

CHAPTER 2

Literature Findings and Methodological Considerations

This chapter presents both findings from the literature and methodological considerations from a worldwide perspective. Despite the paucity of research in this field for Sub-Saharan Africa, the findings from other countries are relevant to countries in the region. However, as demonstrated in this report, some specificities in Sub-Saharan Africa, such as abnormally long cargo dwell times, the dominance of the general trading model, a lack of competition in some sectors of the economy, and the importance of cash constraints, may weaken the incentive to move goods rapidly through the port.

Literature Findings

Cargo dwell time in ports has long been identified as a crucial operational issue of modern logistics. Back in 1978, a seminal report by the National Academy of Sciences in the United States noted, “The old saying ‘time is money’ is especially germane to modern port activity. The greatest saving in total cargo transport time can be made during the port transfer process, not the feeder or shipping transport segments” (National Academy of Sciences 1978, 90).

That report emphasized the importance of dwell time in port operations, and its observations are still relevant today. For example, the report noted the adverse impact of long dwell times on total logistics costs: “It is necessary to reduce time spent in port by vessel and cargo to reduce shippers’ total shipping costs” (National Academy of Sciences 1978, 103). It also rightly identified port dwell time as a crucial factor of competition between ports: “Timely service is the most important ingredient a port can offer to both importers and exporters” (National Academy of Sciences 1978, 95).

Port researchers have studied the issue of port dwell time by looking at four main topics: port operations and, in particular, the means of optimizing port productivity; trade competitiveness, which considers the impact of cargo dwell time on trade; port competition, which has recently been the subject of growing attention in the context of direct competition between port terminals at the regional and global levels; and supply chain performance, with authors such as Robinson (2002) calling for a paradigm shift to focus on the role of ports in global supply chains. Table 2.1 summarizes the main findings in the literature.

To our knowledge, no one has specifically analyzed port dwell time as a subject of research by itself. In other words, port dwell time is generally seen as a determinant of analytical outputs such as port efficiency, port capacity, or even trade volumes, but is not treated as an issue worthy of attention by itself. Nevertheless, research has shown its growing importance and relevance in the context of modern port operations and trade logistics. This study intends to fill this gap in knowledge.

Port Operations

From an operational perspective, researchers are interested in the determinants of the operational performance of ports and the means and resources to optimize it. The primary indicators of operational performance are vessel turnaround time and port throughput. Asset performance indicators are also widely used to compare berth, yard, or gate performance of different ports. Cargo dwell time in terminals appears to be only a secondary indicator, since it depends on the characteristics of the cargo and the shipper (Chung 1993).

Few attempts have been made to model cargo dwell times in terminals as such, with the noticeable exception of Moini et al. (2010), who use data-mining algorithms to estimate dwell times for a U.S. container terminal. Vessel turnaround time, however, has been subject to many modeling attempts, the most traditional being queuing models that depend on three

Table 2.1 Summary of the Main Findings in the Literature on Cargo Dwell Time in Ports

<i>Topic</i>	<i>Literature</i>	<i>Treatment of the dwell time issue</i>
Operations	Moini et al. (2010) UNCTAD (1985), Frankel (1987), Dharmalingam (1987), Dally (1983) Huynh (2006) Farrell (2009)	Estimation of dwell time using data-mining techniques Dwell time as a determinant of container yard capacity Dwell time as a determinant of yard capacity and productivity Two-way relationship between dwell time and throughput
Trade facilitation	Dasgupta (2009) Sengupta (2008) Arvis, Raballand, and Marteau (2010) Djankov, Freund, and Pham (2006) USAID (2004) Hummels (2001) Nordås, Pinali, and Geloso Grosso (2006)	Dwell time as a barrier to trade Necessity for reforms Dwell time as a component of transaction costs; the effect on trade of uncertain dwell times Impact of dwell time on probability of trading with the United States Impact of dwell time on GDP and regional trade Cost of time for international trade Cost of time for international trade and the importance of time in manufacturing and retail supply chains Dwell time as a determinant of port choice
Port competitiveness	Veldman and Bückmann (2003), Nir, Lin, and Liang (2003), De Langen (2007), Tongzon and Sawant (2007)	
Supply chain performance	Sanders, Verhaeghe, and Dekker (2005) UNCTAD (1985) Rodrigue and Notteboom (2009) Nordås, Pinali, and Geloso Grosso (2006) Rodrigue and Notteboom (2009) Wood et al. (2002)	Dwell time as a determinant of port choice and trade generation Long-term storage in ports and the issue of pricing Terminals as extensions of distribution centers Modern supply chains as an essential ingredient for time-sensitive products Ports as strategic storage units in international supply chains Impact of lead time underestimates on dwell times

