DRIVING THE TRAIN:
A MACRO-BASED FRAMEWORK FOR COMMODITY FORECASTING

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ABSTRACT

Patterns of freight movement are the result of economic exchange. That is, at the infrastructure level, demand by vehicle and commodity type is fundamentally driven by buying and selling activities along complex global supply chains. And yet, commodity forecasting techniques used in freight plans and port studies frequently ignore these broad drivers. The fundamental thesis of this paper is that the *macro* level – the global macroeconomic perspective – is increasingly important to making reasonable freight projections at the *micro* level – the infrastructure level. This paper therefore has two goals. First, we briefly review the state of the practice in freight forecasting, ultimately concluding that the macro level is noticeably absent in the majority of forecasting methods and actual studies reviewed. Second, recognizing this gap, we present a method of generating county-level commodity forecasts that embody macro drivers and trends. Specifically, our approach ties together three critical pieces of information: (1) a county-based social-accounting structure representing detailed factors of economic supply and demand, (2) a set of domestic macroeconomic forecasts providing future industry-by-industry production trends that recognizes spatial growth patterns, changing technology, relative industry growth, and broad forces affecting final demand, and (3) a forecast of US international trade recognizing differential economic growth of trading partners as well as pressures from international competition and currency fluctuations. The result of this methodology is forecasted county-level trade flows (in dollar terms) that are analytically (not statistically) tied to macroeconomic growth trends. These forecasts can be used alone for sketch or policy-level analysis, or they can be combined with *meso* and *micro* level information for comprehensive freight forecasting at the infrastructure level. The method presented here is being implemented as the baseline forecast in the TREDIS Transportation Economic Development Impact System.

BACKGROUND

Freight movement is the consequence of economic exchange. Somebody buys something online. A retail store orders spring inventory. An auto assembly plant schedules a year's supply of brake pads. More and more frequently, these exchanges are nested in a complex and dynamic global supply chain. The online purchase may trigger an air shipment from a warehouse in Seattle. Retail inventory likely comes from overseas before being processed by a distribution facility and shipped to the store by truck. Brake pads may be sourced from several domestic or international manufacturers. In each case, the resulting freight moves – vehicle moving across infrastructure – are ultimately driven by patterns of exchange by U.S. and international industries, households, and governments.

When it comes to infrastructure planning, the critical question is clearly at the infrastructure level: how is demand likely to change for a single highway, railroad, intermodal terminal, tunnel, or other piece of transportation infrastructure? Answering this question (or making a reasonable guess) is a prerequisite to making sound investment decisions.

The fundamental thesis of this paper is that in order to answer this question – in order to make reasonable projections for freight demand for a single piece of infrastructure (the *micro* level), one must first address changing patterns of exchange by U.S. and international industries, households, and governments (we shall call this the *macro* level). Critical macro-level questions are:

- Where is international growth most likely to occur, and for what industries (1)?
- What are the patterns of final demand in our trading partners? Are they net producers or consumers (2)?
- How are exchange rates likely to change, and how will that affect bilateral trade between the US and its trading partners (3)?
- Where is domestic growth likely to occur?
- How are industry patterns changing at the national and regional level? Which industries are growing and which are shrinking (4)?
- What are broad patterns of final demand? How are households and government each likely to contribute to final demand (5)?

Of course, these are not the only factors contributing to freight demand at the infrastructure level. Between the macro and micro levels are a host of other complex factors (the *meso* level) that contribute to infrastructure-level demand. These include supply-chain organization, warehouse locations, vehicle and container imbalances (driving empty backhauls), and broad routing options and constraints – for example, size constraints through the Panama or Suez Canal, or polar trade routes. Finally, at the *micro* level, demand for a facility depends on the broad macro trends in exchange, meso level routing and logistics decisions, and ultimately upon aspects of the local network and facility itself, as well as local capacity levels, detailed origin-destination patterns (at the TAZ level) and touring rules.

This paper does two things. First, we briefly review the state of the practice in freight forecasting, ultimately concluding that the macro level is noticeably absent in the majority of methods and actual studies (at least quantitatively). Second, recognizing this gap, we present a method of generating county-level commodity forecasts that embody macro drivers and trends. Specifically, our approach ties together three critical pieces of information:

(1) A county-based social-accounting structure representing factors of actual (i.e. historical, not projected) economic supply and demand. This source explicitly accounts for industry versus final demand, and establishes where commodities are produced and consumed.
(2) A set of domestic macroeconomic forecasts providing future industry-by-industry production trends that recognizes spatial growth patterns, changing technology, relative industry growth, and broad forces affecting final demand.
(3) A forecast of US international trade recognizing differential economic growth of trading partners as well as pressures from international competition and currency fluctuations.

