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The Cost of Being Landlocked:

Logistics Costs and Supply Chain Reliability

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Abstract

A large proportion of the least developed countries are landlocked and their access to world markets depends on the availability of a trade corridor and transit systems. Based on empirical evidence from World Bank projects and assessments in Africa, Central Asia and elsewhere, this paper proposes a microeconomic quantitative description of logistics costs. The paper theoretically and empirically highlights that landlocked economies are primarily affected not only by a high cost of freight services, but also by the high degree of unpredictability in transportation time. The main sources of costs are not only physical constraints but widespread rent activities and severe flaws in the implementation of the transit systems, which prevent the emergence of reliable logistics services. The business and donor community should push towards implementation of comprehensive facilitation strategies, primarily at the national level, and the design of robust and resilient transport and transit regimes. A better understanding of the political economy of transit and a review of the implementation successes and failures in this area are needed.

Keywords: transportation and logistics costs, trade, transit, landlocked, logistics, supply chain, Africa, Central Asia.

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Section 1 Introduction

With current trends in reduction in maritime transport cost and more advanced logistics technology that compensates for the handicap of intercontinental distance, lack of direct sea-access presents growing challenges to the global integration and growth prospects of many landlocked developing countries (LLDCs). At present, about one out of five countries in the world is landlocked[2]. The problem mostly affects the poorest countries: 20 out of 54 low-income economies are landlocked, with a majority of them in Sub-Saharan Africa, while only three high-income economies out of 35 are landlocked (not counting European micro-states and dependencies[3]).

The case of LLDCs has naturally received special attention, including a specific set of development priorities (as spelled out in the Almaty program, see next sections). The problem of being landlocked has been analyzed mostly at a macro-level with a focus on the dependence over transit countries and on LLDCs' transport cost disadvantage. Hence, emphasis has traditionally been set on three kinds of measures: (1) transport infrastructure at the national level, (2) international laws and treaties, and (3) cross-border cooperation.

Notwithstanding the relevance of current approaches, there is a strong case for a deeper analytical and micro-economic understanding of the transit systems serving LLDCs as well as many activities in coastal countries. Indeed, transit logistics is complex, involves many public and private participants and requires adequate procedures and responsibilities. Its performance is determined by a wide range of policies, implementation mechanisms, or organizations of services. This paper tries to develop a comprehensive understanding of how these factors translate into costs. It is rooted in the World Bank Group operational activities: country audits, partnership programs, corridor and trade facilitation projects, and use a substantial amount of data from these various sources.

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[2] 43 out of 193 internationally recognized sovereign states.
[3] four landlocked countries are micro-states in Europe: Andorra, San Marino, Vatican, and Lichtenstein.

We question the notion that costs of transportation supported by developing countries are intrinsically high. Neither the distance covered, nor the unit cost of transportation services, are necessarily much higher in landlocked developing countries than in the wealthiest countries. Yet there are significant variations; for instance, Central and East Africa have higher unit costs than the EU but this is not the case of South and East Asia or other sub-regions in Africa. Unfortunately shippers also support a lot of non-essential overheads resulting from corruption, overregulation and private inefficiencies, the total of which may be very high. Furthermore, transportation costs only explain one part of the real impact of being landlocked. Delays and even more importantly low degree of reliability and predictability of services create massive disincentives to invest and higher total logistics costs.

Much of the cost supported by LLDCs may not be exogenous, as primary sources of cost are associated with poor performance of transit logistics resulting from a combination of (i) bad design or implementation of transit regimes, and (ii) unfavorable political economy of transit and particularly its vulnerability to rent seeking activities. These may be as or even more important in constraining the trading prospects of many LLDCs than poor infrastructure or political disputes.

Previous research is essentially based on macro-modeling and cannot identify the relative importance of possible sources of costs. In order to fill this gap, we propose to follow a supply chain model initially proposed by Baumol (1970). We use micro-level disaggregated data to identify the three components of transit costs: (i) transport costs, (ii) logistics costs and (iii) hedging costs incurred by shippers to cope with unpredictable delivery schedules. This paper identifies the various sources of logistics costs and provides examples worldwide. More detailed data (at shipment level) have been obtained from World Bank projects which we have contributed to appraise in East and Central Africa.

Section 2 reviews the literature on the nexus between geographic location, trade and growth and the induced policy conclusions. Section 3 reviews the transit framework and introduces the supply chain cost model. Sections 4 through 6 identify the dimensions of supply chain performance that determine total transit costs. Section 7 develops a quantitative model and proposes an application to the Northern Corridor, serving Uganda, Rwanda and Kenya from Mombasa in East Africa. The final section derives the policy implications.

Section 2 A Literature Survey and Policy Recommendations

Variants of the new economic geography, new trade theory, neoclassical and endogenous growth theories have been applied to highlight the nexus between geographic location, trade and economic growth. Some of their conclusions are: (1) landlocked countries trade less vis-à-vis coastal countries[4] (on average 30% less than coastal countries),[5] (2) landlocked countries experience weaker growth than maritime countries[6] (being landlocked reduces average growth by about 1.5 percentage points)[7] and (3) on average landlocked countries had longer recourse to IMF than coastal countries.

The impact of being landlocked is based on the idea of dependence over the transit state. It has produced two main corollaries:

- dependence necessarily implies high transaction costs,
- mitigating measures for landlocked countries result of two set of actions: first, adopting transit rules recognized by the international law, secondly, developing regional transport infrastructure.

Dependence over the transit state necessarily implies high transaction costs (notably transportation costs). High transaction costs are perceived as the result of (i) "transit charges"[8] but also (ii) the difficulties to benefit from regional adequate infrastructure.

[4] Irwin and Tervio (2002).
[5] Limao and Venables (2001).
[6] Bloom and Williamson (1997).
[7] MacKellar *et al* (2002).
[8] UNCTAD (2002) gives the example of port charges, road tolls, forwarding fees, customs bonds or transport quota restrictions. Further details and examples are given in section 4.

MacKellar et al. (2002) explain the negative relationship between landlockedness and growth using a neoclassical theory. They highlight that crossing a border implies higher transaction costs due to customs and handling costs. Therefore, landlockedness can be thought as raising import prices and reducing export revenues. It is one reason why Radelet and Sachs (1998) advocate the idea that a re-export model is extremely difficult to achieve in landlocked developing countries due to higher cost of intermediate products. Amjadi and Yeats (1995) point out that the incidence of transport costs fall heavily on the landlocked African countries since they have to adjust their selling price to world prices.

Gallup, Sachs and Mellinger (1999) see two reasons why landlocked countries may be disadvantaged:

- coastal countries may have military or economic incentives to impose costs on landlocked countries.
- infrastructure development across national borders is more difficult to arrange than similar investments within a country,

The specificity of landlocked countries has long been recognized by the international community. The current policy framework, summarized in The Almaty Programme of Action (Box 1), is aimed at tackling the issues of dependence and accessibility, targeting three priorities: (1) ensure the recognition of freedom of transit in international agreements, (2) develop transport infrastructure, and (3) encourage transnational cooperation. Early efforts involved legal measures. Many bilateral, regional and multilateral treaties have been signed since World War II, following the recognition of the right to freedom of transit for landlocked countries by the GATT Art V[9], and the 1958 Geneva Convention on High Seas (further developed in the 1982 Montego Bay Convention). A recent World Bank review of legal instrument transit trade in Africa found that the main problem today is not the inadequacy or lack of agreements and frameworks (Table 1) but their poor implementation stemming from a lack of capacity or

[9]Article V of the GATT states that (1947) “there shall be freedom of transit through the territory of each contracting party, via the routes most convenient for international transit, for traffic in transit to or from the territory of other contracting parties.”

political will. Corridor management arrangements have been established to facilitate trade on several routes and have met some success (Arnold 2007) in solving some implementation issues and overcoming the natural reluctance of transit countries towards transit trade (Sachs, 2004).

Box 1. The Almaty Programme of Action (2003) [10]

The "Almaty Conference" (2003) highlighted five priority areas for landlocked countries.

- **Transit Policy and Regulatory Frameworks:** Both landlocked and transit countries should review their transport regulatory frameworks and establish regional transport corridors;
- **Infrastructure Development**: The need for the landlocked countries to develop multi-modal networks (rail, road, air, and pipeline infrastructure projects);
- **Trade and Transport Facilitation**: The need for the landlocked countries to implement the international conventions and instruments that facilitate transit trade (including the WTO);
- **Development Assistance**: The need for the international community to assist by: (1) providing technical support, (2) encouraging foreign direct investment and (3) increasing official development assistance; and
- **Implementation and Review:** monitoring the implementation of transit instruments and conducting a comprehensive review of their implementation in due course.

Source: *Almaty Programme of Action: Addressing the Special Needs of Landlocked Developing Countries within a New Global Framework for Transit Transport Cooperation for Landlocked and Transit Developing Countries* (2003).

Table 1. The Number of Multilateral Legal Instruments with Relevance for Transit Trade in Africa

Global Instruments	28
Regional Instruments	8
Sub-regional Instruments	90
Including:	
Central Africa	*16*
Eastern Africa	*12*
Southern Africa	*18*
Western Africa	*44*

Source de Matons (2004).

Most existing action plans stress the need for new road construction to boost LLDCs' trade. Current transit infrastructure presents severe problems that often require huge financial resources to maintain continuity of service such as maintaining the existing road

[10] The International Ministerial Meeting of Landlocked and Transit Developing Countries and International Financial and Development Institutions on Transit Transport Cooperation .

networks and developing multimodal services. However, in many cases, delays and logistics costs are not primarily due to infrastructure problems.

Section 3 The Need for a New Empirical and Conceptual Framework to Assess the Impact of Being Landlocked

While there is a consensus on the problems of landlocked countries, the analysis so far has mainly focused on their transport cost disadvantage. Transport costs however account for only part of the real cost of being landlocked as they do not account for the transit delays and unpredictability which are critical in international trade.

In the literature, macro-data are usually used to estimate the transportation costs burden. Using CIF/ FOB margin as a proxy for transport cost, Radelet and Sachs (1998) find these costs to be about 50% higher for landlocked countries. Stone (2001) using the ratio of 'freight payments as percent of total imports' shows that landlocked developing countries, especially in Africa, bear exorbitant transport costs: out of 15 landlocked African countries, 13 had a ratio higher than 10% and for 7 the ratio was even higher at 20% as compared with 4.7% for industrial countries and 2.2% for the US.

These measurements not only have several shortcomings but also do not take into account the impact of transport and transit delays, which are critical for exporters/importers. We demonstrate in this paper that the gap between landlocked countries and gateway countries may not be very high – if transport cost is the only parameter taken into account. Shippers in most African gateway countries already face high logistics costs when adding maritime transport, port charges (which can be ten times higher in some African ports as compared to ports in developed countries), and domestic transport (especially to/from remote areas, as is the case for several export crops). In Africa, many shippers in LLDCs have the same charges to move goods from/to ports as shippers in the gateway country.

Box 2. Shortcomings of Current Macro-Estimation of Transportation Costs

Cif/fob margin masks compositional effect due to their high level of aggregation (Hummels 1999) They are generally unreliable for most developing countries (For several former Soviet Union countries, the fob figure was higher than the cif figure). The issue of inclusion or not of insurance payments in these estimates is not clear depending on the countries. The informal transport charges can be inaccurately reported or estimated. Finally, internal transport costs are sometimes not included in cif estimates by customs even though these costs can be significant. Comparing cif/fob data with real shipping data, Hummels and Lugovskyy (2003) found negative transportation costs for almost 40% of the bilateral US imports.'

In the case of "*freight payments as percent of total imports,*" there are two major methodological problems as well as data collection problems: The registry location of vehicles, and of firms alike, used in transport largely determines whether freight payments are considered as: service export, import or domestic service provision. Changes in registry or cross-border sale (or relocation of the HQ) of transport firms (especially "flagging out" of merchant ships and to a lesser extent, aircraft and trucks) can transform what was a domestic provision or export of transport services into an import of the same, even if the very same ships, aircraft, or trucks can continue to operate on the same routes under the same management. This can cause serious discrepancies between registered data and the real situation in many LLDCs. Even, in developed countries, the ownership restructuring in the transport and logistics industry makes the use of the Balance of Payments data almost impossible. Like cif/fob margin, it is masking disaggregated trends in transport costs. Shifts in the trade composition or trade partners or increase or decrease of transport costs for any product are not measured with this aggregate data.

Additionally, there are several *data collection* problems (as raised in Stone, 2001):

- Customs cif generally represents the burden of import costs up to the country's border. In practice, estimates in some cases include internal transport charges up to the destination city in the landlocked country. The true economic burden of freight costs on imports should indeed include these internal costs, but they are not necessarily included.

- The insurance issue is not clearly addressed: cargo insurance is, in some cases, probably included with Freight, in others it may be separately covered in the Insurance (debit) item.

- We do not know exactly if it includes the 'full burden of informal transport charges at security checkpoints' (Stone 2001). In theory it should be, but in practice it may be problematic.

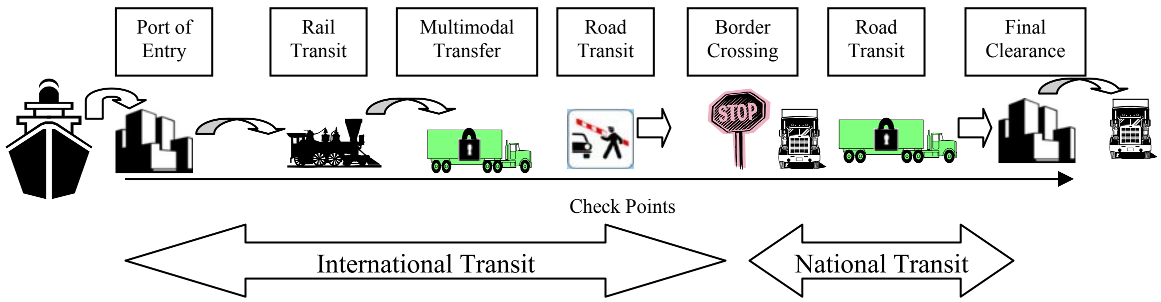
Source: Hummels (1999) exchanges with Prof. Hummels and Prof. Ojala.

A recent innovative body of work combines shipping cost-time information with trade statistics and highlight the value of time as a trade cost (Hummels (2001) and Djankov (2006)). Although more insightful than pure macro-statistics, this approach does not disentangle the various sources of transit trade cost (see section 5.1).

3.1 Transit Systems and the Supply Chain Conceptual Framework

Transit trade describes the inland movement of goods under customs control that is not cleared by customs. Transit can take place in the country of destination/origin of the goods (national transit) or in a third country where the merchandise is carried from an entry post to an exit post (international transit). Hence a complete transit operation is a sequence of international and national transit links (Figure 1). Landlocked countries can trade beyond their immediate neighbors only through transit systems.

Figure 1. The Generic Series of Transit Operation for Imports



By nature, a transit operation is extended in time and space involving several countries and many private and public participants. Hence transit systems tend to be complex and vulnerable to fragmentation and rent-seeking activities. Transit trade requires more oversight than intra-national trade over similar distances. This is because though a transit customs regime is eventually defined at a multi-country level, its implementation is at the national level. Such trade also depends on measures taken by countries to regulate vehicle movement, people (drivers), and trade in services and foreign investment.

