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Visualizing Truck Flows Based Upon Industry Data and Using Truck Visualization as a Planning Tool

Source: INRIX Data
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Introduction

The San Diego Association of Governments (SANDAG) is appreciative to Caltrans for awarding this unique Planning Grant in 2015 and working as a full partner in the development of this Report as well as in the development of an applied freight planning tool. As the Project title implies and as confirmed by the ensuing Project work; this undertaking has been challenging and rewarding, as is to be expected when working with new and rapidly advancing field of what is generically called “big data.” Also, as we discuss big data in this project, most often we will be referring to big data regarding truck movements, but there is also big data becoming available about other freight modes, so at times this report will refer to freight visualization. For the sake of simplicity, we will hereinafter refer to the overall Project as Truck or Freight Visualization, or the Truck and or Freight Visualization Project. This introductory section is organized into three sections:

- Section 1: Overview of Freight Data and Visualization
- Section 2: Policy Issues, Planning Needs and Future Challenges for Freight Data Visualization
- Section 3: Framework of the Study

Section 1: Overview of Freight Data and Visualization

Since at least 1991 when Intermodal Surface Transportation Efficiency Act (ISTEA) formalized the need to integrate freight and intermodal planning in public agencies; federal state and local level have been seeking and testing new ways to better understand truck flows in their communities, along freight corridors and around major freight hubs. Until very recently, the data sources used to count truck traffic have relied upon traditional data sources collected via stationary, fixed point measurement devices. Although these fixed-point capture devices are widely distributed across the roadway networks they are limited to truck data capture only at the location of the sensor. These fixed-point collection efforts include: in-pavement and surface-based sensors, video image detection systems, infra-red sensors, weigh-in-motion sensors and query-based information surveys (i.e. a Caltrans Border Intercept Survey).

Fixed Point Freight Data

Drawing upon the fixed-point truck data, overarching federal agencies with freight responsibilities then moved the state of the practice further along by aggregating large quantities of static truck data and developed and refined truck counting products such as the Federal Highway Administration’s Freight Analysis Framework (FAF developed by FHWA/USDOT), and the Bureau of Transportation Statistics’ freight tracking applications including the Trans Border Freight Flows. Without specialized personnel, many state and municipal agencies found these large freight data products such as FAF and Bureau of Transportation Statistics ’s (BTS) Trans-Border Flows to be technically challenging and cumbersome to use. Hence, many transportation consulting firms built specialized freight consulting practices to assist state and municipal agencies to conduct freight studies, often drawing upon the FAF and BTS among other tools.

Looking back, until very recently, the approach to understanding truck and freight flows has been underpinned by survey driven and record based electronic data sets where data has been locally manipulated to gain insights and interpretations of local freight implications. Most of the past freight studies have relied on historic data, to forecast future implications. With the rapid avalanche of new real-time data that is enabled by real time tracking technologies (i.e. Global Positioning Systems [GPS] and Bluetooth), planning agencies can now gain insights into almost real-time freight traffic flow conditions.
Transition to Location Enabled Freight Data

Starting in the early 1990s, the rapidly evolving current wave of truck data sources can be referred to as location-enabled and wireless technology devices. These devices can allow for continuous spatial tracking of truck movement and can fill in gaps left from traditional truck data collection tools. These devices allow technology within the vehicle to serve as vehicle probe data and started out with technologies such as: GPS, Media Access Control (MAC), and radio frequency identification devices (RFID). More recently embedded roadside traffic sensors such as lidar, microwave radar, and Bluetooth have become increasing reliable sources of data regarding vehicle movements. As these newer data sources become both more ubiquitous and more refined, scrubbed and aggregated, we in the public freight planning business; are experience a whole new way to visualize how truck move in, around and through our planning regions. Public Planning agencies are indeed in the early stages of having the ability to visualize nearly real-time truck flows.

Section 2: Freight Visualization Applications and Future Challenges

General Applications

There are multiple generic applications and planning needs related to freight visualization including the following:

- Development of a better understanding of the rapidly emerging technologies often employed by the private sector freight data integrators which can be used by federal state and local agencies with freight planning responsibilities,
- Exploration of useful applications of this new freight data for agencies to carry out the freight planning, programming and operating responsibilities, for example:
  1. Real time ability to map freight densities and flows
  2. Illustrating freight conditions for public awareness
  3. Environmental planning
  4. Conceptualizing where freight facilities should be planned

SANDAG Specific Applications and Challenges

To expand upon the generic freight visualization applications and challenges, numerous issues were identified that are specific to the San Diego region that will need to be considered as the agency expands into other visualization applications.

SANDAG Freight Planning Issues

- **Economic Issues**: What are critical transportation infrastructure needs within the San Diego region impacting the trucking industry? How do transportation planning decisions impact the trucking industry from an operational standpoint? Is there a clear benefit from freeway/highway capital projects for the trucking industry? What improvements can be made for truck parking needs?
- **Border issues**: How will border issues and the projected growth in goods movement from Mexico affect truck mobility in the region? How will the implementation of intelligent transportation systems (ITS) at the border and the implementation of the new border crossing impact the trucking industry?
- **Environment**: Can relationships be defined more clearly between truck traffic growth and the understanding of and better management or reduction of Greenhouse Gas emissions for baseline and future land use/transportation modeling scenarios? What other relationships can be better understood regarding for particulate matter and other air quality impacts from trucking?
- **Modeling**: What types of resources are needed to integrate and maintain truck visualization tools? What type of benefits can be gained through the addition of new data sources? Can new data sources for truck visualization be utilized to improve model validation/calibration and/or be used to illustrate performance measurement? Can new performance measures be associated from additional truck visualization tools?
• **Data Availability:** What are the most important data sources needed to generate optimal truck visualization tools? What is the level of effort needed whether internal or external to gain access to the use of potential data sets?