The result of this methodology is projected county-level trade flows (in dollar terms) that are analytically (not statistically) tied to economic growth trends. These projections are reflective of realistic economic pressures, both domestic and international. They are inherently market-based, balancing commodity supply and demand, and they aggregate properly – that is, trade flows for U.S. Counties aggregate to State totals, and State trade flows aggregate to US national totals. These forecasts can be used alone for sketch or policy-level analysis, or they can be combined with *meso* and *micro* level information for comprehensive freight forecasting at the infrastructure level.

THE STATE OF FREIGHT FORECASTING PRACTICE

To determine how prevalent macro-level drivers are used in practice, we performed a cursory review of (1) official guidance for freight forecasting at the state level, and (2) about two dozen published freight studies, ranging from state freight plans to rail plans to port studies. Our overall findings are that guidance focuses heavily on the micro-scale, giving economic drivers only a minor role in forecasting techniques. For published freight studies, many forecasts simply extend past growth rates and ignore the *macro* drivers of demand.

Freight Forecasting Guidance

The best statement of official freight forecasting guidance is *NCHRP Report 606: Forecasting Statewide Freight Toolkit* (6). This report, published in 2008 states as its goal "to provide an analytical framework for forecasting freight movements at the state level". Although several data and analytical shortcomings are noted, the fundamental goal of the work is to provide State DOTs and MPOs a snapshot of best practice, with guidance on how to implement it. The heart of the report is laid out in Chapters 4 through 6, which respectively cover Forecasting Components, Data Sources, and Forecasting Models.

In chapter 4, five components of freight forecasting are identified: *direct factoring*, followed by the steps of the standard four-step travel demand model (*trip generation, trip distribution, mode split, and traffic assignment*). Generally speaking, it is the first of these that deals with macro- and meso-level factors, while the last four are inherently micro in nature. However, the direct factoring techniques described are rather limiting with respect to macro scale trends. Essentially, the technique is described as first obtaining an input-output table in dollar terms) at the state or national level. Second, growth factors may be applied either using truck count data or using statistical relationships with economic drivers (such as employment). Next, the input-output table is converted from dollars to tons and aggregated across commodities to determine total commodity demand on an industry-by-industry basis. Finally, the industry demand measure is allocated to smaller geographies (counties, towns, zip codes, or TAZs) on an employment basis. This measure of industry demand is then used as an input to the subsequent travel demand modeling steps.

As will be shown, our method explicitly attempts to improve on this direct factoring technique. For the moment, it is sufficient to point out a few of its limitations (as described in the *Toolkit*) with respect to the macro perspective. First, it is highly static. The techniques for projecting the input-output relationships are limited to local factors, such as truck count and local employment. Second, only a subset of demand drivers are considered. An input-output table is only one component of economic flows in a study area – those among industries. However, industries typically account for less than half of all demand, the rest made up of households and government (final demand). Moreover, industry supply is as important as industry demand to freight flows. Third, the method does not distinguish trading partners. Although from an infrastructure perspective, it might not matter if a truck is bound for a domestic versus international destination. However, in terms of generating accurate forecasts, this could matter a great deal, particularly for port studies. Finally, it does not retain commodity detail. In reality, mode choice is extremely sensitive to commodity-specific factors, such as value, density, time sensitivity, bulkiness, or the ability to be containerized. Eliminating this detail unnecessarily limits the accuracy of mode choice models.

Chapter 6 describes how forecasting models can be built in practice. Five model types are described:

- Direct Facility Flow Factoring – this is used for analyzing individual links but not freight systems as a whole. To forecast future freight demand specific to a particular facility, time series regressions can be constructed to extrapolate future growth rates, or forecasts can be performed on specific economic variables that influence freight demand.
- Origin-Destination Factoring – factors current commodity flow patterns using growth rates. The origin-destination factoring method uses an origin-destination (OD) table (such as TRANSEARCH) as input and combines the mode split and assignment components.
- Truck Forecasting – in the truck model, a gravity model accounts for variation in trip distances and is used to achieve the trip generation component. Then, another gravity model is used to perform the trip distribution. Finally, a network assignment is performed to distribute the freight traffic across links.
- Four-Step Commodity Modeling – the four-step commodity model is a comprehensive methodology that combines trip generation, trip distribution, mode split, and network assignment. In the trip generation phase, trip rates by commodity are calculated using population or employment data.
- Economic Activity Modeling – finally, economic activity models incorporate the same four components as the four-step commodity model. However, the economic forecasts that are inputs to the model are themselves affected by the model's output, using a spatial I-O model. Essentially, this model draws a parallel to the integrated land use-transportation models for passenger travel. The model assigns economic activity across

zones and calculates resulting transportation activity across the zones. Across time, activity is determined in part by activity in the previous periods.

