppliers and contractors for delivering, receiving, and supplying objects. Each Web makes use of the other Webs to improve its performance. (B. Montreuil et al., 2012) presented an Open Logistics Interconnection (OLI) paradigm for the Physical Internet, like the Open Systems Interconnection (OSI) model for the Digital Internet (Hakimi et al., 2012a; Montreuil, 2011).



(Hakimi et al., 2012a)

Figure 3:Components of physical internet logistics web

Several papers have been published outlining the structure of PI-hubs for road, railroad, and road-based transit centers, along with the requirements for intermodal transportation (Ballot et al., 2012; Montreuil et al., 2012). Some studies have aimed to evaluate the impact of the Physical Internet on logistics and assess performance using simulation and analytical models. Hakimi et al. (2012) introduced the first simulator for the Physical Internet environment, which aids in analyzing the effects of transitioning from current transportation systems to open logistics networks in France. This multi-agent simulator can simulate large-scale virtual mobility webs involving thousands of actors and agents moving cargoes and containers across various locations, including unimodal and multimodal hubs. Another simulation model, developed by Hakimi et al. (2012), evaluates the efficiency of a connected logistics network through the Physical Internet, considering parameters such as load delivery time, carbon emissions, and driver trip time. Performance measurements from this simulation are compared with industry key performance indicators in a case study involving fast-moving consumer goods in France. The study concludes that while the Physical Internet reduces carbon emissions and logistical expenses, it does not compromise operational efficiency.

Ballot et al. (2012) proposed an evolutionary strategy to address the challenges of open PI-hub network design, specifically its large scale. This decentralized and distributed routing model offers solutions for flow assignment difficulties in the Physical Internet over traditional network architecture. Furtado et al. (2013) proposed a freight transportation model based on the Physical Internet, where freight is transported between hubs using various tractors assigned to each hub. They explore the concept of combining trailers into road trains and find that consolidation and waiting for return hauling opportunities positively impact overall cost, fill rate, time spent at home, and greenhouse gas emissions.

Lin et al. (2014) developed a mathematical program and breakdown algorithm to optimize space utilization through the deployment of standardized containers, demonstrating greater vehicle space utilization. Protocols for Physical Internet transportation were introduced by Sarraj et al. (2014). Venkatadri et al. (2016) built a systems model to compare conventional and Physical Internet networks, highlighting advantages such as lower inventory costs. Yang et al. (2017) suggested a multi-agent simulation model for freight transportation resilience on the Physical Internet, considering disturbances at hubs. Gontara et al. (2018) presented a novel routing technique, PI-BGP, focusing on exclusive routing of PI-containers to enhance flow and resolve stocking difficulties.

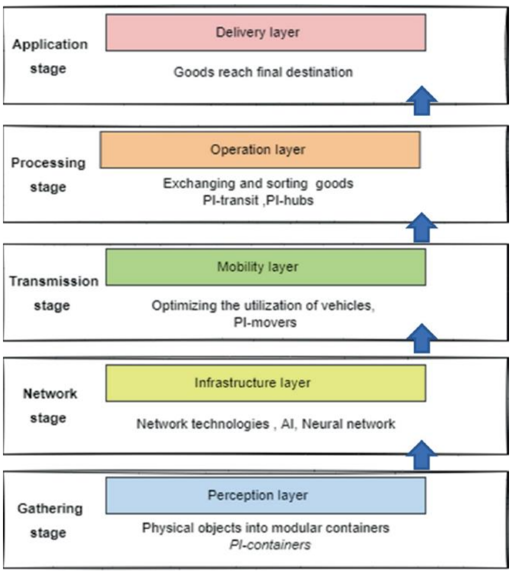
(Ezaki et al., 2021) utilize a simplified model to grasp the essence of the issue, aiming to assess the resilience of a delivery network system with a primary focus on time and total travel costs as performance indicators. Their findings suggest that networks featuring redundancy tend to adapt effectively to demand fluctuations, whereas hub networks lacking redundancy fail to capitalize on the advantages offered by the Physical Internet.

According to (Montreuil, 2011), the Physical Internet presents numerous advantages capable of addressing challenges encountered within transportation systems, thereby enhancing overall supply chain performance. This transformative concept substantially boosts logistics efficiency and sustainability on a large scale. By leveraging the idea of interconnectedness across logistics networks and services, the Physical Internet advocates for encapsulating goods in standardized, eco-friendly, modular containers equipped with smart technology. These containers facilitate swift, reliable, and environmentally conscious multimodal transportation and logistics systems.

Based on previous studies of simulation and studying of physical internet and its tools. there is a variety of research about the PI concept and its tools in the supply chain worldwide. Moreover, there is a lack of studies that measure the capability of investigating the implementation of PI in the Middle East, especially in Egypt.

Theoretical framework

This study builds on the existing framework for using the Physical Internet and its resources to address transportation concerns. It strives to reduce transportation costs, mitigate environmental impacts, and improve overall transportation efficiency. This entails creating a library of shareable assets and standardizing commodities in order to improve collaboration among supply chain actors.



source: (Osama et, al, 2022)

Figure 4:PI framework

Research problem and question.

Today's traditional transportation method confronts numerous issues because there are numerous cars of various sizes linked with various enterprises, each of which consumes a significant quantity of fuel. The vast number of vehicles vary in size, and they can be left loaded and returned empty, as well as not always left completely loaded. All of these issues generate a large amount of garbage, which increases transportation expenses. As a result, this research must look for new technologies that can help to lower these costs, such as the physical internet. Therefore this paper aims to answer these two question: What are the new technologies that could be applied to the transportation system? and What is the effect of applying the physical internet on SMEs In Egypt?

Research objectives.

This research main objectives are to review the current situation of the transportation system, To identify new technologies such as PI that could be applied in the transportation system, and To investigate a PI framework that will enhance the transportation system through transportation cost reduction.

Research hypothesis.