3.2 The Purpose of Transit Systems: A Delayed Customs Clearance

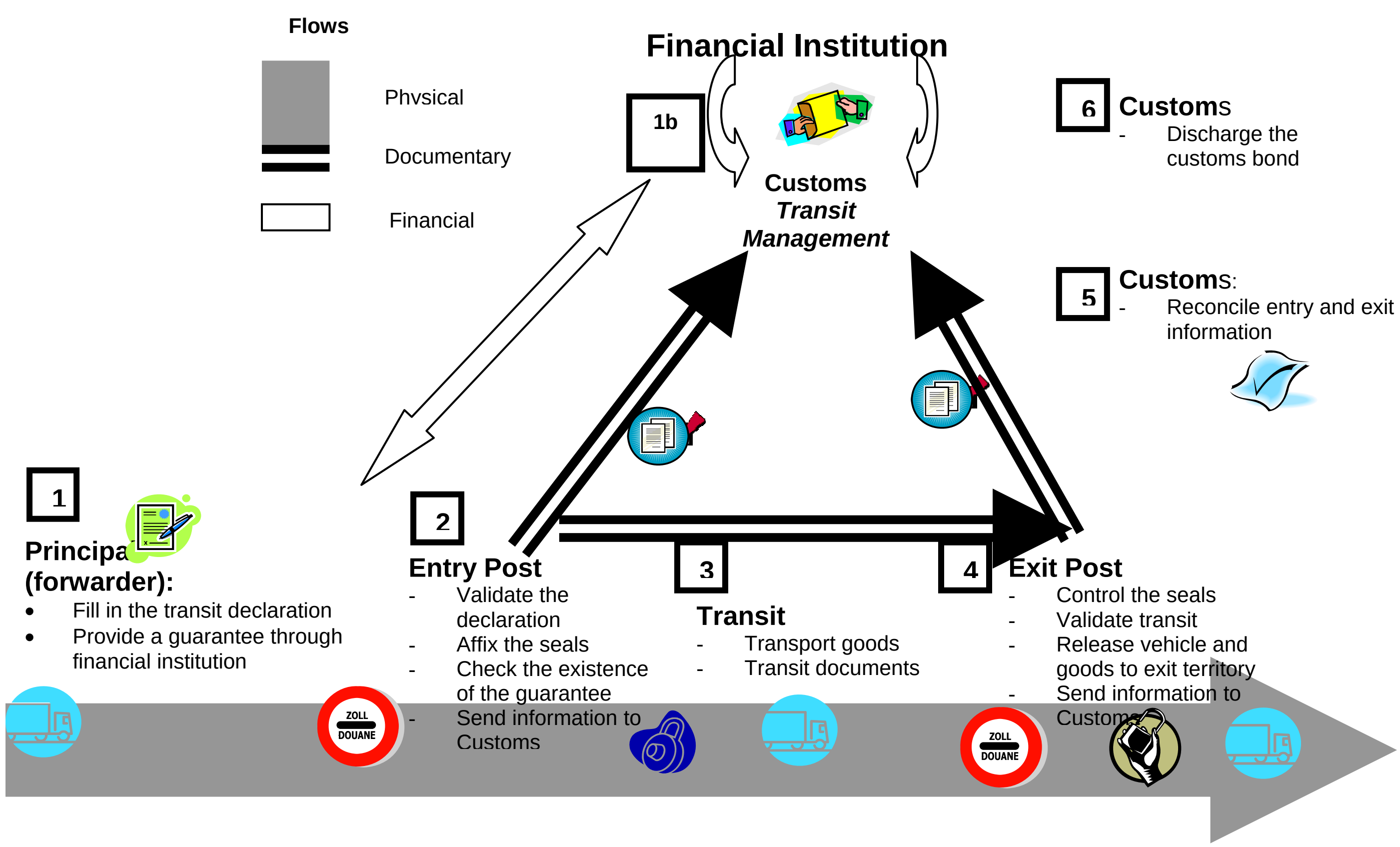
Transit procedures seek to implement the freedom of transit (Article V of the GATT) while at the same time safeguarding the interest of the transit country from potential fiscal loss by ascertaining that goods in transit actually exit the country. Any transit operation has three core principles:

1. The consignee or the designated agent (the principal) provides a guarantee through a financial institution to the transit country's customs (bond) based on the value of applicable duties on transit goods to cover the risk of cargo disappearance within the customs transit territory.

2. Transport has to be in secured vessels and customs affix seals on the vessel (e.g. container) that is checked at the entry port.
3. Customs implement documentary and information systems at borders to reconcile inflows and outflows.

For an effective transit regime, the physical movement of goods must be backed by relevant financial and documentary flows (Figure 2).

Figure 2. Transit Operations Flowchart



This process is repeated in every transit country. In most cases, final clearance does not occur at the border, but may occur in a customs facility located either at the capital or in the main economic center. From a trade facilitation perspective, it is preferable to complete the final clearance close to the economic operator. In such case, international transit complements national transit from the border to the clearance facility. Transit may also include multimodal transport operations, specific customs transit, and border/ control procedures *en route*. In the absence of a customs union, the same constraints apply to regional trade as well.

In Western Europe, transit procedures were streamlined after WWII into the seamless Transport International Routier (TIR) system.[11] While setting transit procedures remains a national prerogative, the TIR introduced several new features for facilitating transit traffic through eliminating duplications.

- The concept of authorized operators whereby only qualified operators participate and self regulation is enforced by national associations;
- A single harmonized manifest (carnets TIR) that is issued in the country of origin and used at every border;
- A mutually recognized system of privately managed guarantees. A guarantee taken with the carnet in the country of origin covers all transit bonds in the transit country due to a chain of mutually recognized insurance systems (like the mechanisms widely available for driver's insurance);
- The integrity of TIR is guaranteed by the overseeing agency - the United Nations Economic Commission for Europe (UNECE) and the International Road Transport Union (IRU), which certifies the compliance of the national entity. Failure to properly implement the systems means suspension and inability of the national operators to benefit from the TIR. Russia came close to being excluded and had to take energetic measures against fraud in 2000.

The following basic transit principles of customs procedures as applied in the TIR system can be traced to the Middle Ages in Europe, when the renaissance of intra-European trade had to overcome a high degree of territorial fragmentation. The principles proved robust and allowed for the implementation of freedom of transit. Transit works smoothly if its key features are not perverted.

[11] The EU is implementing New Computerized Transit System (NCTS) for EU and EFTA countries. This system borrows key features from the TIR.

1. Transit is not primarily a chain of control. Freedom of transit depends on the guarantees provided by operators for covering the potential fiscal loss. In fact, controls *en route* are redundant with guarantees.
2. Transit is a Public Private Partnership and requires consensus between public entities (customs, governments) and private operators (transporters, freight forwarders).
3. Transit is not a transnational procedure but a chain of (preferably) nationally harmonized procedures. Transit is initiated and discharged by a customs agency within a customs territory. However, harmonizing documentation (such as TIR carnets) and cooperation between border agencies can smooth the process by avoiding duplications.
4. The principal of transit is generally the logistics operators organizing the full sequence of operations for the consignee/shipper. This activity requires a high level of professionalism and can be helped by affiliation to an international network (as it is difficult to implement a good transit systems on corridors where shippers operate on their own account or where the logistics chain is fragmented).
5. Customs need a sound information system to report the flow of transit vehicles, which contrary to common opinion does not need to be a real-time monitoring.

3.3 The Real World: An Inefficient Chain of Multiple Clearances

While port delays impact all countries, LLDCs face an added disadvantage linked to transit economics. This is due to the multiple lengthy clearance systems on most corridors.

In East Africa, goods bound for landlocked countries face the time equivalent of at least three clearance processes, while coastal countries face only one:

1. *In the port*, goods dwell time often does not differ much between transit and domestic cargo (although domestic cargo is subject to the clearance process). In Tanzania, the Dar Es Salaam port shows slightly higher dwell time for goods bound to Uganda, Rwanda, and Burundi, as compared to domestic goods since

2004 (over 25 days as compared to 20)[12]. This is also true for transit trade through Mombasa, Kenya.[13]

2. The *border(s)* mean waiting time for further document reviews. On the Northern Corridor to Rwanda, it takes on average more than 24 hours to cross the Kenya-Uganda border.[14]
3. The *final goods clearance* is completed in the capital city.[15]

Ultimately, transit goods will have gone through three to four clearance processes.

Since most developing countries rely heavily on tariff duties, they tend to develop redundant procedures to avoid fiscal loss. The main bottleneck is the inadequacy of the applied transit regime, as it is conceived as a chain of control rather than the freedom of transit given to compliant operators in exchange of guarantees.

The reasons for the supply chain fragmentation are:

- The initiation of transit, often as cumbersome a process as final clearance in the gateway country.
- Inadequate carnets and guarantee systems or bad implementation of good transit systems (TIR) (transit from Douala to Bangui needs seven documents, none of them being a proper transit manifest).
- Uniform implementation of transit controls, irrespective of the principal's reliability and competence.
- Convoy or escort systems not only on risky cargo or insecure vessels (open trucks), but also on containers.
- Excessive controls en route, paving the way for additional illegal controls.
- Obsolete freight regulations (particularly in Africa).
- Regulatory barriers that impact the market structure and the quality of key support services (brokers, finance, insurance…) (Appendix 1 for more details).

[12] TPA, *brief on the Dar Es Salaam Port*, June 2004.
[13] *Kenya Diagnostic Trade Integration Study*, 2005.
[14] *NCTTCA Observatory survey*, 2005, based on a sample of 200 trips by well known transporters.
[15] In Rwanda, 3-5 days (DTIS Rwanda, report, 2005) and in Uganda, 3-4 days (authors interviews, 2004).

3.4 A Supply Chain Conceptual Framework

Any transit system, and especially an inefficient one, impacts traders in landlocked countries much beyond the freight costs. Operators need to hedge in view of the unreliable service delivery - either through increasing inventories or through switching towards alternative but more expensive transport modes.[16] In industrialized countries, supply chain management in the last three decades has led to innovative approaches in management or service delivery approaches that have resulted in reducing non-transportation cost (inventories, administrative costs…). In contrast, most LDCs have remained untouched by these changes. Inventories are high, substantial freight overheads add to transportation costs, when they are a small percentage of transport costs in mature markets. For example in Central African Republic, only 60% of the freight costs goes to the trucking service.

Supply chain literature provides the conceptual framework to disentangle logistics costs deriving from the sequence of transit operations, and subsequently assess the impact of facilitation, regulatory or investment measures. Expanding upon a model initially proposed by Baumol (Baumol 1970), we begin with a consignee or shipper in the landlocked country of destination/origin. This end user supports costs directly or through fees paid to agents providing services such as freight forwarders or transport operators. Figure 3 summarizes the operational chain of responsibilities and agencies in transit. Accordingly, the total logistics cost C supported by the shipper/consignee is broken down in three homogeneous categories (Table 2).

[16] The reliability factor depends on the nature of the product. Current indicators show high level of inventory holdings by retailers of consumer and manufactured goods in developing countries.

Figure 3. Operational Responsibilities and Costs

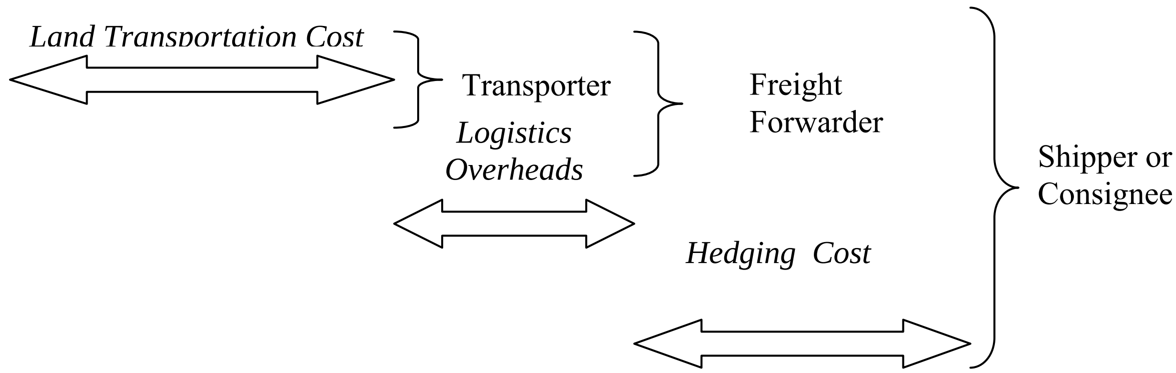


Table 2. The Three Components of Total Logistics Costs

C	=	(1) Transportation Costs	=	*Fees paid for actual transit transportation*[17] *services to truckers or rail operators*
	+	(2) Other Logistics Costs	=	*(2a) transit overheads: fees, procedures, facilitation payments.*
			+	*(2b) Fixed costs of shipments*
	+	(3) Delay Hedging Costs	=	*(3a) in transit moving inventory costs*
			+	*(3b) induced costs to hedge unreliability inventory and warehousing costs, or shift to faster more expensive mode of transportation*

Table 3 provides a snapshot of how the various transit performance bottlenecks mentioned in 3-1, 3-2, and Appendix 2, relate to the source of costs.

[17] Transportation costs are transportation fees while logistics costs also include overheads and inventories costs.

Table 3. Contribution of Selected Supply Chain Links to Cost Factors

	Direct Costs	Overheads	Delay	Uncertainty	Comments
Port Handling	high to very high		variable	variable	Typically higher in developing countries with large differences.
Transit Declaration and Initiation of Transit Procedure	average to high (depending on bond system)	high	high to very high	very high	Responsibilities difficult to disentangle from the many participants in the process, and total port dwell time and variance are typically very high.
Rail Transport	average to high		higher than road	higher than road	Cheaper, but less reliable than professional road service, though concessions often brought dramatic improvements.
Multimodal Facilities	moderate	moderate	moderate to high	moderate to high	Multimodal operations have a potentially high impact on the market structure of road transport.
Regulated Road Transport Market					Trade-off between modern transport companies (which provide more reliable services but at a higher cost) and informal transporters and individuals (which provides cheaper services), but a lower reliability). In a regulated market, direct and overheads costs are much higher for modern companies than in a liberalized environment.
- modern companies,	average to high	average to high	moderate	moderate	
- informal and individuals	high to very high	low to average	moderate to high	high	
Liberalized Road Transport Market					
- modern companies,	average to high	low	moderate	moderate	
- informal and individuals	low to average	low	moderate to high	high	
Transit Convoys	moderate	moderate	moderate	high	
Checkpoints		high (illegal)	moderate to high	low	Checkpoints and illegal activities cost time and money but are rather predictable.
Border Crossing	low	medium	moderate to high	average to high	
Final Clearance	low	high (illegal)	average	average to high	mandatory warehousing may add substantially to the overheads

Section 4 Revisiting the Conventional Wisdom on Transportation Costs

We complemented previous macro-analyses on transportation cost cif/fob margins with data from exporters/importers and freight forwarders operating in LLDCs.[18] Road and rail are the main inland surface freight modes for LLDCs[19]. Historically, rail played a crucial role in the early development of most LLDCs (the railways in Central Asia still do). However, railways have ceded market shares to trucking during the last two decades due to their lower performance and reliability in most regions. Containerized traffic for high value goods is usually through trucks. For most shippers, railway discounts (typically 30% or more in Africa and Central Asia) cannot compensate for the induced costs in terms of delays and reliability. As road transport is dominant, we focus on road transport costs. We use the traditional measure of transport costs by ton and by kilometer expressed in US cents.

The long distance ton*km value is in the range of 4-6 US cents in industrial economies, but varies more than tenfold among corridors serving LLDCs:

- As low as 1.5-2 US cents in Western Asia (Iran, Pakistan).
- As high as 20 cents of Euros in Chad, barely below current air cargo rates on some long distance routes between developed markets.

Due to the trade imbalance, (imports usually exceed exports in developing countries) exporters usually get a discount on outbound road transport. Although freight rates are

[18] Collecting transport costs as part of field work can be confusing. Depending on the source or the commodity, there may be variations of transport tariffs for four reasons. (1) Perimeter of services: depending on their responsibility in the logistic chain, operators include certain costs Typically, freight forwarders who organize the transit trade for the shipper/consignee, charge the latter with not only the transport service cost billed by the truck or rail companies, but also the fixed costs of organizing and administering the transit shipment. (2) Commercial discounts: given to high volumes/preferred customers. (3) Commodity and resulting service quality, and (4) Illegal payments for facilitating the process and these are usually not acknowledged in surveys or interviews.

[19] Multimodal barges or ferry systems do play a role *inter alia* in the case of the Parana River (Paraguay), Congo River, and also on the Caspian Sea.

influenced by many factors, operating constraints, market structure, and regulations are critical elements. One of the most important parameters is the load factor, since:

$$\text{Rate(/ton/km)} = \frac{1}{\text{Nominal Load (tons)}} \text{ x } \frac{\text{Operating Cost of the Truck (cents/km)}}{\text{Load Factor (average \% of nominal load on a trip)}}$$

A large trade imbalance brings the import freight rate up to a factor two compared to the rate implied by a balance trade. Conversely trucks overloading increases the load factor and reduces rates, however, it increases the negative externalities of transport.

4.1 Operating Costs

The equation 1 for freight rate shows that the operating costs, and its structure (box 3) are key to understand the magnitude of transportation cost and the non-trivial factors that affect them: policies, market structure, and infrastructure.

Box 3. Breakdown of Vehicle Operating Costs

Transport companies analyze their cost structure in two categories:

1. Fixed Costs	=	Pro rata temporis independently of vehicle usage
	=	Financial charges, depreciation of investment, wages, facilities, taxes (including vehicle taxes), and margin
2. Variable Costs	=	Proportional to vehicle usage (distance or trips)
	=	Fuel, subsistance, road user charges Maintenance, tires, taxes

Hence,

$$\text{Operating Cost per km} = \frac{\text{Fixed Monthly Cost}}{\text{Distance per Month}} + \text{Variable Costs}$$

The usual benchmark for operating cost (widely used in international comparisons) is the cost of traction per km for a 40’ container or a semi-trailer.

