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Container Repositioning and Agricultural Commodities: Shipping Soybeans by Container from US Hinterland to Overseas Markets
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Abstract
Export by container offers advantages for moving agribusiness products due to the availability of empty import containers that can be repositioned, making accessible inland “dry ports” more important in supply chains. This paper assesses the impact and challenges of increasing containerized movements of agricultural commodities from hinterland points to overseas markets, regarding both operations and governance. Products like soybeans have complex supply chains affected by weather, seasonality, price, equipment availability, congestion, modal delay, cargo ownership, and sustainability or product quality requirements. About 5-7% of the total US soybean export crop moves in ocean containers today; with business and governmental support, 12-15% could be attained, benefitting soybean producers, ports, ocean carriers, and shippers. Our case study of soybeans exported from the US state of Illinois examines a number of major operational issues, actions, rules and policies affecting this containerized flow and its total landed cost. One factor, delays in barge links, is studied with a commodity flow model combining product movement with container repositioning. Study of this case can shape operations practice and decisions for governance of intermodal agricultural product export movements.

1. Introduction
Issues of equipment balance and repositioning of equipment are of growing concern to the maritime industry (Hartman and Clott, 2014; Monios and Wang, 2014). Marine carriers optimize their inland intermodal network based on market demand and the ability to reload empty containers if possible for export destinations. Global trade economics suggests a trade-off between scale economies and transport costs; where a facility is located will have much to do with its supply cost and ability to serve
its potential customers. In the US, several inland dryport destinations have sufficient inbound density of intermodal container shipments and the ability to load export containers to meet demand.

Exporting bulk agricultural commodities from hinterland points in the Midwest to overseas markets has primarily used the lowest cost mode of transportation. Barges on the inland river system are cheapest for bulk transportation, yet are dependent upon public investment to maintain the inland waterway. Rail shuttle trains compete with barges and move goods on a privately funded rail network, faster but more expensively. Both methods rely on economies of scale. Lack of public investment in the US inland waterway system led to deterioration of locks and dams for barge moves (Kruse, 2011). Spot shortages of privately owned rail hopper cars and lack of bulk storage facilities in overseas markets have led agribusiness exporters to identify alternative modes of transportation. The use of ocean containers is a potential solution to moving soybeans for export if a balanced flow of international containers can be identified (Monios and Wang, 2014). To capture the flow of inbound loaded containers and match them to outbound transport lanes, many governance and operational issues must be addressed. These include local truck weight restrictions, investment in adequate storage/transload operations, and equipment availability (Ogard, 2012), as well as infrastructure maintenance and adequate traffic capacity for these products.

In this paper we analyze business decisions related to shipping more agricultural product in containers. We will use the export of soybeans in containers from the hinterland state of Illinois to address the question whether a potentially cost effective export supply chain can aid in the relocation of containers to points of origin, control landed cost, and meet enhanced soybean quality requirements. Can soybean container shipments be increased from the current small percentage of total exports (5-7%) to a larger level (12-15%)? What are the preconditions necessary for this increase, and what steps can ports and policy makers institute to develop additional export potential?

This paper is structured as follows: Section 2 briefly reviews literature on dryport development and its relation to agricultural exports; Section 3 describes the case scenario economics; Section 4 discusses characteristics of transport modes for soybeans; Section 5 analyzes directional flows, strengths and weaknesses; Section 6 models one factor, barge delays, affecting soybean flow and container positioning in this region; and Section 7 concludes with discussion, implications for management and scholarly contribution.

2. Dryport Development

Dryport development has spurred the clustering of logistical activities in locations actively integrated with supply chain management strategies (Rodrigue and Notteboom, 2012). Monios and Wilsmeier (2012) argued that the space and scale of competitive strategies can be understood by the drivers (e.g. port authority, port terminal, rail operator, public organization) and direction of development. The growth of intermodal in the United States has changed the function and layout of dryport terminals. Larger stacking areas, storage areas and higher turnover levels have created the need for large amounts of open space and ready accessibility to maritime and land transport (Wilsmeier et al., 2011; Rodrigue and Notteboom, 2011). Supply chain integration for container shipping has further changed shipper
behavior, with a premium on the ability to respond rapidly to volatile market changes and accessibility to key consumer markets (Lam and Van de Voorde, 2011).

A few intermediary or transshipment ports have developed with specific features, enabling a modal shift from road transport to rail or barge with overlapping service areas of individual inland terminals (Roso and Lumsden, 2010). These large load centers function as cargo bundling points to seaport destinations, or other points in the hinterland. The function of the inland terminal as a point for loading of empty containers is a byproduct of large distribution centers near the central location with intermodal gateway functions. Logistics pools develop by combining strong intermodal orientation with cluster advantages (Notteboom & Rodrigue, 2005). Synergies and economies of scale make certain hinterland locations attractive and encourage further concentration within the area (Van Klink, 1998; Rodrigue et.al., 2010).

The concept of a dry port as a logistics node for container moves of bulk agricultural commodities for export is relatively new in North America (Prentice, 2012). Ocean carriers, as asset owners, control pricing of the transportation they provide or purchase from suppliers such as railroads and trucking companies. The asset owner is ultimately responsible for repositioning empty equipment from surplus points to points of market demand. Shippers who can reposition equipment to desirable markets are often provided favorable pricing (Ogard, 2012). Agricultural commodities with proximity to transportation hubs can utilize a dryport as a connecting station for asset owners to enhance their competitiveness (Bichou and Grey, 2005).