This research main hypothesis is that the PI-tools has a direct impact on the transportation systems

Research justification:

The goal of this study is to transform Egypt's freight transportation sector by implementing Physical Internet (PI) principles. The project's goal is to reduce transportation distances and costs while reducing environmental consequences by constructing a simulation model centered on PI-hubs. This project is consistent with worldwide trends toward sustainable logistics practices and has the potential to considerably improve Egypt's competitiveness and economic development goals in the transportation industry.

Research Design

The research followed the deductive approach to assess the application of physical internet in transportation process efficiency. The research strategy used is a case study to observe and analyze the physical internet and transportation system. A mixed-method approach is followed as data collected from interviews was qualitative as well as the analysis, but quantitively data was for running the simulation model .so it uses semi-structured interviews to get a wide range of information about transportation processes and the impact of physical internet on the efficiency of the process. That's why this research used semi-structured interviews with top-level management because it's a strategic decision. The time horizon was cross-sectional as the research takes a snapshot of the current situation of the market. Finally, the sampling was purposive as interviews were conducted with some companies from trucking startups.

Simulation-based approach

For dealing with logistics challenges, there are three basic simulation paradigms: discrete-event simulation, system dynamics, and agent-based simulation. Discrete-event simulation is usually thought to be proper for analyzing operational/tactical challenges, but system dynamics is a good model for strategic planning (Tako and Robinson, 2012). An agent-based simulation is believed useful for modeling interactive rules between components and understanding how autonomous agent interactions affect the system. Several recent studies used agent-based simulation to solve road freight difficulties, highlighting the rising relevance of such technologies in the governance and planning of complex logistics networks (Sun et al., 2018). This paper used Anylogic agent-based simulation model program to find the results of transporting of the current transportation network and after applying physical internet hubs inside the network on the same company, to see results of fuel consumption and time of journey on a large and small scales as shown in figure 8.

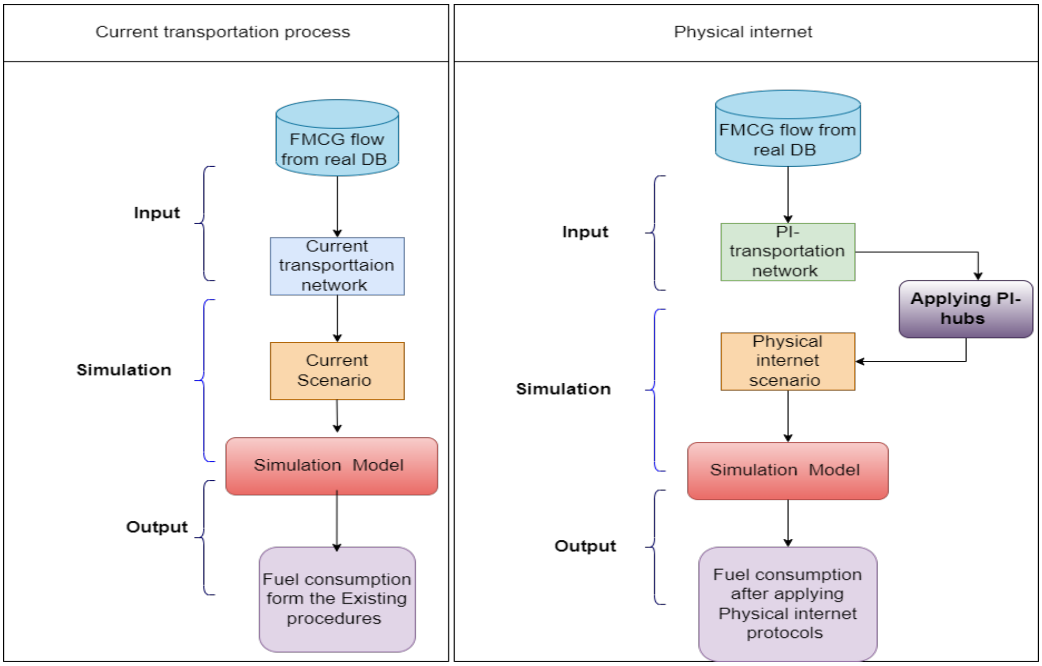


Figure 5: The simulation model- authors' own

Experiment of results

This research collects a real data from a large company who specialized in fast moving consumer goods industry. The company has been operating in Egypt since 1985 with a project that is considered the largest with an acquisition of more than 45% of the market share. As it is considered an extension of a group of companies located in the Kingdom of Saudi Arabia, which is one of the giant companies in Egypt and the Middle East, which was established in 1977 in the Kingdom of Saudi Arabia. As the company is specialized in producing frozen products and it directly distributes their products to many retailers all over Egypt to evaluate the emissions and related costs before and after applying the physical internet hubs. The proposed model measures the difference between the classic transportation process and the process after applying physical internet hubs on two scales large scales and small scale.

The small scale includes areas within Greater Cairo which is a designation given to an administrative entity in an area that includes the cities of the governorates: Cairo, Giza and Qalyubia in Egypt, which has an area of 3084.676 square kilometers (populationstat, 2022). While the large scale includes other governance within Egypt (except Cairo) as the area is about 996,603 sq km (Britannica, 2021).

On large scale, it takes a line that travels from Cairo to Aswan and passes by some governances, and on a small scale, it takes three lines in Cairo Giza to assess the physical internet on it. four simulation models have been created the first two models are about the classic transportation process and the second two models are about using the physical internet in the network to measure the efficiency of the process and the fuel consumption.

Network overview (Sample)

The transportation network on a large scale includes moving the products from Natron valley to Qena, Luxor, and Aswan. On a small scale, the transportation network for greater Cairo is divided into three lines called the Obour line, Maadi line, and Zayed line as each line delivers for four retailers and them the return journey as location of the company is at Natron valley. The classic transportation process for each line is that the truck moves every day from natron valley to distribute products to four retailers and then return to natron valley. The physical internet can be applied in Cairo for example PI-hubs can be built near each area of the three lines to cut the costs of return empty journey and reduce the fuel consumption besides the social benefits for the drivers. As the company uses 40 feet container trucks to distribute their products for retailers.