• Purchasing cost and staffing costs involved and applying a new data source that SANDAG can utilize in carrying out their freight planning, programming and operations functions.

**SANDAG Data Privacy Issues**

• **Data Privacy Challenges:** How will procured data from any potential vendor, which has access to specific vehicle locations, avoid privacy concerns? Do agencies seeking to use location-based data have a privacy assessment plan in place with sufficient documentation to ensure that there are no conflicts and/or risks? How will the private sector view advancements into truck visualization? How can truck visualization data be utilized to ensure anonymity?

**SANDAG Cost and Funding Issues**

• **Project:** What are the staffing resources needs to continually update truck visualization tools and maintain required information, and are these costs justifiable on a cost benefit basis? What are the comparative benefits versus costs of incorporating new data sources versus existing ones?

**Section 3: Framework of the Study**

The overall freight visualization planning grant covered four broad areas of work. First, SANDAG appointed a project development team and conducted a series of information gathering workshops with guidance from that team; the agency then purchased freight visualization data and applied that data to SANDAG freight planning activities, SANDAG also built a new freight website whereby the agency could apply the purchased freight visualization data, and finally a series of Technical Memoranda were developed. The Technical Memoranda are the key product that underpinned the workshops, the data purchase and the revised website. The Technical Memoranda below are the substance of this Report., they are included in this Report:

• State of the Practice for Truck Data Collection and Truck Flows
• Summary of Prioritized Policy Issues
• Methods for Understanding Generators and Attractors
• Summary of Data Collection Needs and Strategies
• Assessment of a Truck Visualization Tool

Each Technical Memoranda section is meant to provide an illustration of the best practices, policy issues, SANDAG technical applications, drivers of truck freight flows, and the development and integration of new freight datasets into these resources.
Using Truck Visualization as a Planning Tool

Technical Memorandum #1: State-of-the-Practice for Truck Data Collection and Truck Flow Visualization

This technical memorandum is intended to provide guidance for consideration to the planning profession and agencies. The memo provides a review of literature to identify approaches that are currently applied or have been considered for the use of data to visualize truck flows at the planning level. The memo is intended to serve as a reference tool for truck visualization-related information, research and best practices available in California, the United States and elsewhere. The memo consists of the following sections.

- Section 1: Introduction/Background – Provides a brief overview of goods movement planning as it relates to trucks and freight, what is meant by the term “truck visualization,” and the various types of visualization for goods movement and data collection methods being studied and implemented.

- Section 2: Case Studies – Reviews applications of truck visualization strategies, including: metropolitan planning organizations (MPOs) – existing use of visualization techniques and state departments of transportation (DOTs) – existing use of visualization techniques.

- Section 3: Literature Review – Describes findings from a review of research documents and government reports, including national level studies, other studies and vendor literature and information as they relate to the use of truck visualization strategies.

- Section 4: Conclusions – Summarizes the findings and provides recommendations of key topics for further consideration.

A list of works cited is provided at the end of this memo.
Section 1: Introduction/Background

Goods Movement Planning

MPOs are tasked with developing appropriate policies and project implementation strategies which align with federal and state mandated guidelines. The importance of a solid tool for goods movement is escalating quickly, as guidance has been changing at a rapid pace of late due to both recent federal and state actions.

Federal

At the federal level, the Fixing America’s Surface Transportation Act or “FAST Act” was passed in December 2017. Once passed, the FAST Act authorized through Congress, freight provisions including a competitive discretionary freight-focused grant program as well as a national highway freight program involving formula funds appropriated at the state level. Combined, these programs will provide nearly $11 billion for freight projects during the five-year cycle, an unprecedented first step in direct and dedicated freight funding. The National Highway Freight Network (NHFN) and its subsystems of roadways, has served as an important factor in determining eligibility for both the competitive grant process and for formula funds.

Figure 1.1: Interim National Multimodal Freight Network

Source: U.S. Department of Transportation, August 2016

Based on the national freight policy established from Moving Ahead for Progress in the 21st Century Act (MAP-21), the Draft National Freight Strategic Plan (NFSP) was developed by the U.S. Department of Transportation (U.S. DOT). The NFSP focused on key trends and challenges, as well as strategies to address infrastructure, institutional and financial impediments. Also stemming from MAP-21 and the NFSP, a notice for request for comments was issued for the establishment of an Interim National Multimodal Freight Network (NMFN as depicted in Figure 1.1).

The complexities involved in the federal processes for these underlying efforts pose challenges, but the importance of clearly identifying freight projects within a state and/or region to either compete within the discretionary grant process or formula fund programs cannot be taken lightly.
As part of the methods used to designate freight projects at the state level in California, the NHFN and interim NMFN, as well as other factors and criteria have been relied upon as resource tools. Currently, funding programs are tied to the NHFN. The need to articulate and illustrate freight project benefits is clear today, and for the future as related to federal freight funding.

State

At the state level in California, both MAP-21 and the FAST Act have been complimentary to policy needs and project implementation strategies as related to statewide guidance. The state has created a policy committee, the California Freight Advisory Committee (CFAC) to provide the appropriate forum for all freight stakeholders, in order to provide for a transparent dialogue of the state’s development and implementation of policies including guidelines and rules as they relate to planning and project implementation strategies.