Few inland US markets have inbound density of intermodal container shipments, the ability to load export containers to virtually every corner of the world, and a surplus of agricultural products for export. Large dryport hubs are located in the inland US State of Illinois. They are unique due to the amount of inbound and outbound cargo that transits, assuring an abundant supply of empty international equipment for export. Illinois and the Midwestern United States is also a fertile region with a gentle topography, a favorable climate and ample water. It has become the “breadbasket” for the world, due to highly efficient farms and its access to multiple forms of transportation. Soybeans are one of the state’s most prominent crops.

3. Study Area Economic Overview
US soybean products compete with product grown in Brazil, Argentina, Russia and Ukraine, among others to supply Asian, Middle Eastern and European markets. Agricultural products are extremely price sensitive and subject to constant fluctuations in supply and demand. Transportation costs are a major factor in whether or not the price is competitive in world markets.

Brazil is the biggest competitor to the US. Its peak season for export is May through September, whereas US exports peak October through February. Table 1 shows various costs for shipments to China. The Illinois-Iowa area had an approximately $30/MT advantage vs. Mato Grosso Brazil in December 2013, out of a total customer cost of nearly $600/MT (STC, 2014). However, averages for the 2013 year indicate advantages for Brazil of about the same size. If infrastructure development in Brazil takes place as planned (Salin, 2014), Brazil transport costs may drop. It is crucial for US costs to keep pace if containerized exports are to grow.
Illinois
Illinois was the largest soybean exporting state in the US in 2013 (the adjoining state of Iowa is also a major soybean exporter), with a value estimated at $3.1 billion and a production of approximately 461 million bushels (ILSOY, 2013; USDA/NASS, 2014). Shipments out of state are about 40% of that, with 35% transported by barge, 35% by rail, and 29% by container. Ninety two percent (92%) of these are for export to China, Europe and Japan; with the majority routed to Midwest and Southeast ports (Eriksen, 2013). Soybeans represent almost 2/3 of all container export agricultural inspections, dwarfing corn and wheat (Eriksen, 2013). Major firms such as Archer Daniels Midland (ADM), Cargill, Louis Dreyfus, and Bunge are involved in all phases. Containerized soybeans for export have grown every year and are now about 8% of the Illinois market. (Ogard, 2012). Inland intermodal locations at Rochelle, Joliet, and DeKalb in Illinois are important container export points for the beans.

Rail carriers are most efficient when they can run full trains from one market to another without intermediate stops. Illinois is one of the few which can support a railroad operating model (Figure 1, USDOT/FHWA 2014). Illinois exports can also use the U.S. inland waterway system (Figure 2, Meyer 2007), with more than 238 locks. Approximately 58% of US farm exports currently move by barge to facilities on the lower Mississippi River where they are loaded on oceangoing bulk ships (Steenhoek, 2013).

4. Transport Modes for Soybeans

**Barge and Rail Hopper Cars**
Movement of bulk quantities of soybeans for export traditionally used river barges through the U.S. inland waterways system to Gulf ports such as New Orleans. For crop producers located more than 60 miles away from the river barge networks, railroad shuttle trains have been an economic transport alternative. These range from 60-120 railcars and move to coastal ports for transloading to bulk vessels. Both rail and barge are more cost effective than trucking due to their ability to move large quantities of heavy dense product efficiently with a minimum of handling. Rail is about 3 times more expensive than barge ($90.91/MT vs $25.98 recently (USDA/AMS, 2014b) but typically moves product to Atlantic or Pacific ports for export rather than Gulf ports, for better transit times.

Table 1 Customer costs and transportation costs from US and Brazil to Shanghai, December and year average.

<table>
<thead>
<tr>
<th>Costs from Davenport IA</th>
<th>Mato Grosso, BR</th>
<th>Davenport IA</th>
<th>Mato Grosso, BR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product cost</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec-2013</td>
<td>Dec-2013</td>
<td>All 2013</td>
<td>All 2013</td>
</tr>
<tr>
<td>Ocean</td>
<td>$466.64</td>
<td>$445.27</td>
<td>$517.76</td>
</tr>
<tr>
<td>Barge</td>
<td>$54.13</td>
<td>$42.50</td>
<td>$46.76</td>
</tr>
<tr>
<td>Rail</td>
<td>$33.90</td>
<td>$21.38</td>
<td></td>
</tr>
<tr>
<td><strong>ADVANTAGE</strong></td>
<td></td>
<td>27.93*</td>
<td></td>
</tr>
</tbody>
</table>

*IA transport cost for year is a blend of rail and barge since river freezes part of year; customer cost reflects blend.
Barge delays can vary from hours at each lock to days over the entire journey, adding significantly to total landed cost and uncertainty of product delivery. Half the locks are over 50 years old and one third over 75 years old with a useful designed life of river locks of approximately 50 years (Kruse, 2011). Major maintenance and rehabilitation investments have prolonged the useful life by about 50% from the original designed lifespan, but time is running out on these life extending measures (Ford, 2013). Control and maintenance of the inland waterway locks in the United States has long been under the U.S. Army Corps of Engineers, with deferred maintenance issues threatening the reliability of the overall system (Belz, 2013; Kruse, 2011).

