Enabling Technologies in Intermodal Freight Transport

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Contributor: Helen Kine

Enabling technologies have wide application in intermodal freight transport (IFT). Their application is observed on components of IFT including, in ports, terminals, transport services, and loading units. Several enabling technologies such as wireless communication technologies, sensors, positioning technology, and web-based platforms are highly utilized in intermodal freight transport globally. In contrast, electronic data interchange (EDI), wireless communication technologies, and web-based platforms also have potential applications in low-income countries, and their adoption should be studied further.

intermodal freight transport | ICT | digitalization | automation | low-income countries

1. Introduction

Intermodal freight transport (IFT) refers to the transportation of goods using more than one means of transport without changing load units during transportation and incorporating the concept of integration, door-to-door service, and the use of a single bill of lading [1][2][3]. Intermodal transport involves several stakeholders and components and thus requires an intensive flow of information, which causes the system to be complex and require technological innovations [4][5][6][7][8][9]. The efficient application of available and emerging digitalization and automation technologies allows the seamless and timely flow of information and goods in IFT. Information and communication technologies (ICT) in intermodal transport include networking and communication technologies, sensors, satellite technologies, cloud computing, web-based platforms, and automation. These technologies are implemented in decision making, port planning and management, chain management, and monitoring. Several studies have shown the adoption of enabling technologies to improve IFT performance [10][11][12].

The digitalization and automation of IFT in low-income countries are in their infancy. The traditional paper-based exchange of information and documents among stakeholders still prevails [13][14][15]. Real-time information and traceability of goods are not widely implemented. Port operations are not automated and remain heavily dependent on manual procedures and labor. By adapting enabling technologies, low-income countries can enhance IFT.

2. Enabling Technologies and Their Applications in Developed Countries

2.1. Applications of Enabling Technologies

2.1.1. Equipment

The existence of more than one means of transport in an intermodal system comes with a challenge in terms of integration of means of transport. Transshipment carried out in ports provides an easy transfer of load units from one means of transport to another. Studies that focused on technological advancements in transshipments dealt with creating a seamless transfer of goods between modes. These included innovation in load units that facilitate the easy handling of cargos, the design of wagons and platforms for suitable handling of load units, and energy-efficient and fast cranes and reach stackers. The studies focused mainly on their application in ports and terminals, including electric cranes for a rapid and low environmental impact and maximizing port utilization, and transshipment technologies that are easy to operate for different kinds of cargo. Applications in main haul included railway wagons designed to reduced vibration and barges for easy loading and unloading.

2.1.2. Automation

The automation of activities in intermodal transport received considerable research attention, as shown in **Figure 1**. One of the applications of automation is the planning of activities at times when an immediate response is required. The automation of equipment used in ports is another application of automation in IFT. Research has also dealt with the automation of vehicles and wagons for the safe and fast transportation of goods. Robots, automated guided vehicles (AGV), and automatic information updating were addressed in the studies.

2.1.3. Web-Based Platforms, Artificial Intelligence (AI), Cloud Computing, and Big Data

Platforms have a wide application in intermodal transport. Previous studies on platform communication technologies included platforms provided by port operators, business personnel, governmental bodies, logistics providers, and external ICT

expertise. With web-based platforms, information can be made easily accessible to the different stakeholders involved in intermodal freight transport. Communicating information at the right time among stakeholders increases integration and provides an efficient system. As a whole, creating an integration between stakeholders is the main application of platforms in IFT. Big data together with AI are applied for the utilization of large amounts of collected and stored data for planning and decision-making in intermodal transport. This is related to real-time data acquisition in decision-support systems (DSS) for managing intermodal transport. All these technologies are based on cloud computing technologies. Cloud computing is also used for purchasing and using the software applied in intermodal transport planning and management.