Though operating parameters are not homogeneous among operators (as in EU and US), haulers in LLDCs in general have high variable costs, low fixed costs and a low utilization ratio. In principle, if there are no artificial restrictions to truck utilization, the lower fixed costs in developing countries should compensate for the higher variable costs, with operating costs is in the same range as in developed countries, e.g. \$0.8 per km in the US and €1 in EU (for long distance services. The table below provides a comparison of operating costs for organized trucking.[20]

Table 4. Comparison of Truck Operating Costs in Western Europe, Eastern Europe and in Africa

	Fixed Costs (per day)	Variable Cost/ km	Distance/Month
Europe (France)	€ 340	€ 0.25 €0.35 (toll roads)	10,000 or more
Transit South-East Europe	€ 250	€0.3	>10,000
Organized Companies in African LLDCs (2005)	$ 90-150	$0.5-$0.8	4,000-8,000

Source: CNTR June 2006 statistics (France), Authors'interviews (Africa) and TTFSE project.

In one of the World's least friendly corridors, Douala-Bangui in Central Africa, where the road is not paved on long sections, the observed traction cost (€1.25) is only 25-50% higher than in EU or the US. The fivefold difference in rate between Douala-Bangui and LA-Chicago (for a distance twice shorter) is mainly due to the load factor differences and the high level of overheads on the corridor.

Table 5. Comparison of the Estimated Structure of Logistics Costs

	Douala/Bangui	L.A./Chicago
Operating Cost per Kilometer	1.25	0.85
Distance	1,450	3,000
Load Factor	0.5	0.87
Transportation Cost (net)	3,625	2,931
Overheads	**66%**	**5%**
Total Logistics Costs	6,017	3,077

Source: Authors' Calculations.

Fixed costs are lower in developing countries because:

[20] Cost structure in developing countries deserves a more systematic research, especially to extend the knowledge beyond the case of medium-large companies, easy to assess. No comprehensive review has been carried out since the Western Africa/South Asia comparison by Rizet et al (1992).

- Labor costs are a small percentage (5% or less) of total operating costs, and constitute half of the operating costs in Western Europe;
- Investment costs are much lower. Even the more structured companies in LLDCs typically buy second hand trucks in Europe at the end of the initial three year leasing period (250,000-300,000 km) and use them for three to six years. Furthermore many trucks operated by individual owners are even much older (10-15 years).

Higher variable cost reflects:

- High fuel consumption stemming from usage, age, and vehicle fleet condition (50 liters per 100 km in some conditions);
- High maintenance costs (due to vehicle age, road conditions, and overloading). Tire usage is, on many corridors, 2 or 3 higher than in EU;
- Truckers' behavior and professional ethics.

A low quality of the infrastructure directly increases variable costs, since bad roads mean more fuel consumption and maintenance needs.

Truck utilization is highly variable and linked to the market structure:

- Organized companies in Southern Africa optimize their usage and have the same usage as European haulers (10,000 km per month);
- Oversupply is common on many corridors (Western, Central Africa and Tanzania), with many individual waiting for days to get cargo. The usage can be reduced to be as low as 3,000 to 4,000 km per month. Organized truckers tend to allocate older trucks on routes where there are usage limitations (waiting time at ports or borders for instance);
- Average fleet age, road quality and overloading increase immobilization time due to frequent vehicle breakdowns; and
- Low usage can be also encouraged by excessive regulation of freight allocation such as compulsory "tour de role."

4.2 Trucking Market Regulation and Structure

In many trade corridors, market organization and formal or informal systems of freight allocation raise transport prices. This situation happens when a cartel or syndicate controls freight allocation in the transit logistics business and there is a mandatory or de facto queuing system ("tour de role"). In many Western African corridors, bilateral treaties define the transport share of both countries (generally 50/50 or a higher share for the landlocked country's operators), and define the freight allocation procedure.

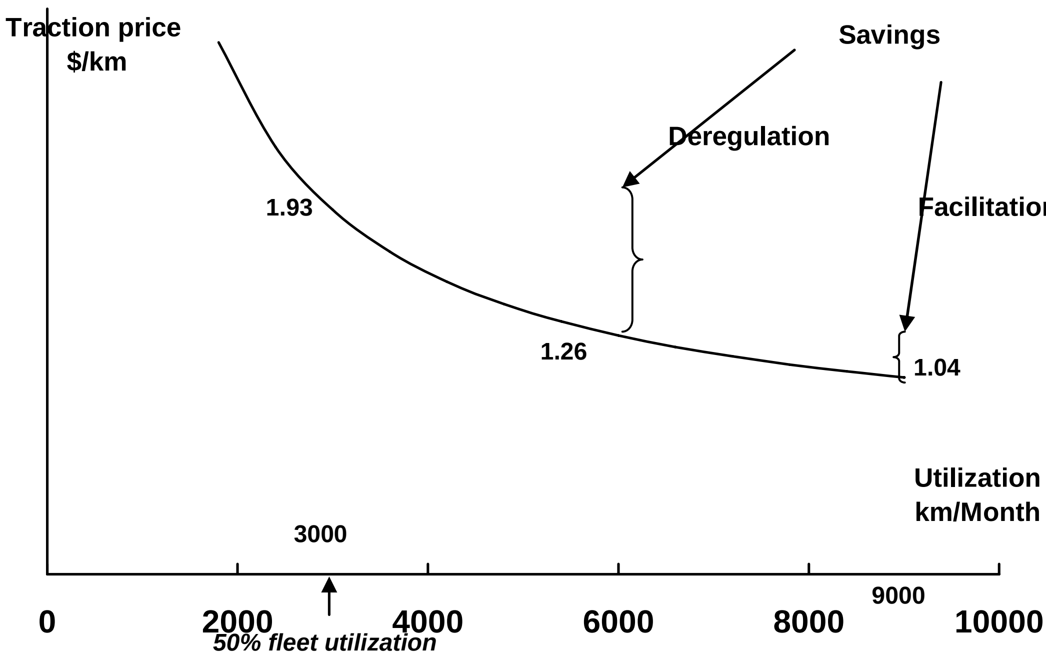
Such system maintains an excess freight capacity of demand. It allows a large number of operators to specialize in transit trade, agreed by the regulator (syndicate, freight bureau). They provide services with limited commercial concerns (such as performance and quality). Since shippers and forwarders are price-takers, the regulator adjusts the price up so that the fixed cost is recovered irrespective of the number of kilometers run per month. The authors found (2006) that on the Chadian corridor freight bureau's intervention double transport prices. This is rather similar to monopolistic taxi organizations at major airports, which tend to drive the price up as compared as competitive rates in the same metropolitan areas.

Breaking traditional tour de role or cartel/cargo repartition systems can significantly lower transport prices. Opening the Laos transit trade to all Thai truckers in 2004 reduced the logistics costs from Bangkok to Vientiane by 30%.[21] Deregulation also creates opportunities for improving the quality of service delivery and for investing in better equipment, since the shipper can reclaim market power over the regulator. The following simulation in (Figure 4) illustrates the nexus between regulation and prices, based on data typical of an African corridor. It shows the price impact of the transition between the regulated corridor market characterized by an artificial excess supply of trucks (and low utilization) over the demand for transit freight and in a competitive outcome where transit and national markets are integrated. The graph also illustrates the consequence of facilitation measures, designed to decrease transit time and increase utilization. Such

[21] Arnold (2005).

measures decrease the price in a competitive market but have potentially no impact in the oversupplied regulated market since there is no change in the monthly utilization of truck.

Figure 4. Trucking Price and Trucking Market Structure[22]



Source: Authors' Calculations.

Section 5 Managing the Risk of Supply Chain Unreliability Risk: Delays and Unpredictability and Their Impact on Economic Operators

Since moving goods through borders takes a longer time than the time warranted by the infrastructure, vehicle, or physical constraints, managing this risk either through increased inventory holdings or alternative modal choices adds to the already substantial logistics costs in developing countries. Anecdotal evidence indicates that in many LLDCs, the formal operators (such as supermarkets) maintain high inventories (three months or more is frequent in landlocked countries) as compared with their peers in advanced countries.[23]

[22] Formula (2) is used with the following parameters: Potential truck use of 6,000 km and 9,000 km with corridor improvement (b) Fixed costs of 4,000 USD per month and variable costs of 0.6 USD per km.
[23] Guasch 2005.

Aggregating the total logistics costs (transport, overheads and inventories), Bowersox (2005) and Ojala (2005) show that a logistics gap is widening between industrialized and developing countries. While the logistics costs as a % of GDP has fallen from 15 to 20 % of GDP in the early 80s to less than 10% of GDP in industrialized countries due to better supply chain management and reduced inventory holdings. In LDCs, logistics costs as a share of GDP can be over 30% (the figures for emerging economies is 15 to 20% of GDP).

The cost of hedging unreliability depends on several factors such as the time value attached to the cargo, the lead-time in transit, its variability, and the cost for the operator of a break in the supply chain (cost of a stockout or of setting up alternative logistics). Typically, this cost can be expressed as equivalent days of inventory.

5.1 Assessing the Value of Time

In the context of a supply chain model, *the value of time is an operational concept*: the cost of ownership of the goods in inventory There are essentially two types of inventories: (1) inventory in motion for goods in transit and (2) inventory in owners' warehouse before processing, distribution, or expedition. In both cases, the costs include financial charges, obsolescence, and loss of damaged or stolen goods. Inventory costs also include the fixed costs of warehousing at destination. Moving inventory costs also include the cost of vessels (container rental, deposit costs or demurrage charges, terminal and storage facilities). These charges do not evolve exactly *pro rata temporis*, but may increase with time, especially for demurrage fees.[24]. The estimates provided in Arnold (2006) and which the authors confirm are:[25]

- The value of containerized manufactured goods in low and middle income countries range between 2,000-5,000 USD per ton (20,000-50,000 per TEU).

[24] However, while shipping line tariffs are designed to encourage container rotations, they give a more favorable treatment to containers in transit.
[25] In the model in the following sections, we use the case of a shipment of 50,000 USD, a value of time of 50 USD a day for a 40'.

- The value of time is put conservatively at 20-30 USD per TEU (40-60 USD per trailer or 40') or 0.1 % of value per day[26].

The operational concept differs from value of time proposed by trade economists (see Section 3). The later implements Samuelson's iceberg principle and looks at the overall impact of time on trade flow, rather than on logistics costs. Hence, this economic value of time includes, depending on the model, not only the value *pro rata temporis* of goods, but eventually the cost of transportation and opportunity costs due to the "time barrier". Unsurprisingly, economic value is much in excess of the operational concept. Hummels (2001) found that the former much depends upon the product, but that on average one more day in transit is valued at 0.8% of the value of goods. Notwithstanding its high relevance for trade economics, the economic value of time can not be used in micro-economic modeling of the supply chain, since it already incorporates overall effects [27].

A third concept of the value of time is the revealed preference for a modal choice between transport modes. This estimate is possible in Central Asia and Caucasus where both rail and road modes are available. Our estimate (Appendix 4) shows that shippers are ready to pay 370 USD for a 40' to gain one day by shifting from rail to road. Again this estimation is much higher than the operational value of time. A plausible explanation, developed below in this section, is that the modal choice preference is also a choice of reliability and flexibility.

5.2 Magnitude and Sources of Delays

Given their existing infrastructure and transport services, LLDCs are not far from their main markets or from a gateway port. Port gateways for economic centers in Africa should be linked in less than a week. Even in the most difficult Central Africa corridor

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[26] A typical interest rate of 15% (for Africa) already contributes to a value of time of 0.04 % a day.

[27] As a result, the economic value of time cannot be used in micro-economic supply-chain models. Its use in appraising trade facilitation projects may overestimate the benefits of average delay reduction from investment or process improvement.

sections, trucks can cover at least 300 km a day - including rest stops and checkpoints (See Appendix 1).

While export transit time is, usually[28], not much above this "infrastructure" time baseline, e.g. one to two weeks, lead time for imports is higher, and often much more than that,:

- Highest lead times are in Central Africa (up to 4-6 weeks or more on the import leg), with marginally better performance in East Africa.
- In Western Africa, average lead time is low. On average, ship arrival-to clearance time in Ouagadougou (Burkina Faso) is 10 days, which is better than clearance time in many advanced countries. This is due in part to the competition between ports on the Gulf of Guinea to capture transit trade in ports.

Yet even in the most favorable situations, lead time is much greater than necessary. On most journeys, shipments spend time waiting for processing due to the multiple clearances in transit logistics (see Section 3).

- The most important source of delay is initiating transit[29] in ports, which typically takes as much time as final clearance.
- The second source is final clearance at destination.
- Border delays are also a concern, particularly in major regional border-crossings[30]. In Southern Africa, border delays between South Africa and Zimbabwe (Beit Bridge) reached six days in 2003 and In Central Asia, trucks can face a delay of three days at the Uzbek border. Delay are due to (1) Congestion created by haulers schedule and inadequate and uncoordinated working hours (2) Slow processing and duplication of tasks.
- Other sources include (1) Mandatory freight procedures; (2) Controls *en route*, including axle-load control (trucks can wait for hours at a weighbridge

[28] There are exceptions such as export trade from Central Asia mainly due to political disputes.
[29] Transit initiation and final clearance immobilize scarcely the vehicle. Hence, the potential of time saving for vehicles is lower than total time savings potential.
[30] Arvis (2004) estimates that the total cost of crossing a border in Africa is the same as the cost of inland transport over 1,000 miles (1,600 km) or the cost of 7,000 miles of sea transport (11,000 km). In contrast, the cost of border crossing in Western Europe is equivalent to only 100 miles of inland transportation.

on the Northern corridor between Mombasa and Nairobi); (3) Infrastructure condition; (4) Trans-shipment at multimodal facilities or at the border when trucks cannot go through and the merchandise needs to be unloaded to a vehicle of another nationality (common in Asia) and (5) Customs convoy requirements which besides slowing traffic can entail wasting days in transit, if convoys are not available daily.

The fact that virtually on every corridor in LDCs, initiation of transit takes as much time, as final clearance is potentially the single biggest anomaly in the current implementation of transit regimes. Transit initiation requires a simplified documentation (manifest) as compared with final clearance. For most shipments, the process should not include inspection or intervention of non-customs agencies. Finally, the Principal of transit is very often a large international forwarder, which can provide customs with appropriate guarantees. Unfortunately:

- Many gateway countries consider transit operations as a minor element of well conceived customs reform programs[31];
- Inadequacy of documents (In a recent mission to the Douala Bangui corridor we found seven transit documents, distributed by three different groups of agencies, none of them being an adequate transit manifest); and
- Risk management is absent: there is no incentive for compliant and reputable logistics operators.

5.3 The Observed Unpredictability of Lead Time

Direct empirical evidence on the distribution curve of lead time over a full transit process is far from systematic. It is more easily available for partial transit processes (such as border-crossing or dwell time at container terminals in ports). As part of the preparation of the East Africa trade and Transport facilitation project, the authors were able to get extensive transit lead time data from one logistics operator on the Northern Corridor

[31] In many coastal countries, transit import is a very small fraction of domestic traffic (often less than 10% in value).

These data include the breakdown of various phases in transit but not data of individual shipments. The lead time probability distribution function (p.d.f.) is asymmetric with a broad tail, as shown in Figure 5 and Table 6 below.