Due largely to uncertainties of barge transportation, farmers are looking to rail lines to haul shipments from the Midwest for export. The western based BNSF, Union Pacific (UP), and Canadian National (CN) Class I railroads have made significant capital investments in rail transport and terminal expansion to move agricultural shipments from the Midwest to the West Coast. In 2013, private sector rail capital investment approached $24 billion (AAR, 2014). The Eastern US based Norfolk Southern (NS) and CSX Transportation railroads have upgraded capabilities in the East and Southeast US to handle agricultural exports to growing ports on the Atlantic Ocean and Gulf of Mexico. However, rail costs have increased more than barge freight rates, and the movement of shale based energy inputs such as fracking sand and oil machinery as well as tank cars of crude oil has caused rail capacity and congestion issues in the Upper Midwest US (Doering, 2014). The increased competition for unit train capacity has created a scenario for rising rail prices; Meyer (2007) modeled a potential 25% increase for agricultural products. Since the rapid adoption of corn to make ethanol, the majority of rail hopper cars are utilized for grain moves out of the Great Plains states, (Minnesota, North and South Dakota, Nebraska, Kansas) to the ports of Tacoma and Seattle (Prentice, 2003; Keith, 2013).

**Containers**

A simple economic advantage for moving soybeans in containers is eliminating competition for scarce rail bulk equipment capacity. Containerized soybeans can move with other intermodal rail cargo, subject to those tariffs, rather than potential price increases for bulk movements. Unit trains for soybeans could be built at some depots, but others could mix soybean containers with other intermodal traffic, say machinery or retail product export in containers. Rail congestion affects intermodal traffic, of course; but there would be increased flexibility in routing, improved reliability, potentially quicker scheduling and movement, and pricing commensurate with other containerized loads. Railroads would have increased cargo to build large intermodal trains for moves to ports.

The need to segregate 'Identity Preserved’ product, which can be traced throughout the chain and can be distinguished from Genetically Modified Organisms (GMO’s), is essential to global soybean buyers (Stein and Rodriguez-Cerezo, 2010). Containerized shipping helps buyers maintain a traceable link between the point of origin, the seeds used, and the designated overseas buyer.
Figure 1 Tonnage of intermodal TOFC and COFC moves, 2011. Source: USDOT/FHWA, 2014.

Figure 2 River and Lock system in central US. Lagrange Lock is key for Illinois soybeans. Source: Meyer, 2007.
The process of linking origin to destination is very difficult in bulk moves designed to channel large volumes from multiple farms that export via barge or hopper car. Few international buyers of soybeans desire a full bulk ship load, or the entire contents of one hold. It is not economical to charter a ship unless it is nearly full, so cargoes are often layered in holds separated by plastic tarpaulins. This increases the possibility of contamination or mixing of one crop by another, posing potential quality and identity problems. Crops that can be traced to a specific growing region and seed stock can bring a higher price. A buyer who pays a premium for a soybean with superior protein content expects all to meet a minimum standard. Contaminated shipments may require additional testing or be refused altogether (Kosior, et. al, 2002).

Soybeans loaded in containers are not subject to additional handling and can be more easily traced back to the origin so the specific characteristics of a shipment are what were contracted for. Containerized soybean exports can be bagged for more expensive food grade soy, shipped in ventilated containers, or blown into an ordinary container and distributed by means of an auger. Containerized cargo can be certified and move intact to interior markets in China which typically have little to no storage. Grain bulk terminals in China and some other countries are less efficient than container terminals, where there has been more modernization to support export growth (Merk and Deng, 2012). Other benefits for soybean producers include scheduling to meet capacity and minimize inventory holding costs. Containers allow for expanded transportation alternatives with minimum public sector investment if they can be loaded at the terminal to full visual capacity of the container (Kulisch, 2013).

There are some problems with the export of agricultural commodities like soybeans in containers.

1) Soybeans loaded away from the rail terminal must conform to Federal, State and Local truck size and weight rules or apply for a permit to move on public highways. Growing concern has been expressed about the damage to highways as a result of overloaded containers; Bilal (2010) estimates overweight trucks approximately quadruple the highway maintenance cost per 1000 mi traveled, from about $100 to about $400. But others (Informa, 2009) say modest weight limit increases, sufficient for fully loaded soybean containers, may cause less damage by reducing miles. State and local truck size and weight regulatory governance limits the potential of container exports (Reese, 2010); smaller rural communities with roads that move agricultural products want to recover increased maintenance costs through local overweight permits, adding increased transaction cost and delay to each move. Policies to unify permitting and weight limits have proved very difficult to implement because of these local interests (Greuling, 2013).

2) Product is located on farms far from the cities that are typically destinations for containerized imports. To alleviate this, import steering alliances, or “matchbacks”, are being pursued by major importers, exporters, ocean carriers and merchandisers, to coordinate supply chains and attempt to utilize inland rail hubs as points for container consolidation (Leach and Mongelluzzo, 2013).