Consistent with the NFSP, the California DOT has developed the state’s freight plan, the California Freight Mobility Plan (CFMP). The focus of the CFMP is to balance the state’s vision and goals for freight with the needs of regions and local agencies from a policy and project implementation perspective. Similar with the NFSP, the CFMP focuses on looking at diverse needs including economic, environmental and efficiency-related issues; and considering these needs within a multimodal freight context.

In July 2015, the Governor of California issued an Executive Order, B-32-15 which directed seven of the state’s agencies including the DOT to develop an integrated action plan by July 2016 that establishes clear targets to improve freight efficiency, transition to zero-emission technologies, and increase competitiveness of California’s freight system.

Figure 1.2: Depiction of global supply chain networks

Source: Material Handling & Logistics Staff Publication, March 2016
As part of this process, many MPOs and both public and private freight stakeholders have provided input into the development of the California Sustainable Freight Action Plan. This has involved direct meetings with California Air Resources Board (ARB) staff, the submission of comment letters on draft policy documents, technical reports and white papers, as well as discussion items at MPO policy meetings and the CFAC.

Similar to federal processes, the state of California has been tasked with balancing freight stakeholder needs and concerns while looking to lead initiatives for the benefit of the state’s economy and sustainability. This charge has greatly involved detailed analysis and assessments to provide structure for project implementation strategies that take complex supply chains into account (see Figure 1.2).

Regional/Local

MPOs, Regional Transportation Planning Agencies, (RTPAs) and County Transportation Commissions (CTCs) are responsible for establishing policy actions and project implementation strategies for their regions, including local jurisdiction municipalities and unincorporated county areas. Many of these agencies have passed sales tax ordinances as a form of local funding to facilitate project implementation capital budget programs. These dollars can now be leveraged with federal FAST Act funds both directly and through state formula programs for freight projects. The burden for regional agencies of limited funds versus project needs is prevalent throughout the country. As such, most incorporate some form of evaluation or analysis for projects in order to develop a constrained list for both near-term and long-term project implementation.

Goods movement planning and project implementation present many challenges, the combination of public and private issues must always be kept in perspective. Some public infrastructure is directly under the purview of government agencies, the dynamics between global supply chains, private enterprises and local communities often pits stakeholders with very different interests into a common policy action or project area.

The spectrum between national and state initiatives versus the regional and local aspects of planning and project development as they relate to goods movement will always be controversial as a result of the dynamic and fluid nature of today’s global freight environment. As such, it is important for all levels of government to be able to work with a multitude of public and private freight stakeholders, and to be able to articulate and illustrate how the processes with which government is tasked can align with the interests of those impacted by the flow of freight goods daily and throughout the world. Planning level and project implementation strategy freight tools need to be accessible and relatable to this fluid environment.
What is Truck Visualization?

Truck visualization by simple definition can be explained as an illustration or graphical representation of a pattern of movement derived from truck trips. In the planning profession, this is most commonly associated with transportation networks within a transportation model framework.

Figure 1.3: Truck peak period travel speeds

From an MPO’s perspective, visualizing trucks may range from showing the types of trucks (how vehicle classifications are organized) to where and when those trucks are moving in the transportation network (see Figure 1.3). This could inform an MPO about the different truck types and their specific cargoes (tractor-trailer, package delivery, waste collection); to utility and other service-based vehicles. In either case, there are policy and planning-related interests; for the purpose of this review, the focus is targeted for visualizing larger freight trucks.

From a planning and policy perspective, understanding the movement of trucks between land use generators and attractors can be highly beneficial for various interests. Useful planning applications may involve traffic and congestion-related speeds and travel times throughout the day; environmental and/or community concerns based upon air quality; operational and maintenance priorities based upon infrastructure needs; and technological innovations supporting greater operational efficiencies and optimal consumption of finite resources.

Today’s modeling, mapping and geographic information system (GIS) capabilities can readily provide the foundation for displaying data for visualizing analysis and technical assessments. Focusing on the truck mode is important as a substantial majority of goods are delivered to wholesale and retail distribution centers and warehouses via trucks.
There is a direct association with the relationship between consumer purchases being made, whether online or from a traditional store, and goods being delivered via truck to that retail location as well as to the consumer after-the-fact if purchased digitally. E-commerce alone has had fundamental impacts as to how long goods are stored as inventory, to the speed at which they are provided to customers after an order is placed. These impacts have affected land use development as well as transportation networks and the different freight modes using them. As these changes have and continue to occur, it becomes more important for planning staff and policy makers to be able to visually understand these relationships so as to make informed decisions.

**Other Applications of Freight Visualization**

It is important to consider other applications for freight visualization. As mentioned, land use changes have occurred due to E-commerce growth, most notably, the development of Amazon order fulfillment centers (see Figure 1.4 below). One example of an impact from fulfillment centers is the need for smaller consolidation facilities, similar as is needed for package delivery companies to deliver packages to residential, commercial and office locations.

**Figure 1.4:** Amazon warehouse and distribution locations

Source: University of California, at Los Angeles Global Supply Chain Blog, July 2015
This type of development would lend itself to visualizing relationships between multiple industrial and residential, commercial and office land uses to better understand generator and attractor dynamics. Even visualizing relationships between traditional store distribution centers and corresponding retail locations within a region can be valuable at illustrating major freight corridors.