These methods have in common a limited treatment of macro-scale drivers of freight. Although the direct flow factoring method can utilize macroeconomic forecasts, those forecasts are used as statistical proxies to drive demand on a single facility or portion of the freight network. They are generally not used to analytically predict demand, and no mention is made of utilizing input-output tables as a way of explicitly mapping industry activity to commodity demand. Origin-destination factoring can similarly use economic growth factors as statistical proxies to drive commodity-specific growth. The last three are variations of the four-step travel model. In their description of the four-step process, it is noted that the entire process is built upon socioeconomic forecasting methods and data (because these are inputs to the trip generation step), but that "while [four-step] commodity models analyze the impact of changes in employment, modal utility, trip patterns, and network infrastructure, they usually do not account for increases in labor productivity, or the interaction between industries." That is, they are not based on input-output relationships, and they are fundamentally tied to employment patterns as opposed to production and consumption patterns.

Freight Studies

We surveyed twenty state and local freight studies (these resulted from an internet search; this is therefore not a random sample). Of these, six (7) (8) (9) (10) (11) (12) do not include any forecasts but simply assess current freight patterns and needs. This fact is puzzling, as these studies were commissioned to plan for freight needs over the next several decades, and yet nothing extensive was done to actually forecast what might take place in the future. Instead, current problems are noted, and some qualitative macroeconomic factors and expectations are discussed in general terms.

The fourteen studies that do include forecasts were then compared with the NCHRP toolkit framework to assess the extent to which it resembles current practice. While many of the studies do not extensively discuss the methodologies employed to complete their forecasts, it is apparent that the level of sophistication in many cases is below what is outlined by the NCHRP. In essence, the NCHRP guidance appears to be a survey of the more exhaustive and robust techniques that have been performed or suggested, but it does not necessarily reflect the state of common practice. That being said, many studies do employ in some form the models discussed in the documentation. Specifically, almost all of them map out current freight patterns (often using TRANSEARCH) and develop various means for forecasting commodity-level activity. It is not always apparent, though, the extent to which these commodity projections are *macro*-based or that they encompass larger trade trends.

Generally, mode splits are performed implicitly by using current modal shares, and one of the studies explicitly makes adjustments based on qualitative expectations (13). There is one case where the direct facility factoring method, designed to be facility-specific and short term in scope, is used as a forecast for the entire regional freight system over a longer horizon (13). Additionally, one study (14) uses national level trade forecasts, identifies commodities that are relevant to the particular region, and derives growth factors as a direct corollary to national growth. Several of the studies qualitatively allude to macroeconomic trends and shifts, but they are generally not directly included as factors in the analyses.

In our review, we also encountered methods that are outside those recommended by the NCHRP. Two studies focus on areas dependent on their ports, and one of the forecasts is largely built of port forecasts that are driven by surveys of port operators. How the operators derive their expectations is unclear. These surveys are commodity-specific, and consumer commodities are adjusted for population projections. Additionally, REMI forecasts were employed to model non-port freight (15). In the other study, nearly all freight is modeled to be directly correlated with container shipments through the port, and the rest of the freight is a linear extension of past growth rates.

Finally, several of the studies used a variation of direct facility flow factoring that incorporates different scenarios. This method examines the likelihoods of various shifts in the determinants of freight demand. Three main factors are identified, which include changes in the transportation network, changes in supply/demand or origin/destination for products shipped through the corridor, and modal shifts. Driving these factors were nine sub-factors, which generally reflect infrastructure investments, market sizes, macroeconomic factors, and competitiveness. Various percent changes in each of these are assessed and each given a specific probability. Then, combinations of sub-factor changes are formed, creating eight possible likely scenarios to be analyzed. For each scenario, a probability is calculated from the sub-factor probabilities, and associated changes in vehicle miles traveled is calculated as a result (12).

The other studies that were surveyed but were not specifically mentioned generally utilize various techniques that do not fall far outside the scope of the NCHRP guidance. TRANSEARCH and FAF are common tools for mapping current freight patterns, and techniques include extrapolating growth rates and utilizing various measures of population and industry employment forecasts (16), (17), (18), (19), (20), (21), (22), (23), (24). Finally, one study provides no measurement of current freight pattern or forecast of future freight; rather, it focuses on qualitative needs and descriptions of proposed projects (25).

MACRO-BASED FORECAST METHODOLOGY

In response to the limited perspective taken by guidance and practice on macroeconomic drivers of freight, we developed a method for generating county-based commodity forecasts that are analytically (not statistically) driven by factors of exchange – supply and demand. These forecasts can be used alone for high-level level planning (for example, in statewide needs analysis or economic analysis), or they can be combined with other data sources to inform micro-level analysis – for example, by dis-aggregating internal county productions and attractions into TAZs for use in the four-step modeling framework.

Data Sources

As discussed above, our approach ties together three critical pieces of information: (1) a social-accounting structure representing factors of economic supply and demand, (2) a set of domestic macroeconomic forecasts providing future industry-by-industry production trends, and (3) a forecast of US international trade by commodity. The following sections describe our source for each.