Source: Authors.

inputs: the distribution of arrivals, the distribution of service times, and the number of servers—that is, berth stations (Tsinker 2004). Vessel service times are an important component of cargo dwell time in congested ports, and it is therefore important to understand the dynamics of these queuing models, but for most ports, the bulk of cargo dwell time is spent in the yard, and vessel turnaround times are of secondary importance to shippers. However, cargo dwell time in terminals enters most operational port models not as an output, but as an explanatory variable.

Traditional attempts to design yard storage capacity—for example, from either a demand or a supply approach—use cargo dwell time as a main variable (box 2.1). In a more recent attempt, Huynh analyzes this relationship between dwell time and yard capacity by taking into account rehandling productivity and storage strategies (Huynh 2006). He concludes that port authorities should be well informed about the impact of dwell time on yard productivity before setting tariffs or free time periods that encourage long dwell times.

Box 2.1

Classic Formulas for Container Yard Storage Capacity as a Function of Dwell Time

Demand approach

$$CY = (C_p * A * DwT) * (1 + F) / 360 \quad (\text{UNCTAD 1985})$$

$$CY = [C_p * A * (Dwt + 2)] / [365 * Z * 10^4 * (H + 2h) * U] \quad (\text{Frankel 1987})$$

Supply approach

$$C_c = GS_A * (0.6 * S) * (K / DwT) \quad (\text{Dharmalingam 1987})$$

$$C_c = (GS_T * H * W * K) / (DwT * F), \quad (\text{Dally 1983})$$

where CY is the required container yard, C_p is the projected container volume (20-foot equivalent unit, TEU), A is the area per container volume (TEU), DwT is the average dwell time in the container yard, F is the peaking factor, Z is the storage utilization factor, H is the average expected stack height by the average number of containers in used stacks, h is the standard deviation of stack height, U is the total area utilization, C_c is the container capacity (per year), GS_A is the available ground slot, GS_T is the total ground slot, S is the ground slot utilization factor, K is the number of days per year, and W is the number of working slots (in TEUs) in a container yard.

Source: Bichou 2009.

Port simulation models also take cargo dwell time as a variable. They consist generally of a set of modules with complex interaction and backward loops: an input module, a ship generator module, a ship operation module, a cargo-handling module, and a warehouse operation module (Hassan 1993). Dwell time is an input to the ship operation module and the warehouse operation module, and most recent techniques take into account the two-way relationship between dwell time and port capacity. This two-way relationship has been explored in analytical papers, such as Farrell (2009), albeit without an explicit analytical formulation of cargo dwell time as a model output.

Trade Competitiveness

Another research field where cargo dwell time has been given specific attention is international trade, specifically in the context of trade facilitation initiatives. However, the impact of long cargo dwell time on trade efficiency has only recently been seen as a major hindrance to the development of low-income countries. When analyzing key issues in India's international trade, Dasgupta identifies port logistics, specifically cargo dwell time, as the area most in need of reform (Dasgupta 2009, 239). Cargo dwell time also enters the equation of trade cost proposed by Sengupta in his book on the economics of trade facilitation (Sengupta 2008, 178). And achieving more time-efficient port clearance operations is often, perhaps always, a main objective of trade and transport facilitation projects that have been designed to address comprehensively the physical and other obstacles to trade in developing countries.

