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ỨNG DỤNG INTERNET VẠN VẬT (IOT) TRONG GIAO HÀNG CHẶNG CUỐI: NGHIÊN CỨU TRƯỜNG HỢP CỦA DHL VÀ KHUYẾN NGHỊ CHO DOANH NGHIỆP VIỆT NAM

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Tóm tắt

Nghiên cứu này điều tra ứng dụng của công nghệ Internet vạn vật (IoT) trong giao hàng chặng cuối, sử dụng DHL làm nghiên cứu điển hình. Bài nghiên cứu khám phá nền tảng lý thuyết của IoT và giao hàng chặng cuối, sau đó phân tích các ứng dụng cụ thể của DHL. Nghiên cứu xác định những đóng góp và hạn chế chính trong cách tiếp cận của họ, cùng với các giải pháp IoT khác được các công ty khác sử dụng. Dựa trên những hiểu biết này, các khuyến nghị được đề xuất cho các doanh nghiệp Việt Nam đang tìm cách áp dụng IoT trong hoạt động giao hàng chặng cuối của mình. Nghiên cứu nhằm hướng dẫn các doanh nghiệp Việt Nam triển khai thành công và bền vững công nghệ IoT trong dịch vụ hậu cần và khách hàng của họ.

Từ khóa: Internet vạn vật (IoT), Giao hàng chặng cuối, Logistics, Chuỗi cung ứng, DHL

INTERNET OF THINGS IN LAST-MILE DELIVERY: A CASE STUDY OF DHL AND RECOMMENDATIONS FOR VIETNAM ENTERPRISES

Abstract

This research investigates the application of Internet of Things (IoT) technology in last-mile delivery, utilizing DHL as a case study. It explores the theoretical foundations of IoT and last-mile delivery, followed by an analysis of DHL's specific applications. Key contributions and limitations of their approach are identified, along with additional IoT options employed by

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other companies. Drawing on these insights, recommendations are proposed for Vietnamese enterprises seeking to adopt IoT in their last-mile delivery operations. The study aims to guide Vietnamese businesses towards successful and sustainable implementation of IoT technology in this crucial aspect of their logistics and customer service.

Keywords: Internet of Things (IoT), Last-mile delivery, Logistics, Supply chain, DHL

1. Introduction

The digital revolution has ushered in an era of unprecedented connectivity and efficiency, transforming the way industries operate. In the field of freight transportation and logistics, advancements are occurring not only in traditional methods like post offices or courier deliveries but also in the implementation of drones, robots, and unmanned vehicles. At the forefront of this transformative wave is the Internet of Things (IoT), a technological paradigm that interconnects physical elements to gather and manage data seamlessly. This shift toward more precise and efficient processes opens up new opportunities for logistics operators

Within the logistics landscape, the last-mile delivery phase plays a pivotal role, exerting considerable influence on both customer satisfaction and the success of businesses. McKinsey's research reveals that the last mile constitutes a significant portion, accounting for 41% of the total logistics cost. This percentage is projected to rise in the upcoming years. As businesses globally grapple with the challenges of optimizing this final leg of the supply chain, innovative solutions powered by IoT are redefining the contours of last-mile logistics. IoT-driven solutions are attaining unmatched efficiency, ensuring on-time deliveries, enhancing customer experiences, and fundamentally reshaping the approaches to transporting goods.

This research, titled "Internet of Things in Last-mile Delivery: A Case Study of DHL and Recommendations for Vietnam Enterprises," delves into a comprehensive exploration of the last-mile delivery landscape, focusing on the case of DHL and offering valuable insights for enterprises in Vietnam. Drawing from diverse sources, including journal articles, official reports, and publicly available records, this study employs a qualitative case study approach to address the research questions. The primary objectives of this research are as follows:

1. Examine and analyze DHL's applications of IoT in last-mile delivery.
2. Evaluate the effectiveness of DHL's IoT implementations in last-mile delivery.
3. Assess the current utilization of IoT in last-mile delivery practices among Vietnamese enterprises, identifying strengths, weaknesses, and challenges.
4. Provide recommendations for Vietnamese enterprises based on the lessons learned from DHL's IoT experiences.

The paper is structured into several sections, beginning with an introduction to set the stage for the research. Following this, the theoretical framework explores key concepts related to IoT, last-mile delivery, and their applications. The subsequent section analyzes DHL's IoT applications in last-mile delivery, offering an overview of DHL and detailed insights into their current practices. Finally, the paper concludes with recommendations tailored specifically for Vietnamese enterprises to enhance their last-mile delivery processes through IoT integration.

2. Theoretical framework

2.1. Internet of Things

In recent years, the Internet of Things (IoT) has emerged as a groundbreaking technology that is transforming the way things connect and communicate with each other. At its core, IoT involves everyday objects collaborating and interacting with each other in an uninterrupted way. This interconnected network allows objects to collect and share data, empowering computers to make sense of the world around them – all without human intervention. (Dorsemaine et al., 2015; Uckelmann, Harrison and Michahelles, 2011; Ashton, 2009).

While IoT is often spoken of as a single idea, experts actually view it through several distinct lenses. Each perspective reveals different aspects of IoT's vast potential and diverse applications. Figure 1 illustrates the three basic perspectives from which the IoT concept can be viewed: thing-oriented, Internet-oriented, and semantic-oriented.