Social Accounting Structure

In our method, IMPLAN provides the database of "current" economic activity ("IMPLAN" is a registered trademark of Minnesota IMPLAN Group, Inc). This is the fundamental source that enables our integrated methodology because, for any US county (or aggregation of counties), industry production is explicitly tied to commodity production and consumption through "make" and "use" tables (26). Thus, industry forecasts can readily be converted to commodity supply and demand (with some balancing, as will be shown). Furthermore, IMPLAN explicitly accounts for all sources of commodity supply and demand – including industries, households, and government (the latter two constituting final demand). Finally, for any given study area, all trade flows are accounted for. That is, IMPLAN estimates regional purchase and sales coefficients describing how much of a commodity is consumed locally versus exported, or how much of a commodity is produced locally versus imported. These flows are calibrated with the commodity flow survey and international trade data (27). One final critical benefit of IMPLAN is that its industry and commodity sectoring is linked to NAICS industry classification system, so relating to other data sources has a common bridge.

The following variables used in the methodology are derived from IMPLAN. In the following list, with the exception of *Employment*, *Byproducts*, and *Absorption*, all variables have units $millions (nominal for year *y*). Also note that whereas there is only one Byproducts table applied to study region, the Absorption table can vary by region.

i – IMPLAN industry (440 total), based on NAICS. See reference (28) for more information.
c – IMPLAN commodity (440 total). See reference (28) for more information.
r – Study region. Any US county, combination of counties, state, combination of states, or the entire country.
y – Data year. IMPLAN is historical, so *y* typically has a two to three year lag on the current calendar year.

$Employment(i, r, y)$ – Average job count in industry *i*, region *r*, and year *y*
$Output(i, r, y)$– Total output (sales) in industry *i*, region *r*, and year *y*
$ValueAdded(i, r, y)$ – Total value added by industry *i* in region *r* and year *y*
$Purchases(i, r, y)$ – Total consumption of goods and services by industry *i* in region *r* and year *y*

$Byproducts(i, c, y)$ – Fraction of industry *i*'s total output yielding commodity *c* in year *y*
$Absorption(i, c, r, y)$ Fraction of industry *i*'s total expenditures going to commodity c in year *y*

$IndustrySupply(c, r, y)$– Total production of commodity *c* by all industries in region *r* and year *y*
$InstitutionSupply(c, r, y)$ – Total production of commodity *c* by households and gov't in region *r* and year *y*
$DomesticImports(c, r, y)$ – Total inflows of commodity *c* from rest of US into region *r* in year *y*
$ForeignImports(c, r, y)$ – Total international imports of commodity *c* into region *r* in year *y*
$IndustryDemand(c, r, y)$ – Total consumption of commodity *c* by all industries in region *r* and year *y*
$InstitutionDemand(c, r, y)$ – Total consumption of commodity *c* by households and gov't in region *r* and year *y*
$DomesticExports(c, r, y)$ – Total outflows of commodity *c* to rest of US from region *r* in year *y*
$ForeignExports(c, r, y)$ Total international exports of commodity *c* from region *r* in year *y*

Industry Forecasts

Moody's Analytics publishes industry forecasts at the national, state, and county level, with a 30 year horizon (currently forecasting to 2041). The forecasts are at a highly detailed industry level. Although not quite as detailed as IMPLAN, Moody's 196 industry sectors are NAICS bases and are therefore easily related to the IMPLAN scheme. Moody's state and county forecasts are ultimately based on their U.S. National econometric model, briefly described as follows:

> In the broadest terms, the model system is specified to reflect the interaction between aggregate demand and supply. In the short run, fluctuations in economic activity are primarily determined by shifts in aggregate demand, including personal consumption, gross private investment, net exports, and government expenditures. The level of resources and technology available for production is taken as given. Prices and wages adjust slowly to equate aggregate demand and supply. In the longer term, changes in aggregate supply determine the economy's growth potential. The rate of expansion of the resource and technology base of the economy is the principal determinant of economic growth (29).

Allocations of national employment and value added to states and counties are made based on the same government data sources used by IMPLAN to develop current economic characteristics. These sources include Bureau of Labor Statistics (BLS), Current Employment Survey (CES), and the Quarterly Census of Employment and Wages (QCEW), and Bureau of Economic Analysis (BEA).The benefit to this approach is geographic consistency – that is, for each industry, employment and value added always aggregate up (from counties to states and from states to national) without double-counting.

In the context of our methodology's goals, this model has three primary benefits. First, it captures broadly changing industry trends across primary, manufacturing, and service sectors (including government). This differential industry growth therefore influences commodity demand because different industries produce and consume different commodities. Second, in projecting industry activity, the model explicitly accounts for all sources of demand. Therefore, industry activity is influenced by (net) household and government spending. Finally, the model captures differential regional growth rates in the US. As such, the resulting commodity flows will reveal how origin-destination patterns are likely to change in the future.