3) The seasonal nature of agricultural production concentrates high demand during particular harvest periods, and must be balanced against variable import demand for consumer goods (Leach and Mongelluzzo, 2013). 75% to 80% of all U.S. export soybeans move in the September to February period,
prior to the South American harvest season, to maximize farmer profit (Keith, 2013). Containers must be available at that time to be used for export.

4) Crop yields can rise and fall dependent upon weather related variables from year to year. Drought periods can stay for multiple years while bumper harvests can be difficult to predict with certainty. The hedging of prices for agricultural commodities through institutions such as the Chicago Board of Trade (CBOT) has long been in place to manage these supply and demand discrepancies. This means that cargo ownership can change during transit. Both price and supply volatility challenge operations planning and governance has limited effect in the US in these areas.

5) The heavier weight of agricultural commodities bulk or bag loaded into containers creates the need for 20 foot containers that will weigh out vs. predominant moves of consumer imports in 40 foot containers that cannot be loaded to full cubic capacity with soybeans, due to truck size and weight restrictions on U.S. highways. There is relatively less demand for imports of 20’ containers in the interior of the U.S. compared to 40’ containers. Containers may be loaded on a truck scale to meet weight distribution limits for over the road movement, and to comply with ISO standards for containers for cargo carriage. Blocking and bracing is required to protect whoever opens the container door from product cascading over workers. As ocean carriers have largely ceased to provide wheeled chassis for U.S. moves, truckers, transloaders and draymen are investing in the more robust apparatus for legal permitted movement.

6) Timing issues regarding rail cut-offs to the West Coast put a premium on the ability to share information electronically on the location and status of equipment. Agricultural shipments tend to move in very large quantities requiring 50-80 containers for a single load, with attendant storage costs and limitations of trying to manage the inventory (Clott, 2014).

5. Directional flows
Constraints on long haul trucking due to a driver shortage and rising fuel costs have created new market opportunities for the major U.S. rail carriers. They have invested heavily in developing intermodal terminals where there is space for containers to be mounted or unloaded from rail cars, and where there are available chassis to move product for short hauls. An industry transition in the United States from ocean carrier owned and managed pools to a new business model in which pool operators, trucking and leasing companies supply wheeled chassis is changing the business and responsibility for equipment management.

Market demand creates “headhauls” from original import to consumer, and equipment moves with the load. “Backhauls” are needed to help reload containers and relocate them to an import market. Headhauls often pay a premium for transportation, with a nominal repositioning fee included in the overall rate. Backhauls are needed to get equipment back in circulation. The oversupply of ocean capacity in recent years has led carriers to avoid empty repositioning costs. Many ocean carriers reduced the number of inland points they support and simplified inland networks. If a lane was not balanced, carriers might discontinue service. For example, Canadian Pacific Railroad recently closed the Milwaukee Intermodal Terminal and now Wisconsin exporters must truck containers to intermodal load
centers in Illinois (Ogard, 2012). Supply chain integration, driven by improved inventory management by retailers, is reducing transportation costs for shippers (Lam and Van de Voorde, 2012). Transloading and cross dock consolidation have lowered cycle times for transportation equipment. Shippers who can reload equipment quickly for preferred markets in Asia can enjoy beneficial export rates (Ogard, 2013). The key to this integration is the information on where ocean containers are. The United States Department of Agriculture launched the Ocean Shipping Container Availability Report (OSCAR). It tracks various container sizes and provides a forward looking estimate of capacity. Weekly updates are provided by ocean carriers of the Westbound Transpacific Stabilization Agreement. Private firms such as Loadmatch.com in the Chicago area provide lists of drayage companies and terminals for the intermodal industry. The Drayage Dictionary website also links drayage providers with product shippers (Ogard, 2013). But there can still be a delay before a container gets returned.

Governance issues are also a factor for agricultural products. Many states, since the 1930’s, have imposed regulatory separation between farmers and elevators, to assure farmers get paid for their crops. Larger farmers may invest in on-site storage so they can hedge sales each month in order to take advantage of fluctuating demand; most small farmers sell to local elevators because they lack it. Farmers must sell to merchandisers or local elevators, unless they are federal export certified to sell directly to international buyers. Few choose certification because of the reporting and documentation required; but many Asian buyers want to buy soybeans directly from the farmer. Recently, transloading firms have located at Midwest intermodal locations. They fill ocean containers within intermodal complexes with private roads, so that overweight containers can move without permits. Transloaders also locate near barge sites for container on barge (COB) moves through the inland waterway via container (Clarkson, 2013). Currently there may be an oversupply of transloaders (Ogard, 2013).

The advantages of putting soybeans in containers for export are many, but clearly there are operational and governance challenges if this export supply chain is to increase to almost double the number of containers that flow today. As an example, we look in more detail at the effects of barge link delays on the matching of containers with product.

6. Modeling effect of delay cost on soybean chain

Coping with delays in this regional soybean export supply chain is an important managerial issue. Delays en route to the port, particularly on a barge link, not only raise the total shipment cost, but could substantially alter supply paths and flows, making planning for capacity and deploying empty containers difficult. From a policy standpoint, cost increases affect the competitive position of US farmers relative to Brazil, the major competitor, for export markets; unreliable and untraceable delivery patterns also discourage foreign purchasers. Operationally, the increased variability is hard to manage; the peak season of October through February stresses capacity, making delays more costly. Such factors could prevent increasing container exports of soybeans from the region. Management and policy efforts might be needed to reduce these delays.