Another example of visualization relates to the identification of freight assets, or inventory. This can be used in the context of assets including seaports, airports and land ports, rail yards, truck stops, truck terminals, interstates and highways, rail lines, among others. These assets can be considered as major arteries and points for which goods moved depend upon.

Other sources for freight information relate to the value of goods, commodities, tonnages and/or units of goods moved through regions, states, countries and the world (see Figure 1.5). There is a myriad of information related to commodities representing cost inputs and final sales for products, as well as economic indicators which signal trends for sales of goods and supply and demand balances.
At the regional, state, or national level, visualizing international trade value may be an important component for a policy or project implementation strategy; while understanding and illustrating tonnage may be vital for another decision related to infrastructure maintenance needs.

**Data Collection Sources**

The core component for any form of visualization is dependent upon data sources. The primary foundation for evaluating and/or disseminating data is through transportation models, GIS and other applications including web-based and mobile. For planning-level truck data, typical data sources have included survey instruments, truck counts collected manually, loop detection, weigh-in-motion devices and GPS.

**Figure 1.6: Diagram of Existing versus New Freight Data**

<table>
<thead>
<tr>
<th>Existing</th>
<th>Newish</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing = Widely used for a while, often includes legacy government data programs</td>
<td>Newish = Has been around for a while but not yet widely applied</td>
<td>Really New = Increasingly available and not yet widely applied / understood</td>
</tr>
<tr>
<td>Commodity Flow Survey</td>
<td>Truck GPS Data</td>
<td>Crowd Sourced Data</td>
</tr>
<tr>
<td>Freight Analysis Framework</td>
<td>Business Data</td>
<td>Vehicle Data Streams</td>
</tr>
<tr>
<td>Transsearch</td>
<td>Truck Permit Data</td>
<td>Non-vehicle Device Data Streams</td>
</tr>
<tr>
<td>Satellite Accounts</td>
<td>Billing Sourced Data</td>
<td>Image Data</td>
</tr>
<tr>
<td>Vehicle Data (e.g. VIUS)</td>
<td>Land Use</td>
<td>Road Sensor Data</td>
</tr>
<tr>
<td>STB Waybill</td>
<td>Real Time Truck Parking</td>
<td>CFS PUMS</td>
</tr>
</tbody>
</table>

Source: CPCS, Truck Data, Visualization and New Data Sources for Addressing Metropolitan Freight Challenges PPT, October 2016

More recently, and driven by smartphone technology, internet-based devices including Bluetooth and Wi-Fi readers have begun to emerge. These forms of data collection have also sparked interest and debate related to privacy concerns due to the potential for personal identification (see Figure 1.6).

Government agencies including the California DOT, California Highway Patrol (CHP) and U.S. Customs and Border Protection (CBP) have access to closed-circuit televised cameras (CCTV), but these video sources are not necessarily available for dissemination to other government agencies. In the event CCTV data were available, it would also require additional resources for analysis.

Other states within the U.S. and facilities in California utilize radio-frequency identification (RFID) tags on trucks to allow access on certain roadways and/or points providing access to terminals to pick-up and drop-off goods. Examples include toll roads as well as terminals at both rail and seaport facilities. Access to these sources of data is dependent upon toll/terminal operators. For private rail and seaport terminals, this information is not available to public agencies.

For regions such as southern California, data sources have typically included Caltrans truck counts, and a wide variety of surveys including those from carriers, shippers and receivers, border users, and diverse commercial vehicle users. Other studies and data sources have included vehicle occupancy studies, trip diaries, classification counts, weigh-in-motion station data, speed/flow surveys, American Trucking Research Institute (ATRI) GPS data, INRIX fleet data and various broad-based discussions with planning partners, including advisory committee members. These same methods have similarly been practiced throughout the United States.
The initial challenge for public agencies has been that very few regional models have maintained robust and comprehensive truck data for a variety of vehicle classifications. This has been triggered by limited budgets and resources internally, as well as dependence on many different static data sources, incremental third-party consultant assistance, and data access challenges from the fact that a large amount of the direct data is privately held.

**Figure 1.7: Available Freight Data- Truck O-D Survey Data**

![Available Freight Data Survey Data](image)

- **GDOT conducted truck O-D surveys in 2005**
- **Surveys provide data on**
  - Through truck traffic,
  - Commodity distribution, and
  - Trading partners

Source: Georgia Statewide Freight & Logistics Plan, March 2011

Internally, maintaining a broad coverage of truck counts or other primary and secondary data sets has often been cumbersome, while other spot-location data sources have only provided a portion of information for a region’s needs.

Survey instruments have sometimes presented skewed data results, though they have been historically useful to public agencies (see Figure 1.7). This effect is often compounded when budgets preclude purchasing larger sample sizes. The reliance upon and tendency to commingle survey-based primary and other secondary data involving multiple agencies and/or consulting firms can potentially also place data quality at risk. As financial resources in general remain tight at many government agencies, often data-related projects and resource needs are not able to encompass as broad of a range as desired to provide the informative pieces necessary to guide project and/or policy objectives. Surveys tend to be a single point of reference and/or time, not always providing a continuous view of how things are changing.

For these reasons among others, new data generally referred to as “Big Data,” which rely upon third-party data mining to extract specified data analysis, are becoming more popular. Big data databases often have millions upon millions of records, which typically process information daily based upon user account activities.