A final convenience of this source is that historical data (used to calibrate their forecasts) is reported in the same sectoring scheme as the forecasts. This enables the forecasts to be accurately tied back to the most recent IMPLAN "base year". The following Moody's variables are used in the freight flow module (while employment forecasts are not used to drive forecasts, they are included to show a complete picture of forecasted economic activity):

i' – Moody's industry (196 total). Sectoring is NAICS based.
$Employment(i', r, y)$ – Average job count in industry i', region *r*, and year *y*
$ValueAdded(i', r, y)$ – Total value added by industry i' in region *r* and year *y*

International Trade Forecasts
University of Maryland's INFORUM group models and forecasts international trade based on US growth, international growth across trading partners, and other factors such as exchange rates. Their LIFT model is a 97-sector representation of the U.S. national economy that combines an inter-industry input-output (I-O) formulation with extensive use of regression analysis to employ a "bottom-up" approach to modeling industry and commodity activity. Like IMPLAN, LIFT explicitly maps industry activity to commodity production and consumption. However, domestic and international commodity flows are projected through relationships with US trading partners.

Countries linked in this system include the U.S., Canada, Mexico, Japan, China, South Korea, and the major European economies. Through this system, detailed commodity exports and imports of the U.S. economy respond to commodity-level demand and price variables projected by models of U.S. trading partners. In summary, the LIFT model is particularly suited for examining and assessing the macroeconomic and industry impacts of the changing composition of consumption, production, foreign trade, and employment as the domestic and international economies grows through time (30).

While there are clear overlaps in some aspects of Moody's model and the LIFT model, both are used because they have different underlying foci. Moody's model focuses on domestic production and consumption trends (at a highly detailed regional and industry level) while using aggregate variables to describe international trade. In contrast, INFORUM-LIFT is highly detailed in its international trade variables (by trading partner and commodity), yet more aggregated at the domestic level. The following variables are incorporated into our methodology:

c' – INFORUM commodity (97 total).
$ForeignImports(c', US, y)$ – Projected foreign imports of commodity c' to the U.S. in year *y*
$ForeignExports(c', US, y)$ – Projected foreign exports of commodity c' from the U.S. in year *y*

FORECASTING METHODOLOGY

Fundamentally, our method does three things. First, it uses Moody's industry forecasts to "walk forward" the baseline IMPLAN social accounting structure. Second, it uses an INFORUM-LIFT to forecast foreign imports and exports. Finally, it balances several elements of supply and demand to ensure that all trade is accounted for and that trading patterns aggregate properly.

National Forecasts

Although the method is primarily directed at sub-national applications (county, metro, or state-level), it first requires a consistent national forecast. State and county forecasts then utilize aspects of the national forecast. Starting from a national perspective is important in that it ensures, first, that international trade imbalances are offset by domestic consumption imbalances. That is, a trade deficit must be financed by government and household borrowing. Second, domestic supply explicitly meets domestic demand. Moreover, in order for supply and demand to balance, industry technology is adjusted at the national level. National forecasts are derived by the following steps.

Index Moody's Forecasts to Base Year

The first step in the method is to select base year. This is the last year for which reliable IMPLAN data is available. All forecasts will be based on this year. Next, a growth index is created for each of Moody's 196 distinct industries. These are simply ratios to the base year value added and employment levels:

$$ValueAddedForecastIndex(i', y, US) = ValueAdded(i', y, US)/ValueAdded(i', 2008, US)$$

$$EmploymentForecastIndex(i', y, US) = Employment(i', y, US)/Employment(i', 2008, US)$$

Converting to index accommodates variations in sectoring between Moody's and IMLAN, while preserving fundamental growth projections. Because Moody's industry sectoring is more aggregated than IMPLAN, a single Moody's index may be applied to more than one IMPLAN sector. This many-to-one application is based on the NAICS category of both. For many sectors, Moody's and IMPLAN have the same industry detail. For others, a single Moody's index is used to scale several more disaggregated IMPLAN sectors. For example, the single Moody's index for NAICS 3341 (computer manufacturing) is used to scale three IMPLAN sectors: 234-Electronic computer manufacturing (NAICS 334111), 235-Computer storage device manufacturing (NAICS 334112), and 236-Computer terminals and other computer peripheral equipment manufacturing (NAICS 334113 & 334119).