Figure 5. Distribution of Dwell Time of Transit Containers in Mombasa Port

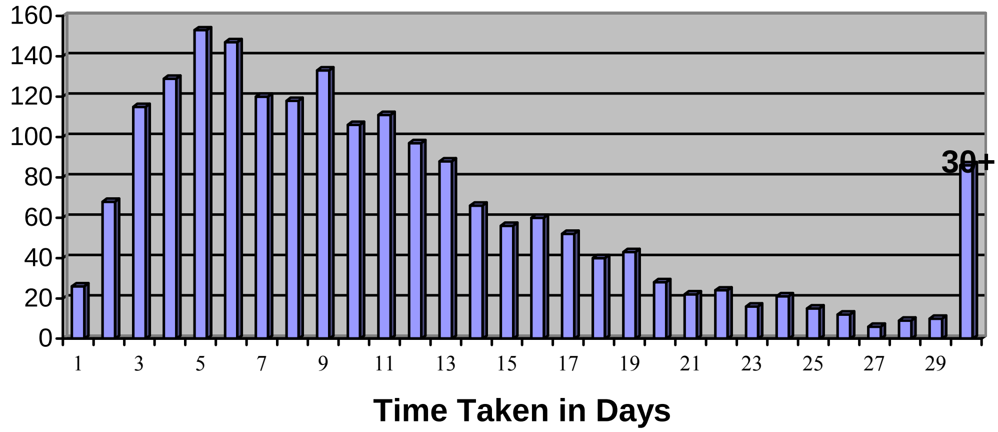


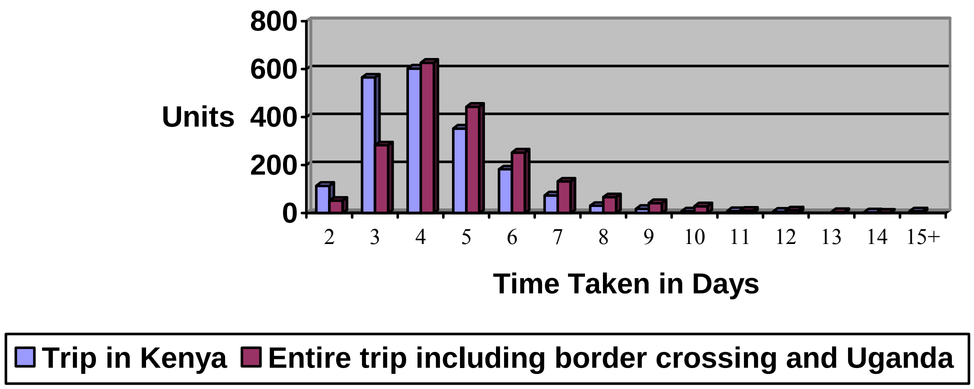
Table 6. Various Transport Times in Mombasa Port and on Transit Between Kenya and Uganda (2005)

	Mode	Median	Mean	95th Percentile
Port Dwell Time in Mombasa	4.5 days	8 days	13 days	27 days
Transit Through Kenya and Uganda	3.5 days	4 days	5 days	10 days

Source: Authors'surveys.

In East Africa, along the Central corridor from Dar-es-Salaam to Kampala, transit time usually reaches eight days, which imply a return trip of less than twenty days. However, according to some freight operators the return trip may take up to 45 days (20 days to go, 5 days for clearance, and 20 days to return) (Figure 6 for distribution of transit time between Mombasa and Kampala). Similarly, bringing goods from Douala to Chad can take between 1 and 5 weeks. Along the Northern Corridor, depending on the departure date from Mombasa and the size of the convoy, difference in transit time can be of more than 3 days to reach the Ugandan border.

Figure 6. Distributions of Transit Time Between Mombasa and Kampala



Data on border-crossing delays from other corridors in Africa, Eastern Europe, and Latin America show that the dispersion of lead time is a universal phenomenon (Appendix 3 and 4). The stylized facts are:

- The lead-time is an asymmetric broad tailed distribution, which for practical purposes can be described by a log-normal distribution for lead time in excess of a baseline representing the minimum feasible time of transit considering current infrastructure, procedures, and services;
- The coefficient of variation for the excess over baseline lead time is from 0.5 to 1.5; and
- The shape of the curve allows for the not so rare occurrence of lead time largely in excess of the median or even the mean.

The broad tail paradigm is the reason why uncertainty has a huge impact on costs.

Appendix 4 proposes a quantitative analysis based on the log-normal distribution, which will be used in applications.

5.4 Impact of Low Reliability of Logistics on Firms Competitiveness

Inventories and Hedging Costs

A fragmented transit chain and variance in processing time not only causes delays but also causes uncertainty and unpredictability. This increases the logistics cost for economic operators who are willing to pay premium for reliable logistics solution or need to maintain high inventories

For maritime transport, a standard deviation of 20% of transport time increases transport costs by nearly 45% (Frankel 1999). Although difficult to quantify, the non-transport costs may be even more for shippers. Dobberstein *et al.* (2005) show that in Asian emerging markets, non transport-related logistics costs were 10% of the GDP and this was almost equal to the extent of transport costs in total logistics costs. Allen *et al.* (1985) demonstrate that increasing transit time and variance in transit time causes higher inventories and ultimately higher logistics costs.[32] Due to uncertainty, companies need to maintain high safety stocks in order to avoid any shortage of raw materials or intermediate products. Spoornet,[33] the main railway company in Southern Africa, undertook a customer survey to assess its customer concerns. Reliability was considered as the prime concern before predictability, whereas time and speed were ranked respectively 7th and 8th in this list. In the textile industry, product quality, reliability and time to supply goods from developing countries to Europe or the US are as important as the price.

Fafchamps *et al.* (2000)[34] also demonstrate that the incidence of delayed deliveries has a strong positive effect on inventory holdings. Based on a sample of firms, the authors find that Zimbabwean firms hedge delivery risk by building input inventories. In developing

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[32] Baumol (1970) in his model had already raised this issue of the impact of uncertainty on inventories. Consequently, exporter/importer wishes to pay more or may wait for one or two additional days in transit to have more reliable deliveries. See futher sections for the application of the model.

[33] Interview with B. Le Roux on March, 6th 2004, former CEO of Spoornet.

[34] Fafchamps, M., Gunning, J.W., and Oostendorp, R. (2000), "Inventories and Risk in Manufacturing," *The Economic Journal,* Number 110, pp.861-893.

countries, safety stocks due to uncertain transport delivery can even reach one year of expected sales[35]. For two branches of auto-parts supplier of the same automobile maker, while the inventory level reached 7 days for the branch located in Italy, inventory level was 35 days for the branch located in Morocco.

Another way of managing risk is through altering modal choice. Arnold (2007) found that garment producers in Bangladesh shipped up to 10% of their production by air to meet delivery schedule.

The Case of the LLDCs

In small developing country markets, supply chain management faces:

- Unpredictable supply chain due to uncertainty in shipment delivery time.
- Low level of demand, whether predictable or stochastic. For the same industry the volumes are typically lower in a landlocked country vis-à-vis a gateway country, leading to larger inventory costs as compared to its turnover; and
- Poor private sector capacities.

Exports, Imports, Linkages, and Asymmetries

In LLDCs, inventory management is not advanced. Time is often not perceived as sensitive and sales upon goods arrival are still dominant in many places. Yet, even in cases where the value of time is not internalized by the trader nor passed to the consumer, a theoretical approach of inventory cost may be applied to assess the opportunity cost to the economy, especially for imports of manufactured or intermediate goods. The model is particularly relevant for exports since transformation activities are directly affected by the backward linkages in the supply chain (inputs), and there may be a high penalty for producers in LDCs due to the current level of uncertainty on imported inputs, for example:

- Exports of processed manufactured goods: for these goods, the threshold of supply chain failure is lower than for imports. The cost of failure may be high

[35] Despite difficulties to access data, Guasch and Kogan (2001) estimate the cost of additional inventory holdings to 2% of GDP for developing countries.

either in terms of loss of contract or in terms of switch towards an alternative but expensive transport mode (air cargo); and

- Time sensitive perishable exports (horticultural products): the cost of failure is also high (lost cargo) but may not be explicitly hedged.[36]

In both cases, the expected level of reliability is very high and can be measured by the acceptable level of failure. Classical inventory theory allows equivalence between non-delivery and a measure in terms of inventory level (number of days) and hence a percentage of the value. Exporters/importers based in landlocked countries experience excessive obstacles to allow them to be fully integrated into the global supply chains.

In the case of non time-sensitive commodity exports, the issue of reliability is less stringent and quality of service delivery is less critical. Usually logistics involved constitute a seasonal push towards the gateway ports. For example, cotton in West Africa is shipped during the season to public warehouses in coastal countries and shipped on demand. However even in such cases, reliability concerns may exist. Tea exporters from Malawi prefer to go through Durban rather than through the much closer Mozambican ports.

Section 6 Non-transportation Costs: Rents and Market Failures

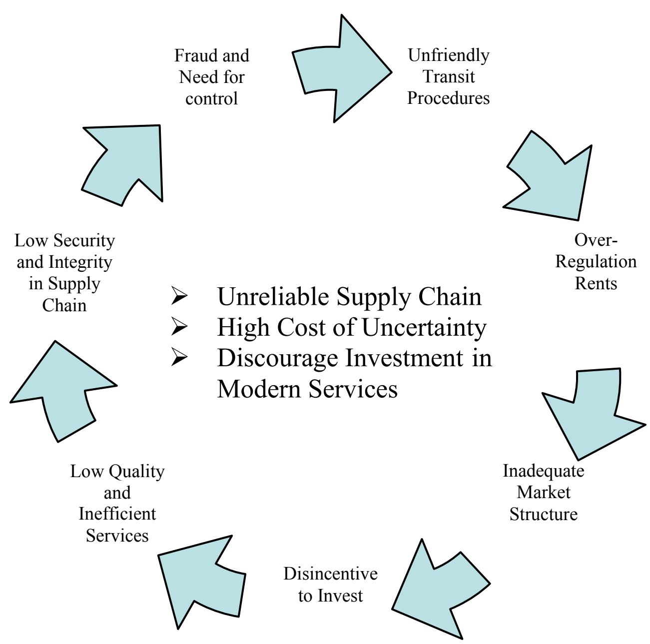
Ordering and processing shipments imply a series of overhead expenses, which fall into two categories:

1. Transit overheads attached to transit and added to transport fees: These include procedural fees, illegal facilitation, mandatory private or public services associated with transit. The shipper may internalize the overheads but, in practice, fees are paid to other parties either directly or through agents (e.g. freight forwarders) who will charge an additional fee for processing; and
2. Administrative costs for shipments.[37] These are the fixed costs that the shipper has to take into account to make the logistics possible.

[36] For example current transit bottlenecks in Uzbekistan, limit the potential of fresh products exports from Kyrgyz and Tajik Republics.

The first category pertains to procedures and regulations while the second reflects quality and affordability of key services. However there are deep systemic linkages between the two as well as with the overall political economy of transit. Since transit is extended in space and time and often takes place in countries with poor governance and business practices, it is especially vulnerable to rent-seeking activities. Countries become trapped in vicious circles, where inefficient regimes sustain low service quality (e.g. transport, customs broking), or even informal activities which in turn perpetuate unfriendly regimes (Figure 7). Transport is trapped in equilibrium, where a transit system is optimized for a certain type of traders and service operators, and cannot evolve towards a system compatible with the requirements of global logistics networks, which could link the country to international markets.

Figure 7. The Vulnerability of the Supply Chain to Rent Seeking Activities



[37] Unlike the transit overheads, administrative costs stem from purely private transactions and happen irrespective of the landlocked status of destination or origin. However, they are potentially much higher in the context of small distant economies and therefore should be retained in the analysis.

6.1 Transit Is Extremely Vulnerable to Rent-Seeking Activities

The Link between Transit and Overheads[38]

Several overheads are associated with transit processes such as bonds. However, other overheads are not transit overheads since they apply to both transit and domestic trade such as port charges. Finally, some costs do exist in both cases, but are substantially higher in the case of transit trade and hence contribute to overheads such as agents' fees.

The main categories of logistics overheads related to transit operations are the following:

Corruption and "Facilitation" Payments en Route or at Origin and Destination

A well-known and documented[39] phenomenon is the multiplication of facilitation payments at scheduled/unscheduled roadblocks. This is serious on some corridors (for instance, roadblock in West Africa add 10% to overheads and these roadblocks may occur every 30 kilometers, or even shorter distances). These are usually small and predictable payments made to local police, military, or customs agents. Transit initiation, or border crossing, carry the potential of much bigger payments between transit operators, customs and/or transport parastatals staff.

Corruption may be severe at border crossings. In Central Asia, Megoran *et al.* (2005) show that above the official mandatory costs for a Kyrgyz truck transiting through Uzbekistani territory, around 450 USD[40], there are the unofficial costs to be paid for speeding up the process. These can range between 150-200 USD for a single truck. In total, a Kyrgyz truck entering Uzbekistan has to pay approximately 700 USD to cross the border, a quarter of which are unofficial costs. Weighbridges may also be a source of

[38] Since transit overheads are the most important in terms of delays and unpredictability, we focus on transit-related overheads in this section. However, terminal and handling charges, excluding port charges, may be considered as overheads and similarly compulsory change of vehicles (for example from India to Bangladesh (Petrapole/Benapole)) or compulsory warehousing is common in Africa and in Chamber of Commerce owned facilities.

[39] Including in Western Africa, where with World Bank assistance ECOWAS created an observatory of those practices.

[40] The breakdown in 2004 was the following: USD 300 for a transit charge, USD 75 for insurance, USD 60 for sanitary control, USD 10 for a visa, road user and escort fee charges, and an environmental tax (Data provided by the Osh Chamber of Commerce).

delays and illegal costs when they are not properly managed. Along the Northern Corridor, trucks can wait a day at the first weighbridge after Mombasa and truckers often bribe the weighbridge operators to go through it.

Mandatory Transit-Related Procedures

These include bonds or guarantees, compulsory transport of customs documents, escorts, transit fees and compulsory insurances. Many transit related mandatory fees are overpriced and, in some cases unjustified and akin to rents (for instance, the various documents issued by freight organizations, transit documents of the Chambers of Commerce and compulsory insurance schemes). Some additional services in the public administration in landlocked countries may also add to costs. In Rwanda, Magasins Généraux du Rwanda had, until 2006, a monopoly for warehousing and added between three to five days to the clearance process, while collecting 4% of the goods value as a fee (3% directly in favor of the government's budget, 1% as a cost recovery fee).

Agency Costs (freight forwarders)

Transit logistics for many landlocked countries also tend to increase the rate charged by freight forwarders. In some cases in Central Africa, these rates may add 30% in overheads. The procedural complexity and multi-step processes imply that each shipment requires attention, staff, and costly intervention otherwise unnecessary in a seamless transit environment. Fixed operational cost (office and staff, including expatriate) become very significant on corridors where the number of shipment is low. On some corridors, weak competition means higher margin for high quality services.

Magnitude of Transit Overheads for LLDCs

Overhead is seldom disentangled from transportation costs. So far, only facilitation payments at roadblocks have received attention from policy makers and trade facilitation advocates. The reason for the knowledge gap is the limited incentives for agencies and operators to be transparent in their cost breakdown. Even World Bank trade facilitation audits have not so far provided consistent information in that respect. While rent seeking mentality and facilitation payments are common in all regions, the degree of proliferation varies among corridors: in Western and Central Africa, rent seeking activities has been more prevalent than in other sub-regions. Table 7 provides a simulation of the breakdown for the Lomé Corridor. Less is known in other sub-regions; however, it seems quite likely that transit overheads are in the range of 30% to 100% of transportation costs, while they should probably be in the range of 5% to 20%[41].

[41] The DOT in the USA estimates them at 4%.

Table 7 Simulation of Transit Overheads from Lomé (Togo) to Ouagadougou (Burkina Faso)

Reference a 30 MFCFA 40' container, January 2006.	Value FCFA	% transportation
Baseline transportation fees	***1,100,000***	100%
Facilitation payment at road blocks	***100,000***	9%
Other facilitation payments for transit (estimated)	***200,000***	18%
Official transit fees in Togo	***111,000***	10%
Freight bureau	10,000	1%
Transit Terminal (Chamber of Commerce)	10,000	1%
Convoy fees (customs)	10,000	1%
Shippers 'council waybill	10,000	1%
Transit Carnet Togo (Chamber of Commerce)	6,000	1%
Transit Bond in Togo (0.25%)	75,000	7%
Official transit fees in Burkina Faso	***119,000***	11%
Transit Carnet Burkina (Chamber of Commerce)	6,000	1%
Transit Bond in Burkina	75,000	7%
Shippers' council waybill	2,500	0%
customs IT fee at border	5,000	0%
Convoy fees (customs)	5,000	0%
Warehousing fee in Ouagadougou (Chamber of Commerce)	31,500	3%
Freight forwarder's fees, including*:*	***170,000***	15%
Togo (initiation of transit)	*75,000*	*7%*
Border	*20,000*	*2%*
Ouagadougou (termination of transit)	*75,000*	*7%*
Mandatory insurance on transit goods (min 0.3%)	***90,000***	8%
Total transit logistics overheads	**790,000**	72%
Facilitating payments	300,000	27%
Avoidable public procedures.	156,250	14%
Avoidable private services	175,000	16%
Total avoidable costs	***631,250***	***57%***
Total non-avoidable costs (bonds, forwarders fess at half current level)	***158,750***	***14%***

(Unit CFA Francs 1 Euro= 655.957 FCFA)

Source: Authors' Calculations. The simulation excludes the cost of final clearance

Quality Issues of Clearing Agents

In some cases, the freight forwarders' behaviors also distort transit efficiency. In several countries, access to the Clearing and Forwarding (C&F) business is not difficult. One consequence of this easy access is "suitcase" companies with low capacity, low training, and low professionalism. These may bribe officials to stay afloat instead of following procedures properly. In this case, customs clearance, dwell time and uncertainty increase significantly and the responsibility for low performance is not due to public parastatals. Small traders are harmed because they are less likely to use large and expensive C&F agents. Statistical evidence from Cameroon suggest that more than 50% of dwell time in the Port of Douala is caused by the C&F low capacity to properly fulfill documentary requirements or inability to provide the necessary payments or securities[42]. When the Cameroon Facilitation Committee tried to set quality criteria for clearing agents in 2005, less than 10% managed to fulfill them even after one year. In Kazakhstan, small size operators are specialized according to the types of commodities. Competition between freight forwarders does not exist in practice, with predetermined market shares.