To estimate the possible size of the effect, a multiple objective container matching model was constructed. Such flow models have been used for related problems. Kuroda, et. al (2005) model ocean carrier service link scheduling and shipper route selection networks in Japan, constrained by supply of
slots equaling shipper demand, and link prices set via perfect competition, fixed by cost per demand unit. Iannone (2012) models port hinterland distribution in Campania, Italy for containers by rail or truck modes, emphasizing social and environmental cost and transport cost, using a Nash equilibrium constraint. In our model the supply chain, led by customer demand, optimizes flow costs from a selection of source nodes to its destinations, considering the cost of obtaining boxes in the right place from a box source node, and the use of different modes of transport.

Figure 3 is a typical product network. Farms or local elevators (F) are product supply nodes. Distribution (D) nodes receive product from F sites via FD links, and move it onward, transloading from bulk to container. The chosen FD link depends on proximity, cost, and capability. For instance, some D nodes might provide drying or packaging services, whereas some farmers have those capabilities at the farm or local elevator. Port (P) nodes provide containerized export service by ocean; they can export anywhere, but some routes would be cost prohibitive, or there might be uneconomical multiple hop service. They could also transload on premises, receiving bulk beans, though not in our example. Some D nodes link directly to ports via a DP link, or to other distribution nodes via a DD link. Customer (C) nodes have demands for product, and are reached by PC links from P nodes.

There is an overlapping network of box nodes (B), sources of containers suitable for the crop. They might be existing nodes, such as P and D nodes, or might be other sources of boxes (O nodes), such as nearby intermodal facilities or retailers. B nodes have a supply of containers, and connect via BF or BD links to each node that loads beans for export.

Each F node has a supply measured in container loads. A FEU for export holds about 23.6 MT (metric tonnes) (866bu) and a TEU about 17.24MT (633bu), the production of about 18 or 13.1ac on an Illinois farm, based on current truck weight limits in Illinois (ILSOY, 2012; STC, 2009). Direct rail loading of containers or use of overweight permitting would allow loading up to about 56000 lbs. or 25.40 MT in
an FEU. An earlier study (PLC, 2006) indicated only 733 bushels per container on average. Material price at the F node for the product is separate from the transport cost, and depends on quality and processing. C nodes have demands similarly measured. Each product link has a capacity and a cost; box links have only a cost of deployment of the box, which assumes carriage can be found for deployment trips. Separate links are identified for modes truck, rail, barge, and ship. In the example, links PC are only ship; links FD are only truck. Because of the particular geography modeled, DD links are only truck; but DP links may be truck, rail, or barge.

Optimization of the two interlocking networks, for product flow and box provisioning, first minimizes cost of product transport by selecting paths for product, and then box movement cost, linked by requiring product demand be satisfied by movement of box supply. In an agricultural environment, when product is ready it must move; the model covers a short time frame, with static assumptions about costs and contracting.

A small example emulates a freight forwarder securing the lowest cost for two customers. It uses a few regional F locations, certain barge and rail D nodes, one O node, and a small set of possible export ports, with two C nodes, Busan, Korea and Tin Can Island, Nigeria (4th largest importer of US soybeans) ordering in the same time frame. Link costs were estimated using available data (USDA/AMS 2014a; Steenhoek, 2013; Ogard, 2012), and some field research with carriers.

Link delay can occur through port congestion, handling and loading; rail and barge availability issues; waiting for equipment; yard congestion; contention for delivery slots; or waits for a run, and applies to PC links and to modal DP links. Box delays apply to B nodes; these could be locating a container to use, finding drayage, and delays on the move itself. Delay produces an increase in cost (Kuroda et al, 2005), using an increasing exponential function of a ratio U of usage to capacity; \( d = \alpha U^\beta \). Linear delay cost functions have been used in the literature also and \( \beta=1 \) captures these; here delay cost escalates with the congestion or time, and \( \beta>1 \) is appropriate (Mallinckrodt, 2010).