Recent events driving the shift to big data analysis have largely stemmed from the proliferation of mobile devices, which have led to increasing amounts of data and information available for capture through Internet use and transactions. As a result, big data sources for freight data analysis and visualization could be many. Some vendors with access to fleet telematics or cell phone data could extract travel speeds, or origin/destination type information to build upon freight transportation and land use relationships. Others may have access to freight payment networks and/or other direct information through the billing process which could have the potential to be used for optimizing basic supply chain infrastructure needs and planning appropriately as commodities and/or volumes may change over time. Overall, many of these forms of analysis can be structured into the same issues and needs facing government agencies today.
The primary task of the Using Truck Visualization as a Planning Tool is focused on the many opportunities before public agencies to utilize various forms of big data in order to capture a compelling analysis of truck traffic and flow. Through the identification and understanding of current truck data collection and analysis, third-party data vendors using big data may be able to offer solutions to provide greater context for some of the issues associated with current methods. It should be mentioned, that while these sources usually provide continuous data, they also do have their own biases or limitations. As an example, data may only include one type of truck classification, such as long-distance carriers, excluding short haul, drayage, package delivery or other trip types. Additionally, vendors may be able to offer cost-competitive solutions with more frequent and larger population sizes than ever before, with the flexibility to adapt to changing policy and project implementation strategy needs.

Section 2: Case Studies

MPO Case Studies – Existing Use of Visualization Techniques

There are several examples of MPOs which have incorporated the use of visualization techniques, including the truck mode within their regularly updated planning documents and/or tools. This has included freight mobility plans and strategies, among others. Three MPOs have been highlighted for case studies which provide current information including the Atlanta Regional Commission (ARC), Southern California Association of Governments (SCAG) and Delaware Valley Regional Planning Commission (DVRPC).

Atlanta Regional Commission – Atlanta Regional Freight Mobility Plan Update, May 2016

The ARC Atlanta Regional Freight Mobility Plan Update (RFMP Update) represents the freight component of the region’s Regional Transportation Plan (RTP). The objectives of the most recent plan update include the following:

- Assess the current plan against the latest understanding of existing conditions and forecasts;
- Update the plan based on the latest federal, state and Atlanta regional policies;
- Support the development of a FAST Act compliant RTP as it relates to applicable freight provisions;
- Identify projects of national, state and regional significance; and
- Define a path forward for project investment and establishment of responsive strategies and initiatives.

These primary elements are a direct representation of the items discussed in ARC’s goods movement planning introduction. Through freight visualizations, the ARC was better able to provide valuable information for multi-modal freight systems, assessments of regional plans and freight trends, assessments of performance measures, opportunities and needs, and freight project prioritization.
One of the key assessments of the RFMP Update was the identification of freight intensive clusters (see Figure 1.8). Cluster identification deeper levels or details were addressed by depicting low-to-high range of densities for warehouse/distribution center, manufacturing and vacant industrial space land uses. Truck trips ends were also assessed by a range of the number of trucks stopped throughout the region. Through these visualizations, the nexus between the intensity of certain freight-related land uses and truck traffic demand were strongly correlated.

When combining these sources of information for the Atlanta region, the clear distinction between the locations of the most intense manufacturing, warehouse/distribution center and truck activity becomes much more presentable for freight stakeholders and advisory committees. By including the identification of vacant industrial space, planning processes could begin to analyze future locations for these industrial activities, which would in-turn be a driving factor for truck traffic demand. These are the types of discussions that can be highly informative when considering all aspects within an RTP development process.
In addition, the RFMP Update went beyond the identification of supply and demand factors as highlighted above (see Figure 1.9). Further assessments for speed and reliability measurements were analyzed for the region as well as within specific identified cluster areas.

Providing this type of information quickly allows freight stakeholders to recognize potential problematic congestion locations within major interstates, as well as for last-mile connecting arterials with direct access to facilities within cluster areas.

Reliable travel distance was also assessed at each cluster area based upon peak one-hour travel sheds. From a regional context, this type of information can be valuable in providing a clear perspective of the type of access by travel time.

Source: Atlanta Regional Freight Mobility Plan Update, May 2016
Depending upon freight truck trips whether short- or long-haul, the region would be able to identify challenges for shipments entering and exiting the Atlanta area based upon travel sheds, as well as by travel speeds within a travel shed depending on the time of day (see Figure 1.10).

These examples are valuable in that they relied upon a regional transportation model as the primary tool for disseminating information. Data sources and methodologies for the RFMP Update involved ARC, the state of Georgia, consultant work, and vendor information.

Southern California Association of Governments – Transportation Goods Movement System Appendix, April 2016

Similar to the ARC, the SCAG region has developed a Transportation Goods Movement System (TGMS) strategy as an adjunct to the RTP process. The vision of the TGMS is to promote the improvement of the goods movement system in order to:

- Maintain the long-term economic competitiveness of the region
- Promote local and regional job creation and retention
- Increase freight and passenger mobility
- Improve the safety of goods movement activities
- Mitigate environmental impacts of goods movement operations
Again, these vision items are clearly tied closely to federal and state guidelines and policies as discussed in the goods movement planning introduction. SCAG relied upon freight visualization techniques to illustrate regional system assets, highlight facilities for the PHFS, display relationships between manufacturing firms in the region and multimodal supply chains and performance measurement for freight facilities. The SCAG region includes a diverse set of multimodal facilities for seaports, land ports, air cargo, Class I railroads, warehouse and distribution centers and interstates, and highways and local roads.

Highlighting these freight assets and facilities is important for the SCAG region due to the substantial amount of international trade that occurs at the seaports which is distributed throughout the state of California and the United States, as well as the amount of domestic consumption which occurs in the metropolitan region and in southern California.