Low Quality of Some Transport Operators

Quality of service providers and mismanagement of fleet is a key factor of uncertainty for traders to/from landlocked countries. Tanzania Railways Corporation has an error margin of 4 to 5 days to predict the arrival of any shipment due to locomotive shortages and wagon mismanagement. As a result, although the rail mode is cheaper, road transit traffic to Northern Tanzania from Kenya has increased by more than 20% per year in the last five years.[43] It also explains why today more than three quarters of the Rwandan trade is through Kenya, while three years before over 50% was through Tanzania.

[42] Cameroon Guichet Unique du Commerce Extérieur, 2004.
[43] Source from NCTTCA, 2005 and the Tanzania DTIS Study, Transport report, 2004.

6.2 Who Is to Blame? Process and User Disconnect: Shipper's Responsibility and the Impact on Lead Time

From a policy perspective, a key question is whether the consignee (or the shipper) is responsible for the high lead time. In many countries, small-scale traders often wait to start to clear the imported goods until they have been pre-sold, thereby using the port as a free or cheap storage. Changes in demurrage charges by terminal operators have sometimes dramatically eliminated dwell time. However, such strategy, which makes sense for a small trader in a crowded port city, is likely to be suboptimal for a consignee located days away from the port and with less space constraints. Furthermore, the nature of transit systems in LLDCs makes the process in the end very independent from the shipper or consignee:

- The latter has to rely on few agents and for containerized shipment on international forwarders with consistent quality of service. Some "suitcase operators," who are part of the problem when involve in the clearance processes, do not have the capacity to organize transit.
- The procedures (and especially additional control procedures) are non-selective and essentially independent of the nature of the shipment.
- The reasons for the delays at various phases in transit are essentially in the end irrespective of the shipper/consignee.

Disconnect between process and users is less frequent in more advanced and friendly transit regimes which rely on incentives on quality and selectivity procedures. In less advanced environments, even compliant shippers or consignees can never establish a fast track[44]: the transit operations of the World Food Program face the same problems as other shippers in Africa. Conversely, consignees using the service of non-professional freight

[44] Such operators need to be 100% immune to hassle and rent seeking behavior, the most notable exceptions are escorted supplies to bases of NATO countries. For instance, the supplies of the French peace-keeping force in Ndjamena take one week ex-Ship from Douala, instead of 2 to 5 for others, using the same services and abiding to the same procedures, with the escort of an army jeep with a visible flag.

forwarders might be worse off, but data do not necessarily show a much better performance by large ones.

Rightly or not, the natural tendency of a public agency or terminal operator is to allocate the responsibility for long delays to the users or their agent. They will tend to dismiss the tail of the distribution as non-representative and use lead time indicators close to the median or even the mode to benchmark their own efficiency when dealing with efficient operators.

A contrario, a quality driven shipper, will look at the probability of a container coming late to assess the induced inventory or opportunity cost. For them the relevant indicators will not be the mean, but the 95th or 99th percentile lead time and exporters will likely be more demanding than importers. The next section (model) will provide a precise formulation of the link between inventory and distribution of lead time. However, we can already indicate that given the shape of the typical p.d.f., switching from the median to the 95th percentile translates into a twofold to fivefold difference.

This question is still very much open especially for port-dwell time, and is worth further investigation based on individual shipment dataset: one may consider alternative model, where different shippers have different p.d.f. of lead time. Although we do think (as was indicated above) that in the case of transit in LDCs observed distributions of lead-time are essentially process dependent, to avoid shipper's bias, we have used data and information provided by international freight-forwarders who are experiencing stochastic lead-time, independent of the shipper.

6.3 The Curse of Small Shipments

High land transportation costs may be partially attributed to the fact that (i) landlocked countries export less than they import and (ii) low trade volume from/to landlocked countries prevent economies of scale.

Small Is Not Beautiful

The impact of trade imbalance and low volume is less documented than transit overheads, but anecdotal evidence show that this is a major concern. Weak positioning in the global market entails low trade and prevents most LLDCs from reaping scale economies. The average traffic at many "major" border posts is often in the range of 5-10 containers per day and the busiest border post in East Africa (Malaba) only sees 200 to 300 vehicles per day. Rwanda or Burundi's annual containerized imports would fit into a single large container vessel. This implies that almost no shipper has the required scale to have a strong bargaining position with global logistics groups. Transit to Rwanda and Uganda is dominated by large freight forwarding groups with large truck fleet. In the case of Tanzania, Tanzania Railways Corporations charges 30% more for a transit container to Rwanda from Dar Es Salaam to Isaka (990 km) than for the same container for domestic traffic to Mwanza, while this town is 1,230 km from Dar on the same railway line[45].

The relatively minor share of traffic to/from landlocked countries also limits their bargaining power for preferential treatments in coastal ports: in West Africa, transit traffic has not reached 10% of the total traffic through Abidjan, even when more than two thirds of Mali and Burkina Faso trade transited through its piers. The same can apply to Chad and Central African Republic with Douala and even Uganda is not more than 15% of the Mombasa port traffic, while the port handles 90% of its external trade.

In small developing economies, including landlocked countries, arranging small-scale shipments and consolidating them in a single container remains an issue both in terms of cost and in terms of service availability. In a case study of Laos, Arnold (2005) showed that availability and cost of these services are critical to export growth and diversification. In Central Asia Ojala et al (Ojala 2005) documented the steep increase occurred by loads below one container size.

[45] Data collected from the Northern Corridor TTCA and TRC, 2005.

Table 8. Comparison of Indicative Transport Costs from Central Asia to Antwerp/Rotterdam for Large and Small Exporters

Origin	Freight tariffs in USD/ton (including unofficial payments)	
	Full Unit	One Ton Parcels
Dushanbe (TAJ)	230	500
Khujand (TAJ)	220	480
Tashkent (UZB)	175	300
Almaty (KAZ)	180	300
Ashgabat (TKM)	200	400
Baku (AZB)	163	280
Tbilisi (GEO)	150	300
Yerevan (ARM)	170	420
Chisinau (MOL)	100	280

Source: Ojala 2005, prices as of Spring 2004. Large exporters use full 40' containers; small exporters rely on consolidated parcel shipments of 1 ton.

While the supply chain may be optimized for large and routine shipments (e.g. consumer goods (imports) or commodities (exports)), it seems that small or exceptional shipments face additional constraint in terms of cost and delays because of the current practice of logistics[46].

Advanced logistics services for small shipments face serious trade facilitation constraints. In LDCs, applicable procedures under customs control constrain logistical optimization at sub-regional or corridor levels. Furthermore, given a lack of modern Supply Chain Management culture, shippers may prefer to organize consolidations themselves and use traditional transport means rather than pay for professional services.

Diseconomies of Scale

Some routine trade processes, such as placing international orders or arranging finance (e.g. letter of credit), might be more difficult and expensive in landlocked countries which are smaller economies with less developed trade supporting services. While transit

[46] The causes of these shortcomings have yet to be fully clarified in case studies.

overheads amount to a percentage upon transportation fees and reflect the proliferation of procedures and rent seeking activities, administrative costs reflect the diseconomies of scale and impose a high penalty on smaller shipments in small and distant markets.

Trade Imbalance

Transport costs are asymmetric worldwide, especially for LLDCs. Along the Northern Corridor (Rwanda to Mombasa) transporting one 20' container by road costs 1,850 USD and 2,300 USD from Mombasa to Kigali (TTCA 2005) the export transport rates can be close to 50% of import on some rail and road links with limited return traffic.[47] Transport companies experience difficulties to find backload and charge the empty return in their import tariffs. In Central Asia, the cost of transporting a 40' container by road between Central Asia and Europe varies from USD 6,000 for the West-East direction, to the East-West charge for transport is only USD 4,000[48]. With few exceptions, shippers are unable to find freight for the return journey.

Expansion of the Concept of Landlocked Countries: The Emergence of "de facto" LLDCs?

The quest for scale economies is vital for maritime transport. Hummels and Skiba (2002) demonstrate that although Japan and Ivory Coast are equidistant from the US (West coast in the first case, East coast in the second case), shipping costs for imports from the Ivory Coast is twice as that of Japan, even adjusting for differences in the commodity composition. Large trade flows are conducive to scale economies in transport, which lower transport costs and thereby increase trade. The lack of scale economies creates *de facto* landlocked countries, and can apply to coastal LDCs. Because of the low volumes in smaller ports, shipping lines set higher tariffs to call in these ports.[49] To illustrate this tendency that will probably increase in the coming years, we give the example of exporters of fruits and vegetables from South Mauritania. Because of the maritime

[47] Goma (DRC)-Mombasa transport costs are 2,000 USD for exports and 4,000 USD for import.
[48] For Data between Paris and Tashkent, *see* Raballand et al. 2005.
[49] Like Cullinane and Khanna (2000) demonstrate, the container market expanded with ever growing container vessels. Higher tariffs also depend on voyage length and port efficiency. The scale economies in ship size decline as route lengths shorten and port efficiency worsen. The last factor is weak in several African ports, which is conducive to higher tariffs.

transport price differential between Nouakchott and Dakar, exports are processed through the Dakar port. Despite border-crossings costs and a longer distance, they gain from this shift. Maritime transports differential may be very high: in West Africa, shipping lines charge 1,650 USD for a 40' container from Northern Europe to Douala, but 3,450 USD to Malabo, which is located only 100 kilometers offshore from Douala[50].

Section 7 A Quantitative Model of the Transit Supply Chain

7.1 The Model

This section presents a quantitative supply chain model identifying the impact of cost, delays and uncertainty in lead time. The shipper in the landlocked country bears the transit cost of inland logistics operations from/to port and to/from warehouse or factory (of a 40' container). The supply chain breakdown of the logistics costs is (see section 3):

C	=		Freight Transportation Costs	*Fees paid for actual transit transportation services to truckers or rail operators*
		+	Other Logistics Costs	*transit overheads +administrative costs per shipment*
		+	Delays Hedging Costs	*Translated in equivalent inventory cost*

Notations

The transit chain is broken into steps. Some are transport-related (moving goods between borders), many are not (container storage in the port terminal, transit documents, customs processing/ warehousing at the operator's facilities). For simplicity, we consider one mode of transport in transit:

[50] Data from the Europe West Africa Trade Agreement is available at www.ewata.org.

O	=	Transit overheads
A	=	The administrative costs of organizing transit operations : internal costs or costs paid to logistics providers (for example to arrange small shipments)
T_{mean}	=	The average lead time (days) of transit operation, for instance: Ex Ship to consignee (imports) Shippers to FOB (exports)
S	=	The average time (days) between identical shipments required by the level of demand for such shipment (replenishment cycle)
α	=	Fixed costs of transportation.
β	=	Variable cost of transportation (e.g. fuel, maintenance)
Dis	=	Average distance covered in the period
λ	=	Load factor of truck
m	=	Moving inventory cost
w	=	Warehouse(d) inventory cost
V	=	Value per shipment
T_i	=	Mean time taken by step i
D_i	=	Distance covered during step i
T_{trans}	=	Usage of transportation vehicle (including waiting time and return)
T	=	Total lead time (random variable)
D	=	Distance covered in transit (one-way)
N	=	Number of trips of transit vehicles (per month)

Freight Transportation Costs

For modeling purposes, we assume that the shipper /consignee is operating its own fleet (the transport operators are passing the cost to the customer). The total cost is decomposed into: Fixed and Variable costs. The equation is:

$\alpha + \beta \times Dis$ is the cost of operating per truck over the period (α is the fixed cost).

Dis*λ is the average distance covered with a commercial load.

And, $\frac{\alpha}{\lambda \times Dis} + \frac{\beta}{\lambda}$ (1) is the Ton Per Km (TKM) transport cost charged to the user. The TKM is widely used in developing countries as a reference (including in freight contracts).

The transport cost depends on how the market is organized.

a) Efficient Trucking Market. An efficient sector, though not specialized in transit operations. The user pays for truck usage based on the time of immobilization in the transit operation T_{trans} (as if the shipper was renting the truck) and the variable cost adjusted for the load factor. The transit takes place over a distance D:

   $\alpha \times T_{trans} + \frac{\beta}{\lambda} \times D$ (2)

   Where $T_{trans} = \sum_i ti + return\_time(1-\lambda)$ (3) is the time usage of truck for a transit trip. The transport time includes the time taken on the various steps for which the vehicle is mobilized plus the fraction of the return journey not paid for.

b) Cartel/Syndicate. This situation happens when a cartel or syndicate controls transit freight allocation. The price is adjusted by the cartel for recovering the fixed cost (irrespective of the usage). Then, the cost per trip takes in account the average number of round trips (N) per truck per month (or unit of time) on the transit route:

   $\frac{\alpha}{N\lambda} + \frac{\beta}{\lambda} \times D$, (4)

   which is independent of the transit transport time. This is above the value observed in efficient markets, *ceteris paribus* (same cost coefficients α, β, and transport time).

Administrative and Overhead Costs of Transit Shipments

The two components of the administrative and overhead costs of transit shipments are:

O = overheads per unit shipments due to the transit related procedures and activities. O is fixed cost by container or trailer.

A = Administrative costs depending on the size, nature of shipments, and the cost of potential consolidation. (In inventory theory, A is inversely proportional to the number of shipment needed to consolidate in a full load).

Hedging Costs, Inventory Costs

Moving Inventory Costs.

For simplicity, we retain the following time linear formula based on the operational value of time and the mean lead time in transit:

$mobile\_inventory = m \times T_{mean} \times V$, where m is a cost per day of the mobile inventory.

Inventory Costs Induced by the Randomness of Lead Time

Optimal inventory management faces constraints from:

- Supply chain unpredictability and uncertainty in shipment delivery time. That is, lead time is a random variable.
- The level of demand, whether predictable or stochastic. For the same industry, volumes are typically lower in a landlocked country as compared to the gateway country. This leads to their higher inventory levels (Section 1).

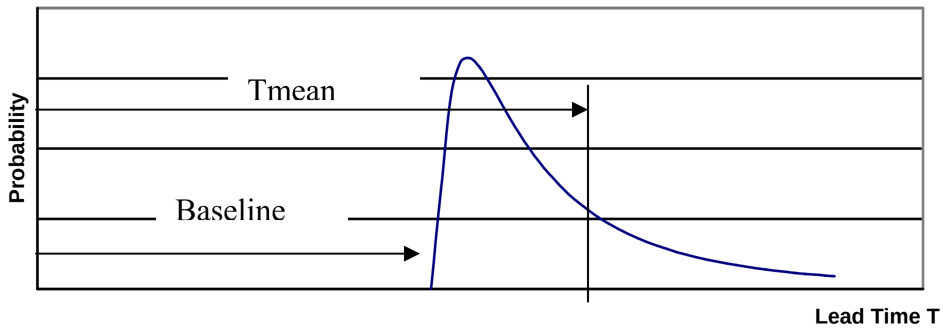
A comprehensive inventory model under logistics constraints is beyond the scope of this paper.[51] Intuitively, the value of the optimal inventory (Baumol, 1970) is the sum of:

1. The classical (s,S) buffer to satisfy demand in between two shipments. The average level of the buffer is $V \times S / 2$ in value, and the average cost of this buffer is:
$w \times V \times S / 2$, where w is the cost of warehousing by unit of value and time.

2. Hedging inventory to account for unpredictability. This depends on variance in lead time (Section 5 and Appendix 4). A simple strategy would be based on the following parameters to determine the safety inventory level.

[51] Optimal inventory under logistics is a operational problem with research potential (Kaplan 1970).

- A buffer to hedge delivery delays not exceeding a threshold lead time value T.
- The cost of stock-out exceeding the cost of warehousing w by a factor γ.
- A probability distribution of lead time P(t).



The choice of T should minimize the following logistics cost.

average cost of buffer *(which should be zero when $T=T_{mean}$):*

+ cost of stock-out

Or per unit value: $w \times (T - T_{mean}) + \gamma \times w \times \int_T^{\infty} (t-T) \times P(t)dt$

The minimum is reached when T is the hedging lead time T_h such that:

$\Pr ob(t > T_h) = \int_{Th}^{\infty} P(t)dt = 1/\gamma$ (5), namely T_h is the lead time not happening more than 1/γ.

