NCHRP 8-43 –

Tutorial 3: Linked Trips & Markets

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1. Introduction

Complex supply chains and national and international economic integration implies linked trips and markets. In general, commodities are dug out of the ground or grown somewhere, usually some distance from locations where they are processed and markets where they are consumed and converted into waste, which itself has to be either recycled or disposed of in some manner.

Understanding these linkages between economic sectors and understanding the economic geography of the nation turns out to be critical to understanding freight flows. Freight movement is a derived demand, and forecasting the driving relationships between industries of goods production and consumption can be more helpful than attempting to forecast flows directly using either a factoring method or a trip generation method. On the other hand, freight commodity flows are one of the easier quantities to measure, compared to the underlying economic activity that drives it.

1.1. Linking Trips and Markets

The first step towards a better understanding of the supply chain is to match up trips on the same mode to produce origin-to-destination flows (e.g. Railroad re-billing in Chicago; matching inbound and outbound shipments through a transshipping center) and the chaining of trips through terminals without changing the ultimate destination. The next step is to match up shipments intermodally (e.g. matching air markets to air facilities). A third and final step is to use an input-out matrix to understand the relationship between raw materials movement, manufactured product movement, and scrap movement. We will not be treating the economic modeling aspect of this task in detail, but we will present examples of how these matching might be done to create linked trips and to understand the supply-processing-consumption relationships.

2. Some Analytic Examples:

One of the best ways to understand both the challenges and opportunities of linking trips is to review a series of actual examples. Those selected for this discussion reflect the following scenarios:

- Linking trips within a single mode; The Railroad Re-billing Problem.

- Linking trips between modes; Air Cargo Markets and Facilities.
- Linking industrial supply and consumption markets; Input-Output Modeling.

In each of these examples, the problem is identified, along with the specific data linkages that are missing. There is an explanation about why the data linkage is important, what steps modelers have to match the different data to affect the linkage.

1.2. Linking Trips; The Railroad Re-billing Problem

1.2.1. Background

Prior to deregulation in the 1980's, railroads were required to publish rates that covered movements from the origin to the destination, whether or not these flows represented "local" (single railroad at both origin and destination) or "interline" (different railroads at origin and destination) movements. Rates were published in widely distributed tariffs generally based on combinations of commodity, car type, and mileage, and railroad revenues were divided based on established "divisions" of revenue.

Rail routing was determined by shipper preference, largely without impact to rates, which were generally the same for all legitimate route alternatives.

In 1980, the pricing freedoms granted under deregulation (1) permitted railroads to route traffic to more efficient gateways (and thus close less efficient interchanges); (2) allowed railroads to establish confidential shipper contracts that specified routes, rates and service; and (3) eliminated the need to publish only "through rates" for interline movements.

Many railroad seized upon this opportunity to surcharge unprofitable business, establish new revenue divisions, and to publish independent revenue factors for interline movements. Railroads also began constructing confidential contracts to cover only *their portion* of an interline movement. Reluctantly, shippers agreed to pay railroads individually for what had previously been a single-invoice through movement.

Railroad waybills reflected these changes in the commercial structure by providing movement instructions only from the point of origin to the point of interchange, where the delivering carrier would "re-bill" (create a new waybill) the car to cover the movement from interchange to final delivery. Delivering rail carriers would then invoice for only the service they provided, while the originating rail carrier invoiced independently for its services.

This process disconnected the previously linked trip of a railcar from origin to interchange to destination into two distinct segments. While this procedure was commercially attractive to the railroads, it instantly undermined the integrity of railroad movement reporting. Cars moving from a single origin on the West Coast to a single destination in the East might have one, two, three or more individual movement records, each recording an origination (or interchange) and termination (or interchange), but ultimately reflecting a single coast-to-coast movement of freight.

Since 1980, railroad data management has included significant manipulation to connect these individual movements to reflect the interline nature of the actual car movement, rather than the divided nature of the car billing. "Fixing the railroad re-bill problem" has been a consistent topic of discussion for users of the Surface Transportation Board's Carload Waybill Sample (CWS) which currently makes no attempt to link through movements. *It is estimated that over 30% of all carload freight is re-billed at interchange.*

The re-bill problem creates a number of data anomalies that misrepresent the true nature of rail freight movements. These include the appearance of excessive volumes of originating and terminating freight at major interchange points such as Chicago, St. Louis or Memphis.