**Figure 1.11: Primary highway freight system**

Source: SCAG Transportation Goods Movement System Appendix, April 2016

SCAG also included a visual representation of the PHFS within its region to illustrate the regional highways already designated for federal funding programs (see Figure 1.11). The SCAG region includes six counties and 191 cities translating to a robust interstate and highway network. Irrespective of large volume goods being shipped by ocean, rail and air carriers, the majority of goods distributed within SCAG’s region are by the truck mode, as truck moves are integral to every aspect of global or domestic supply chains.
Adding to this complexity are the vast amounts of manufacturing firms including their warehouse and distribution operations. When focusing on manufacturing firms in the SCAG region by total employment, the majority is within Los Angeles County, followed by Orange, San Bernardino and Riverside counties.

As one would expect, these major manufacturing clusters are located within the most industrial areas for each respective county. Additionally, many other facilities are located in these same industrial areas, including warehouses, regional and national distribution centers, fulfillment centers, intermodal rail yards and truck terminals. Clearly SCAG’s industrial clusters are correlated to the identified PHFS and local roadways which provide access to gateways such as the seaports and airports and all other facilities which have been mentioned.

**Figure 1.12:** Average 2012 weekday truck speeds on highways – PM peak period

As part of the long-range planning process, SCAG provided average weekday truck speeds on highways for both the AM and PM peak periods (see Figure 1.12). This information is included for the base year as well as for future year forecasts. Truck speeds and travel time reliability are important factors for the industry. Many companies have integrated GPS and freight optimization systems to provide visibility for their customers. With strong visualization tools, government agencies can provide insights into how infrastructure investments may be able to relieve issue areas allowing for the potential of creating greater operational efficiencies and cost reductions.
In SCAG’s case, the identification of truck bottlenecks has been one way to get at prioritizing problematic areas within the region. This approach has been in alignment with the NFSP’s infrastructure impediment strategies. Overall, the TGMS relied upon its SCAG internal capabilities, consultants and outside vendors to develop its visualization tools for its planning needs.

**Delaware Valley Regional Planning Commission – PhillyFreightFinder**

The DVRPC received funding through the second Strategic Highway Research Program (SHRP2) for its Local Freight Data Improvement project. The core objectives of this project were to:

- Identify and adapt disparate sources of data;
- Refine current data sources for regional or sub-regional applications;
- Establish, pool, and standardize a portfolio of core freight data that supports planning, programming, and project prioritization; and
- Improve and update *PhillyFreightFinder* platform

This project was unique in comparison to the previous two case studies in that it sought to use a web-based interactive platform as a communicative and sharing framework, specifically creating a visualization tool called *PhillyFreightFinder*. This provided substantial value for all freight stakeholders. Through the development of the visualization tool, a robust process for data inventory and processing was used, which encompassed considering freight network supply, freight activities by mode, freight activity data, commodity flows, and freight performance measurement and data collection priorities.

*Figure 1.13: Heavy truck volumes and freight highway network*

Source: Making Freight Data More Accessible, SHRP2 C20: Local Freight Data Improvement

Through this process, the DVRPC was able to incorporate countywide truck count data from an ongoing program through the Pennsylvania DOT, as well as incorporate a modified highway network including National Performance Management Research Data Set (NPMRDS) and HERE probe data for cars and the American Transportation Research Institute (ATRI) probe data for trucks, among other data sources (see Figure 1.13).
The result has been a valuable visualization tool resource which has provided a menu of information for multiple freight modes, which can be used for a variety of planning and programming needs, grant applications as well as for a diverse set of freight stakeholder needs.

A valuable aspect of the project was the opportunity to improve upon existing data. As part of the data inventory analysis and processing, data sources were assessed between local and state agencies, gaps were identified for truck counts, and a collection plan for future count needs was highlighted and suggested for future development. The development of the PhillyFreightFinder tool included resources from the DVRPC, DOT, federal partners, consultants and an extensive list of vendor applications (see Figure 1.14).

**DOT Case Studies – Existing Use of Visualization Techniques**

There are also examples of DOTs which have incorporated the use of visualization techniques, including the truck mode within their regularly updated planning documents and/or tools. This has included statewide freight plans and strategies, among others. Two DOTs have been highlighted for case studies which provide current information including the Washington State DOT and Florida DOT.

**Washington State Department of Transportation – Truck Freight Economic Corridors**

The Washington State DOT (WSDOT) has developed Freight Economic Corridors (FECs) for roadways, railways and waterways. WSDOT worked with its Freight Mobility Strategic Investment Board, MPOs, Regional Transportation Planning Organizations, counties, cities, tribal governments and ports in developing objective criteria to define the statewide system of FECs.

WSDOT has received and included over 250 regional strategies from these partners and a list of freight priority improvement projects on the FECs was developed and included in the 2014 Freight Mobility Plan capital project list. The FECs are updated on a two-year cycle, coordinated with the update to the Freight and Goods Transportation System.
The intent of the FECs is to identify and map the relationships between supply chains, identify system condition and capacity issues and to develop performance measures to improve freight mobility. The Puget Sound region has a confluence of freight activity stemming from its Seattle and Tacoma seaport facilities, airports and interstate and state route roadway networks.

For truck FECs a classification structure has been developed including T1 freight corridors that carry more than 10 million tons per year; T2 freight corridors that carry four to 10 million tons per year; alternative freight routes that serve as alternatives to T1 truck routes that experience severe-weather closures, and carry 300,000 to four million tons per year; and first/last mile connector routes between freight-intensive land uses and T1 and T2 freight corridors.