In this model the truck that move the products is a large truck which carries 40 feet container, the speed of the car is 90 km/h and trucks are loaded with 60% of their capacity and trucks are transporting the products each day during the week in the normal situation according to data retrieved from the company.

The data of the current transportation network is entered to the program for large scale and small scale as points with x and y coordinates have been figured out on the GIS map inside Any logic then distance and time are calculated as the distance is measured on kilometers and time is measure by minutes. After that, the fuel consumption is calculated according to the following equation.

$$\text{Fuel consumption (liter/100km)} = \frac{\text{Quantity of fuel consumed to distance}}{\text{liters used by KM traveled}} \times 100$$

Then physical internet hub is applied for large scale and narrow scale as the location of each PI-hub is calculated by http://www.geomidpoint.com/ according to the following equation

$$\text{Midpoint} = (X_{M,}\ Y_M) = \frac{X1 + X2}{2}, \frac{Y1 + Y2}{2}$$

The greenhouse gases and emissions has ben calculated with emission calculator by https://www.ecotransit.org/en/emissioncalculator/ based on distance between each two nodes and truck type , and the emissions has been recorded using Tank-to-wheel as it describes during driving the emissions.

Simulation

The simulation models are created using Anylogic which is software that creates and analyzes a digital model of a physical model to forecast how it will behave in the actual world. As it allows simulation scenarios from numerous perspectives in different areas in the supply chain. Analogic has three methods of simulation modeling: system dynamics (SD), discrete event simulation (DES), and agent-based simulation (ABS). this research used Agent-based simulation which is used in logistics areas as it allows for the creation of diverse persons as agents who interact with one another and with their environment.

1- **classical transportation model**

In this model, the data is entered into the program to measure distance, time of journey, fuel consumption rate, and CO_2 emissions on both a large scale and small scale. As the factory is located in Natron valley after the production the commodities are stored in the warehouse which exists also in natron valley then each line delivers its commodities from natron valley to the retailers of each line and then goes back to natron valley as shown in the following figure.

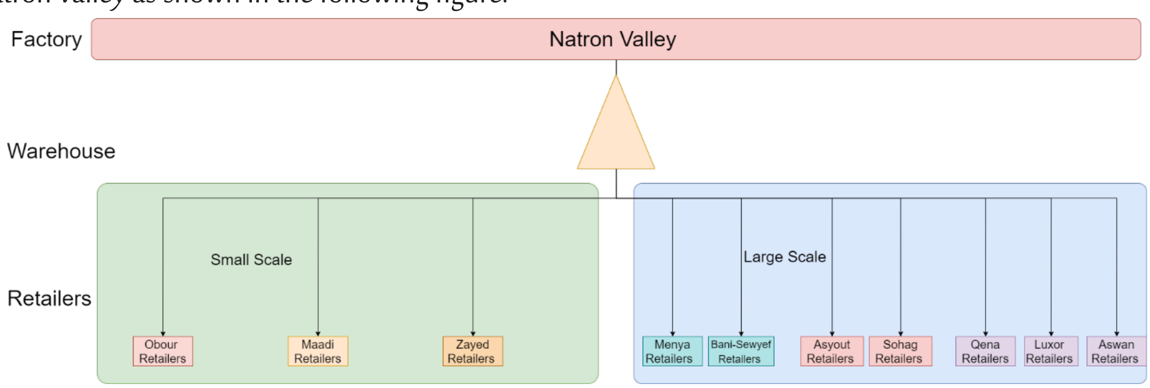


Figure.6 classical transportation network- author's own

A- **classical transportation network in small scale**

this section provides the fuel consumption with all the related data for small scale as shown in figure 7 the location of the company is at Wadi Natron and three trucks must distribute each day their products to three lines: Obour line, Maadi line, and Zayed line. Where trucks move from the main location of the company at Natron valley and distribute products for four retailers in the three lines.

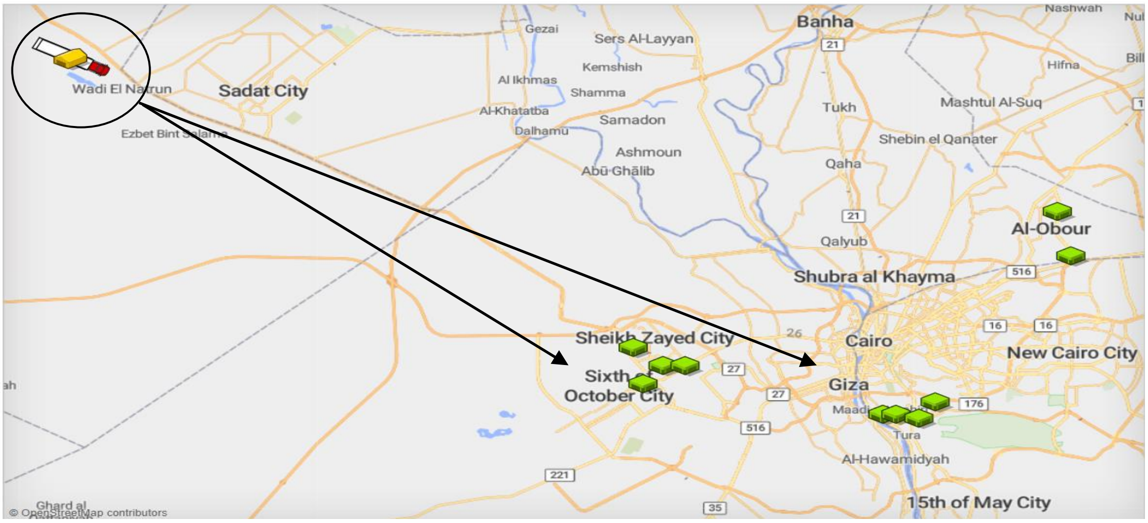


Figure 7:classic transportation network- small scale

The classic journey takes place each day when trucks move loaded from Natron valley to the three lines Zayed line, Maadi line, and Obour line where the truck move from the factory and pass by four stations to unload their goods to retailers then return to the factory at Natron Valley.