**Table 2 Model variables, parameters, and calculated quantities**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Relevant Links/nodes</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>( X_{ij} )</td>
<td>No of containers of beans moved on link ( ij ) (by mode ( m ))</td>
<td>FD, DD, DP, PC</td>
<td>Choice, integer</td>
</tr>
<tr>
<td>( Y_{ij} )</td>
<td>No of empty boxes moved on link from ( i ) to ( j )</td>
<td>BF, BD</td>
<td>Choice, integer</td>
</tr>
<tr>
<td>( C_{ij} ), ( C_{ijm} )</td>
<td>Cost of moving one loaded container on link ( ij ) (using mode ( m ))</td>
<td>FD, DD, DP, PC</td>
<td>Parameter</td>
</tr>
<tr>
<td>( B_{ij} ), ( B_{ijm} )</td>
<td>Backhaul cost of deploying empty container via link ( ij ) (using mode ( m ))</td>
<td>BF, BD</td>
<td>Parameter</td>
</tr>
<tr>
<td>( F_{supply} )</td>
<td>Supply of beans at node ( i ) (containers)</td>
<td>F (nodes)</td>
<td>Parameter</td>
</tr>
<tr>
<td>( Demand_{j} )</td>
<td>Demand of beans at node ( j )</td>
<td>C (nodes)</td>
<td>Parameter</td>
</tr>
<tr>
<td>( B_{supply} )</td>
<td>Supply of Boxes at node B</td>
<td>B (nodes)</td>
<td>Parameter</td>
</tr>
<tr>
<td>( d_{ij} ), ( d_{ijm} )</td>
<td>Delay or congestion cost added to link ( ij ) (by mode ( m )) as percentage of link cost</td>
<td>DP, PC</td>
<td>Calculated</td>
</tr>
<tr>
<td>( d_{i} )</td>
<td>Delay or congestion cost added at node ( i ) for provision of empties</td>
<td>B (nodes)</td>
<td>Calculated</td>
</tr>
<tr>
<td>( Req_{b} )</td>
<td>Net requirement for boxes at node ( b )</td>
<td>B (nodes)</td>
<td>Calculated</td>
</tr>
<tr>
<td>( Out_{b} )</td>
<td>Net boxes sent out at node ( b )</td>
<td>B (nodes)</td>
<td>Calculated</td>
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<tr>
<td>TC</td>
<td>Transport cost</td>
<td>Network</td>
<td>Objective</td>
</tr>
</tbody>
</table>
Table 2 specifies the variables and parameters for the model. Table 3 gives the formulation. Objectives 1-2 are minimized in order, assuming backhauls will be found because timely bean shipment is of first
priority. Constraints 3-6 express the material balance in beans; all demand is met, all supply shipped if
feasible, and intermediate nodes do not store. Constraints 7-9 express a similar balance for boxes;
supply is not exceeded and all shipments get a box. Constraints 10-11 assure that box supplies at B
nodes are not exceeded. Auxiliary constraint 12 calculates the box output at a B node, and 13-14
calculate net box requirements at nodes which have flows in and out.

<table>
<thead>
<tr>
<th>Description</th>
<th>Objectives</th>
<th>ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize TC =</td>
<td>Σ_bj e F C_0 X_bj + Σ_ijm e DD C_ijm X_0jm + Σ_ijm e DP C_ijm X_0jm (1 + d_ijm) + Σ_ik e PC C_ik X_ik (1 + d_ik)</td>
<td>1</td>
</tr>
<tr>
<td>Minimize BC =</td>
<td>Σ_bj e BF B_0j Y_bj (1 + d_bj) + Σ_ik e BD B_0j Y_0j (1 + d_bj)</td>
<td>2</td>
</tr>
<tr>
<td>Bean Balance constraints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance (f e F)</td>
<td>Σ_bj e F D_bj X_bj ≤ F_supply_f</td>
<td>3</td>
</tr>
<tr>
<td>Balance (d e D)</td>
<td>Σ_ijm e DD X_ijm + Σ_ijm e DD X_ijm = Σ_ijm e DD X_ijm + Σ_ijm e DP X_ijm</td>
<td>4</td>
</tr>
<tr>
<td>Balance (p e P)</td>
<td>Σ_iqm e DP X_0jm = Σ_pj e PC X_pj</td>
<td>5</td>
</tr>
<tr>
<td>Balance (c e C)</td>
<td>Σ_ib e PC X_ib ≥ Demand_c</td>
<td>6</td>
</tr>
<tr>
<td>Box Balance constraints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance (b e B)</td>
<td>Σ_bj e BF Y_bj ≤ B_supply_b + Req_b</td>
<td>7</td>
</tr>
<tr>
<td>Balance (f e F)</td>
<td>Σ_ijm e BF X_fjm Y_fjm = Req_f</td>
<td>8</td>
</tr>
<tr>
<td>Balance (d e D)</td>
<td>Σ_ijm e BD Y_idm = Req_d</td>
<td>9</td>
</tr>
<tr>
<td>Box Capacity constraints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity (b e O,P)</td>
<td>B_supply_b ≥ Σ_bj e BF Y_bj + Σ_bj e BD Y_bj</td>
<td>10</td>
</tr>
<tr>
<td>Capacity (b e D)</td>
<td>B_supply_b + Σ_ijm e BD X_ijm Y_bj + Σ_ijm e BD X_ijm Y_bj + Σ_ijm e BD X_ijm Y_bj ≥</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Σ_bj e BD X_bj + B_supply_b</td>
<td></td>
</tr>
<tr>
<td>Calculated variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outb (b e B)</td>
<td>Σ_bj e BD, BF Y_bj = Outb</td>
<td>12</td>
</tr>
<tr>
<td>Req_b (b e F,B)</td>
<td>Req_b = F_supply_b - B_supply_b</td>
<td>13</td>
</tr>
<tr>
<td>Req_b (b e D,B)</td>
<td>Req_b = Outb - B_supply_b</td>
<td>14</td>
</tr>
</tbody>
</table>

We used AMPL modeling language (Fourer et al, 2003), NEOS (Dolan, 2001) server, with MINLP (Leyffer,
2014) optimizer. Runs were made with business as usual (BAU) and increased delay (Delay) penalty on
the barge link, such as would occur if a lock was disabled for maintenance with reduced traffic capacity.
BAU results were shipping cost of $344549 for 200 containers; with Delay, shipping costs rose to
$358986, from decreased use of the cheap barge link, a difference of $72.19 per container or about
$3.06 per MT. These are similar to Kruse (2011), who independently estimates a $2.45 per MT decrease
in price from the closure for 2 weeks of La Grange Lock on the Mississippi River, serving this region. This
10% of the swing between Brazil and the US in Table 1 would disadvantage US soybean exports, and
make increasing exports by intermodal means harder. A concurrent rail intermodal price increase would
be even worse (Meyer, 2007).