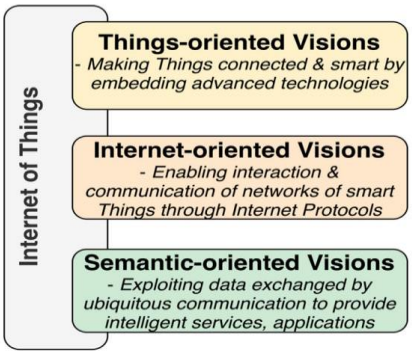

Figure 1. IoT concept with three visions

Source: Compiled by author

The things-oriented vision of IoT revolves around making everyday objects, both physical and virtual, "smart" by integrating sensors, computing power, and communication capabilities (Al-Fuqaha et al., 2015), while the Internet-oriented vision views IoT as a vast network where everything, not just computers, can connect and chat. Each object gets its own unique IP address, similar to computers, allowing them to communicate and share information seamlessly. (Vasseur & Dunkels, 2010). As the number of connected devices in IoT increases, they generate massive amounts of diverse data, including types, sizes, content. This variety creates interoperability issues within the network. The semantic-oriented vision emerges to solve this by using semantic technologies to organize and understand the data. It essentially translates raw data into meaningful formats for both humans and machines, enabling better decision-making within the IoT system (Song et al., 2010).

2.2. Last-mile delivery

2.2.1. Definition

Last-mile delivery is defined, by Hoa and colleagues (2023), in logistics, as the very last procedure of the supply chain, where the goods are delivered from the seller's transportation hub to the final delivery destination. With the main purpose of distributing the ordered products

to the end-consumers as fast as possible, the application of last-mile delivery also helps optimize the traditional means of transportation and improve customers' satisfaction.

Within the recent years, more research has been focussed on last-mile delivery with the purpose of facilitating logistics. Gevaears (2009) has concluded that last-mile delivery in logistics is the last part of the B2C distribution process. Also, Lim et al (2015) stated that last mile delivery is considered as the final segment of a shipment of the goods from the business to the consumer.

2.2.2. Opportunities and Challenges of last-mile delivery

Last-mile delivery stands high opportunities of development with the interference of advanced technology. For example, drones and autonomous vehicles could revolutionize the delivery of goods, making it faster, cheaper, and more environmentally friendly. Likewise, AI can be integrated to optimize delivery routes, predict traffic patterns, and personalize delivery options. The IoT is also increasingly applied by many big companies to help streamline the process and optimize cost, time and efficiency. This can lead to faster deliveries, lower fuel costs, and improved customer satisfaction. Moreover, the trend of sustainability also helps businesses gain a competitive edge in the last-mile delivery market. For example, electric vehicles and low-emission zones could help to reduce the environmental impact of last-mile delivery.

On the other hand, last-mile delivery entails difficulties that challenge the business. In terms of costs, last-mile delivery accounts for between 13% and 75% of total costs in the supply chain, depending on the characteristics of different regions (Gevaers et al., 2009). Therefore, optimizing last-mile delivery costs is a big challenge for businesses and countries around the world. Moreover, the application of last-mile delivery has met with other challenges such as: urbanization, traffic congestion, delivery times and so on, demanding the business to strictly administrate the process.

2.3. Applications of IoT in Last-mile Delivery

IoT promises far-reaching payoffs for logistics operators and their business customers and end consumers. These benefits extend across the entire logistics value chain, including last-mile delivery. IoT in the last mile can connect the logistics provider with the end recipient in exciting ways as it drives dynamic new business models.

For example, one application of the IoT in Last-mile delivery is IoT enabled sensors, which keep optimal conditions for products through location tracking. Other applications are robots, drones and self-driving vehicles which can help drastically facilitate last-mile delivery and improve the logistics industry. Other key trends of IoT in last-mile delivery include smarter tracking and greater visibility, analytics to drive efficiency, autonomous vehicle and robotic delivery and so on.

Many companies have taken advantage of the Internet of Things in their last-mile delivery process, such as DHL with many use cases, Walmart, Fedex and so on. With the help of the Internet of Things, businesses can mitigate the disadvantages of last-mile delivery in terms of cost, foster delivery efficiency and increase customers' satisfaction. Companies can also harness data, optimize routes and offer process efficiency by reducing cost. In Vietnam, the

application of IoT is also prominent in last-mile delivery, though improvement is needed to increase the efficiency of last-mile delivery.

Within the scope of this research, emphases are placed on the four use cases of application of the Internet of Things in last-mile delivery, namely optimized mail/parcel collection, automatic replenishment, flexible delivery and pick-up and next-generation visibility. From then on, the advantages of this technology can be further highlighted.

3. Analysis of IoT in Last-mile delivery of DHL

3.1. Overview of DHL

3.1.1. Overview of DHL

DHL, part of Deutsche Post DHL Group, is the world's largest and leading provider of domestic and international pickup, delivery, and returns solutions for freight and e-commerce to individuals and corporate customers globally (DHL Company Portrait, 2024). Established in 1969 by Adrian Dalsey, Larry Hillblom, and Robert Lynn, DHL pioneered a groundbreaking courier service model dedicated to transporting non-commercial documents between San Francisco and Honolulu. Comprising over 600,000 shipping professionals, DHL operates as both innovative as a start-up and as a powerful international organization, multiplying its operations and providing a logistic global business channel with a current presence in over 220 countries (DHL Company Portrait, 2024).