Finally the cost of unpredictability in lead time per shipment is:

$$w \times (\gamma \int_{T_h}^{\infty} tP(t)dt - T_{mean}) \times V = w \times \left(\frac{\int_{T_h}^{\infty} tP(t)dt}{\int_{T_h}^{\infty} P(t)dt} - T_{mean} \right) \times V .$$

Total Transit Logistics Cost

Using previous notations:

$$TotalTransitCost = A + O + \alpha \times T_{trans}(efficient) or \frac{\alpha}{N\lambda}(cartel\_or\_syndicate) + \frac{\beta}{\lambda} \times D$$

$$+ (m - w) \times T_{mean} \times V + w \times \left(\frac{\int_{T_h}^{\infty} tP(t)dt}{\int_{T_h}^{\infty} P(t)dt} \right) \times V + w \times \frac{S}{2} \times V \qquad (6)$$

Since it is difficult to distinguish between the value of time in motion and at the warehouse, the term $(m - w) \times T_{mean} \times V$ can be omitted as much smaller than the hedging inventory level $w \times T(\gamma) \times V$, where

$T(\gamma) = \left(\frac{\int_{T_h}^{\infty} tP(t)dt}{\int_{T_h}^{\infty} P(t)dt} \right)$ is this level measure in unit of time. Hence:

$$Totaltransit\cos t = A + O + \alpha \times T_{trans}(efficient) or \frac{\alpha}{N\lambda}(cartel\_or\_syndicate) + \frac{\beta}{\lambda} \times D$$

$$+ w \times T(\gamma) \times V + w \times \frac{S}{2} \times V$$

Operational research typically look at probability level of stock out of 1% to 5%. For a log normal distribution,

$$T(\gamma) = Tmean \times \frac{\Phi(\sigma - k)}{\Phi(-k)} = Tmedian \times \exp(\sigma^2 / 2) \times \frac{\Phi(\sigma - k)}{\Phi(-k)}$$

where Φ is the standard cumulative normal distribution function, and Φ(-k)=γ.

γ can be estimated by looking at fast shipping by air cargo as the alternative to stock out. For most countries under review, the incremental cost of shipping a ton of goods is in the range of 2,000-4,000 USD or 50,000-100,000 USD per shipment for a 40’ container. Supposing that the shipment is replenished every S days to satisfy the demand, the stock out equals a cost of 50,000-100,000/S per day as compared to 50 USD of inventory holding cost per shipment per day. Hence:

γ = (1,000-2,000)/S (days)

Realistic values for S for a given shipment are in months. If S = 1 month, then γ = 33-67. For two months, γ = 17-35. (these values are consistent with typical probabilities of stock-outs).

For distributions such as the ones listed previously and consistent with observations of shipments to/from LLDCs, it means that **T(γ) is a multiple of the observed average lead time by a factor of three or more** (Appendix 5). The hedging inventory level is computed below for the example of a median time of 13 days, including a baseline of 3 days, and various levels of standard deviation. This data is typical of LLDCs in Western or Southern Africa.

Table 9. Inventory Levels and Transport Time Standard Deviation

Stock Out Level	Standard Deviation (days) 2.5	5	7.5	10
	T(γ) days			
10%	25	30	35	38
5%	28	35	41	46
2.5%	31	41	49	55
1%	35	48	59	68

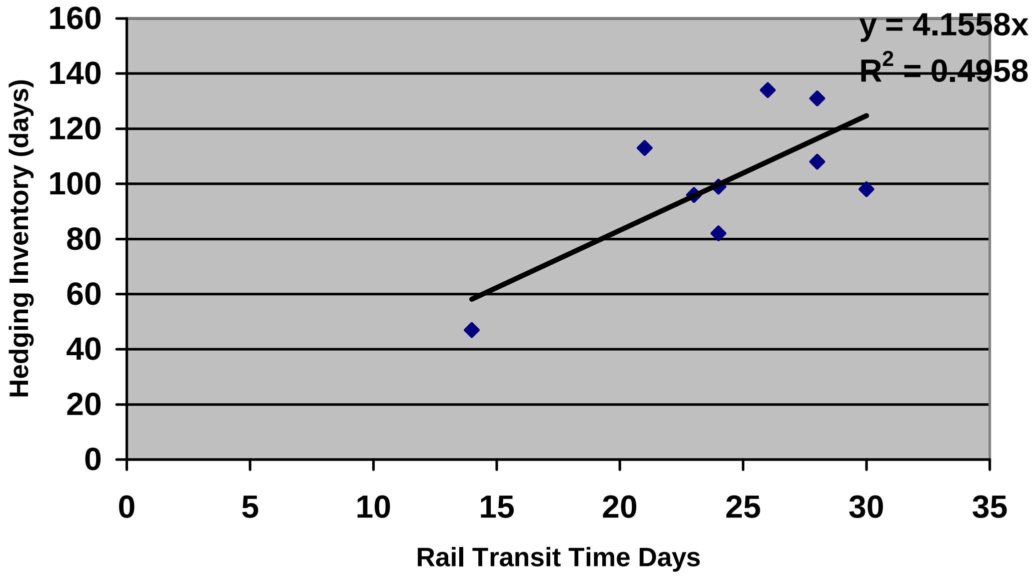
T(γ) are at least equal to twice the lead time. This implies that the economic impact is twice that of inventory costs linked to the lead time. Another illustration of this multiplier is from the road/rail modal choice for exports from Central Asia (Appendix 4). Supposing that the modal choice is due to the low reliability, hence high T(γ) of rail *vis-à-vis* that of road transport:

$$Road\,Premium = RoadRate - RailRate$$
$$= valueofinventory \times (T(\gamma)\, forRail - TmeanforRoad)\text{'}$$

or $T(\gamma) = Road\,Premium / valueoftime + TTmeanforRoad)$

The data provides for a plot of T(γ) estimated with vs. transit time for exports by rail in Central Asia (see Figure 8). The multiplier effect is over 4.

Figure 8. Rail Transit Time vs. Hedging Inventory Level Estimated from Road Premium



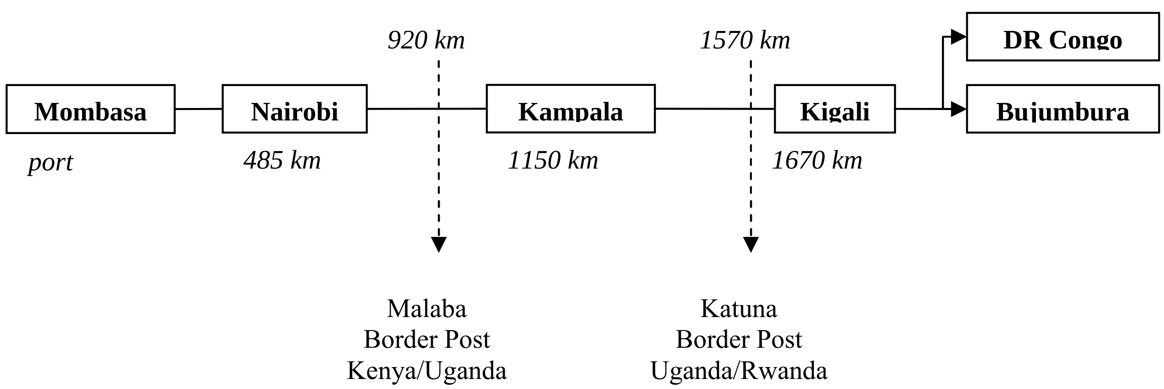
Data Source: Ojala 2005.

7.2 An Empirical Application to the Northern Corridor

The Northern Corridor is the main transport artery linking the landlocked countries in East and Central Africa (Rwanda, Uganda, Burundi, Eastern DR Congo and South Sudan) to the Mombasa port (Kenya). Up to Kampala (Uganda) transit cargo is *via* trucks or on the Kenya-Uganda railroad (Figure 9).

The corridor's performance is hampered by two factors related to infrastructure management and quality: (1) Kenya's infrastructure quality and (2) rail poor performance. The Governments along with donors (the World Bank and the EU) and complementary efforts by trans-national entities (NCTTCA and COMESA) are also addressing facilitation related issues through harmonizing transport and documentation policies (e.g. third party insurance and mutual recognition of insurance). Despite improved road transport delivery in the corridor since late 1990s (due to the well structured haulers and freight forwarders) the time taken to reach Rwanda is up to four weeks, (for a cost of 4,000 USD for a 40' container by truck). Also, supply chain predictability is low as the container may require two months to reach Rwanda. This unpredictability is a major constraint for processing activities in Kenya and Uganda.

Figure 9. The Northern Corridor



The main issues are: (1) the initiation of transit in Mombasa, (2) transit overregulation (escorts and load control) and (3) border-crossing conditions (at the Kenya/Uganda border). Regional Customs, ports, other public agencies and NCTTCA are working with the World Bank and African Development Bank in the East Africa Trade and Transport Facilitation Project to improve processes and infrastructure at critical points (through facilities, risk management and automation). We also expect the transit regime to be streamlined when the project is completed. Table 10 summarizes the impact hypotheses made for the various elements.

These parameters are used as inputs into the model. Although the reduction in average delay is significant, the expected improvement in predictability is even more dramatic (as shown on the next page).

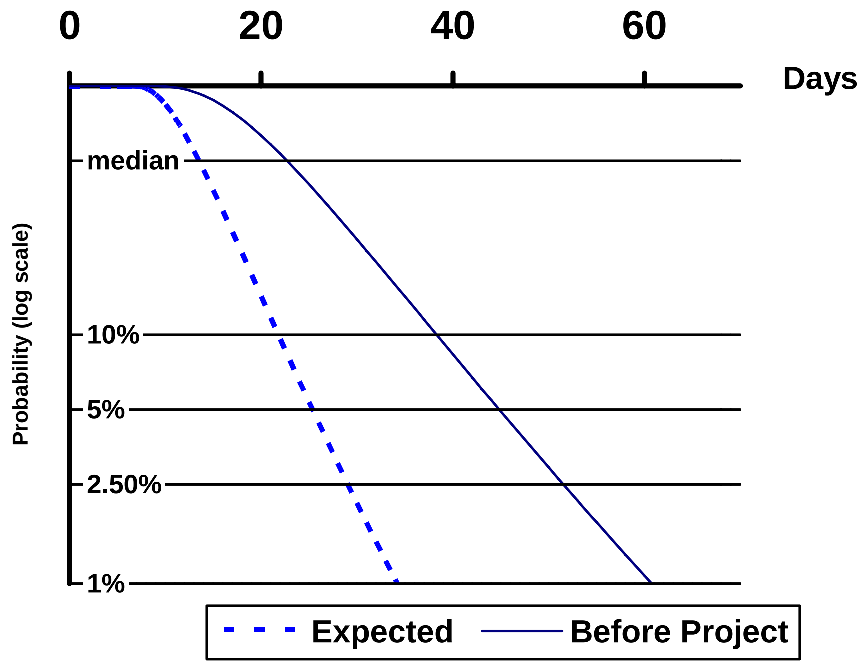
Table 10. Baseline and Expected Outcomes of the Project on Mombasa-Kigali

Link	Observed 2005 (days) Avg. delay	Std dev	East Africa Trade and Transport Facilitation Project Measures	Expected from Project (days) Avg. delay	Std dev
Port	13	9.5	Single window system	7	5
Transit Kenya (t)	4	2.5	Customs automation and risk management	3	1.5
Border (t)	1	1.5	Joint border post	0.3	0.8
Transit Uganda (t)	2	1.5	Customs automation and risk management	1.5	1
Final Rwanda	5	3	Customs automation, single window system and risk management	3	1.5
Total	25	10.5		14.8	5.6
Technical Minimum	5			5	
Average Excess	20			9.8	
σ log normal		0.493			0.530

(t) = link with truck transportation.

On the next page, Figure 10 summarizes the probability of a shipment from the ship in Mombasa to a consignee in Rwanda exceeding a given delay (in days), based on the lognormal shape (semi-log scale).

Figure 10. Expected Impact of the East Africa Project on Transport Predictability



As expected, the transport gains from the corridor facilitation initiative are modest (2.2 days on average saved for the truck transport leg, with a cost of 130 USD/day, which amounts to 286 USD). However, the inventory impact is significant, with the inventory level halved and entailing a in cost saving of 1,000 USD per shipment (or 25% of the cost of transport).

Table 11. Simulated Inventory Gains Depending on the Sensitivity of Shippers to Stock Out

Risk Level	10.0%	5.0%	2.5%	1.0%
Prior Inventory Level Days	43.0	49.9	56.9	66.7
Inventory Level $	1720	1996	2276	2670
Expected Inventory Level	22.2	26.0	29.9	35.5
Gains Days	20.9	23.9	27.0	31.2
Gains $	835	956	1080	1250

Section 8 Areas of Maximum Impact and Recommended Implementation Measures

8.1 Which Trade Facilitation Measures Are Likely to Bring Most Gains?

The three areas with the largest potential gains in total logistics costs are the following:

1. Any measure that enhances supply chain predictability and thereby reduces hedging costs.
2. Measures, some of which may be part of broader governance reforms, reducing rent-seeking activities and therefore overhead logistics costs.
3. Reforming market structure by moving from a cartel/syndicate freight organization to an efficient market structure, inducing decreased fixed cost of transportation.

Fortunately, these objectives are essentially consistent and policy measures or investment will typically aim at the three simultaneously. Improvement in market structure triggers lower costs of transportation, reduce rent opportunities, cost overheads and boosts professional service quality, which opens the possibility of a streamlined and efficient transit regime.

In contrast, other objectives often sought after within trade facilitation projects (border-crossing infrastructure, IT…) might (a) have less impact than expected or (b) prove difficult to be implemented. For example:

a) Reducing transit time through corridor facilitation measures time will not be passed to transport prices if the market is not efficient (a day gained in transit may mean an extra day in queuing if there is a regulated overcapacity as seen in section 4.2).
b) Influencing variable cost of transportation (e.g. fuel, maintenance) may not be easily achievable by simple policy measures and require substantial lobbying or multi-stakeholder work.

Since the scope of this paper does not aim at identifying macro linkages, we cannot capture and have not focused on all potential benefits of physical investments. However, we can identify two direct mechanisms through which infrastructure impacts trade costs:

(1) Poor infrastructure quality increases the variable cost component of transport (maintenance, tires, and fuel consumption).

(2) Poor quality of infrastructure increases transport unreliability of the route and the cost of hedging unpredictability (through inventory holdings or need to choose an alternative mode). Reliability is a critical concern when the road is not always passable (e.g. unpaved sections of corridors), or when the bad condition of the infrastructure contributes to service breakdown (due to excessive pressure on road vehicles, washouts, or derailment). Hence, failure to minimally invest in infrastructure is likely to induce service interruption.

Table 12 summarizes the potential gains on each of the variables impacting logistics costs.

Table 12. Potential Impact of Trade Facilitation Measures on Various Costs

Types of Logistics Costs	Environment Specificities	Potential Impact	
Overhead Costs		ΔO 30 to 100% of transportation cost	Reduction of non-transportation cost can be obtained in most cases by addressing overregulation
Administrative Costs		ΔA	To be assessed (especially for small shipments)
Fixed Cost of Transportation	Three cases: 1. Efficient market 2. Cartel/syndicate 3. Transition from a cartel syndicate to an efficient market (decreased turnaround time)	i) $\alpha \times \Delta T_{trans}$ efficient trucking market ≈$ 90-150 xΔTrans ii) 0 for cartel/syndicate structure iii) Δ (price of traction)*distance/load factor	Only a few days (2-3) can be gained on typical trips Limited possible gains iii) Substantial reduction through better use of trucks (30% or more)
Variable cost of transportation		$\frac{\Delta\beta}{\lambda} \times D$	Limited without major change in infrastructure condition or tax policy
Inventory	1. improvement in transit time 2. improvement in predictability	≈ $50*ΔT $w \times V \times \Delta T(\gamma)$ ≈ $50*Δ T(γ)	Can be significant, but less than the improvement in predictability Very important as improvement in predictability can reduce T(γ) by weeks.

Looking at the various links in a given transit supply chain, the main sources of improvement in predictability and performance are, in order of importance:

1. Improved initiation of transit at the gateway (typically the main source of delay and unpredictability), through a streamlined transit regime (such as carnet system).
2. Improved clearance at destination. It is typically faster than the initiation of transit, but is potentially a source of complication, especially for non-recurrent shipments due to the lack of customs capacity in small countries.
3. Improved and more reliable service quality. The service sector, especially trucking, is sometimes fragmented and some forms of queuing systems prevent forwarders from selecting transporters. Improvement can also target truck maintenance and drivers' practices[52].
4. Improved efficiency of multimodal nodes: In terms of reliable service delivery, road transport is usually more reliable than rail transport and shippers are willing to pay premium for more reliable road services if rail road interfaces are not optimized.
5. Simplified or removed en route transit procedures, such as escort, removal of roadblocks and other controls *en route*.
6. Improved border-crossings management.
7. Improved quality and management of infrastructure to reduce transport uncertainty, notably under bad weather conditions, when the road is not paved or extremely deteriorated.