For intermodal movements, the re-bill problem is more acute, as some 60% of the interline freight is delivered between rail carriers via "rubber-tire" (truck delivery) rather than "steel-wheel" (rail carload delivery) interchange, and hence re-billed.

1.2.2. <u>Linking Rail Trips</u>

Linking interline rail trips represents a particularly vexing problem for planners. The increase in independent factor rates among Class 1 railroads exacerbates the problem of rebilling while the consolidation of these same railroads decreases it. Likewise the increase in shortline railroads expands the re-bill problem as most recent sale agreements provide some amount of ratemaking authority to purchasers.

While through waybills provide a single record number, car initial and number, routing and net weight for the entire movement, only the car initial and number (or trailer/container initial and number) are consistent across the multiple waybills of a disconnected movement. Matching movements on the basis of individual car initials and numbers is difficult in that cars are frequently repositioned for reloading within a day or two of unloading. It is nearly impossible to determine if a car originating in Chicago was originally loaded in Los Angeles for New York or loaded in Los Angeles for Chicago and merely reloaded in Chicago for New York. The CWS sampling methodology it even less likely that the two or more individual waybills needed to construct a single interline movement will be selected from individual carrier databases in the extraction process.

Unable to link waybill numbers, car initial and number or routings, planners are often left to model the interchange of freight to estimate the impact of railcar re-billing and to determine the true volume of through movements.

Reebie Associates has sought to link rail carload and intermodal trips in the development of its Transearch database. The procedures rely heavily on direct data exchange with rail carriers, and secondary data sources. The process used by Reebie Associates is somewhat different for carload and intermodal freight.

For carload traffic, Reebie Associates utilizes direct carrier Data Exchange[1] information to identify the "best quality" interline record. Generally this data comes from the

[1] Data Exchange is Reebie Associates process of collecting movement data directly from rail, motor, and

originating rail carrier whose record often carries the full route of movement. As not all rail carriers participate in Reebie Associates data exchange program, some through movements must be estimated using a variety of modeling techniques including: (1) identifying re-billed movements in the CWS based on routing and "re-bill" flags; (2) modeling re-bills by analyzing collecting interchange data from individual carriers; and (3) modeling interchange activity based on a commodity-by-commodity matching of flows at gateway locations, netting out for local manufacturing activity. These data and models attempt to link carload trips between carriers, and provided better insight into freight movements than can be obtained through the use of the CWS alone.

For intermodal traffic, Reebie Associates has modeled linked trips through the use of direct carrier data exchange (for steel-wheel interchange) and through intermodal gate survey data (for rubber-tire interchange). With over 60% of intermodal interchange taking place in Chicago, the issue of intermodal re-billing is more localized. The popularity of rubber-tire interchange however, reduces the effectiveness of carload-style techniques to link intermodal trips.

Utilizing surveys of trailers entering and leaving major intermodal yards, Reebie Associates is able to construct models to simulate the over-the-road interchange of freight in Chicago between eastern and western rail carriers. The survey data provides information on what portion of traffic is moved to each carrier, and in some cases provides the final destination of the freight. These data are used to model a distribution of total rubber tire interchange activity in the Chicago region, and to estimate the final destination of non-interchange intermodal freight. These two data elements provide much needed insight into the interline movement of rail intermodal traffic, and help to establish the national and international scope of intermodal movements that in the unmodified CWS appear as regional movements.

Linking trips within a mode such as rail can help planners understand the true nature of freight movement, and better accommodate its needs. But if linking trips within a single mode is difficult, the growth in intermodalism has created a need to link trips across modes; such as between air transport and truck delivery, or rail transport to barge delivery. Linking intermodal trips means matching movements across modes using disparate data sources, often with intermediate goods processing (break-bulk, subassembly, or transload)

1.3. Linking Trips: Air Markets and Facilities

1.3.1. <u>Background</u>

The past three decades has seen explosive growth in freight "intermodalism": the use of multiple transport modes for the transportation of a single shipment from origin to

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package carriers in order to improve the reliability of its proprietary Transearch database. The carrier data is usually "exchanged" annually for market share information that the carriers find useful in marketing and operational planning efforts.

destination. Shippers seek to utilize the relative economic and service advantages of several modes (low cost, transit speed, residential door delivery etc.) to provide superior service at competitive costs.