Forecast IMPLAN Industry Activity

Next, the value added and employment growth indices are applied to IMPLAN industry data. Specifically, Moody's employment index is used to scale IMPLAN employment, and Moody's value added index is used to scale IMPLAN sales (output) as well as components of value added ("other property income" undergoes a distinct treatment because it can frequently be negative in the base year. As mentioned above, employment is not used as a driver of freight forecasts, but is included here to show as complete a picture of industry growth as possible.

$$Employment(i, y, US) = EmploymentForecastIndex(i', y, US) * Employment(i, 2008, US)$$

$$Output(i, y, US) = ValueAddedForecastIndex(i', y, US) * Output(i, 2008, US)$$

$$ValueAdded(i, y, US) = ValueAddedForecastIndex(i', y, US) * ValueAdded(i, 2008, US)$$

$$IndustryPurchases(i, y, US) = Output(i, y, US) - ValueAdded(i, y, US)$$

National industry forecasts derived by this methodology are summarized in Table 1 by two-digit NAICS sector.

TABLE 1 National Industry Forecasts Results (millions, $2008)

	Output			Value Added			Purchases		
NAICS2	2008	2040	AAGR, 2008-2041	2008	2040	AAGR, 2008-2041	2008	2040	AAGR, 2008-2041
11	410,814	387,020	-0.2%	163,689	156,681	-0.1%	247,125	230,339	-0.2%
21	560,905	689,754	0.7%	330,707	402,369	0.7%	230,198	287,385	0.8%
22	476,659	899,032	2.8%	315,334	592,517	2.7%	161,324	306,514	2.8%
23	1,519,875	1,716,249	0.4%	630,619	717,533	0.4%	889,256	998,716	0.4%
31	1,055,096	1,104,677	0.1%	221,688	214,182	-0.1%	833,407	890,495	0.2%
32	2,488,835	4,376,085	2.4%	574,060	1,208,904	3.5%	1,914,776	3,167,181	2.0%
33	3,249,868	6,440,152	3.1%	852,173	1,733,680	3.2%	2,397,695	4,706,472	3.0%
42	1,238,780	4,496,612	8.2%	808,469	2,934,637	8.2%	430,311	1,561,974	8.2%
44	899,990	2,681,237	6.2%	615,124	1,830,929	6.2%	284,866	850,308	6.2%
45	426,851	1,555,894	8.3%	291,808	1,054,625	8.2%	135,042	501,269	8.5%
48	650,757	2,191,049	7.4%	335,712	1,042,292	6.6%	315,046	1,148,758	8.3%
49	198,965	465,017	4.2%	145,485	351,158	4.4%	53,479	113,859	3.5%
51	1,460,608	7,387,227	12.7%	625,935	3,024,755	12.0%	834,673	4,362,472	13.2%
52	1,963,989	2,547,847	0.9%	1,103,743	1,304,973	0.6%	860,246	1,242,874	1.4%
53	1,367,268	2,684,974	3.0%	1,008,669	1,985,623	3.0%	358,599	699,351	3.0%
54	1,766,763	3,793,624	3.6%	1,080,505	2,328,361	3.6%	686,258	1,465,263	3.5%
55	450,747	749,590	2.1%	280,501	466,669	2.1%	170,246	282,920	2.1%
56	685,937	1,121,444	2.0%	444,638	717,838	1.9%	241,298	403,606	2.1%
61	215,269	296,245	1.2%	124,932	170,534	1.1%	90,337	125,711	1.2%
62	1,569,918	2,140,895	1.1%	994,041	1,359,595	1.1%	575,877	781,299	1.1%
71	297,258	659,952	3.8%	147,106	337,056	4.0%	150,152	322,896	3.6%
72	739,517	1,534,980	3.4%	392,260	805,672	3.3%	347,258	729,308	3.4%
81	655,860	531,939	-0.6%	354,043	301,410	-0.5%	301,816	230,529	-0.7%
92	1,959,082	2,149,076	0.3%	1,772,387	1,942,311	0.3%	186,695	206,765	0.3%
TOTAL	26,309,609	52,600,569	3.1%	13,613,629	26,984,305	3.1%	12,695,980	25,616,264	3.2%

Forecast Industry Commodity Supply

With industry activity forecasted to 2040, the next step is to use select production variables to estimate national industry commodity supply. This is done by "matrix-multiplying" industry output by the byproducts matrix. It should be noted that the byproducts matrix itself is assumed to be static through the forecast period. This simplifies commodity production, allowing for estimation of a dynamic absorption matrix (discussed below).

$$IndustrySupply(c, y, US) = \sum_i Output(i, y, US) * Byproducts(i, c, 2008, US)$$

Forecast Institution Commodity Supply

Although industries produce the vast majority of all commodities, IMPLAN accounts for the small fraction (2.8% in 2008) of commodities produced by household and government institutions. For each commodity, these are forecast as a fixed portion of industry supply:

$$InstitutionSupply(c, y, US) = \left(\frac{InstitutionSupply(c, 2008, US)}{IndustrySupply(c, 2008, US)}\right) * IndustrySupply(c, y, US)$$