Table 1 shows the distance from the main warehouse of the company in Natron Valley and the distribution for the three lines as each line contains four retailers and the return journey, the time it takes for transporting the products between each station after that the amount of fuel consumed along the journey and finally the greenhouse gas emissions according to the distance taken.

Table 1: Data for the classic transportation network

line	Stations	Distance (km)	Time (Minutes)	Fuel consumed (l)	GHG emissions (tons)
Obour	Carrefour Obour	138	106	72	0.075
	Carrefour Sherouk	15	15	7	0.0069
	Hyper 10th	19	15	10	0.0085
	Panda Obour	35	30	18	0.018
	return	149	125	78	0.079
	Total	**358**	**291**	**187**	**0.19**
Maadi	Carrefour Maadi	123.98	80	64.94	0.066
	Oscar Maadi	4.69	15	2.46	0.0039
	Spinneys Maadi	4.82	5	2.52	0.0028
	Saudi Degla	2.52	3	1.32	0.0035
	return	124.20	100	65.06	0.066
	Total	**260.22**	**203**	**136.30**	**0.14**
Zayed	Spinneys MOA	87.93	60	46.06	0.048
	Saudi Zayed	5.83	12	3.06	0.0024
	Hyper Zayed	4.52	8	2.37	0.0022
	Spinneys Mazar	10.72	15	5.62	0.0063
	return	88.13	68	46.16	0.048
	Total	197.13	163	103.26	0.11

Figure 8 shows the fuel consumption for the three lines which reveals that the first trip from the factory to the retailer and the return journey takes the largest amount of fuel because the factory is too far away from the three lines. In the Obour line, the first journey from Natron valley to Carrefour Obour covers more than 38%, and the return journey from the last retailer at Panda Obour to Natron Valley covers more than 42%. In the second line -Maadi the first journey from natron valley to Carrefour Maadi covers 47% and the return journey from Saudi degla to Natron valley covers 47%. in the Zayed line, the first journey from natron valley to spinneys mall of Arabia covers 44% and the return journey from Spinneys Mazar mall to Natron valley covers 44%.

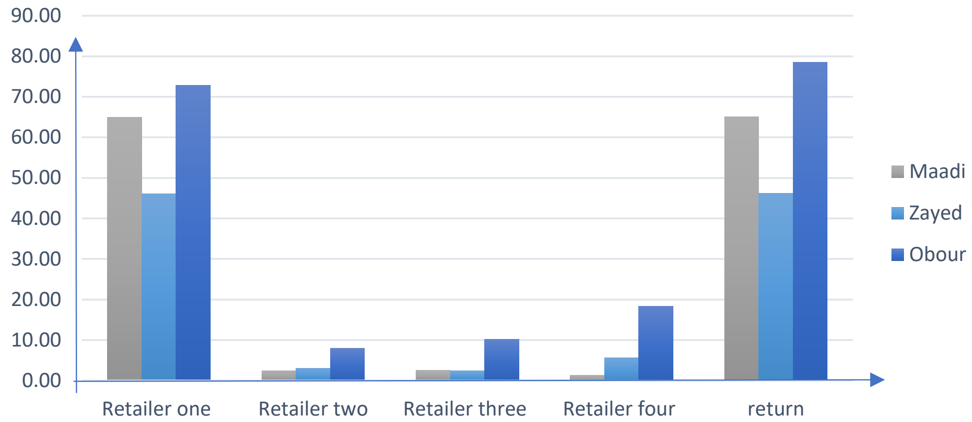
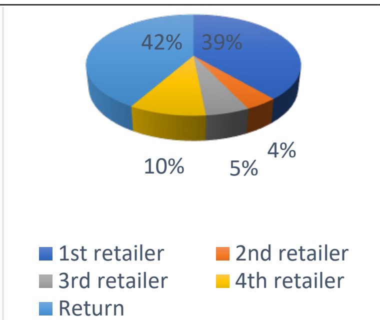
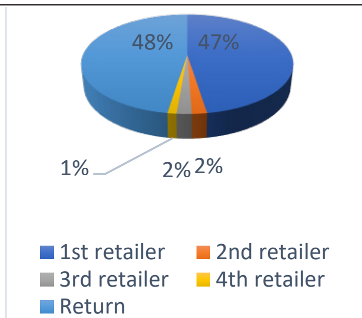
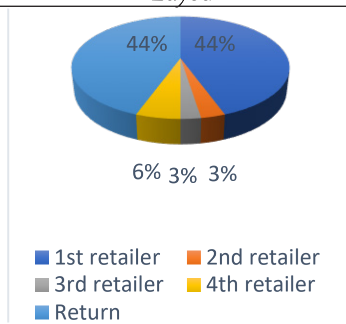


Figure 8: Fuel consumption for the three lines in the classic model

Table 2: Fuel consumption in the classic scenario- small scale

Obour	Maadi	Zayed
		

According to table 2, the fuel consumed during the first and last journeys presents the highest percentage, as they went for long journeys as shown in table 2 in Obour line first and last journeys represent more than 80%, in maadi line they represent more than 90% and even in Zayed line, which considered the closest area to natron valley, they represent more than 85%.

B- Classical transportation network on a large scale

This section provides data on fuel consumption, distance, and time needed per journey on a large scale as the midpoint coordinates have been selected in the middle of the governances, as trucks distribute products for many retailers in each governance, but this model relies on the midpoint in the center of the governance.

As shown in figure 9 the classic journey on large scale takes place each day when trucks move loaded from Natron valley to the three lines Aswan line, Asyuot line, and Bani-swyef line where the truck move from the factory and pass by retailers exist in the three areas to unload their goods to retailers then return to the factory at Natron Valley.