The delivery of foreign goods to US manufacturers may require the use of ocean shipping, rail intermodal and truck delivery for a single shipment. Deliveries to consumers may include the additional steps of breaking down containers[2], sub assembling components, and reshipping via a package carrier for residential delivery. Planners seeking to understand manufacturing and consumer supply chains must find a method to link these disparate activities to produce a door-to-door record of goods movement.

Linking multi-modal movements is extremely complex, and often requires significant modeling effort to gain insight. While shippers can ordinarily track a shipment through its entire intermodal movement through a single bill of lading number, this data is not generally available to public planners seeking to link multi-modal trips. Often, the best available method for linking intermodal trips is to use commodity information to connect multiple movements via multiple modes.

One example of linking different legs of intermodal movements can be found in matching air cargo markets to air cargo facilities. Since it is practically infeasible to deliver freight to individual consumers and businesses directly via aircraft, air cargo is generally loaded on to trucks at the airport for final customer delivery. This means that the actual origin or destination market of the air cargo may be some distance from the closest air cargo terminal. For domestic air freight, distribution patterns are generally localized, with most truck trips less than 100 miles.

For international air cargo however, the situation is much more complex. The majority (by weight) of international air cargo – whether charter or regular route – enters the United States through one of five major air cargo airports. These are Miami (MIA), New York (JFK), Chicago (ORD), Los Angeles, (LAX), and Anchorage (ANC)[3]. From these airports, freight may be trucked several hundred or more miles, or transferred to a domestic flight for regional delivery. Linking these distant markets to the international air cargo hubs requires some understanding of transportation economics, and commodity distribution patterns.

1.3.2. Linking Intermodal Trips

Linking intermodal trips, such as in domestic and international air cargo, is generally a process of estimation. Because of the involvement of freight forwarders, air freight consolidators, and other intermediaries, sometimes the air cargo carriers themselves do

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[2] Goods are shipped from foreign manufacturers en bulk in 40' ISO international shipping containers. However, retail stores generally do not accept full containerloads of a single item; instead the single-commodity containers are "unstuffed" at intermediate warehouses and reorganized into daily truckloads (53' domestic trailers) to retail locations containing mixed goods. This process is informally termed "breaking down containers".

[3] Cite from FAA data

not have actual origin-destination data. However, planners can approximate the airfreight volumes by studying the geographic distribution of like commodities by other modes such as less-than-truckload (LTL) freight, or by understanding the distribution of air cargo "consumers" within the study region. Essentially, the available airfreight volumes at a nearby facility are expanded into diverse geographic destinations based on geographic distribution of commodities within an LTL network.

2.1.1.1 Using LTL Freight as a Proxy for Air Cargo Distribution

The characteristics of freight hauled by LTL and air cargo carriers are similar, and the distribution patterns of one can be used as a proxy for the other. While LTL carriers do not routinely move air freight volumes in their network, there is a strong correlation between LTL and domestic air freight users. Package sizes are often similar between the two modes, and there is a similar mix of commodities between the two modes.

It is not unreasonable to presume that shippers and receivers of LTL freight are also air freight users: when resupply or manufacturing schedules permit, cheaper LTL service can substitute for air freight. Long-distance LTL distribution patterns would then be expected to mirror supplier-to-consumer airfreight activities, while regional LTL patterns might mirror airport-to-consumer drayage moves. Thus an examination of regional (less than 200 O-D miles) LTL volumes can help planners link air cargo facilities with local markets. The volume distributions of LTL to individual markets could also serve as an apportionment scheme for air cargo volumes. The basic assumption in such an analysis is that a similar shipper and receiver base for LTL and air cargo volumes will distribute volumes equally between modes in common lanes.