2.1.4. Internet of Things (IoT), Sensors, and Wireless Communication Technologies

The articles in this category studied radio frequency identification (RFID), ultra-high frequency (UHF) radio, optical character recognition (OCR), near-field communication (NFC), optical scanner, IoT, and real-time information communications. Data can be transferred quickly and wirelessly using these technologies. Smart mobile phone applications can be provided using NFC. Notification of arrival at the port can easily be made via apps. Micro-electromechanical system (MEMS), radiation, and electronic seal were the sensors covered in the articles to ensure optimum temperature, moisture, vibration, etc. during transportation. Articles also covered smart sensors capable of processing signals and performing pre-defined functions. When summarized from **Table 1**, these technologies work on increasing the visibility of chains. In addition, safety, security, and ease of planning are the main applications. The three together enable monitoring of intermodal transport along chains.

2.1.5. Positioning Technologies

Positioning technologies, such as global positioning systems (GPS), global navigation satellite systems (GNSS), a differential global positioning system (DGPS), and automatic vehicle identification, have been covered in the literature together with their versatile applications. Deploying satellite technologies on vehicles and port equipment was discussed in the research. These are installed on vehicles and containers to receive updates on the location of goods. When used with sensors, they ensure that the security of cargo is monitored. They are installed on reach stackers to remotely control their work and are used to identify the location of straddle carriers.

2.1.6. Electronic Data-Sharing Tools

A number of documents have to be communicated between IFT agents. This is especially true in the case of international transport. Both port operators and customs require documents that identify the goods transported, their value, and legal requirements. Electronic data interchange (EDI) and the application program interface (API) are some of the tools available. EDI is a system of standardized electronic data transfer from one computer to another. EDI improves the system by minimizing paperwork and the involvement of people in the process, and it is mainly used to reduce the time involved in obtaining and processing information. It reduces the time loss that would be incurred with manual communication of information. The EDI/XML interface can also be used for electronic document transfer, minimizing software costs.

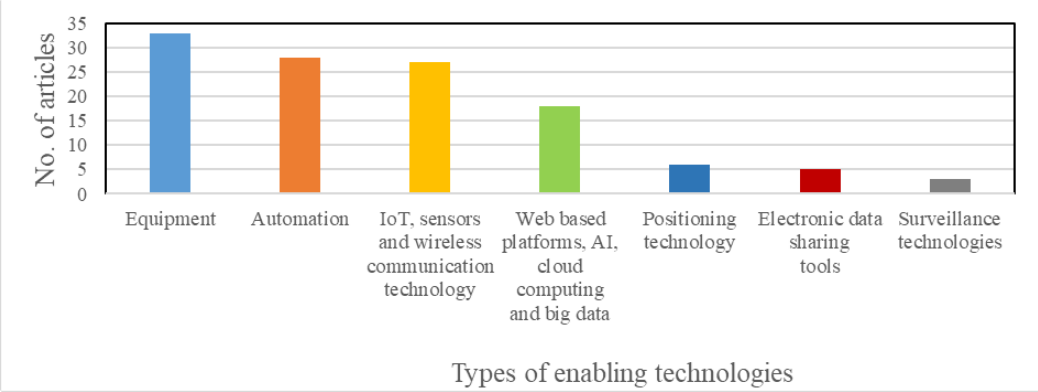

Figure 1. Enabling technologies applied in intermodal freight transport discussed with the articles.

Table 1. Application of technologies on different components of intermodal freight transport.

Enabling Technologies	Components of Intermodal Transport				
	Ports and Terminals	Chain Management and Monitoring	PPH	Main Haulage	Load Unit

Automation		*	Collect automatic data from port operators, logistic providers and carriers for an excellent decisions support system Automated trucks and platoon operations work to reduce road congestion, environmental impact and improve safety	Autonomous underground transport and ships provide a fast and reliable service	*
IoT, sensors, and wireless communication technology	Provides automatic identification of units at gates, security of containers and real-time tracking and tracing in ports Optimize port call	Ensure security of cargo by sending signals for risk conditions and safety of perishable products Optimize mode choice using real-time data	Used for the efficient port calling process Provide real-time information from trucks to stakeholders	Monitor vibration during transportation and report for anticipated risk	*
Web-based platforms, AI, cloud computing, and big data	Broadcast schedules in port Clear presentation of required information and procedures to stakeholders	Used to select the best chain in choosing transport service Enable fast and reliable decision support system Provide visibility of goods in transport	Provide a decision support system for logistics providers Establish collaboration between carriers to reduce empty running Online matching between shipping request and service	Easy access to information of the status of the long-haul vehicle to stakeholders	Provide centralized and fast container booking system
Positioning technology	Used to locate trucks, containers, and equipment in ports for efficient work planning	Ensures traceability by locating the cargo throughout the chain	Identifies the real-time location of trucks Used to determine shortest path routes	Provides real-time location of cargo while in the main haulage (e.g., a location where any mishandling of good occur)	*
Electronic data-sharing tools	Provide easy and quick port	n/a	Exchange booking and boarding	Information about the	n/a