3.1.2. Overview of DHL Supply Chain

DHL Supply Chain, part of the DHL Group, is the world's leading logistics provider. At its core, DHL Supply Chain specializes in providing tailored logistics services and supply chain solutions with the overarching objective of simplifying complexities for clients while delivering sustainable value. The extensive product portfolio encompasses warehouse operations, transportation services, and a spectrum of value-added offerings. With operations in over 50 countries, DHL Supply Chain employs approximately 185,000 individuals and operates a fleet of around 10,500 vehicles, establishing itself as a prominent player in the third-party logistics (3PL) sector (DHL Supply Chain, 2024).

Distinguished for its innovation, DHL Supply Chain has been named a Leader in 2022 Gartner Magic Quadrant for Third-Party Logistics, Worldwide for the 7th time in a row (Gartner, 2023). Utilizing state-of-the-art digital solutions, DHL Supply Chain integrates technology across its operations, with more than 80% of locations incorporating advanced digital systems. This includes the deployment of over 4,000 collaborative robots and approximately 38,000 smart wearables. The company leverages data analytics to drive operational efficiencies and enhance the overall customer experience, seamlessly combining physical and digital supply chain solutions (DHL Supply Chain, 2024).

According to the Statista Research Department, DHL Supply Chain was the second largest third-party logistics provider in 2022, with revenues of over 45.59 billion U.S. dollars (Statista Research Department, 2024). In the competitive contract logistics market, estimated at EUR 231.3 billion in 2021, DHL stands out as the global market leader with a noteworthy 6.0%

market share and operations spanning more than 50 countries (DHL Annual Report, 2022). This dominant market position reinforces DHL Supply Chain's status as a key player in the ever-evolving landscape of global logistics.

Contract logistics market 2021[1]

€ billion	Asia Pacific	Americas	Middle East/Africa	Europe	Global
Contract logistics	81.6	67.4	7.9	74.4	**231.3**

[1] Company estimate.

Figure 2. DHL's contract logistics market in 2021

Source: DHL Supply Chain

3.2. DHL's applications of IoT in Last-mile Delivery

3.2.1. Optimized mail/parcel collection

The traditional image of mail delivery often involves a postman making numerous stops, checking each mailbox regardless of whether there is mail waiting. This approach, while reliable, can be inefficient and time-consuming, especially in sprawling urban areas. However, DHL is pioneering a change using the power of IoT to transform last-mile mail collection.

Intelligent sensors play a crucial role in optimizing daily mail collection routes. Embedded within the mailbox, they accurately detect the presence of mail. If the mailbox is empty, the sensor transmits a real-time signal, allowing delivery personnel to efficiently bypass unnecessary stops and focus on mailboxes requiring collection. This not only reduces the time spent on each delivery route but also allows DHL to serve more customers within the same timeframe, improving overall productivity. This increased efficiency contributes to higher customer satisfaction levels, potentially leading to greater customer loyalty and retention. Moreover, the application helps minimize fuel consumption and emissions, contributing to a more sustainable logistics operation.

3.2.2. Automatic replenishment

Automatic replenishment consists of the implementation of automated transportation, storage, and/or management systems to speed up the supply of raw materials or finished products to warehouse locations or production lines. This logistics concept can be applied to topping off stock in different storage systems or areas as well as in production centers. Automated inventory replenishment should take into account the various inventory replenishment strategies, such as just-in-time (workstations resupplied as required), reorder point (inventory is replenished when the minimum stock thresholds set are reached), and top-off, which takes advantage of fluctuations in order prep to replenish the picking shelves during slow periods.

At DHL, the seamless integration of automatic replenishment is a pivotal aspect of its operational efficiency. This sophisticated system operates on multiple fronts, empowering both intelligent products and home appliances, along with the shelves at retailers, to autonomously initiate order scheduling the moment a product approaches a low-stock scenario. This innovative approach not only significantly mitigates lead time but also serves

as a proactive measure to prevent costly stock out situations, thereby enhancing overall supply chain resilience.

The implementation of automatic replenishment technology at DHL extends its benefits beyond mere inventory management. In the realm of freight logistics, this cutting-edge system plays a pivotal role in affording DHL greater control over its expansive warehouses. By optimizing the scheduling and fulfillment processes, DHL ensures on-time delivery, fostering customer satisfaction and reinforcing its reputation as a reliable logistics partner. The automated replenishment system also contributes to the meticulous control of the company's inventory turnover.

3.2.3. Flexible Delivery and Pick-up

The integration of IoT in last-mile delivery has led to innovative solutions in flexible delivery and pick-up services. One notable application is the utilization of smart home technology to determine the recipient's presence, enabling secure remote access for delivery personnel.

Traditionally, consumers could select a preferred delivery address or alternative delivery options, such as parcel stations. IoT-enabled solutions now provide enhanced visibility by tagging parcels, allowing recipients to track expected delivery times. This technology facilitates real-time adjustments to delivery addresses, considering factors such as the recipient's location or availability.