As shown in table **3** the first and last journeys consume most of the fuel and represent the highest percentages which cause excessive costs of fuel and a long time to travel as drivers may drive for an exceedingly long time which causes them many problems of exhausting and lack of social life

Table 3: classic transportation network- large scale

line	stations	Distance (km)	Time (Minutes)	Fuel consumed (l)	GHG emissions (tons)
Aswan	Qena	680	442	356	0.35
	Luxor	66	90	34	0.035
	Aswan	325	215	170	0.16
	Return	1050	730	550	0.54
Total		**2121**	**1478**	**1111**	**1.09**
Sohag	Asyut	490	330	256	0.24
	Sohag	190	180	99	0.061
	Return	615	435	322	0.3
Total		**1295**	**945**	**356.19**	**0.60**
Bani Swyef	Minya	360	270	188	0.19
	Bani swyef	167	150	87	0.079
	Return	250	210	130	0.11
Total		777	630	407	0.38

The table 3 shows the distance for the three lines which reveals that the trip from the factory to governance and the return journey takes the largest amount of fuel because the factory is too far away from the three lines. In Aswan line, it covers more than 82%, in Asyout line covers 85% and in Menya line, it covers 78% as the distances are too long among governances.

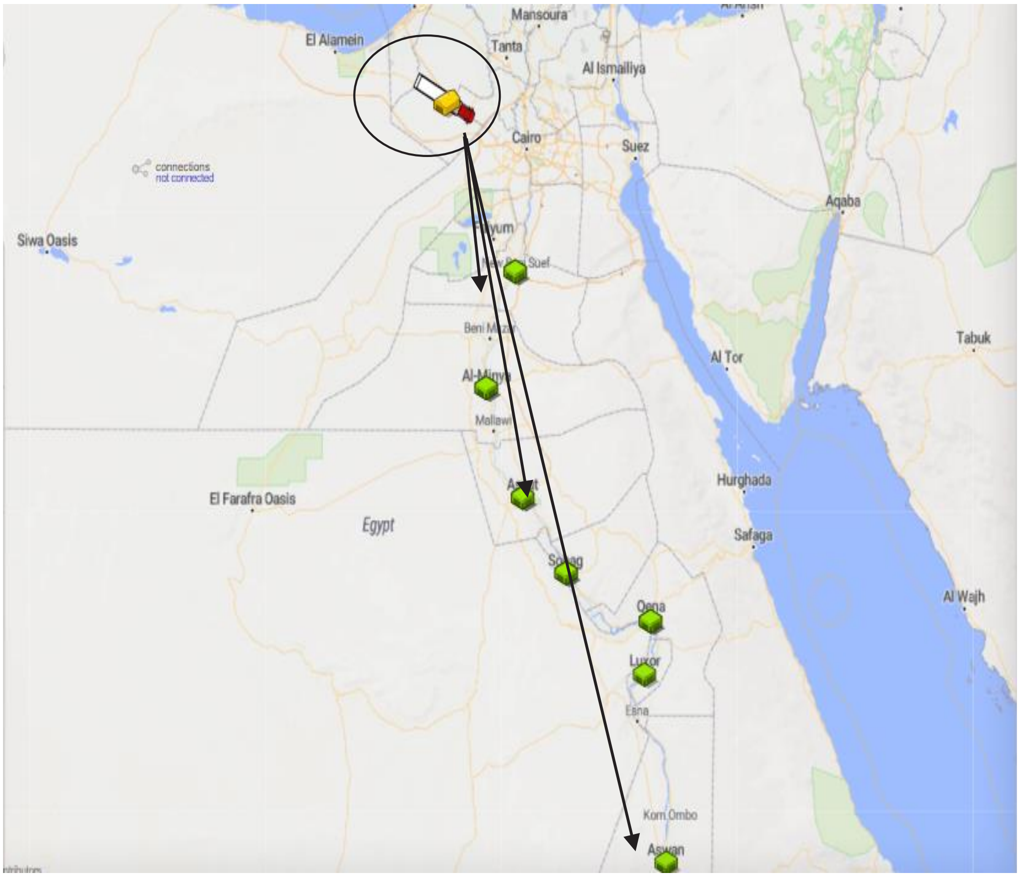
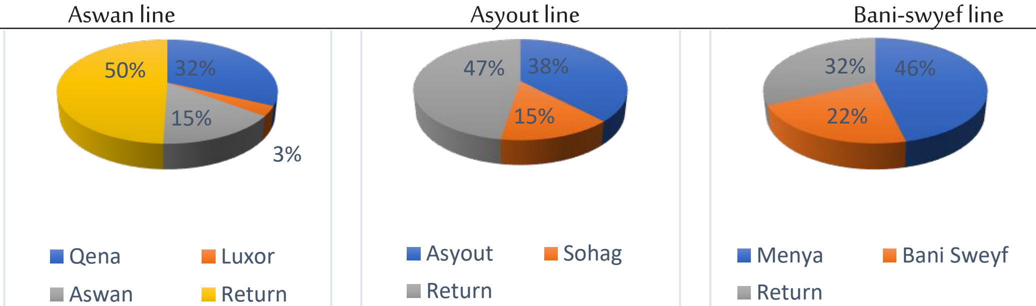


Figure 9:classic transportation network- large scale

Table 4:Fuel consumption in the classic scenario- large scale

Aswan line	Asyout line	Bani-swyef line



Source-author's own

Physical Internet - transportation model

In the physical Internet model PI- hubs have been put according to the midpoint location of each area of the three lines instead of moving from the factory to distribute the product the PI – hubs will shorten the distance and save time and fuel consumption.

After applying physical internet hubs in the middle points for each line according to the middle point equation between x and y coordinates. As shown in figure 10 after the production of commodities in natron valley it stored in the warehouse of the company at natron valley. the central warehouse at natron valley feeds the PI-hubs once weekly. Each day the trucks go from PI-hubs to retailers instead of Natron valley warehouse which will shorten the distance.