Forecast Foreign Imports and Exports

At this point, all aspects of domestic commodity production are known. In order to resolve domestic demand, foreign imports and exports must first be known. These are estimated by applying the commodity-specific LIFT forecast indices for imports and exports. As with the Moody's indices, the LIFT indices are applied on a one-to-many basis, so that a single LIFT index is used to scale several IMPLAN commodities. In the following equations, recall that c' is a LIFT commodity sector and c is an IMPLAN commodity sector. Both are based on NAICS codes, providing a bridge to map one to the other.

$$ForeignImportsForecastIndex(c', y, US) = \frac{ForeignImports(c', y, US)}{ForeignImports(c', 2008, US)}$$

$$ForeignExportsForecastIndex(c', y, US) = \frac{ForeignExports(c', y, US)}{ForeignExports(c', 2008, US)}$$

$$ForeignImports(c, y, US) = ForeignImportsForecastIndex(c', y, US) * ForeignImports(c, 2008, US)$$

$$ForeignExports(c, y, US) = ForeignExportsForecastIndex(c', y, US) * ForeignExports(c, 2008, US)$$

Forecast Total Domestic Demand

The previous step allows for the calculation of the balance of trade for each IMPLAN commodity – which, in turn, allows for the calculation of total domestic demand. This is simply equal to domestic production minus balance of international trade. What is not shipped abroad (net) must be consumed in the US. The calculation is as follows:

$$
\begin{aligned}
&TotalDomesticDemand(c, y, US) \\
&\qquad = IndustrySupply(c, y, US) + InstitutionSupply(c, y, US) \\
&\qquad + ForeignImports(c, y, US) - ForeignExports(c, y, US)
\end{aligned}
$$

Balance Commodity Supply and Demand

The final step in establishing national-level commodity forecasts is balancing supply and demand. At this point, all aspects of supply are known (domestic industries and institutions as well as international imports). Whereas total demand is known, the domestic demand still combines intermediate and final sources. Furthermore, while trade is balanced for each commodity, the absorption matrix is unknown for forecast years.

The final step simultaneously resolves the absorption matrix and breaks out intermediate versus final demand for each commodity in all forecast years. First, recall that industry purchases (total spending across all commodities) were previously forecasted. Recognizing that industry and institution purchases must equal total commodity sales (net of foreign trade), total institution spending (a single number for each forecast year) is calculated as follows:

$$
\begin{aligned}
&InstituionPurchases(y, US) \\
&\qquad = \sum_c [IndustrySupply(c, y, US) + InstitutionSupply(c, y, US) \\
&\qquad + ForeignExports(c, y, US) - ForeignImports(c, y, US)] \\
&\qquad - \sum_i IndustryPurchases(i, y, US)
\end{aligned}
$$

The preceding steps yield row and column totals for the following (yet unfilled) matrix for each forecast year. In order to fill the matrix, the previous year's absorption matrix is scaled so that rows sum to 1 – that is, it is scaled up to total purchasing activity (rather than scaling up to total output). This is used to "seed" the commodity demand by industry portion of the matrix. Similarly, the previous year's institution demand (by commodity) is used to seed the bottom row of the matrix. Finally, doubly-constrained (Fratar) matrix balancing method is applied, and the seeded values are adjusted until commodity supply and demand are balanced. The result of this process is a fully-specified absorption (technology) matrix for each forecast year. Table 2 summarizes how industry absorption changes from 2008 to 2040.

TABLE 2 Industry Absorption by 2-Digit NAICS Commodity (%)

NAICS2	Industry			Institution		
Commodity	2008	2025	2040	2008	2025	2040
11	2.7%	2.0%	1.2%	0.5%	0.4%	0.3%
21	5.8%	5.5%	3.7%	1.0%	1.1%	0.8%
22	2.7%	2.5%	2.2%	1.9%	2.0%	1.8%
23	1.1%	0.7%	0.6%	9.4%	6.9%	5.7%
31	3.2%	2.5%	1.6%	5.4%	4.3%	3.0%
32	15.8%	14.1%	12.6%	4.7%	5.2%	5.2%
33	15.3%	13.9%	14.0%	11.8%	10.9%	11.7%
42	4.6%	5.9%	7.7%	3.5%	5.1%	7.0%
44	0.6%	0.5%	0.5%	5.6%	7.2%	9.3%
45	0.3%	0.3%	0.4%	2.6%	4.0%	5.3%
48	2.9%	3.4%	4.0%	1.8%	2.5%	3.2%
49	1.3%	1.5%	1.6%	0.2%	0.2%	0.1%
51	5.5%	8.7%	14.4%	3.3%	4.9%	7.8%
52	8.7%	7.0%	4.9%	5.3%	5.5%	4.5%
53	7.1%	7.2%	6.7%	3.4%	3.7%	3.6%
54	11.3%	13.5%	15.2%	3.9%	4.8%	4.8%
55	3.2%	3.1%	2.6%	0.0%	0.0%	0.0%
56	4.3%	4.4%	3.5%	1.0%	1.1%	0.9%
61	0.1%	0.1%	0.1%	2.1%	1.9%	1.5%
62	0.2%	0.2%	0.1%	12.0%	11.1%	8.8%
71	0.4%	0.6%	0.7%	1.8%	1.8%	1.9%
72	1.3%	1.4%	1.3%	3.8%	4.5%	4.3%
81	1.5%	0.7%	0.5%	3.2%	2.0%	1.5%
92	0.2%	0.1%	0.1%	11.8%	9.2%	6.9%
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Sub-National Forecasts