Annual LTL volumes (regional origins & destinations only)

	INBOUND		OUTBOUND	
County	**Tons**	**% Total**	**Tons**	**% Total**
Abel	3,200	13%	12,100	35%
Baker	4,600	19%	7,200	21%
Charlie	2,700	11%	2,300	7%
Outside Area	14,300	58%	13,200	38%
Total	24,800		34,800	

Disaggregated airfreight volumes

	INBOUND		OUTBOUND	
County	**% Attributed**	**Tons**	**% Attributed**	**Tons**
Abel	13%	439	35%	1,808
Baker	19%	631	21%	1,076
Charlie	11%	370	7%	344
Outside Area	58%	1,960	38%	1,972
Observed Airfreight		3,400		5,200

Table 1: Simple Example for Attributing Airfreight based on LTL Volumes

In the simple example shown above, the annual LTL volume for counties Abel, Baker, and Charlie are charted on the left hand side. The percentage of total LTL freight is calculated separately for each county and direction. These same percentages are then used to distribute observed airfreight tonnages at the serving airport to the three counties, including a column for "outside the study area". Although this is a simple methodology based on numerous assumptions, it is nonetheless a reasonable way to achieve some intermodal linkage without substantial survey efforts.

2.1.1.2 Using Industrial Activity as a Proxy for Air Cargo Distribution

With some basic knowledge of the air freight commodities, planners can distribute traffic to potential users based on industrial activity. While air freight comprises both consumer and industrial goods, the largest volumes are industrial[4]. Industrial activity metrics, such as employment, sales, or production (output) can be used to apportion air cargo traffic to localized areas in the service region. While it is possible to allocate volumes purely based on overall levels of activity, SIC and commodity information is likely to produce better and more credible results.

Industrial data providers, such as Dun and Bradstreet® or InfoUSA®, can often provide information about business activity in a region, including detailed geographic data, sales or production volumes from individual facilities, and industrial classification data such as SIC codes.[5] While an apportionment scheme based on regional business activity is unlikely to capture heavy air cargo users in a region, it can serve as a reasonable estimate of regional volumes, and provide planners with the ability to link regional air freight facilities to local markets.

Sectorized Annual Economic Activity

	SMALL PACKAGES		AUTO PARTS		BIOTECH		MACHINERY	
County	**Packages**	**% Total**	**$ millions**	**% Total**	**Establish-ments**	**% Total**	**Tons**	**% Total**
Abel	0	0%	1.52	36%	3	17%	27,320	74%
Baker	14,572	82%	0	0%	2	11%	4,122	11%
Charlie	3,242	18%	2.73	64%	7	39%	121	0%
Outside Area	0	0%	0	0%	6	33%	5,123	14%
Total	17,814		4.25		18		36,686	

Disaggregated Airfreight Volumes, by Commodity & Geography

	SMALL PACKAGES		AUTO PARTS		BIOTECH		MACHINERY	
County	**% Attributed**	**Tons**	**% Attributed**	**Tons**	**% Attributed**	**Tons**	**% Attributed**	**Tons**
Abel	0%	0	36%	1,502	17%	218	74%	5,004
Baker	82%	622	0%	0	11%	146	11%	755
Charlie	18%	138	64%	2,698	39%	509	0%	22
Outside Area	0%	0	0%	0	33%	437	14%	938
Observed Airfreight by Commodity		760		4,200		1,310		6,720

Table 2: Simple Example for Attributing Airfreight by Commodity

In the second example shown here, commodity detail for the observed airfreight data is available (as often is from port authority statistics, although generally FAA data is not commodity specific). Given the commodity detail, it is possible to attribute airfreight to geographic regions most likely to generate that specific commodity. In this case, only Baker and Charlie counties feature small-package processing facilities, hence all small package tonnages are assigned to those two counties. Similarly, for auto parts the attribution is based on revenue, and in biotech the attribution is based on establishments.

[4] Cite from Transearch

[5] See NCHRP 8-43 Case Study 1 on Data Conversion for more information about SIC codes and private industrial establishment databases.

Although this makes the attribution methodology somewhat inconsistent across commodities, the tacit assumption is that tons of airfreight materiel received by every biotech firm is roughly equal, while tons received by auto plants are proportional to revenue. These are not unreasonable assumptions, and to an extent the assumptions should be governed by the local availability of good econometric data.