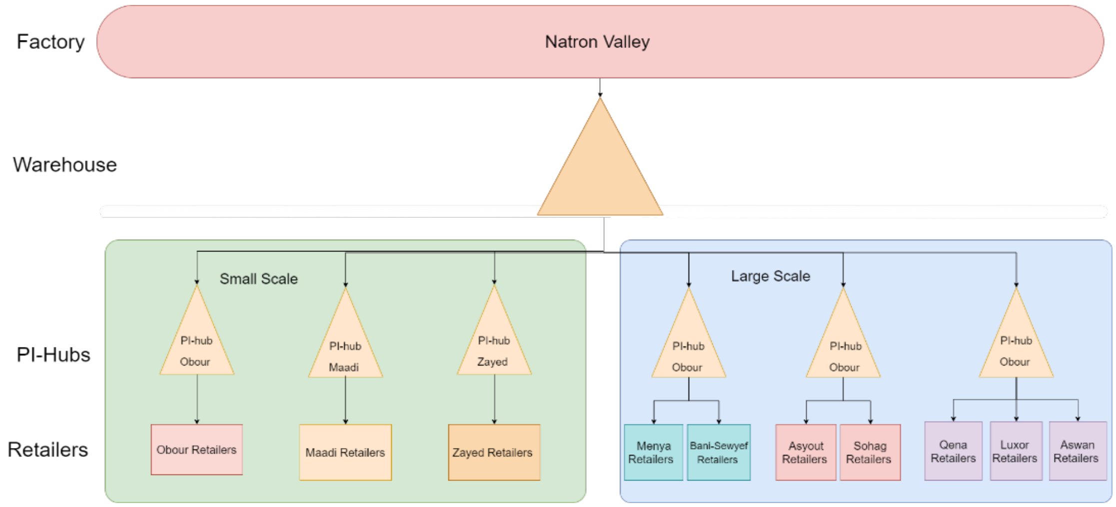


Figure 10: classical transportation network- small scale

2- Physical internet transportation network on a small scale

The PI- hubs have been located according to the midpoint between the retailers in each area, as the trucks will move from natron valley to feed the three PI-hubs with products, and the distribution for the retailers will be from the PI-hub that becomes near to the retailers for each location, which makes the distance, fuel consumption and time reduced as shown in the below table.

Table 5 shows the distance from the main warehouse of the company in Natron Valley to the PI-hub that has been calculated according to the midpoint among retailers in each area in Obour, Maadi, And Zayed, then distribution for the three lines as each line from back to PI-hub and also the distance between PI-hub to natron valley, the time it takes for transporting the products between each station after that the amount of fuel consumed along the journey and finally the greenhouse gas emissions according to the distance taken.

The fuel consumption at the three lines has been reduced as shown in figure 11 as the total fuel consumption for Obour has been reduced from 188L to 128L and in the Maadi line, it is also reduced from 136L to 58L and finally, Zayed line has been reduced from 103L to 74L. as the distance for the three lines reduced in Obour line it reduced from 358km to 244 km. in maadi line it reduced from 260 km to 110 km and in Zayed line it reduced from 197 km to 142km.

Table 5: physical Internet -transportation model

line	Stations	Distance (km)	Time (Minutes)	Fuel consumed (l)	GHG emissions (tons)
Obour	Natron- PI-hub Obour	166	120	87	0.081
	Carrefour Obour	1.5	5	1	0.0072
	Carrefour Sherouk	15	10	8	0.0069
	Hyper 10th	19	13	10	0.0085
	Panda Obour	35	23	18	0.018
	PI-Hub-Obour	6	10	3	0.011
	Total	**78**	**61**	**41**	**.05**
Maadi	Natron- PI-hub Maadi	86	124	45	0.066
	Carrefour Maadi	3	8	2	0.0032
	Oscar Maadi	4	3	2	0.0039
	Spinneys Maadi	4	3	3	0.0028
	Saudi Degla	2	1	1	0.0035
	PI-Hub - Maadi	8	13	5	0.0018
	Total	**24**	**28**	**12**	**.02**
Sheikh Zayed	Natron- PI-hub Zayed	90	66	47	0.048
	Spinneys MOA	11	20	6	0.0024
	Saudi Zayed	4	3	3	0.0024
	Hyper Zayed	5	3	2	0.0022
	Spinneys Mazar	11	7	6	0.0063
	PI-Hub - Zayed	20	26	10	0.0035
	Total	52	59	27	.02

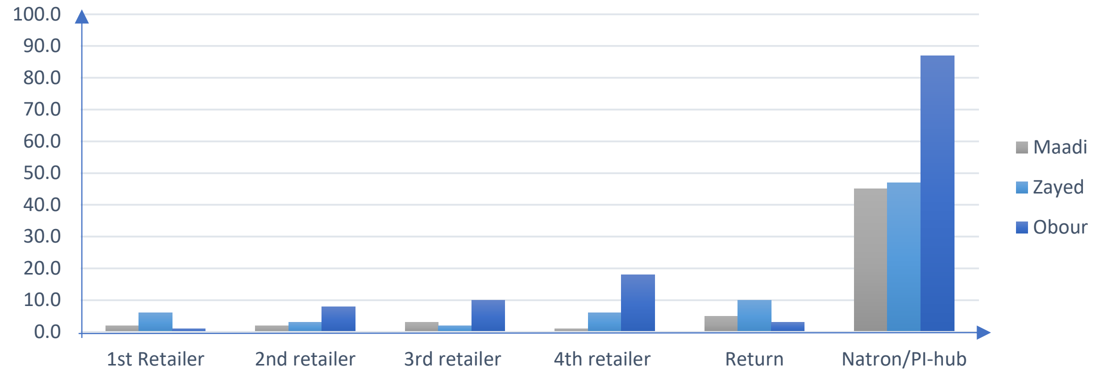


Figure 11 Fuel consumption for the three lines in the PI- model- small scale

3- Physical internet transportation network on a large scale

The PI- hubs have been located according to the midpoint between governances in each area, as the trucks will move from natron valley to feed the three PI-hubs with products, and the distribution for the governances will be from the PI-hub that becomes near to the governances for each location, which makes the distance, fuel consumption and time reduced as shown in the below table.