With a consistent national forecast explicitly balancing all sources of commodity supply and demand, it is now possible to forecast sub-national commodity flows. As the process closely mirrors the steps taken above, this process is presented in outline form rather than in its full detail. There a few differences worth noting, however. First, sub-national social accounting data (and therefore forecasts) must explicitly account for domestic imports and exports in addition to international imports and exports. Second, as foreign import and export forecasts are calibrated exclusively at the national level, sub-national foreign trade is estimated by apportioning national totals by base-year patterns. Finally, the technology matrix derived at the national level is taken as exogenous at the sub-national level. The general steps are as follows:

1. Build the IMPLAN social accounting database for the study area
2. Generate Moodys' forecasts for study area
3. Index Moodys' forecasts to base year and forecast study area industry data
4. Forecast commodity supply
   4.1. Apply national byproducts table to industry output
   4.2. Estimate institutional supply as constant portion of total supply
5. Forecast study area foreign imports and exports
   5.1. Estimate study area foreign imports and exports as constant fraction of national totals

6. Forecast study area industry demand
   6.1. Estimate industry purchases as output minus value added
   6.2. Normalize national absorption matrix
   6.3. Apply normalized national absorption matrix to industry purchases to yield industry commodity demand
7. At this point, everything is known except domestic imports, domestic export, and institution demand. These three unknowns are estimated together with the following three equations: (1) total supply equals total demand, (2) domestic exports are a fixed portion of total supply, and (3) domestic imports are a fixed portion of total demand.

CONCLUSION

The fundamental thesis of this paper is that reasonable demand projections for a single piece of freight infrastructure (at the *micro* level) must acknowledge changing patterns of economic exchange – supply and demand at the *macro* level. Fundamentally, future local commodity movements will depend on which industries are growing and which are declining, where this growth occurs (both domestically and internationally), as well as exchange rate trends and the balance of intermediate versus final demand (again, both domestically and internationally). While there are no freight models that can incorporate all these factors, a number of economic models do address them.

The method proposed in this paper brings two such models together – a domestic model focusing on detailed aspects of industry and spatial change, and an international model focused on detailed aspects of international trade. These models are used to drive changes in a social accounting structure such that all aspects of supply and demand are forecasted together in a consistent framework.

Of course, there are many simplifying assumptions taken in this approach. Generally, these assumptions are made to lend enough structure to the social accounting framework so as to be able to solve for all its components. Given this, there are clear opportunities for improvement. It should be stated, however, that one of the goals is to provide a method that that is relatively straightforward (and low-cost) to implement – that is "shovel ready" to be incorporated into the state of the practice. Because our method is assembled using readily available data sources, the methodology need not be re-created for each application. Rather, it can serve as a ready-made foundation upon which the micro-scale techniques discussed in the Toolkit can be applied, thereby completing the link between macro and micro.

As with all forecasting models, our method must be properly vetted. Initially, there are three main concerns. The first relates to techniques used to fill in suppressions in the social accounting matrix. For example, suppressed employment data from BLS is typically filled in using proportional fitting to control totals. While these may be unproblematic at higher spatial and industry levels, these may over or under-represent the actual amount of activity at the source's full detail. A second potential issue is the proper location of industry activity with respect to commodity production and consumption. In many cases, the assignment of industry activity at the collection level (by BLS or BEA) may not distinguish between production activities versus headquartering activity. The underlying risk is that metropolitan areas (where headquartering activities are) may overstate commodity production and consumption trends. Finally, our process fundamentally ties two forecasts to a social accounting structure for a single base year. One risk of this approach is that any base-year eccentricities in a certain study area or industry are "locked in" to the entire forecasts. Recent economic history makes this issue particularly important. The results shown above are based on a base year of 2008, even though 2009 data was available. 2008 was chosen because, due to the steep contraction over the course of 2009, there were a number of negative value added components across industries that are typically positive. As such, one possible extension might perform some smoothing when tying forecasts to a base year (or years)

Despite these concerns, we believe the approach has the potential to improve freight infrastructure planning by providing a macro-based foundation upon which micro-level analysis can easily be built.

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