2.1.1.3 International Air Cargo Distribution

Linking international air freight facilities and markets is a more complex task because significant volumes can economically move over long-distances. For international air cargo, the market-to-market freight density limits the number of domestic destinations. That is, there are few overseas markets that can regularly generate planeload quantities of freight to any but the largest domestic markets. Some international carriers operate dedicated freight services between Asia and the US and between Europe and the US that provide heavy-lift capabilities for industrial goods such as machinery or manufacturing components. Smaller or more irregular volumes of air freight are likely to move as "belly cargo", loaded in the cargo holds of wide-body international passenger aircraft. These shipments naturally move through high-volume international passenger airports that provide the necessary service frequency and air cargo handling capabilities to accommodate this freight. Depending on the available service frequency from the originating international market, freight may flow through airports hundreds of miles from the shipment's final destination. This means that it is not uncommon for freight heading to Kentucky to move through JFK, or freight going to Florida to be handled at ORD.

Linking international air freight to its local markets is most reasonably done through survey of local shippers and receivers, although it can be modeled by analyzing the service frequency of origin markets (using FAA data), and by calculating the comparative transportation economics of moving freight to regional destinations from the available air cargo hubs.

Presently, international air freight volumes are significantly less than domestic volumes. Unless it is apparent that international air freight volumes are a significant component of the analysis, planners may be wise to invest more effort in developing information for domestic volumes than for international air cargo.

1.4. Linking Markets: Input-Output Modeling

1.4.1. <u>Background</u>

One of the least understood aspects of linking markets is the relationship between producer economies and consumer economies. For most planners, the local region will contain both producer and consumer economies, but questions often arise about the nature of these economies, such as:

1. How large is each?

2. What consumer and producer markets is our region linked to?
3. How much of the freight volume in the region is associated with each of these economies?
4. What is the projected growth rate of each, and which is better for our overall economy?

While planners can develop some understanding of these markets by studying employment levels in producer and consumer sectors, segments such as transportation, warehousing, and wholesale trade often contain elements of both. One method for analyzing these economies is by linking markets using input-output modeling.

1.4.2. Linking Markets with Regional Economic Models

Input-output modeling seeks to identify changes in outputs as a result of possible changes in inputs. Many forms of input-output models exist from simple ratio analysis models to sophisticated regional economic models. For planners, the level of detail required will dictate the appropriate level of model complexity. Simple correlations of employment growth to retail spending can help illuminate the importance of local industrial development, but such models fail to consider the role competing or complementary regional economies will have on the study area. Such analyses are best conducted using a regional economic model that is calibrated to the local economic conditions, but also provides information on the forecasted performance of external economies and their potential impact to the local market.

One commonly used model is the REMI® Policy Insight model, maintained by Regional Economic Models Inc. This model seeks to answer "'what if...?' questions about state, regional, and local economies."[6] As with most input-output models, the REMI model requires the development of a base case against which various scenarios are evaluated.

Planners using regional economic models can through an iterative process, understand the impact of local changes on a number of regional economic metrics such as Gross Regional Product (GRP), Personal Income (PI), and direct employment. These models help planners understand the linkages between competing markets (one may gain at the expense of another) and the boundaries of the local economy (commuting patterns, retail impacts in adjacent regions resulting from local employment gains).

1.4.3. Linking Markets through Flow Analysis

Another method of linking markets utilizes freight flow data such as Reebie Associates TRANSEARCH® database. Freight flow data helps planners link complementary producer markets (external traffic originations with local terminations) and consumer markets (local traffic originations with external terminations). Using the commodity

[6] http://www.remi.com

classifications available in some freight flow databases helps segment local producer and consumer economies.

The construction of freight flow data is in itself an input-output modeling process. In the production of any manufacturing output there is a requisite input process. Industrial input-output models help to understand the relationship between the production of "widgets" and the demand for raw materials associated with that production. The construction of freight flow data often utilizes these input-output relationships to project region-to-region trade, and to insure that the appropriate inputs are recorded as inbound freight to manufacturing locations. Less sophisticated input-output models are publicly available from the Bureau of Economic Analysis of the US Department of Commerce in their Regional Input-Output Multipliers (RIMS) or their Transportation Satellite Accounts (TSA)[7].

Freight flow based input-output analyses help identify what portion of freight activity is related to producer and consumer economies, and helps identify the markets (both consumer and producer) that are linked to the local economy. For planners, this information can be used to coordinate economic analysis between complementary regions, and to help facilitate opportunities for multi-jurisdictional investments, programs, and cooperation.

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[7] http://www.bea.doc.gov