8.2 Conclusion and Policy Recommendations

Transport costs explain at best part of the high logistics costs of LLDCs. Unreliability and vulnerability of the supply chain are even more important in constraining their trading and thereby growth prospects. A case-by-case, comprehensive analysis of supply chain bottlenecks in terms of costs (transport or overheads, time, and variance) is critical to identify the constraints, which have the strongest impact on competitiveness. The conceptual framework and quantitative tools here proposed should help in this assessment.

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[52] some truckers stop frequently for their own entertainment or to make side money by transporting passengers or small goods.

Donors and policy makers should focus on effective implementation strategies for existing transport regimes and targeted enabling reforms (ports and customs) as well as private sector participation in service delivery. Indeed, multilateral rules for facilitating transit trade are well-defined and in most cases these have been endorsed in bilateral or sub-regional agreements by transit and landlocked countries. Policy and implementation initiative should target primarily the country level including the gateway country where many of the potential gains are to be materialized.

Within these objectives the most important reforms to undertake are the following:

1. **The re-engineering of the transit system of landlocked countries to change the paradigm from a multiple inefficient clearance system to a single efficient clearance.** With this end in view, these should focus on identifying and establishing the prerequisites for efficient transit regimes tailored to local conditions and specificities instead of redesigning new transit regimes. The main problem along several corridors lies, at least for imports, in the lack of substantial difference between the initiation of transit in the Port of entry and the final clearance in the landlocked economic center. Transit control at the border is artificially made complex, resulting in a “triple clearance” time. Historical experience suggests that a carnet system with a simple initiation may be the way to go, following the example of the TIR. The post war TIR had a strong impact on boosting intra-European trade. The carnet systems relied on a public-private partnership which supported the modernization of the logistics sector, while existing transit arrangements in LLDCs sometimes involve inefficient or rent-seeking parastatals. An efficient transit regime will not only reduce transit time but will also eliminate many sources of uncertainty at initiation, en route, and at destination.

2. **Customs reform at the national level, as a prerequisite for functional sub-regional systems:**

- In the gateway, customs reforms should convey a positive approach to transit, implement proper documentation and transit information management, and promote implementation of working carnet systems.
- Inland transit and destination countries capacities should be reinforced to operate transit (border management) and final clearance.

3. **Transport services reforms through policy or incentive measures**:
   - *Termination of obsolete freight repartition systems* (queuing and "tours de role");
   - *Concession of transport activities*, such as railways, port operations, and road and logistics services when they still remain in the public domain (as in several African and Central Asian countries); and
   - *Support to industry consolidation and partnerships* with global logistics operators, through transparent business regulations, appropriate incentives and, in road transport, enforcement of axle-load control. Financial assistance from international business partners and international financial organizations to allow the emergence of structured operators may also help (IFC provided initial support to key players in consolidating Kenya's trucking sector in the early 2000s and more recently in Rwanda).

Other important measures are:

- *A coordinated corridor facilitation program*, as it can bring several benefits such as improved border-crossings, better information-sharing, bottleneck identification and solutions finding to address them. Corridor cooperation can also lead to for more in depth re-engineering of the transit systems.
- *Investing in road infrastructure and maintenance*, so as to maintain all weather capability of corridors and reliability of service delivery. This qualitative threshold is important to eliminate a significant source of unreliability. Improvement in rail infrastructure and rolling stock is also crucial in some corridors to improve service efficiency. On the other hand, creating supply driven infrastructure may not always bear fruits, especially as there as few capacity

constraints on corridors serving LLDCs, except localized congestion in the vicinity of capital or port cities. In general, maintaining existing infrastructure in a reliable condition is the priority and can require significant external funding.

- IT investment can also bring tangible benefits. Computerizing transit documentation as part of a customs modernization reform can reduce the time spent in initiating transit or in final clearance. ASYCUDA and other systems comprise transit modules technically easy to implement when border posts are connected to headquarters. While real-time cargo tracking may bring improvements, it remains controversial. It is enhancing a vision of transit as a chain of control and thereby imposing intrusive constraints on the private sector instead of implementing a better partnership with compliant operators. For this reason, real-time tracking is not a pre-requisite for functioning transit systems in industrialized countries.

The possibility of developing air transport-based trade needs exploration. Indeed, most constraints experienced in land transport would not apply to air transport services (even if the small scale of many economies tends to limit services to landlocked countries to feeders). Empirical evidence in Africa suggests that no landlocked country has tried to establish strong air transport based trade policies even though public investment levels needed are much less than for the other modes, and air transport should be ideal to develop highly time-sensitive and high value-added activities.

Complementary research is required in at least three areas: (1) An understanding of the mechanisms linking the structure and magnitude of logistics costs (especially the cost of uncertainty) and competitiveness; (2) Deeper understanding of the necessary pre-conditions and enabling policies to implement efficient transport and transit schemes: trucking sector reform, case of small shipment, political economy of transit friendly reform…. ; and (3) Empirical investigation of supply chain performance and its nexus with traders' behaviour, inventory holdings or modal choices needs detailed assessment, when shipment level data is available for various type of products.

Finally the main objective of transit facilitation projects is to provide an enabling environment that offers global market connectivity and links locally based logistics services to global networks. The measures needed are not necessarily high in terms of monetary resources, but require strong political commitment.

In terms of donor funding, most actions above do not require major investment, except for critical infrastructure but the donor community's intervention may be critical to provide an external "honest broker" role (and to crystallize sometimes conflicting positions within stakeholders).

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Appendix 1. Features and Performance of the Main Trade Corridors Serving Landlocked Developing Countries

	West Africa	Central Africa	East Africa	Southern Africa	Central Asia
Ports of Entry (main)	Abidjan, Tema, Lomé, Cotonou, Dakar	Douala	Mombasa, Das es Salam	Durban, + Walvis bay, Mozambique, Dar	Baltic ports, Turkey, Iran, China
Landlocked Countries Served	Mali, Burkina, Niger	Chad, Central African Republic	Uganda, Rwanda, Burundi, Eastern DRC Southern Sudan.	Bostwana, Malawi, Zambia, Zimbabwe, Lesotho, Southern DRC	Central Asia
Geography of Corridors	Interconnected corridors competing to serve the landlocked countries	One multimodal corridor	Two parallel corridors with limited competition between them.	A main corridor from Durban and Johannesburg, through Harare. (Alternative Maputo and Walvis bay). Landlocked countries are also served directly by corridors in Mozambique (Beira) and from Dar es Salam.	Extensive rail and road network inherited from the Soviet Union.
Remoteness of Landlocked Countries	1000 km	1200-1800 km	1000 to 1600 km	1000 to 2000 km	3000-4000 km
Performance					
Typical Transit Time (boat <> inland center) Import Exports	 10 days-2 weeks 5 days	 4-6 weeks 1 week	 3-4 weeks 1 week	 10 days <1 week	Depending on mode of transportation: 2-3 weeks (Baltics) 7-10 days

Appendix 1. Features and Performance of the Main Trade Corridors Serving Landlocked Developing Countries

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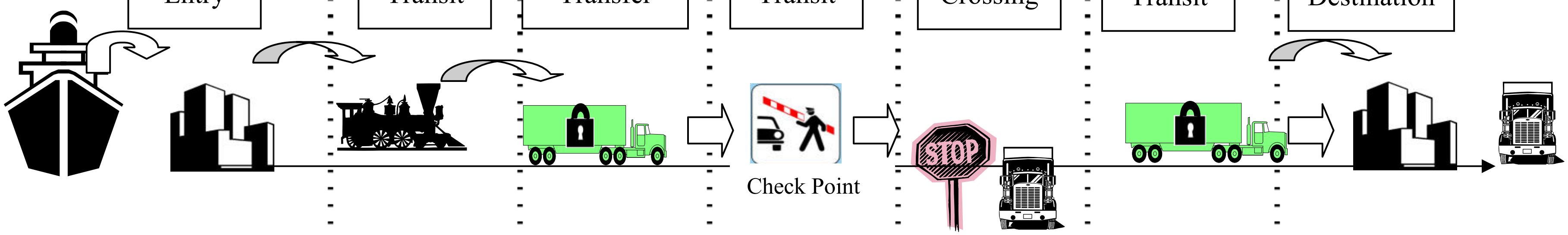
Directional Unbalance of Trade	Medium	High	High	Moderate to High	Moderate to High
Operating Cost of Land Transportation	Medium ≈ *Europe*	Very high ≈ *2 xEurope*	High ≈ *1.5x Europe*	Medium ≈ *Europe*	Moderate for road, low for rail (but very long distances)
Import 40' or Trailer	€2500	€7000	$3000- 4000	$3000	$7000
Transit Facilitation Framework					
Institutions	UEMOA, (ECOWAS)	CEMAC	COMESA, (EAC)	SADC + COMESA	
Regional Integration Transit	Customs and transport integration (high in UEMOA, less with Anglophones countries) Regional and bilateral transit treaties	Customs and transport integration (less effective than in UEMOA) Bilateral transit treaties	Transport harmonization COMESA Northern Corridor agreement	Effective role of SADC in enforcing regional transportation policies. Gaps with Mozambique	Nominally, European transit instruments are available (TIR, TIF).
Intensity of Rent Seeking Activities	High	Very high	High	Medium-High	High
Trucking Services	Very fragmented. Excessive overloading.	Very fragmented. freight allocation and rates controlled by official bodies and interest groups with compulsory.	Consolidated in Kenya Fragmented in Tanzania	Consolidated, with dominance of South African Protected cartels in landlocked countries	Very fragmented.

Appendix 1. Features and Performance of the Main Trade Corridors Serving Landlocked Developing Countries

	West Africa	Central Africa	East Africa	Southern Africa	Central Asia
Train Services	Good	Good	Poor	Adequate from South Africa but not much in use for general cargo. Very poor on other corridors.	Adequate, but slower than road.
Main Facilitation Issues	Overregulation of trucking, and queuing systems. Overloading and inadequate vessels. Hassle en route Inefficient transit regime. Final customs clearance. Crisis in Côte d'Ivoire	Transit time in port Overregulation of trucking, queuing systems, and rent seeking activities. Hassle en route. Inefficient and inadequate transit regime. Final customs clearance. Infrastructure.	Transit time in ports. Road transit provisions. Checkpoints and controls. Border delays. Final clearance. Infrastructure.	Congestion in Durban, Border delays. Distance from Durban. Low attractivity of shorther alternate corridors through Mozambique or Tanzania, due to very poor performance and predominance of SA as a hub.	Border delayas and number of crossings. Political issues between countries in the sub-region. Lagging customs reform in core countries. Market structure limits the implementability of TIR.
Positive Factors	Improvement in port and customs efficiency due to effective competition between corridors.	Facilitation measures in Douala.	Active Northern (Mombasa) corridor organization and stakeholders (haulers). EAC Customs Union project.	Customs reforms in the landlocked countries and leading role of South Africa (customs, private sector) in trade facilitation.	

Appendix 2. Sequencing of Transit Logistics

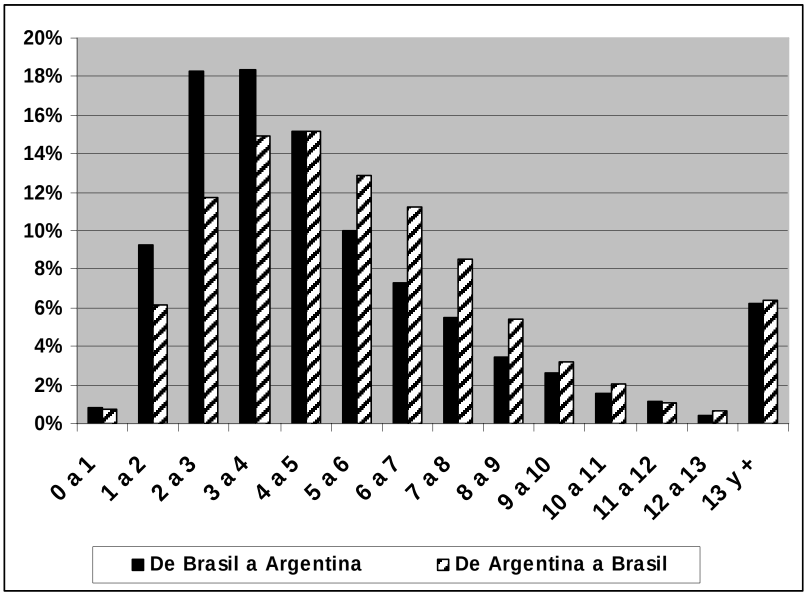


	Port of Entry	Rail Transit	Multimodal Transfer	Road Transit	Border Crossing	National Transit	Clearance Destination
Procedures/ Operations	Port Handling Customs Transit Declaration Issuance of guarantee	Seals, Transit Doc Loading Transport	Transfer (new waybill + update of transit document)	Transport Eventually Checkpoints	Transit • Discharge (exit) • Declaration (entry)	Transit Doc Transport Eventually Checkpoints	Clearance at Destination. Inspection Payment of Duties
Participant Ppublic	*Port Authority* *Customs*	*Customs* *Port Authority*	*Transport Regulator* *Customs*	*Customs* *Police*	*Border Police* *Customs and Other Border Agencies*	*Customs* *Police*	*Customs and Other Border Agencies*
Participant Private	*Forwarder* *Shipping Agent*	*Rail Operator*	*Road Transporter* *Forwarder*	*Road Transporter*	*Road Transporter* *Forwarder*	*Road Transporter*	*Forwarder* *Consignee*
Charges	Port Charges		Transfer Charges	Road Transit	New Bond	Road Transit	Duties

	Bonds			Fees (foreign trucks)		Fees (foreign trucks)	VAT
Potential Bottlenecks & Problems	Port efficiency and infrastructure Customs delay Excessive bond guarantee amount. Unjustified inspections Information management in port community	Inefficient transfer operation Unreliable road service Quality of infrastructure	No continuity of transport customs doc. Over-regulated freight market and tour de role	Customs escort and convoys Illegal checkpoints Quality of infrastructure	Delays Reprocessing of transit declaration and documentation No continuity of bonds and delayed discharge of old bonds	Customs escort and convoys Illegal checkpoints	Delays Inspection Mandatory warehousing

Appendix 3. Examples of Dispersion in Lead Time in Latin America, Southeast Europe, and North America

1. Argentina-Brazil border on the Buenos Aires-San Paolo Corridor (data in hours)



Source: World Bank.

2. Border Crossing Time in Southeast Europe

Border Post	Country of Entry	Crossing Time (minutes) Average	Std Dev	95th Percentile	Trucks Observed
Durres	Albania	204	393	345	1438
Qafe Thane	Albania	69	127	160	870
Tirana1	Albania	731	491	1355	96
Tirana	Albania	418	622	1561	721
B.Gradiska	Bosnia	40	67	135	3175
Banja Luka	Bosnia	239	229	772	913
Grude	Bosnia	90	91	200	1771
Izacic	Bosnia	64	113	240	3269
Orasje	Bosnia	211	262	824	8556
Raca	Bosnia	108	152	450	3010
Gyueshevo	Bulgaria	27	103	70	5068
Plovdiv A	Bulgaria	202	219	450	239
Plovdiv B	Bulgaria	39	96	126	238
Plovdiv	Bulgaria	182	661	435	2350
Plovdiv Special	Bulgaria	17	10	33	46
Rousse	Bulgaria	36	46	99	11073
Vidin	Bulgaria	70	61	132	214
Gradiska	Croatia	21	42	90	2510
Jankomir	Croatia	220	255	590	11186
Macelj	Croatia	83	105	208	406

Source: Customs Adviser to the TTFSE Project and Authors' Calculation. (2002 survey one month period)

3. USA Land Borders

Border Post	State of Entry	Baseline	Average	95th Percentile
Ambassador bridge	Michigan	5.7	8.8	13.9
Blaine Crossing	Washington	8.1	17.3	35.6.3
Blue Water	Michigan	11.1	34.2	80.3
Peace Bridge	New York	8.3	21.5	83.4
World Trade	Texas	12.2	31.2	54.9

Time in minutes
Source: DOT (2002 survey). Office of Freight Management .