For instance, if a recipient is at work during a planned delivery, the system could suggest changing the address to a neighbor or workplace in proximity. Smart home products with proximity sensors can contribute to this flexibility by sensing the recipient's presence and communicating with the delivery person in advance, ensuring optimal delivery conditions. Logistics providers can also initiate a flexible delivery address service, leveraging predictive analytics on the recipient's historical mobile device location data (with their consent) to confirm delivery windows and locations.

Moreover, the IoT opens up opportunities for new business models, particularly in monetizing and optimizing return trips. By connecting delivery personnel with surrounding vehicles and individuals, logistics providers can explore innovative approaches to pick-ups. Startups like Shyp exemplify this trend, allowing consumers to send items conveniently through an app. The integration of IoT enables logistics providers to identify people or businesses along their delivery route interested in sending items, fostering dynamic pricing models and adding value to return trips for both the provider and the consumer.

3.2.4. Next-Generation Visibility

Visibility is the ability to track and monitor the status and location of parts, components and products as they move along through the supply chain from origin to destination. The applications of IoT in Logistics, particularly in Last mile delivery, has revolutionized the way Company delivers the products and services to customers, creating Next - Generation Visibility.

- **Radio frequency identification (RFID)**

Radio frequency identification (RFID) is a form of wireless communication that incorporates the use of electromagnetic or electrostatic coupling in the radio frequency portion of the electromagnetic spectrum to uniquely identify an object, animal or person. RFID can be in the form of item-level tags, sensory tags, NFC smart tags, etc., which are directly affixed to the packaging of goods.

CAEN RFID has provided a temperature monitoring solution for international freight forwarder DHL since 2008. DHL's pharmaceutical customers requested a service to protect temperature-sensitive products such as vaccines and drugs, and CAEN RFID modified their existing RT0005 tag into the DHL data logger for this purpose.

DHL is using this custom tag in their new ThermoNet shipping network, with RFID checkpoints installed in their shipping hubs. ThermoNet is a unique new service in the market—this cold chain validation and temperature tracking service utilizes RFID technology to alert customers if the temperature of their life science and healthcare products goes outside safe limits. This global air service is available for a fee to DHL's Pharma B2B customers with temperature-sensitive products which must be tracked. This service saves resources and time, allowing companies to focus on their core business (CAEN RFID)

Figure 3. RT0005 tag in DHL Data Logger

Source: CAS-Data Logger

Another significant application of RFID in DHL was the Semi-Passive UHF RFID tags. The existing SmartSensor data logger that DHL employs in its ThermoNet service is built upon the RT0005 RFID Temperature Datalogger from CAEN RFID. These temperature sensors function on battery power and use UHF RFID technology for easy data accessibility and collection. The tags are equipped with in-built temperature sensors to track the temperature inside or outside the package they are attached to

Figure 4: Semi-Passive UHF RFID tags.

Source: CAS-Data Logger

Using RFID in last mile tracking allows companies to track their packages in real-time, enabling them to make changes to the delivery route if necessary and track down lost or stolen packages. This can be particularly beneficial for ensuring the timely and secure delivery of temperature-sensitive products like vaccines and drugs. CAEN RFID's modification of their RT0005 tag into the DHL data logger specifically addresses the need to protect temperature-sensitive products such as vaccines and drugs during the last mile delivery. This customized solution enhances the reliability and safety of delivering these critical products to their final destination.

- **Near-field communication (NFC)**

Near-field communication (NFC) is a short-range wireless technology that makes your smartphone, tablet, wearables, payment cards, and other devices even smarter (Tardi, 2019). It can be called a type of RFID. The biggest highlight of NFC technology is its ability to add peer-to-peer communication capabilities, allowing for quick establishment of wireless point-to-point communication.

NFC is widely applied in DHL Global Chicago Hub, DHL's largest world-wide facility, handling international freight for specialized customers in the high-tech, pharma and food and beverage industries.The company has made an investment including its 9,882 square-foot Life Science Cold Chain Certified Competency Center.

Using Near Field Communication (NFC) technology, sensors log in-transit ambient environmental temperature conditions during shipping, functioning at temperatures between -40 and +60 degrees Celsius. The sensors allow uploading of temperature data directly to the DHL mobile app and LifeTrack web portal, making them cost effective and easy to use without the need for specific scanners or devices. According to Steffen, DHL has seen a 40% increase in operational capabilities using these scanners. (Clark, 2019a)

- **Beacons**

Bluetooth technology was initially developed in the mid-1990s as a wireless communication standard for short-range data exchange between devices. It has facilitated the

implementation of beacon solutions in supply chain management by enabling seamless and energy-efficient communication between devices.

Beacons are small devices strategically placed in various locations within the supply chain infrastructure. They transmit signals that can be picked up by handhelds, smartphones, or other Bluetooth-enabled gateways, allowing for accurate tracking, monitoring, and data exchange. By integrating Bluetooth-enabled sensors or tags into packages, pallets, or containers, we can collect and monitor real-time information about location, temperature, humidity, and other conditions in a central system.

The technology has helped enhance transparency, reduce inefficiencies, and allow for proactive decision-making, ultimately improving the overall efficiency and responsiveness of supply chain operations. The introduction of Bluetooth Low Energy (BLE) is helping to extend the battery life of even smaller devices, which is paving the way for smart labels.(DHL, 2023b)

3.3. Evaluation

Having explored DHL's use of IoT in last-mile delivery, this section aims to provide a comprehensive evaluation of these applications. We will examine their key contributions, identify potential limitations, and propose additional IoT technologies employed by other companies that DHL could potentially adopt to further enhance its operations.