Table 6:physical Internet -transportation model- large scale

line	Stations	Distance (km)	Time (Minutes)	Fuel consumed (l)	GHG emissions (tons)
Aswan	Qena	160	150	83	.078
	Luxor	66	90	34	.035
	Aswan	325	215	170	0.16
	Return	219	132	114	0.12
	Natron=PI-hub	830	600	434	0.43
	Total	1600	1187	838	.823
Sohag	Asyut	55	60	28	0.2
	Sohag	60	72	31	0.061
	Return	58	72	30	.061
	Natron=PI-HUB	525	372	275	.034
	Total	698	576	365	0.329
Beni swyef	Minya	80	66	42	.044
	Bani swyef	77	72	40	.079
	Natron-PI-hub	302	204	158	0.15
	Total	540	412	282	0.312

Table 6 shows the distance from the main warehouse of the company in Natron Valley to the PI-hub that has been calculated according to the midpoint among retailers in each area in Aswan, Sohag, and bani-sewyef, then distribution for the three lines as each line from back to PI-hub and also the distance between PI-hub to natron valley, the time it takes for transporting the products between each station after that the amount of fuel consumed along the journey and finally the greenhouse gas emissions according to the distance taken.

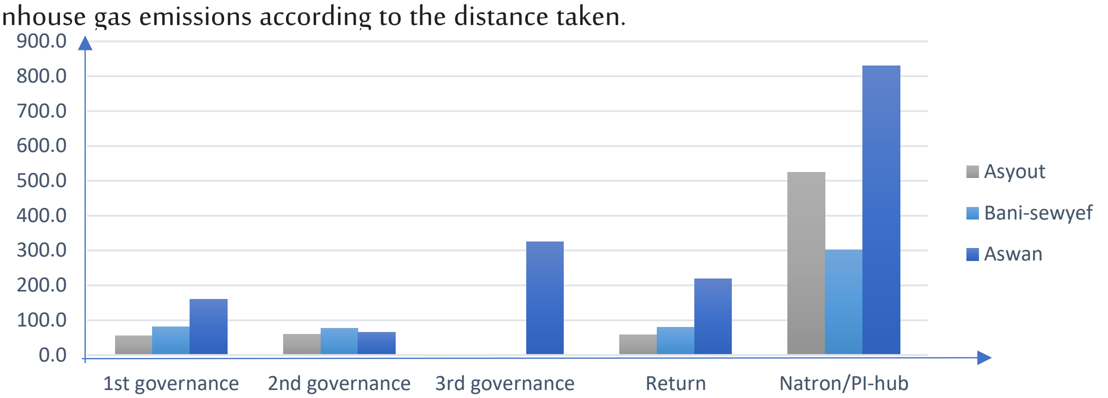


Figure 12 Fuel consumption for the three lines in the classic model- large scale

fuel consumption at the three lines has been reduced as shown in figure 4.11 as the total fuel consumption for Aswan has been reduced from 1111 L to 838 L and in the Sohag line, it is also reduced from 678 L to 365L and finally, Beniswyef line has been reduced from 407L to 282 L.

Results and data analysis

According to (GlobalPetrolPrices, 2022) the diesel price in Egypt is 6.75 LE. The total costs of fuel have been calculated for each journey by multiplying the fuel consumption x 6.75 LE. On small scale After applying the PI-hubs near each zone for the three lines, the total costs of fuel have been reduced as in Obour line the total fuel cost was 8877 LE and after applying the physical internet model the cost has been reduced to 5445 LE with the reduction of 39%, the fuel cost of Maadi line was 6440 LE and has been reduced to 2414LE with the reduction of 63%, and Zayed line was 4878 LE and has been reduced to 3184LE with a total reduction of 35% of the total fuel cost. So, the total costs of small scale have been reduced from 20196LE to 11043LE with a reduction of 45%.

On large scale After applying the PI-hubs near each zone for the three lines the total costs of fuel have been reduced as in Aswan line the total fuel cost was 52494 LE and after applying the physical internet model the cost has been reduced to 36665 LE with the reduction of 30%, the fuel cost of Sohag line was 16830 LE and has been reduced to 15419 LE with the reduction of 8%, and Beniswyef line was 19230 LE and has been reduced to 12297LE with a total reduction of 36% of the total fuel cost. So, the total costs of small scale have been reduced from 88555LE to 64381 LE with a reduction of 27 %. and after communicating with the transportation manager of the company he revealed fuel consumption costs represent around 37% of the total cost for the transportation journey. Moreover, according to (Martino et al., 2009) Fuel prices range from 19% (in Austria) to 36% (in Romania) of total expenditures, and from 24% to 49% of total operating costs (VAT removed). So, the reduction of the total cost of fuel will reflect 37% total cost for transportation journeys as shown in table 7.

Table 7: Weekly transportation network

	Distance		Time		Fuel consumed		price LE		GHG emissions	
Total calculations for small scale										
	classic	**PI**	**classic**	**PI**	**classic**	**PI**	**classic**	**PI**	**classic**	**PI**
Obour	2510	1540	2037	1147	1315	806	8877	5445	1.3	0.8
Maadi	1821	682	1421	940	954	357	6440	2414	1.0	0.5
Sheikh Zayed	1379	900	1141	809	722	471	4878	3184	0.7	0.4
Total	5712	3123	4599	2896.0	2992	1636	20196	11043	3.06	1.8
Total calculations for large scale										
	Distance		Time		Fuel consumed		price LE		GHG emissions	
	classic	PI	classic	PI	classic	PI	classic	PI	classic	PI
Aswan	14847	10370	10348	7711	7777	5431	52494	36665	9.7	3.2
Sohag	4760	4361	6615	3660	2493	2284	16830	15419	5.6	0.4
Beniswef	5439	3478	4410	2685	2849	1821	19230	12297	3.8	2.3
Total	25046	18209	21373	14057	13119	9538	88555	64381	19.14	5.98

There are many benefits from applying the physical internet in transportation network as shown in table 8 as the distance has been shortened, the time to move from the main warehouse to each retailer or time taken among retailers has been reduced, fuel consumed during the journeys has been reduced also which affect the percentage of GHG. The reduction in GHG affects many aspects including harmful emissions that harm the environment, reduction in fuel costs needed, and other things such as the social life of the driver will be enhanced as they will work close to their area of living, number of accidents may also reduce as they won't be obliged to take drugs that made them awake for long hours, etc,..