In addition to the long duration of container stays in the port, Arvis, Raballand, and Marteau (2010) identify the unpredictability of cargo dwell times as a major contributor to trade costs because shippers need to "compensate for the uncertainty by raising their inventory levels" (Arvis, Raballand, and Marteau 2010, 47). In other words, delay is not the only issue of importance when considering the impact of dwell time on the performance of trade; predictability and reliability of cargo dwell times are equally important because they have a major impact on the total costs of trade logistics.

Some modeling works have been instrumental in showing the direct impact of longer dwell times on trade. Djankov, Freund, and Pham (2006), for example, use a gravity model to calculate that each additional day that a product is delayed prior to being shipped reduces trade by at least 1 percent. In an attempt to show the broad economic impact of port

inefficiency, Kent and Fox (2005) use a general equilibrium model to calculate the impact of port delays in the port of Puerto Limón, Costa Rica, on the regional economy of Central America (USAID 2004). They conclude that removing port inefficiencies, including long dwell times, would improve the gross domestic product (GDP) of Costa Rica by 0.5 percent.¹ Two major shortcomings of the general equilibrium model are the impossibility of separating containerized maritime trade from other modes and the robustness of the estimated inventory cost per day. In an earlier work that serves as reference on the matter, Hummels (2001) estimates that each additional day that cargo spends in transport (including port dwell time) reduces by 1–1.5 percent the probability that the United States will source from that country. And each day saved in shipping time is estimated to be worth 0.8 percent ad valorem for manufactured goods. Nordås, Pinali, and Geloso Grosso (2006) use comparable techniques to estimate trade flow probability as a function of lead time. They conclude that port efficiency is crucial to the successful integration of a country into the global trading system (Nordås, Pinali, and Geloso Grosso 2006, 36).

Port Competition

The container revolution started during the late 1950s in the United States. Two decades of international trade boom followed, leading to the development of modern container ports, especially in Western Europe and North America. As a result, port competition has attracted much scholarly attention in these regions, with a special focus on the “North Range” in Europe (ports of Antwerp, Bremen, Felixstowe, Hamburg, Le Havre, and Rotterdam) and the main U.S. ports (Chang and Lee 2007). At that time, global transport chains were still fragmented, uncoordinated, and inefficient. Competition was driven mainly by cost (Magala and Sammons 2008).

Later on, following the rise of powerful economies in East Asia and trade globalization, port competition shifted toward trade-offs between cost and quality of service. By the end of the 1990s, competition among modern container-based ports was at its peak (Chang and Lee 2007), and the top five container ports in the world were located in East Asia, principally China, following a short period of domination by ports in Japan, the Republic of Korea, and Taiwan, China, which had all invested heavily in port infrastructure to develop regional superhubs (Wang and Slack 2004). In other parts of the world, including North America, the same trends were evident, and container superhubs had developed in Northern

Europe (Antwerp, Hamburg, Rotterdam), Southern Europe (Algeciras, Gioia Tauro), the United States (Long Beach, Los Angeles, New York–New Jersey), and other markets (Dubai).

It is in this context that port dwell time started playing a crucial role in the competition between ports. Competition shifted from competition for lower cost to competition for faster, better, and more cost-effective access to international markets (Magala and Sammons 2008).

Because of this intense competition, various studies have highlighted the determinants of port choice and port competitiveness in contestable hinterlands.² Several of these studies identify cargo dwell time as a critical explanatory variable in port selection that enters the formulation of demand function (Veldman and Bückmann 2003; Nir, Lin, and Liang 2003; De Langen 2007; Tongzong and Sawant 2007; Sanders, Verhaeghe, and Dekker 2005). But since the objective of these models is usually to forecast traffic growth or market shares, there is little discussion of the actual importance of port dwell time for port clients. The techniques used tend to be “broad-brush” and “mechanistic” in nature, with “their success being judged by their predictive power rather than their explanatory ability” (Mangan, Lalwani, and Gardner 2002).