3.3.1. Contributions of DHL's applications of IoT

DHL's pioneering applications of the technology of IoT deliver a myriad of benefits, impacting both the company's operations and the customer experience. Some of the key contributions derived from these applications that differentiate DHL in the field of logistics are:

- **Efficiency gains**: By leveraging sensor data to streamline delivery routes, DHL achieves not only substantial cost savings but also a notable reduction in travel time and fuel consumption. The positive environmental impact of these streamlined routes is undeniable, as lower emissions contribute to DHL's overarching sustainability goals. The optimization of resource utilization further magnifies these benefits, ensuring that resources are allocated precisely where they are needed most, creating a remarkable effect of efficiency and positive environmental impact.

- **Customer satisfaction:** Beyond mere efficiency gains, DHL's IoT applications elevate the customer experience to new heights. Faster deliveries, facilitated by optimized routes, represent just the initial step in DHL's route of customer satisfaction. Real-time tracking, made possible by IoT, empowers customers with valuable insights into the whereabouts of their shipments at every stage of the delivery process. The flexibility of pick-up and drop-off options adds an extra layer of convenience, tailoring services to individual needs and schedules. This transparency and control not only enhance customer satisfaction but also foster trust and loyalty, positioning DHL as a customer-centric leader in the logistics landscape.

- **Future prediction**: DHL's Next-Generation Visibility (NGV) is a groundbreaking development in operational efficiency. With its predictive capabilities, NGV analyzes vast

amounts of data to anticipate potential issues before they can disrupt operations. This proactive problem-solving extends to inventory management, ensuring optimal product placement at all times. DHL's predictive capabilities not only sets a new standard for operational efficiency but also fortifies their logistics network's resilience and responsiveness, marking a significant stride into the future of logistics management.

3.3.2. Limitations of DHL's applications of IoT

While DHL's pioneering use of IoT in last-mile delivery offers increased efficiency and customer satisfaction, it is important to acknowledge that these innovative applications also come with challenges that need careful consideration and strategic solutions:

- **Data security and privacy:** Protecting the privacy and security of data is of utmost importance across all applications. From sensor data in optimized mail collection to mobile device location data in flexible pick-up/drop-off services, concerns about unauthorized access, data breaches, and individual privacy require robust security protocols.

- **Technology dependence**: DHL's applications heavily rely on technology, making them vulnerable to technical hiccups. System crashes, connectivity issues, or software glitches can disrupt processes, leading to delays, errors, and inaccurate data. This can result in increased costs, operational inefficiencies, and even reputational damage.

- **Cost and scalability:** The initial investment in infrastructure and technology can be substantial, particularly for RFID/NFC technology with its specialized readers, routers, and proprietary systems. Additionally, scaling these technologies can be complex and costly, making them less accessible for smaller businesses.

- **Power and infrastructure constraints:** Powering data loggers, beacons, and other wireless devices used in asset tracking presents a challenge. Not all environments have readily available power sources, and the diverse lifecycles and values of tracked assets make a universal solution difficult. Ensuring sufficient onboard power or storage, developing suitable monitoring and charging infrastructure, and addressing midlife battery replacements are key considerations.

- **Cybersecurity threats:** The increased use of wireless connectivity in supply chains attracts cybercriminals seeking to intercept communication, steal sensitive information, or disrupt operations. Securing these IoT devices against exploitation by criminal groups is necessary, as compromising them can have significant financial and reputational consequences.

3.3.3. Additional IoT applications used by other companies in last-mile delivery

- **Amazon's Connected Mobility Solution**

Besides DHL, Amazon has also taken advantage of the IoT to improve their last-mile delivery efficiency. One of the prominent applications is Amazon's Connected Mobility Solution - an innovative application of the IoT designed to enhance the efficiency of vehicle-based operations (Amazon Web Services, Inc., n.d.). This solution leverages Amazon Web Services (AWS) infrastructure to provide a centralized platform for engineers and developers. It simplifies collaboration, asset deployment, and operation management for connected

vehicles. The system securely onboards vehicles into AWS IoT Core, ensuring reliable communication through well-architected components.

The application of Amazon's IoT in last-mile delivery brings forth numerous advantages. By focusing on a centralized collaboration platform, developers and engineers can work cohesively, deploying reusable code assets and accessing comprehensive documentation. Secure onboarding processes guarantee that vehicle data is efficiently transmitted and managed. Standardizing and storing data using AWS tools enable seamless analytics, allowing for insights that can optimize routes and enhance overall delivery performance. Furthermore, event-based alerting ensures that operational thresholds and anomalies trigger quick notifications, empowering swift responses to unforeseen challenges.

From this case, DHL can learn the lesson by harnessing the power of Amazon's Connected Mobility Solution to elevate its last-mile delivery services. By establishing a centralized collaboration hub, DHL's tech team can enhance coordination and streamline deployment processes. Securely onboarding vehicles into a platform like AWS IoT Core ensures that DHL's delivery fleet communicates reliably and securely. The standardized data and analytics tools enable DHL to gain valuable insights into its delivery operations, allowing for route optimization and improved overall performance. The event-based alerting system ensures that DHL can respond promptly to any unexpected issues during the last-mile delivery, leading to a more efficient and customer-centric delivery experience. In adopting Amazon's IoT solution, DHL can align itself with cutting-edge technology to meet the evolving demands of the modern logistics landscape.