	administration in port calling, customs declaration, clearance notification Port-EDI for a one-stop service (single window)		instructions between consignee and freight forwarders	position of ships	
Surveillance technology	Ensures the safety of cargo under port process Identifies plate numbers of trucks entering port	Ensures cargo safety throughout the chain	Controls security of cargo and drivers in inland transport	*	Automatic extraction of container identity code

* No article found. “n/a” not applied.

2.2. Pre-Conditions and Barriers for Implementation of Technologies in IFT

Certain conditions need to be in place for the successful implementation of enabling technologies in IFT. The extent and type of these pre-conditions vary depending on the types of technologies. Networking technologies and the internet are fundamental requirements for the proper functioning of digitalization and automation. Communication in ports and sensors in trucks need networking technologies to function properly [16][17]. These include wireless personal area network (WPAN), global system for mobile communication (GSM), global navigation satellite system (GNSS), and cellular data. Innovative networking systems such as 4G, long-term evolution (LTE), and 5G are required to establish fully automated smart ports.

Software and skilled labor who can operate the software are also requirements for technologies such as EDI and web-based platforms [18]. Another barrier to the adoption of technologies in IFT is the lack of standardization [16][17][19]. Standardization in digitalization devices, load units, trucks, and railway gauges are requirements for the adoption of technologies [17]. The interoperability of technologies is also a requirement for their adoption in IFT. Since intermodal transport mostly involves more than one country, interoperability is an important characteristic. This calls for strong cooperation between countries and the many stakeholders involved in IFT [20]; otherwise, it may block trade partnerships between countries and between large companies and small and medium-sized enterprises (SMEs).

The introduction of technologies such as the automation of trucks and transshipment technologies is very costly. Cost and uncertainty around the financial return from technologies are other barriers to adopting technology [21][22]. The economic and market benefits of transshipment technologies are not well researched, creating uncertainties that prohibit their adoption in ports. There is also a fear of job losses whenever automation is introduced to the system. Freight forwarders also fear that they will lose their jobs if electronic communication and single window systems materialize. However, there is a shortage of skilled labor to operate these technologies.

Satisfaction with how operations are currently carried out is also a barrier that hinders companies from accepting technologies. This is especially true for SMEs, as stakeholders seem to be satisfied with the current paperwork and traditional communications [14].

For information technology solutions, most companies have concerns about sharing information due to trust and security issues [20]. Some information is confidential, and they have a fear that they may lose customers if they provide customer information.

3. Applications of Enabling Technologies in IFT for Low-Income Countries

3.1. Characterization of IFT in Low-Income Countries

Low-income countries have limited infrastructures, including low road densities and limited quality of road infrastructure [23]. Therefore, some technologies cannot be successfully implemented. Road and rail connectivity are also very poor in these countries [9][24][25]. This has resulted in the low utilization of railroad intermodal transport.

A limited variety and old trucks with minimum installed technologies prevail in the context of low-income countries. Internet availability and access are required for digital technologies to work [26]. High-income economies have a widely implemented ICT infrastructure with over 80% of the population in high-income economies using the internet, whereas this number falls to 20% for most low-income countries [27].

Domestic intermodal transport is mainly used in high-income economies, while the concept barely applies to low-income economies [26][28][29] where international intermodal transport features more prominently. The main reason for using intermodal transport in high-income countries is environmental concerns, while in low-income countries, it is the existence of obstacles such as mountains and water bodies and economic factors [17][19].

The interconnectivity between countries in terms of their physical network and regulations plays a major role in the successful implementation of international IFT. In the case of high-income countries such as in Europe, there is multinational cooperation. However, this is not the case in low-income countries [30]. The lack of interconnectivity and cooperation will have an impact on the effectiveness of any technological or structural changes incorporated in the system.