Supply Chain Management

The very focus of port management has changed radically in recent years with the advent of containerization and the “terminalization of supply.” The objective of optimizing the use of port facilities has been gradually replaced by performance objectives that seek to gain competitive advantage over other ports. Since 1995, the United Nations Conference on Trade and Development (UNCTAD), for example, has recommended the implementation of performance-based yard tariffs that would encourage shippers to reduce the dwell time of containers in terminals. However, in many places, the promotion of efficient behavior among port users has met with resistance from shippers, who tend to use the terminal as a storage area—hence the difficulty of finding acceptable optimum levels of use. Specific pricing objectives have been proposed, but the implementation of effective storage tariffs is very complex (UNCTAD 1985).

Similarly, Rodrigue and Notteboom (2009) argue that freight forwarders use terminals as an extended component of their distribution centers and try to take full advantage of free time, while terminal operators try to restrict such behavior. Nordås, Pinali, and Geloso Grosso (2006) use a few case studies to show that a broader range of products are becoming

time sensitive following the adoption of modern supply chain management practices in the manufacturing and retail sectors.

The functional use of terminals as a cheap storage area brings new challenges to terminal operating companies that are not limited to pricing issues. High dwell times are no longer indicators of poor terminal performance in general but, in some circumstances, are “perceived as an indicator of a higher level of integration between the port and inland freight distribution brought by supply chain management” (Rodrigue and Notteboom 2009). The objective of helping port users to achieve better supply chain performance would therefore lead terminal operating companies to accept or even support long cargo dwell times. Rodrigue and Notteboom conceptualize this paradigm shift from “bottleneck-derived terminalization,” where the port terminal is essentially a source of delay and a capacity constraint in the shippers’ supply chain, to “warehousing-derived terminalization,” where the terminal replaces the warehousing facilities of shippers and gradually becomes a strategic storage unit (Rodrigue and Notteboom 2009).

Such a functional shift comes with a few prerequisites: extra terminal capacity (low occupancy rates), modern supply chain practices (such as integration and synchronization of supply and demand or just-in-time manufacturing), and good liner shipping connectivity, which is indispensable for responsive supply chains. These assumptions would probably not hold in most Sub-Saharan African countries today: liner shipping connectivity is very low, with most countries being in the lowest tier of the UNCTAD liner shipping connectivity ranking (UNCTAD 2009),³ most container terminals have occupancy rates higher than 80 percent, and supply chain maturity is at an early stage, with a dominance of producer-driven supply chains based on cost-efficiency rather than responsiveness.

The use of terminals as warehouses is nevertheless prominent in African ports, as is demonstrated in this report. In fact, no attempt has been made to model the demand of shippers for long-term storage in a way that is applicable to ports in Sub-Saharan Africa. Yet the problem has been identified for a long time: “As far as they are interested in warehousing, shippers are biased in favor of utilizing the port facility as much as possible” (UNCTAD 1985). They tend to have negative perceptions about the reliability of shipping services and “build delay time into their production planning” to cater to the worst situation. If the container happens to arrive on time, shippers delay the shipment until they need it (Wood et al. 2002, 169).

Methodological Considerations

The time a container spends in port can be divided into three segments: entry, storage, and exit. For inbound containers, these segments refer to the times spent on the following:

1. Unloading the vessel and transferring containers to the storage yard, t_1
2. Waiting in the container yard, t_2
3. Processing the container out of the port, t_3 .

The time spent undertaking the physical transfer—activities 1 and 3—depends primarily on the efficiency of the terminal operator. The time spent waiting in the container yard depends on the time spent completing the various procedures associated with clearing import cargo, completing an intermodal transfer, and arranging for the inland transfer. For ports with off-dock container yards (ODCYs), additional time is required to transfer the containers from the port to the ODCY, t_4 . As a result, the average dwell time for a port alone is $t_1 + t_2 + t_3$. But for the containers, it is $t_1 + (1 - \alpha)(t_2 + t_3) + \alpha(t'_2 + t'_3 + t_4)$, where α is the proportion of containers going to the ODCY and t'_2 and t'_3 are the average times for activities 2 and 3 in the ODCY.