- **Alexa Integration**

Along with this IoT application in last-mile delivery, Amazon also has integrated its IoT voice assistant, Alexa, with its last-mile delivery operations. Customers can link their Alexa-enabled devices to their Amazon accounts and receive real-time delivery notifications. When a package is out for delivery, Alexa can provide voice updates, allowing customers to stay informed about the status of their packages without having to check their phones or computers. Moreover, customers can provide feedback on their delivery experience through Alexa. This feedback helps Amazon improve its last-mile delivery operations and enhance customer satisfaction. Amazon also developed the “Alexa, Thank My Driver” feature, which allows customers to directly thank drivers for making their deliveries. Any time a customer says “Alexa, thank my driver,” or searches “thank my driver” on Amazon.com or on the Amazon shopping app, the driver who completed their most-recent delivery will be notified of the customer’s appreciation. Customers can thank their driver via the feature all year round, and drivers are able to see the number of times they are thanked within their app. This means more than just the packages that they deliver - Amazon is forming relationships with customers, providing support to the community in tough moments. That is to say, according to Tomay (2024), IoT connectivity allows seamless communication between customers and Amazon's delivery network. In the same way, DHL can also integrate Artificial Intelligence voice into their operations so as to increase customers’ experience, develop strong and long-lasting relationships with customers as well as boosting the efficiency of last-mile delivery.

- Wingcopter Drone Delivery

Wingcopter specializes in the development of autonomous electric Vertical Take-Off and Landing (eVTOL) drones, specifically designed to enhance the efficiency and sustainability of last-mile delivery solutions. In the context of last-mile delivery, Wingcopter heavily relies on the IoT to ensure the efficient and secure operation of its drones. The incorporation of sensors and cellular connectivity facilitates real-time tracking and communication, providing continuous updates on the drone's location, battery status, and flight parameters. Furthermore, AI algorithms leverage this real-time data, along with weather conditions, to optimize flight paths and ensure safe navigation. Sense-and-avoid technology, utilizing LiDAR and other sensors, enhances the drones' ability to detect and evade obstacles, thereby improving safety and reliability. Additionally, the data collected during operations is subjected to analytics, generating insights that contribute to ongoing enhancements in safety measures, operational efficiency, and strategic planning.

In comparison to DHL's endeavors in the realm of drone delivery, Wingcopter exhibits notable superiority in several aspects. While DHL's drone delivery initiatives are primarily confined to smaller-scale pilot projects, Wingcopter has successfully transitioned to commercial operations in multiple countries. Technologically, Wingcopter's drones outperform DHL's current capabilities with their longer range, higher payload capacity, and the ability to operate in diverse weather conditions. Wingcopter has also demonstrated proactive engagement with regulatory bodies, securing approvals for commercial drone operations—a facet that DHL needs to address for broader adoption. Operationally, Wingcopter seamlessly integrates its drones into existing delivery networks, highlighting a gap that DHL must bridge by developing robust infrastructure and processes for large-scale drone delivery.

In light of these disparities, DHL can draw valuable lessons from Wingcopter's drone delivery model. DHL should consider investing in advanced drone technology to match or surpass the capabilities of competitors, prioritize the development of a robust communication and data infrastructure for comprehensive drone management, actively seek regulatory approvals and compliance, and focus on seamlessly integrating drone delivery into its existing logistics infrastructure by starting with targeted applications before scaling up. These lessons position DHL to enhance its drone delivery initiatives and remain competitive in the evolving landscape of last-mile logistics.

4. Recommendations for Vietnamese enterprises

4.1. Current practice of Vietnamese enterprises in using IoT in Last-mile Delivery

Logistics as a key economic sector is the driving force for Vietnam's economic development, so the need for digital transformation or IoT application is becoming urgent. In Vietnam, the initial results and successes in such processes of logistics businesses are remarkable, however, such technological footprint is not so clear in Vietnam ‘s last-mile delivery as a country with many large seaports, logistics businesses in Vietnam often pay more attention to transportation at ports and warehouses. Therefore, new technologies applied in the young logistics market are also concentrated at this stage.

The growth rate of Vietnam's logistics industry in recent times has reached about 14% - 16%, with a scale of about 40 - 42 billion USD/year. Currently, the Vietnamese logistics market has the participation of more than 3,000 businesses. Of these, 89% are small and medium-sized Vietnamese enterprises with capital of less than 10 billion VND, about 5% of this group have capital of 10 - 20 billion VND; 10% are joint venture enterprises and 1% are 100% foreign-owned enterprises (about 30 enterprises) providing cross-border logistics services, with big names such as DHL, FedEx, Maersk Logistics, APL Logistics, CJ logistics, KMTC Logistics, etc… Currently, there are only a group of large companies that can meet the conditions for IoT applications such as DHL, Fedex and leading Vietnamese brands such as Vietnam Post.