Table 4 shows movements on links under BAU and Delay conditions. Empty container deployment did
not change, as expected. Routings by barge from Quincy to New Orleans went from 88 to 49, a 44%
reduction. Changes in source occurred as well, with three F nodes switching D location, one by 83%. F
node changes affect specific farmers; changes at D or P nodes affect volumes at those inland ports, and would significantly impact port and distributor planning and profitability. This variability is of significant terminal management concern, especially at the inland D ports, and governance and operational measures to eliminate potential barge delays might be called for. Pricing will not be effective in resolving the problem; cost of fixing the delay is exogenous to the shipping market.

Price differences at farms (due to quality or handling) also could motivate buying from specific farms and leaving others out; these would affect transport costs through selection of F nodes, and would also affect choice of supply routes; but in our model all beans were shipped and the farm price paid.

Table 4 Supply link container volumes, business as usual (BAU) and Delay, with changes.

<table>
<thead>
<tr>
<th>From / To</th>
<th>BAU</th>
<th>Distribution</th>
<th>Delay</th>
<th>Change (% of total shipped from)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 B61368</td>
<td>25</td>
<td>7 Quincy</td>
<td>0</td>
<td>-83%</td>
</tr>
<tr>
<td>2 K60560</td>
<td>25</td>
<td>8 Decatur</td>
<td>0</td>
<td>+83%</td>
</tr>
<tr>
<td>3 S51053</td>
<td>18</td>
<td>7 Quincy</td>
<td>14</td>
<td>-10%</td>
</tr>
<tr>
<td>4 S61774</td>
<td>0</td>
<td>8 Decatur</td>
<td>0</td>
<td>+10%</td>
</tr>
<tr>
<td>5 TISK5</td>
<td>0</td>
<td>7 Quincy</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>6 W61473</td>
<td>20</td>
<td>8 Decatur</td>
<td>14</td>
<td>-30%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>From / To</th>
<th>BAU</th>
<th>Distribution</th>
<th>Delay</th>
<th>Change (absolute quantity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 QUINCY</td>
<td>98</td>
<td>10 New Orleans</td>
<td>39</td>
<td>-59</td>
</tr>
<tr>
<td>8 DECATUR</td>
<td>5</td>
<td>11 Norfolk</td>
<td>24</td>
<td>+19</td>
</tr>
<tr>
<td>Total</td>
<td>103</td>
<td>12 Los Angeles</td>
<td>63</td>
<td>+24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>From / To</th>
<th>BAU</th>
<th>Port to Consumer</th>
<th>Delay</th>
<th>Change (absolute quantity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 NORLEANS</td>
<td>79</td>
<td>13 Busan</td>
<td>41</td>
<td>-38</td>
</tr>
<tr>
<td>11 NORFOLK</td>
<td>18</td>
<td>14 TincanIs</td>
<td>40</td>
<td>+22</td>
</tr>
<tr>
<td>12 LOSANGELES</td>
<td>53</td>
<td>13 Busan</td>
<td>69</td>
<td>+16</td>
</tr>
<tr>
<td>Total</td>
<td>150</td>
<td>14 TincanIs</td>
<td>150</td>
<td>-</td>
</tr>
</tbody>
</table>

**relocated BD then used on farm**

7. Discussion and Conclusion

Summary

Containerized soybean delivery chains for export are of growing interest in the US and elsewhere due to a convergence of supply chain interests. Export customers want traceable product while merchandisers want to preserve quality. Ocean carriers want to reduce empty repositioning costs while railroads would like to make more money on full loads vs. empty repositioning rates. Overall, export operations
desire the means to adjust to volatility in the many system factors. Illinois, a chief soybean producing area, is located where import containers are available for backhaul, offering maximum potential to increase this trade. Several factors which enhance and impede it are highlighted by this study.

1. Preserving low transportation cost and reliability on inexpensive barge links is important in maintaining the competitiveness of U.S. sources. Significant challenges to the global position of the US in agricultural exports could arise from catastrophic lock failure or unscheduled closure (Kruse, 2011). These not only impact cost, but force supply chain alterations and increased volatility due to reliability issues and equipment pricing and availability. Limiting delay and keeping infrastructure in operating order requires infrastructure investment to repair key locks and dams along the inland waterways. The United States Water Resources & Reform Development Act signed into law in June, 2014 will provide some badly needed federal funding to begin infrastructure repairs. The majority of soy and agricultural products from the US Midwest, containerized or bulk, will still need to move to overseas markets from inland points via barge. Investment in more containerization will not increase substantially without effective container barge movements.