Factors to Be Modeled While Looking at Dwell Time

For individual shippers, the length of port dwell time is determined by three factors: the efficiency of container-handling operations, the complexity of the transactions for border control and intermodal exchange, and the requirements of the consignees for storing cargo in the port. The basic cargo-handling operations in a container terminal are the movements of goods across the berth, in and out of the storage area, and entering and exiting the port from the landside. The efficiency of these operations affects the time and costs of the transfer. Each operation has capacity constraints, and delays occur more frequently as the level of use approaches this capacity. Both the port and the terminal operator are responsible for the efficiency of these operations.

Transactions are associated with the intermodal transfer of cargo across a border. They include the procedures of customs and other border agencies that control the type and quality of goods entering and exiting a country. They also include the financial transactions associated with the transfer of ownership and liability for the cargo as well as with the collection of duties and taxes on it. In the case of imports, the transfer of

ownership involves exchanging the bill of lading between the shipping line and the consignee. The transfer of liability between the shipping line, port operator, and provider of land transport involves the exchange of documents for receipt and delivery of the cargo. The minimum time required to complete these transactions is determined by parties other than the cargo owner; however, the actual time is determined by the efforts of cargo owners and their agents to coordinate with these parties and to cooperate in completing the transactions.

The decision of the consignee to store cargo in the port rather than elsewhere along the supply chain is based on cost and convenience. The period of storage depends on the delivery time as well as on the cost of alternative storage outside the port. The use of port storage therefore depends on its pricing and the amount of duties and taxes payable when cargo leaves the port.

Current Policy Orientations

The primary focus of policy makers has been on costs, and there is growing awareness of the need to equip least developed countries with efficient transport networks, including modern ports. The private sector has been called upon largely to operate and manage these new facilities. The impact of these investments has been subject to increasing attention, and operating costs or productivity measures have been monitored closely.

In parallel, global trade negotiations have progressively raised the issue of trade facilitation as a critical component of the economic development of poor nations. The focus has been on simplification and transparency of border-crossing procedures, and vast programs have been undertaken to modernize customs administrations.

Finally, logistics performance has recently been given attention as part of global benchmarking initiatives to evaluate the ease of doing business in different countries, and the efficiency of logistics and transport services is increasingly considered a major contributor to high import costs and long delays.

What seems to be missing in the body of knowledge about barriers to international trade in developing countries is analysis of the business strategies of market players. The competitive context in these countries is such that market inefficiencies are many, and suppliers or users can therefore take advantage of the situation to increase their revenues to the detriment of the final users.

Although studying infrastructure stock and productivity, border-crossing procedures, logistics performance, and private sector strategies is useful, our primary focus in the case studies presented in this report

is on private sector strategies. In particular, the focus is on shippers, terminal operating companies, and logistics providers. Other approaches are also needed in order to document the success or failure of recent reforms and investments and to complement the formulation of policy recommendations.

Disaggregated Analysis

The parallel clearance formalities undertaken by shippers can be classified into three main constituents of dwell time in ports:

- *Operational dwell time*, which refers to the performance of physical operations
- *Transactional dwell time*, which refers to the performance of clearance formalities
- *Storage dwell time*, which refers to the voluntary storage of cargo in the container yard as part of a wider inventory management strategy.

The importance of each component of total dwell time needs to be analyzed with regard to the context. The interrelationships between them are also of critical importance because high correlations tend to support the existence of behavioral determinants of long dwell time.

Operational dwell time is evaluated in this report using extensive shipment-level data and performance indicators that are generally collected by terminal operating companies. Customs administrations have implemented electronic procedures that allow for close monitoring of the efficiency of the border-crossing process as a proxy for transactional dwell time. The cargo-tracking instruments used by carrying and forwarding operators and shippers are instrumental in gaining insight on typical statistics and strategies for storage and overall dwell time.