Part of the supply chain mapping exercise focused on agricultural processing facilities and facility clusters, which were defined by top agricultural products by value. Other land use classifications included industrial land in urban areas, commercial land within five miles of T1 and T2 highways in rural areas, industrial land within five miles of T1 and T2 highways in rural areas and Puget Sound Regional Council (PSRC) manufacturing and industrial centers.

From a big-picture perspective, these truck FECs connect the entire state of Washington based upon supply chain needs, as well as for local, national and international consumption. From an economic competitiveness standpoint, this type of information can be highly valuable over time. Based upon the two-year cycle update, the state can monitor performance trends and proactively look to develop strategies to solve new issues.

Key data sources involved in the WSDOT truck FEC development process included statewide land parcel data compiled and published by the Department of Ecology, Agricultural Commissions data and the National Highway System (NHS).

**Florida Department of Transportation – Freight Mobility and Trade Plan Policy Element**

The Florida Department of Transportation (FDOT) has taken a proactive role in establishing its Freight Mobility and Trade Plan (FMTP), including 2012 Florida Legislature in HB 599. Similar to other states, the FMTP is aligned with federal policies and guidance including MAP-21 and the FAST Act, as well as with the 2060 Florida Transportation Plan.

The broad goals of the FMTP are to:

- Increase the flow of domestic and international trade through the state’s seaports and airports
- Increase the development of intermodal logistics centers (ILCs) in the state
- Increase the development of manufacturing industries in the state and
- Increase implementation of compressed natural gas (CNG) and liquid natural gas (LNG) and propane energy policies
These objectives are shaped by Florida’s strengths and potential which relate to the state’s highway system, deep-water seaports, spaceports, aviation facilities, rail lines and pipeline networks. These multimodal systems are classified as the cargo “dimension” of the overall freight system. Florida has developed five dimensions of freight with the other four including economic, geographic, supply chain and modal.

Specific to truck visualization, FDOT has developed similar illustrations and techniques as other state and regional peers. The primary focus has been on identifying truck flows in relation to national highway systems designated within MAP-21 and the FAST Act.

FDOT has relied upon Federal Highway Administration (FHWA) information and tools to visualize internal as well as interstate truck flows (see Figure 1.15). This information has helped the state’s story regarding freight activity. Similar to the state of Washington, Florida has a diverse freight activity relationship with local, national, and international consumption.
FDOT, similar to the SCAG region, has utilized and visualized data to provide the context for both congestion and highway bottlenecks (see Figure 1.16). The FMTP’s first broad goal is to increase the flow of domestic and international trade through the state’s seaports and airports. Like most major gateway regions with strong performing seaports and airports, the majority of Florida’s tonnage flows are moved by the truck mode as trucks are the primary transitory method for getting freight to intermediary locations. Trucks accounted for nearly 75 percent of Florida’s total freight flows by mode.
As part of the FAST Act, an emphasis on identifying freight bottlenecks has had a greater focus (see Figure 1.17). The term bottleneck has a wide-reaching scope as this could relate to any major gateway including seaports, airports and land ports, but has typically been associated with problematic areas for interstates and highways.

FDOT was able to rely upon the state's planning office to supply the required data to identify Florida's highway bottlenecks. Underlying data was used from the private data vendor INRIX with some exceptions where the data was not available or did not meet the sample size requirements.
Like other peers, FDOT also considered the freight land use relationship to its Interstate and highway networks. The FMTP relied upon a previous Florida Trade and Logistics Study completed during 2010 to identify distribution centers throughout the state (see Figure 1.18). Clearly, there is a relationship between the location of freight distribution centers, heavily congested corridors and highway bottlenecks. Many of these major distribution clusters are equally within proximity to major metropolitan areas adding the complexity between both freight and passenger demands.
It is important from a planning perspective to also highlight freight facility needs so that planning and project implementation strategies do not solely focus on passenger vehicles and infrastructure, but rather balance economic interests and competitiveness with greater systems efficiencies for freight stakeholders. The FDOT relied upon an industry participation approach, rather than a government-only focus, to better reflect the needs of freight stakeholders and to be more proactive and responsive to streamline freight investments. The FMTP relied upon internal FDOT resources, previous studies, consulting and vendor data for the development of its truck mode focused visualizations (see Figure 1.19).

**Section 3: Literature Review**

While there is a substantial amount of research focusing on the relationships between land use development and passenger vehicle travel correlations, a similar level of research does not exist currently for freight-based land uses and freight travel for visualization applications. Newer studies are beginning to focus on freight systems and infrastructure and the relationships to the many industrial areas and employment centers, which drive a large amount of freight travel patterns. The information below provide some context and information which can be applied to truck visualization tools.

**National Level Journals, Studies & Publications**

*Journal of Geography and Regional Planning – Exploration and Visualization of Highway Freight Flow Movements in the United States Using Geographical Information System (GIS), May 2012*

This research paper provided a national overview of transported goods, classified by Standard Classification of Transport Goods (SCTG) commodities and their movements on highway networks in the United States using TransCAD, a geographical information system and the Freight Analysis Framework (FAF).
The analysis included national views of from, to, within, and through freight flows by state; at the more local level, total freight flows focused on the state of Oklahoma to illustrate how these flows varied. A linear regression model was established by linking state freight flows to state major socio-economic indicators, such as employment, revenue, income and payroll (see Figure 1.20). Total freight flow demand categories included tonnage, commodities and value. This information was provided for a base year and future-year forecast.