The initial phase of digital transformation within Vietnam's Logistics sector is exemplified by the inception of the "ICD Vinh Phuc Logistics Center - SuperPort" project. This initiative, a collaborative effort between T&T Group (Vietnam) and YCH Holdings (Singapore), involves substantial investments to establish an advanced and intelligent logistics center in Vietnam. The project seamlessly integrates an inland container depot (ICD) with a cutting-edge, multi-modal logistics hub that stands out in the region.

In parallel, Vietnam Post has developed the VMap map platform and a real-time address database, facilitating the precise location, addressing, and coding of residential addresses. This postal address code platform possesses the capability to digitize and accurately pinpoint customers' locations. It serves as valuable information for businesses across various industries, facilitating efficient searches. This solution significantly enhances the optimization of goods delivery for postal, transportation, logistics, and e-commerce enterprises.

Saigon Newport Company, following the successful implementation of electronic port and delivery order systems, as well as advanced production management and operational programs, has achieved a remarkable 55% reduction in the time ships spend at the port. Delivery times have been cut by three-quarters, leading to a 60% decrease in labor requirements and a substantial improvement in traffic safety. FPT Corporation, leveraging the Customer Insights Platform for customer data analysis, has retained 38,000 customers, resulting in a monthly revenue increase of hundreds of billions of dong.

Despite these success stories, when considering the entire landscape of the Vietnamese logistics industry, only a small proportion of businesses have undergone a profound transformation similar to Saigon Newport or Vietnam Post. To fully embrace IoT, logistics enterprises in Vietnam require additional internal resources and support from the government.

4.2. Evaluations of IoT adoption in last mile delivery of Vietnamese enterprises

- **Success**

Vietnam Report's survey shows that 100% of large businesses have increased investment in digital transformation in the past year, of which 86% of businesses expect the application of technology, digitalization and digital transformation will brings significant benefits in terms of productivity and business performance in the future; 36% of businesses believe that introducing technology into the logistics journey will improve global customer experience; About 68% of large enterprises have deployed the application of technological advances of the 4.0 industrial revolution in business activities such as: Internet of Things (86%), cloud computing (82%),

intelligence artificial (45%), big data and blockchain, Blockchain (42%)… (Minh Duc, 2021). Many significant successes have been recorded, typically the significantly improved processes of Saigon Newport or Vietnam Post as mentioned above. These successes initially created confidence for other businesses to apply digital technology to logistics processes, gradually raising Vietnam's position internationally.

- **Limitation**

However, only a few large enterprises such as Saigon Newport and Vietnam Post have started implementing IoT technology in their operations, setting a precedent for other businesses in the same field. This also promotes competition and encourages the development of applications related to digital transformation in general and the IoT specifically. However, the majority are small and medium-sized enterprises with limited capital, which poses a challenge to the widespread adoption of IoT technologies.

- **Causes of limitation**

Insufficient financial resources: Businesses themselves need capital to acquire advanced technologies and high-quality human resources to effectively apply those technologies. Additionally, when adopting new technologies, businesses are required to replace outdated equipment with more intelligent devices that are compatible with the new technology. In Vietnam, only Saigon Newport and Vietnam Post, which are two state-owned enterprises, receive full support in terms of financial resources and personnel, enabling them to implement Internet of Things technologies. However, the scope of application is still limited to simple positioning technology, as mentioned above.

Lack of high-quality human resources: According to the latest logistics forum report in Hai Phong in 2022, in a deep discussion, according to a survey conducted by the Vietnam Industrial Research and Consultancy Company, 60% - 80% of interviewed businesses stated that the capacity of their logistics workforce, including both direct personnel and management staff, is at a relatively low level and does not meet internal needs, requiring retraining or additional training. Currently, there are about 3,000 logistics businesses in Vietnam, and it is estimated that by 2030, the demand for logistics human resources will exceed 200,000. Meanwhile, the ability to meet the demand for logistics human resources only reaches nearly 20% of the market's needs. In order to improve technology and apply technological achievements, the company's human resources are the most important factor in promptly addressing emerging issues and building long-term optimization strategies.

Lack of synchronization among businesses: Internet of Things applications, such as DHL's last-mile delivery, require partner brands to have equivalent technology to be compatible with the carrier's technology. Meanwhile, in Vietnam, it is quite evident that businesses in general have low technology adoption, not to mention the majority of individuals participating in online sales with simple infrastructure, which has a significant role in the Vietnam supply chain.

Difficulties from the technology supplier. Even when the company has adequate financial sources to develop the IoT, there are challenges to be concerned about. Most of the IoT market share for Vietnamese enterprises is currently provided by foreign giants. The advantages of foreign IoT systems include comprehensive and detailed processes, systems designed to ensure

common standards, and the ability to transmit and connect data quickly, etc. . However, these giants often do not fully understand the actual production conditions in Vietnam, and their policies and planning may not be compatible with the regime and regulations in the areas where projects are deployed.

4.3. Recommendations for Vietnamese enterprises

As mentioned above, logistics companies in Vietnam are gradually adopting technological advancements related to IoT, especially large enterprises with strong financial resources and good professional support. From the case study of DHL and the limitations we have identified, Vietnamese businesses can draw experiences to strengthen resources and prepare the necessary infrastructure for improving their logistics services through IoT.