According to(Sarraj et al., 2013) study there was a reduction in GHG emissions by60% when they applied the physical internet using the railroads

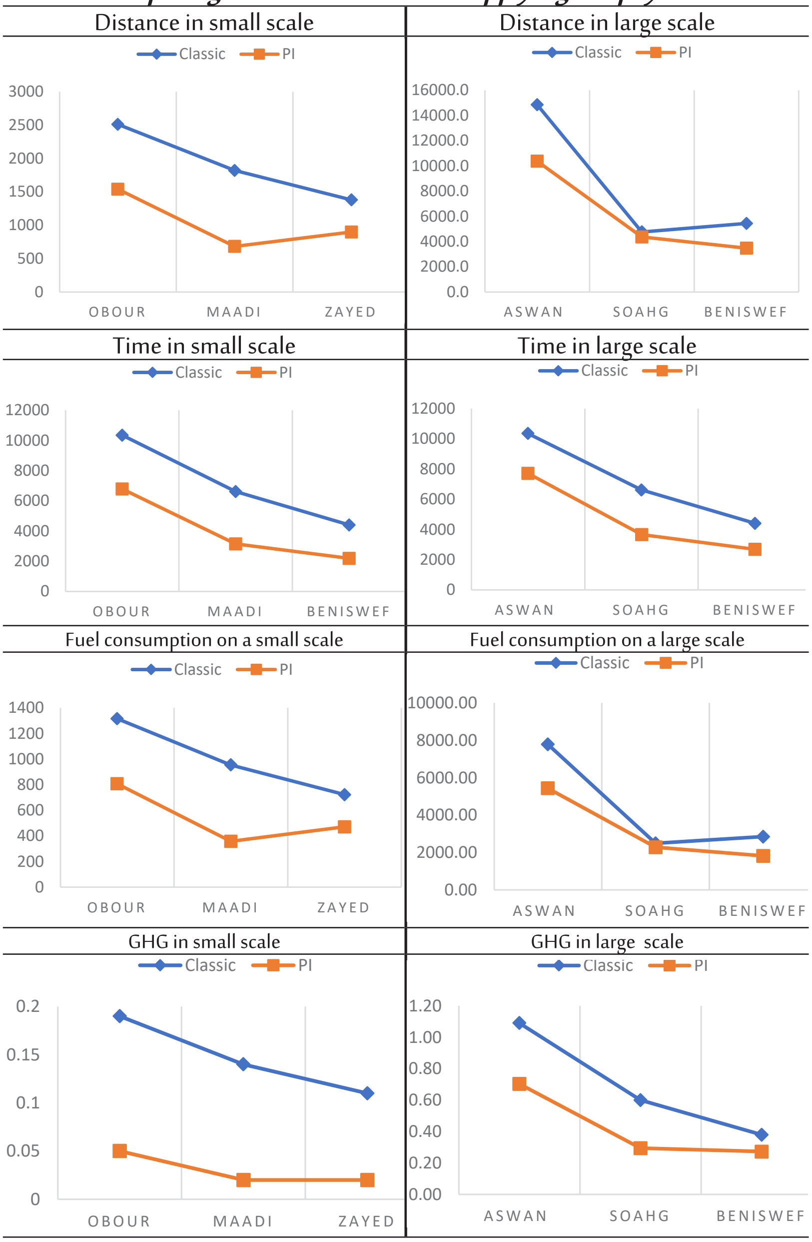
Conclusion

The physical internet is a novel idea that attempts to transform how things are carried through supply chains. It functions similarly to the digital internet, with items packaged in PI containers and transported to hubs via linked channels. Two multi-agent simulation models were developed to assess the efficiency of conventional and physical Internet distribution networks in terms of fuel consumption and greenhouse gas emissions. The findings revealed that the physical internet network is more efficient in terms of both time and distance traveled, resulting in lower fuel consumption expenses. The model may be enhanced by use physical internet containers to calculate the precise number and size of containers required.

Recommendations

Physical internet technology will change the supply chain and logistics and the way of handling, moving, and transporting the goods. As it aims to create a shareable network across the world to share resources such as big trucks to consolidate products, sharable hubs in each region with PI-tools to facilitate the process of handling the products, and other tools. That's why this research applied a case study for one of the physical internet tools PI-hub to shorten the long distances that can be taken by trucks and reduce the main transportation problems.

Table 8: Comparing data before and after applying the physical internet



It's recommended that companies in Egypt start to apply the physical internet, startups have a big opportunity to implement the PI-tools as they are solving problems innovatively and creatively, and some of them have an agile business model which enables them to cope with the market in a good way. Moreover, they exist in many fields so they connect the supply chain easily for example startups specializing in trucking who provide solutions for the industry can communicate with startups who are providing solutions for managing the warehouse in a good way, and they can also deal with startups who are specialized in customs clearance, etc. to formulate the whole supply chain.

The physical internet concept was developed in Europe, and they have the vision to be implemented soon, further research should focus on the concept with its tools and the needed infrastructure to be implemented in Egypt, and constraints that will be faced to be able to cope with international trade.

Limitations

The models provided by the research have many constraints and limitations that can be enhanced in future research. This research applied simulation models based on the data collected from the distribution network of one company in FMCG in 2021, and interviews were conducted for startups in trucking industries only, and results and analysis are based on this data. The case study also applied in the research focused on the lines of the company for small scale and large scale considering the demand constant as the current plan of the company that one 40-feet truck will distribute products in each line and return to the factory. To overcome these limitations, the simulation model can be applied for data several years before instead of one year with details about any possibility of increasing or decreasing the demand, and more interviews can be conducted for other participants in the supply chain such as warehousing area.

To summarize, this study focuses on using the physical internet to tackle the problem of transportation because of its relevance in the supply chain, as the case study has been applied to startups as they have the opportunity to adapt to technology faster than large companies. And the results show that implementing PI-hubs enhances the efficiency of the transportation process and make savings for the company. this research also provides limitations of the study and future research to encourage researchers to study more in the physical internet to be able to cope with the new transition in international trade. The model can be enhanced by applying the physical internet containers to figure out the exact number and sizes that need to be moved as these containers could increase the efficiency of the process and enhance capacity optimization.

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