Establishment of a Demand Model. The bulk of cargo dwell time (up to 90 percent) is spent in the storage areas of the terminal or the ODCY. To interpret (long) cargo delays in ports requires understanding the determinants of yard storage times. This analysis is performed at two levels:

- At the supply level, by looking at the performance and organization of terminal operating companies and intermediaries, such as logistics providers or customs brokers, and the processes established by public authorities in the import process
- At the demand level, by modeling the behavior of shippers with regard to port storage.

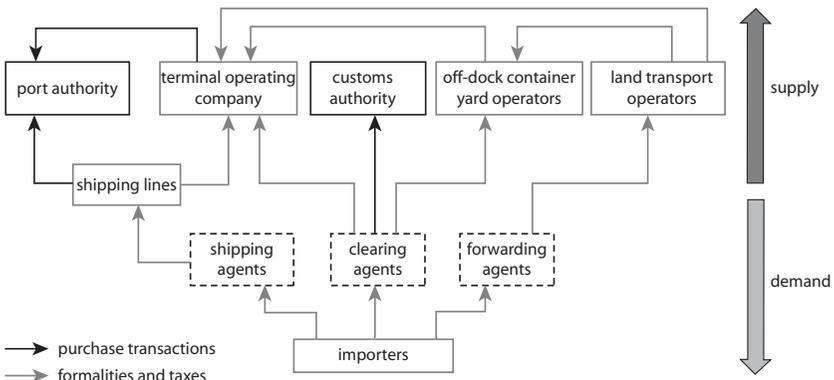
The general framework of the research problem is depicted in figure 2.1. A system of players is involved in a set of commercial or administrative transactions that are performed to allow containerized goods to enter the country. Each player in the system operates in a specific competitive context and within a given set of constraints and incentives. Analysis is necessary to gain insight into the decision-making process of all these players, their efficiency, and the interactions between different players that can explain the reason for long cargo dwell times.

This analytical work was complemented by field investigations with three main objectives:

- *Data collection.* The analytical models are data intensive, and parameters were defined or updated using the latest available data.
- *Qualitative analysis.* Qualitative analysis was undertaken to refine assumptions of the model, identify new ways of approaching the problem, and eventually distinguish between conclusions that are applicable at a regional level and those that are specific to each country.
- *Evaluation of clearance procedures.* Physical port clearance is clearly affected by the inefficiencies of clearance transactions, and the interdependencies between both processes were sounded out. In particular, we sought to identify those formalities or processes that have a substantial impact on cargo dwell time.

Having presented the main findings of the literature and an analytical framework in this chapter, the next chapter presents the main

Figure 2.1 Port System Model for Container Imports



Source: Authors.

findings of the case studies undertaken within the framework of this study.

Notes

1. Port efficiency is computed through the parameter *ams* of the Global Trade Analysis Project (GTAP) model, which is a computable general equilibrium model of the world economy. The port of Puerto Limón (Costa Rica) has an excess delay of 13.5 hours as compared to the port of Cartagena (Colombia), and additional costs of US\$18 per 20-foot equivalent unit (TEU) are incurred, mainly because of vessel costs. Kent and Fox (2005) use Hummel's inventory cost estimate (0.8 percent per day) and an average cargo value of US\$26,919. The formula for parameter *ams*, which simulates an additional tariff on goods, is $t = (13.5/24) \times 0.8 + (\text{US\$}18/26,919 \times 100) = 0.517$. The higher cargo dwell times in the port of Puerto Limón are therefore equivalent to an additional tariff of 0.517 percent on manufactured cargo, which exerts a drag on the national economy. The aggregate impact simulated through the GTAP model is 0.5 percent of GDP.
2. These models are only applicable to contestable hinterlands, where the competitive advantage of container terminals determines market share. In Sub-Saharan African countries, most gateway ports operate with a vast captive hinterland and have no need to compete over time or cost to attract traffic.
3. With the exception of South Africa, which is ranked thirty-second.

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