4.3.1. Solutions for strengthening financial resources

One of the biggest weaknesses of Vietnamese Logistic Enterprises is financial resources, which have a significant impact on the quality of physical infrastructure, equipment, and expertise when applying IoT technologies in the company's operations. Ensuring sufficient financial resources will help the company avoid infrastructure constraints and promptly address system errors.

Vietnamese logistic enterprises can seek support from the government to strengthen their financial resources. The Vietnam Logistics Business Association (VLA) has recommended that the government provide a financial support package specifically for logistics businesses. This can include measures such as reducing taxes and costs for logistics enterprises, as well as offering financial incentives to promote digital transformation and improve efficiency in logistics management and development

In addition, enterprises can explore partnerships and collaborations with other businesses in the logistics industry. This can include forming strategic alliances with logistics service providers, technology companies, or e-commerce platforms. By leveraging the expertise and resources of their partners, enterprises can access additional financial support and expand their service offerings.

Vietnam is a hot market, a transit point for goods between Southeast Asian countries and a factory producing many international goods, a potential import and export market. Therefore, Vietnamese logistics enterprises can take advantage of the Location advantage according to the OLI theory to attract foreign investment and provide benefits, exchange values with partners to conduct bilateral cooperation.

4.3.2. Solutions for upgrading technological capabilities and human resources

Logistics companies need to proactively update their knowledge about the logistics industry as well as the technological trends being applied in major global logistics companies such as DHL, UPS, Amazon, FedEx,... At the same time, they should consult with experts to strengthen the professional capacity of their staff and make new improvements in optimizing efficiency. This is very important because the logistics field involves many policy regulations and large-scale applications, not to mention new technology applications related to IoT or other smart technologies that may face many risks with regulations in Vietnam.

When applying IoT in the company's operations, an important part of the company will depend on technology. Therefore to secure information and accompany businesses in the long term during the digital transformation, businesses should have their own experts to promptly handle arising issues immediately and build strategies and digital transformation roadmaps that are suitable.

Logistics businesses need to proactively cooperate and seek advice from digital transformation service providers, logistics technology software solution companies to apply new technology or order specialized applications for businesses to maximize the effectiveness of each application.

4.3.3. Solutions for data management optimization and data security

The use of smart data will help businesses make decisions based on accurate and timely information. However, without a suitable plan and lack of knowledge in the technology process, it will cause information leaks and other risks related to the company's and customers' data security. Even DHL, a giant company in the Logistics field, also recognizes this as one of the limitations of IoT. When Vietnamese enterprises want to implement IoT, they need to pay even more attention to issues related to Data Security and cyber security threats by solutions that we recommend as below

- **Data management optimization solutions**

Integrating cloud technology is an effective method in the digital transformation process of the Logistics industry. This technology helps businesses enhance operational efficiency and optimize operational processes. By using cloud computing, businesses can tightly manage specific transportation processes in their operations. Through cloud technology, businesses can track the location of transport vehicles in real time, plan space in logistics, and manage transported orders.

Utilize the company's Big Data to store information, forecast demand more accurately, understand more about the customer's buying cycle, and estimate warehouse capacity in the future based on available data. In addition, Big Data also helps analyze goods data, quantity, status, propose transportation methods to ensure quality, improve operational efficiency for businesses by transparentizing all types of invoices, documents, licenses, helping businesses manage effectively and limit risks.

- **Data security solutions**

Purchase storage support programs, software with high security features such as Dropbox, Onedrive or Fshare... to set up a safe internal network system. Medium and small enterprises in Vietnam can currently consider applying Vietnamese technology with suitable prices such as V-Eagle software and V-AZUR solution set is a server system and internal machines that allow users to work on the internal network, still access the Internet without needing to connect to the Internet. This solution helps businesses ensure safety when working remotely, avoid data loss and malware infection, especially very simple to use, reasonable cost for small and medium-sized logistics businesses in Vietnam.

4.3.4. Lessons learned from the success of DHL

Vietnamese enterprises should recognize the potential of IoT to bring significant business benefits to the logistics industry. By exploring the use of IoT across their warehousing, logistics, and transportation systems, they can analyze data generated at critical points, better manage inventory, predict system maintenance, and monitor and control supply chains.Furthermore, Vietnamese enterprises should prioritize customer satisfaction, considering customers as the focal point, in order to enhance services and technologies to meet customer needs, especially in final-mile delivery. Vietnamese enterprises should focus on innovation and collaboration in their use of IoT. Developing and realizing solutions in collaboration with partners can help them stay ahead of trends and produce value through smarter, faster, and more sustainable approaches.

5. Conclusion

From the above cases of how the Internet of Things can be applied in different use cases, conclusions can be drawn, which is that IoT is an important facilitator to improve the efficiency of last-mile delivery. DHL is one of the companies that successfully applied IoT into their business. From such applications, many achievements can be acknowledged thanks to the Internet of Things, such as optimizing daily mail collection routes, effectively controlling warehouses, ensuring on-time delivery, supervising the company's own inventory turnover and so on. However, it cannot be denied that besides the above mentioned achievements, drawbacks are also detected, demanding the company to invest more into researching and developing more IoT-integrated solutions to help optimize the productivity of last-mile delivery. From then on, Vietnamese enterprises can learn the lessons on how to make good use of the IoT technology to foster the business, therefore upgrading technological capabilities and human resources, as well as strengthening cooperation with foreign partners and technology solution providers.

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