Appendix 4. Revealed Modal Choices and the Value of Time

Central Asia is one of the few regions where rail and road are effectively competing, since the modal choice is between:

- A faster but more expensive road freight; and
- A slower (twice as slow) but cheaper (60%) rail or multimodal service,

The combined price and delay data reveals information about the value of time for the shipper. A back of the envelope estimate is:

$$Value of time = \frac{road freight - rail freight}{days saved by road transport}$$

Table 13 Indicative Transport Cost and Transit Time for Large Exporters for a 40' Container by Road or Rail to Antwerp/Rotterdam, (in USD, including unofficial payments)

	Freight in USD		Rail/Road Discount	Typical Transit Time (in days)		Implied Value (time)
	Road	Rail & Sea[53]	%	Road	Rail	USD/day
Dushanbe (TAJ)	9,200	3,400	63%	15	28	446
Khujand (TAJ)	9,000	3,000	67%	14	26	500
Tashkent (UZB)	7,000	2,800	60%	12	23	382
Almaty (KAZ)	8,000	3,000	63%	13	21	625
Ashgabat (TKM)	8,000	3,300	59%	14	28	336
Baku (AZB)	7,000	2,700	61%	13	24	391
Tbilisi (GEO)	6,000	2,500	58%	12	24	292
Yerevan (ARM)	7,000	2,800	60%	14	30	263
Chisinau (MOL)	4,000	2,000	50%	7	14	286

Source: Ojala 2005 and Authors' Calculations.

This data implies a rather high value of time, on average, about 370 USD per day for a 40' container, a value close to Hummels' estimate, although the data and the reasoning are completely different. However, shippers' preference is likely to include other information, which explains why the figure is largely in excess of plausible inventory cost for a 40' (less than 100 USD). For instance, for time-sensitive goods, the choice is likely to be influenced more by the predictability (low) of the railroad system, meaning that the denominator in the above formula should not be the difference in mean lead time, but higher value reflecting a safety coefficient. As argued in the section on inventories, delays and predictability, and according to the model in Appendix 5, this coefficient can be high.

[53] For Central Asian countries, rail transport to a Baltic port and from there by container feeder ship to Antwerp; for South Caucasus countries, by ship to Odessa in Ukraine and from there on by rail; for Moldova, rail all the way.

Appendix 5. The Distribution of Lead Time and the Log-Normal Fit

Trying to provide a robust stochastic model of trade logistic processes is beyond the scope of this paper. However, intuitive reasoning points to a distribution of lead time, as observed, very asymmetric with a broad tail. Indeed, transit in developing countries is the sum of component processes for which the lead time is widely distributed, due to their effective unpredictability. A sum of a finite number of such processes will converge slowly towards a bell shaped normal law and will look rather governed by an asymmetric distribution law of positive numbers.

The problem is analogous to other problems of distribution of sizes or intensities over wide ranges found in other branches of science such as: reliability theory (distribution of failure of mechanical devices), geology, biology, signal theory, and of course size and income distribution in economics.

Hence, there are few natural candidates to fit the actual distribution of lead time, such as Weibull, Gumbel (extreme value distribution), or Birbaum Saunders. Empirically, the ubiquitous lognormal is very adequate to simulate asymmetric broad tail distribution of positive numbers, departing from the Gaussian shape, but not too dramatically. In assessing reliability/inventory costs, we are essentially interested in fitting a range of intermediate values, (within two sigmas in log) which incorporates rare (1%), but not extreme events. Hence the asymptotic properties of the distribution are not as relevant, as the flexibility in fitting intermediate values.

Beyond, the good fit with existing data (examples below), two practical considerations back the choice of the lognormal law for modeling. First, it is most versatile for calculations in closed form (at least in terms of special functions), including all the formulas of the proposed inventory model. Furthermore, the sum of log-normally distributed independent distribution, with similar scale parameter, is with a good level of approximation, very close to a log-normal distribution, the two first moments (mean, variance) of which are the sum of the moments of the components (Fenton-Wilkinson approximation).. It means that one can extrapolate the distribution of the overall transit lead time, from information on the component process, and the hypothesis of statistical independence. This property has been used to simulate the cost on the Northern Corridor (section 7.2)

Addition of Log-Normal Random Variables

The sum of normally distributed random variables is also normally distributed. Hence, as it is well known, the product of log-normally distributed random process is also a lognormal process. However, in the case of the distribution of lead time, we are looking for the distribution of the total lead time of a sum of individual steps in the logistics chain, each of which has an asymmetric log-normal type of lead-time distribution.

Unfortunately, there is no such simple rule for the sum of log-normal random variable. In fact, even the characteristic function of the log-normal distribution cannot be expressed in terms of elementary or special functions, which would have allow for a closed estimate of the sum, supposing that the components are independent log-normally distributed variables.

However, for practical purposes, the probability distribution function (p.d.f.) of a sum of log-normally distributed independent variables is itself very close to another log-normal distribution, with the same mean and variance. With the increase of the number of components, the trend towards a Gauss Curve occurs through the narrowing of a family of asymmetric quasi-lognormal curves. The parameters on the compound log-normal will be estimated by equating the fist two moments (average and variance), rule known as the Fenton-Wilkinson approximation (Fenton 1960).This observation, of high practical interest to scientists and engineers has been made for a long time initially by communication engineers.

We could not find a definitive rigorous explanation for this empirical good fit, in the literature. A plausible argument stems from Cramer's large deviation theorem, which extends the central limit theorem to large deviations from the mean. In loose terms[54], the theorem states that the Sum of N identically distributed variables converges, for large N, uniformly towards a distribution expressed in terms of a loss or Cramer's function S:

$$\mathrm{Log}\left[\mathrm{PDF}(X = \sum_{i=1}^{N} X_i)\right] \approx -N\, S(\frac{X}{N}) \ \text{ for large N}$$

In the case of the log-normal distribution: $S(x) = \frac{1}{\sigma^2}\mathrm{Log}^2(x/x0)$. The limit normal law corresponds to the first Taylor's term around the minimum of S.

[54] A primer on this not totally trivial convergence phenomenon, is:U. Frisch, D. Sornette "Extreme deviations and applications". Phys. I France 7, 1155-1171 (1997), or Arxiv.org/cond-mat/9705

Log-normal fit of actual data.

The lognormal distribution of lead time is given by:

$$\mathrm{P(t)} = \frac{1}{t\sigma\sqrt{2\pi}}\exp\left(-\frac{(\ln t-\mu)^2}{2\sigma^2}\right) \quad \text{A1,}$$

where the parameter μ is related to the median lead time T_{median} by $\mathrm{T_{median}} = \exp(\mu)$.

Alternatively,

$$\mathrm{Prob}(t \geq T) = \Phi\left(-\frac{1}{\sigma}Ln\left(\frac{\mathrm{T}}{\mathrm{T_{median}}}\right)\right) \quad \text{A2}$$

where Φ is the standard cumulative normal distribution function.

$$\Phi(x) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{x}\exp\left(-\frac{u^2}{2}\right)\mathrm{du}$$

While the T_{median} lead time is the scale parameter of the distribution, its shape parameter σ is linked to the coefficient of variation CV (standard deviation of t divided by the mean time).

$\mathrm{CV} = \sqrt{\exp(\sigma^2)-1}$ (A3), and conversely $\sigma = \sqrt{\ln(1+\mathrm{CV}^2)}$. It means that for practical range of CV observed for our problem (0.5 to 2), σ will be relatively close to one.

The mean, modal and median lead time, T_{mean}, T_{mode}, T_{median} are related by:

$$\mathrm{T_{mean}} = \mathrm{T_{median}} * \exp\left(\frac{\sigma^2}{2}\right) = \mathrm{T_{median}} * \sqrt{1+\mathrm{CV}^2} \quad \text{(A4)}$$

and

$$\mathrm{T_{mode}} = \mathrm{T_{median}} * \exp(-\sigma^2) = \mathrm{T_{median}} \big/ 1+\mathrm{CV}^2 \quad \text{(A5)}$$

Depending on the source, the data on lead times in available either by individual shipments or already in terms of a discrete cumulative distribution function (histogram of the cdf). In the first case, the parameters of the fitting distribution are estimated from the distribution of ln(t). In the second case, ln(t) is fitted against the inverse normal distribution of the cumulative values (normal probability plot).

Example 1 Distribution of Dwell Time of Transit Containers in the Port of Mombasa

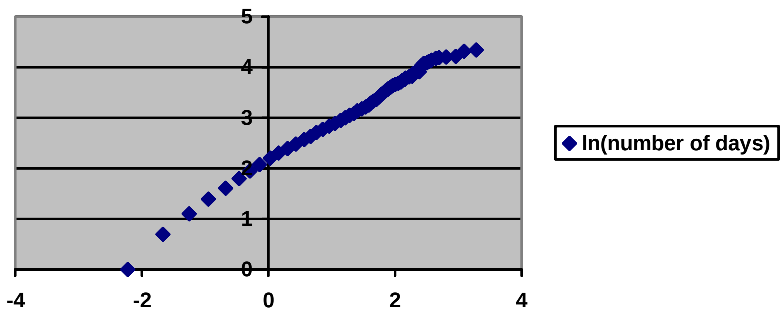


Fig A5 1

In this case the data was given as the histogram of the cdf, and the underlying equation is:

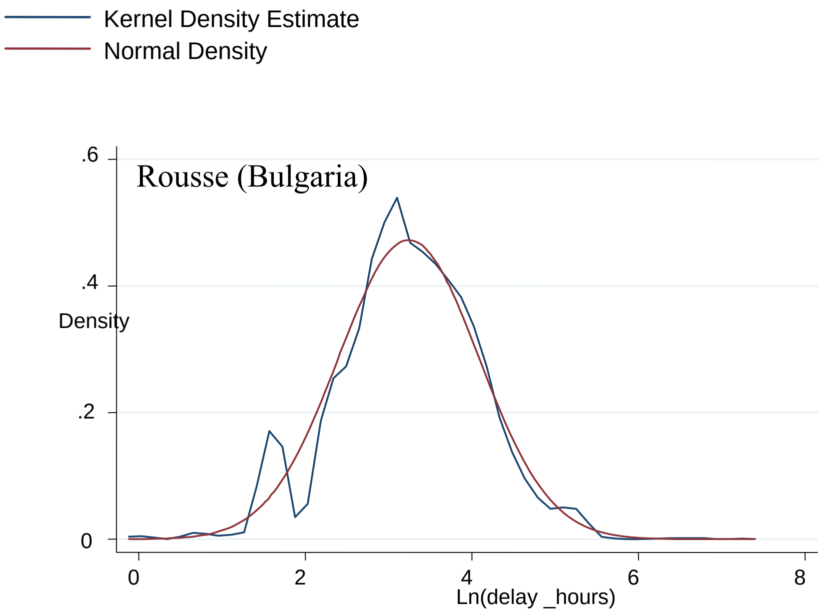
$\ln t(\text{days}) = \sigma \times \Phi^{-1}(\%dwelltime > t) + \ln(\mathrm{T}_{\text{median}})$, and the parameters are:

Σ	.774 (t=86)
$Ln(T_{median})$	2.08 (t=126)
R^2	.99
1997	Containers 60 cumulative values
Lowest-highest	Same day (1)- 79 days
Implied values	
CV	.91
T_{median}	8 days
T_{mode}	4.4 days
T_{mean}	11 days

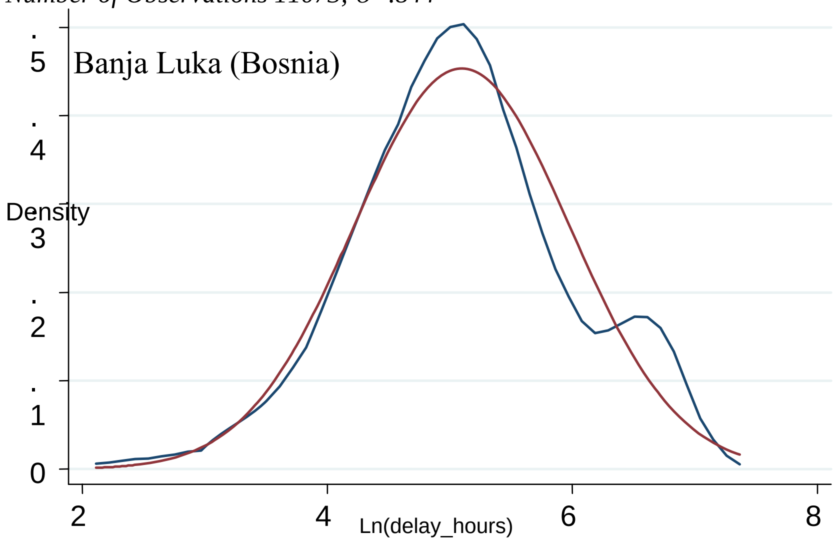
Example 2: Distribution of Delays Taken at Selected Entry Points in Eastern Europe

The source is a 2002 one month truck survey, implemented as part of the Trade and Transport Facilitation For Southern Europe Survey (TTFSE).

Observations are the delays (hours) experienced by trucks entering the country in transit.
Kernel densities are plotted for the logarithm of the delay as well as the fitting (log-normal) distribution.

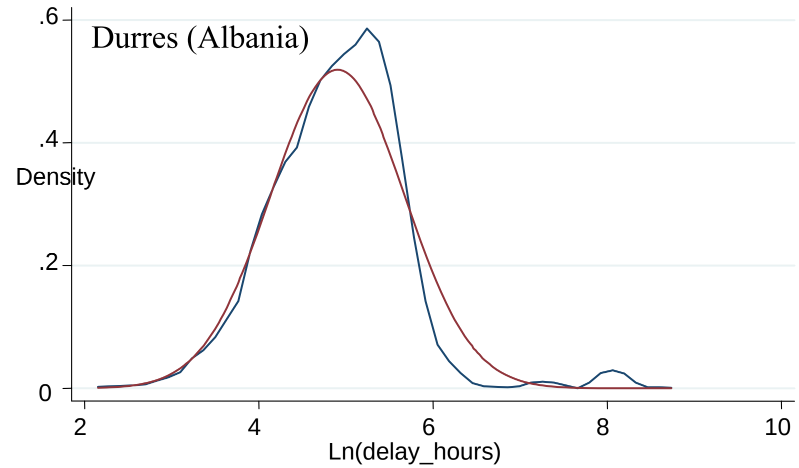


Number of Observations 11073, σ=.844



Number of Observations 913, σ=.88

Number of Observations 214, σ=.53



Number of Observations 1438, σ=.768

Simulation of the Optimal Inventory Level

According to the result (XXX), the level of inventory hedging the risk level γ is T(γ) given by ($\mu = \ln(T_{median})$):

$$T(\gamma) = \frac{\int_k^\infty \exp(u) \times \frac{1}{\sqrt{2\pi\sigma}} \exp(-\frac{(u-\mu)^2}{2\sigma^2})du}{\int_k^\infty \frac{1}{\sqrt{2\pi\sigma}} \exp(-\frac{(u-\mu)^2}{2\sigma^2})du} = \frac{\int_{k-\sigma}^\infty \exp(\sigma^2/2 + \mu) \times \frac{1}{\sqrt{2\pi\sigma}} \exp(-\frac{(v-\mu)^2}{2\sigma^2})dv}{\int_k^\infty \frac{1}{\sqrt{2\pi\sigma}} \exp(-\frac{(u-\mu)^2}{2\sigma^2})du}$$

where k is the number of standard deviation corresponding to the risk level γ (inverse standard normal function): $\gamma = \Phi(-k) = \int_k^\infty \frac{1}{\sqrt{2\pi\sigma}} \exp(-\frac{(u-\mu)^2}{2\sigma^2})du$ (A6)

Risk Level γ	Number of std dev k
10.0%	1.28
5.0%	1.64
2.5%	1.96
1.0%	2.33

Finally, the inventory level is simply related to the average lead time (over the minimum value) by:

$T(\gamma) = Tmean \times \frac{\Phi(\sigma - k)}{\Phi(-k)}$ (A7), combining this expression and the one for the coefficient in variation, the plot shows a quasi linear dependence of the ratio $T(\gamma)/Tmean$ upon the coefficient of variation, with rather steep multiplier. For a 5% risk level and a coefficient of variation of 1, the inventory level is about 4 times the mean (Fig A5-2). **These large multipliers are a consequence of the broad tail in the lead time distribution**. They are substantially higher than the traditional rule, based on normal distributions (Baumol, 1970). It adds to the mean a buffer time which is the number of standard deviations multiplied by a coefficient k which is the confidence interval of the normal law:

$Tmean + Tmean \times k \times CV$ (A8)

For instance, for a risk level of 5% the corresponding values for the two models are:

	CV	0.5	0.75	1
Proposed model	$T(\gamma)/Tmean$ log-normal pdf	2.41	3.29	4.17
"Traditional"	$T(\gamma)/Tmean$ normal pdf	1.82	2.23	2.64

Fig A5-2