2. An adequate supply of empty containers of the right kind is crucial because of the limited opportunity to move product. Locations within competitive trucking distance to the Chicago metropolitan region, for example, can benefit from the existing imbalance of imports over exports, but the supply chain manager must be able to match available containers to product loads. While Illinois has an advantage over neighboring states in access to transportation and speed to market, these can be replicated elsewhere in slightly different configurations. In the US, Kansas City and Memphis are major points for potential consolidation of agricultural product in ocean containers. With increased information about availability and routing status, major Asia-to-Europe transit points could determine the volume of product that might be nearby and available to be loaded in a cost effective manner. Freight intermediaries are the best informed stakeholder group with the most up to date information on where the equipment shortages and surpluses are, what carriers’ requirements are, and what regulatory issues might be changing. Visibility of loads and containers is therefore the key to making the process work. State and local agricultural agencies such as the Illinois Soybean Association work in collaboration with farmers and intermediaries to share information on transport and determine what types of beans are needed for unique markets. Cooperative information exchange is often viewed as risky by competing supply chain participants; government initiatives like the OSCAR report can help make the participants more competitive globally. As with container drayage in general, matching truckers with loads one by one has proved effective in improving turnaround, and 3PLs can also facilitate it if they and their clients benefit rate-wise.

3. Rail to the West Coast is the next most competitive option to barge, and players on these links have both incentive and resources to apply to the problem. Any faltering in the barge arena will allow the long distance rail links to benefit. Rail lines profit more from bulk cargo transport in shuttle trains which move hopper cars than from container moves of low value product. The interest of ocean carriers as container owners is to negotiate rail rates from particular inland markets on market volumes, balance and density. Hence rail operators’ desire to invest is conditioned by the current low volume of containers relative to bulk traffic. However, when bulk rail loading is constrained by lack of cars, and
prices rise, shippers may be able to moderate rates by using containers, which may be mixed with other containerized product on unit trains. Containerizing also increases flexibility of routes, a help in congested periods.

4. Network models inform supply chain design by customers in this market and also allow investigating sensitivity of route choice to important factors: supply, demand, empty container positioning, on farm product cost, and costs of transit, delay and congestion. Delays cause substantial realignment of supply networks, even when demands are met. With complex multi-player supply chains, instability will tend to reduce cooperative partnerships. Producers, processors, and soybean elevator operators (storage), as well as governance, using modeling, can be informed about effects of changes.

5. Variability in agricultural movements is a problem, unlike some other cargo. Planning begins for farmers many months before the crop is planted; the seed selected and the land used depends on the market the product is destined for. Producers investing in on-farm storage are better able to utilize the container option and hold their product until market prices meet objectives. Modeling inventory position, effects of futures vs. spot pricing, container placement options, and supply of empties would be valuable extensions.

**Contribution to Scholarly Knowledge**

Transport of food related commodities by container in specialized supply chains such as soybeans has not often been addressed in the academic literature to date. Containers will play an increased role in agricultural exports, and other agricultural export chains could face similar governance and operational issues. This research on policies or practice that enhance private sector equipment flows could benefit other commodities such as scrap, food and raw materials. With increasing standards of living of countries in Asia and elsewhere, innovative ideas to address the empty container problem should include more sophisticated modeling of port choice (Monios and Wang, 2014). The soybean export chain in Illinois provides a look into the future of this trade, identifies factors necessary for success, and governance and operational issues impeding it.

**Implications for Managerial Practice and Policy**

Analysis of the UK port system by Wilmsmeier and Monios (2013) suggested that container imbalances will hurt dryports in peripheral regions with fewer direct links to the volume of transportation options at larger regional ports. This is occurring for soybean producers in the neighboring state of Iowa that are hard pressed to find adequate equipment to ship their product. We suggest that overall transportation costs should be part of larger issues of state and regional infrastructure development. Small steps are happening now, but the US has to date not done the type of overall transportation planning commonly done elsewhere. This case shows that attention to supply chain details is an operational necessity, and affects longer term planning and regional policy initiatives governing trade.

The total landed cost of commodities has a direct impact upon their competiveness in the marketplace. The soybean container case shows that policy makers must understand the variables and timing that make up transportation costs. Local, state and federal levels must harmonize to achieve overall
transportation objectives. The Illinois State Freight Advisory Committee has strongly urged statewide and regional partners from the public and private sectors to build an economic development freight coalition creating a state freight plan and supportive public activities (ISFAC, 2014).

**Conclusion**

The critical nature of key export products such as soybeans demands coordination of information, supply chain visibility and collaboration to improve competitiveness and increase reliability while limiting costs. Partnerships between neighboring states and regions can be problematic due to the political process; however solutions that benefit all participants are particularly important, due to factors exogenous to the markets. Addressing key regulatory barriers such as weight limits demand joint solutions to succeed.

Further research in agricultural product containerization could include regional characteristics differentiating dryports by shipper and carrier needs. More study is needed on visible, flexible supply chains that can allow producers and consumers to adjust readily to risk. Better governance and operational practice in agricultural exporting and container repositioning should accompany increased collaboration and information sharing.

**References**