Up to 90% of businesses worldwide are SMEs, and it is important to connect these enterprises to intermodal transport. In the case of high-income countries, small trucks or non-motorized transport (NMT) are used to bring goods to or from these enterprises to a collection center, while in low-income countries, it is common to walk (in the case of animal transport) with back-loading and pulling by animals in addition to trucks. These enterprises are not economically strong and do not collaborate with one other in low-income countries [31]. Most of the labeling, packaging and value-adding of goods are finished at the production point for high-income countries, making the system easy for intermodal transport.

Studies have also identified that IFT in low-income countries faces challenges such as low interconnectivity and coordination, lack of capital, political interference in the system, etc. [32][33][34].

3.2. Enabling Technologies with Potential Applications in Low-Income Countries

3.2.1. Ports and Terminals

One of the challenges for ports in low-income countries is network unavailability that causes port management to be time-inefficient. A lesson can be taken from a case study from the Humber port region that uses cellular network technology with a lower rate deal from operators [20]. This networking system does not require extra infrastructure or IT experts adept in the likes of wireless fidelity (WiFi), wireless local area network (WLAN), or wireless personal area network (WPAN) technologies; thus, it is an easy and cost-effective solution. The application of EDI is a technological solution to the high prevalence of paperwork and human interaction in exchanging documents and information in ports, and extensible markup language/electronic data interchange (XML/EDI) is an even less expensive option for low-income countries [18]. Another way of electronically exchanging information is the application of a single-window system. A single-window system is a good practice because it minimizes the waste of time in ports by providing a single electronic gateway that is used to disseminate a single document to several stakeholders at a time [35]. The application of this technology alleviates repetitive and lengthy customs checks.

Inadequate labor skills can be compensated for by the automation of some activities in port. Full automation of ports may not be feasible in low-income countries. Congestion upon arrival and at the departure from gates is a recognized challenge in low-income countries. RFID is applied to optimize port calls and minimize the time spent at gates with digitized truck/driver identification systems [20][35]. However, it requires the installation of tags on containers and readers at gates and the collaboration of numerous stakeholders, which can impose extra costs and is hard to put into practice for low-income countries.

3.2.2. Chain Management and Monitoring

As illustrated above, traceability and tracking, real-time information, chain management, and monitoring are all challenges in low-income countries [36][37]. With the application of RFID and networking technologies, traceability can be achieved. However, RFID readers are required at segments of the intermodal transport chain. This involves additional infrastructure costs and could be a problem, especially in landlocked countries, because the decision will require the willingness of the neighboring country. However, multinational cooperation between countries, as in the case of European countries, should be promoted to make this effective in issues concerning cross-border transport. GPS installation is another technology that can be used to track the location of trucks in the PPH sections instead of RFID, and it is also applied for route optimization [17].

Web-based platforms improve coordination between stakeholders for the better management and monitoring of goods flows, and this technology should be promoted to overcome poor coordination between stakeholders in low-income countries. The adoption of tracking and tracing technology will also minimize the time spent in ports by helping plan the arrival of containers.

3.2.3. Pre and Post-Haulage

Cooperation among transport operators is important in IFT [4]. Empty haulage is significantly reduced when the planning and scheduling of transport services are carried out with cooperation between carriers [26]. Web-based platforms are good practices to increase this coordination. The implementation of these technologies will significantly minimize fragmented PPH transport in low-income countries. The use of sensor technologies (weight sensors) on vehicles can regulate the overloading issues prevalent with most post-haulage of IFT.

3.2.4. Main Haulage

The main haulage of IFT in low-income countries is mainly carried out by vessel [25][34]. Therefore, vessel efficiency is an important aspect of the system. Implementation of the automated port call system will enable the efficient use of vessels. Real-time communication between vessels and ports will enhance the timely facilitation of space and equipment for the loading and unloading of containers by ports [14][38]. This practice will reduce the turnaround time of ships and result in better utilization of the already scarce vessels in the context of low-income countries. The integration will also address the problem of long lead time in IFT of low-income countries.

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