Origin and destination freight flows were provided at both the national level and for the state of Oklahoma as examples. The information from the FAF tool is capable of illustrating tonnage and trade value for different commodity types, as well as origin and destination information. Additionally, these flows are capable of being displayed by truck mode via roadway networks, providing further applicability for different regions. Illustrative techniques do require technical expertise including model and GIS analysis.

Traditional modeling techniques are typically focused on vehicle traffic demand for truck trips rather than tonnage, commodities or trade value. But these additional visualization techniques made available by the FAF tool offer perspective for the relationships between global international and national domestic flows, as they relate to a state, as evidenced by the state of Oklahoma example. Relationships became clear between major producing and consuming regions based on these flows.
For state level geographies, this type of tool provided multiple potential visualization benefits. States are often called upon to analyze how particular commodities, commodity tonnages and trade values flow to other states. This visualization technique allows for the ability to highlight the importance of a particular project implementation strategy that could have regional, national, or international impacts (see Figure 1.21). These types of visual techniques can provide greater analytical tools to identify important highway projects, and/or corridors for grant funding opportunities. The capability of performing intrastate assessments through truck visualization allowed both regions within Oklahoma and/or the aggregate state level, to illustrate an overview of the entire truck demand flow perspective.
The following graphic illustrations (Figures 1.22-1.24) depict the variations between from and to flows for the state of Oklahoma, as well as the through and within flows for the state. The FAF tool directly provides to, from, within, and through flows, as well as other granular illustrations that were developed by other entities outside of the U.S. DOT.

Figure 1.22: FAF freight origin flows from the state of Oklahoma

![Figure 1.22: FAF freight origin flows from the state of Oklahoma](image1)

Source: Exploration and Visualization of Highway Freight Flow Movements in the United States Using GIS, From Flow

Figure 1.23: FAF freight internal flows through the state of Oklahoma

![Figure 1.23: FAF freight internal flows through the state of Oklahoma](image2)

These types of graphic illustrations provided clear details regarding how truck freight flows along interstates, highways and corridors were organized. For the state of Oklahoma, for example, there was a strong amount of truck flows to and from the state, followed by flows through the state, and flows within the state. Applying this commodity flow information, regions and states can visualize internal consumption of products, production and manufacturing relationships, as well as the internal freight-related services provided and freight flow demand for their state.

INTECH – Application of Geographic Information Systems: A Primer on Recent Advancement on Freight Transportation, October 2012

INTECH through InTechOpen is the world’s largest science, technology and medicine open access book publisher. This publication has provided a similar assessment as the previous journal review incorporating FAF data. However, this review provided further information regarding the Center for Transportation Analysis (CTA) of the Oak Ridge National Laboratory (ORNL) and the Commodity Flow Survey (CFS), which are tied to the FAF visualization tool. Additionally, the paper included the geographical spatial component through GIS rather than TransCAD.

As stated in this document, numerous forms of research have identified that the freight transportation system is highly complex. The demand for the movement of freight involves multiple decisions as organized below:

- Producers of goods and services who decide how much and how to produce, and where and at what price to sell;
- Consumers, either intermediate (production companies) or final (households, business, public agencies, etc.), who decide what to consume and how much; and
- Transportation companies (shippers and carriers) who decide how to provide transportation services
- Commodities are reflected throughout the entire decision process. In order to assess freight demand, an understanding of commodities whether finished goods or semi-finished or raw materials needs to be understood. Additionally, the need to understand vehicle types is important in order to match commodity types and shipment sizes.

Source: Exploration and Visualization of Highway Freight Flow Movements in the United States Using GIS, Within Flow
Combined, these challenges relate to the “basic transport mode systems” including truck, rail, water, air, multiple-modes and pipeline. However, “sub-networks” also exist which include transfer terminals such as seaports and airports, and intermodal points such as rail yards. The complexities of the variables associated with commodity inputs and outputs through these freight systems are what pose substantial challenges for freight data collection and visualization.

As noted in the publication, the CFS is arguably the most comprehensive survey for freight flows in the U.S. This survey is conducted every five years as part of the Economic Census by the U.S. Census Bureau, in partnership with the Bureau of Transportation Statistics (BTS) under the Research and Innovative Technology Administration (RITA) of the Department of Transportation (DOT).

Figure 1.25: Schematic of FAF geographies within the U.S. and associated global freight flows

The FAF integrates CFS data, as well as data from a variety of supplemental sources for industry sectors not in the CFS. Additionally, the FAF can be configured to picture major freight flows from metro areas, state areas and international destinations (see Figure 1.25). As noted earlier, this data includes two-digit SCTG classifications, and tonnage and value freight flows by these commodity types.

Source: A Primer on Recent Advancement on Freight Transportation
The CTA and ORNL maintains a computerized representation of the national intermodal and multimodal network system. The primary purpose of the CTA network is to provide a pathway for freight system impediments from the use of a standard GIS system which have been identified.

Impediments are related to the overlapping of geographic features such as logical links of the same physical link, and the representation of many geographic features such as terminal links and interlines over a single point (see Figure 1.26). As such, a special version of the CTA has been prepared to reduce unnecessary link connections and/or complications. This attempts to get at the realistic nature of freight flows and the many interchanges for different modes.

Source: A Primer on Recent Advancement on Freight Transportation
A large portion of the paper included a detailed review for demand modeling and the CTA’s freight models for reference. These resources provide for a good representation of methods used to enhance freight flow modeling. Through the incorporation of the FAF tool, the outcome from the previous review is similar in depicting multimodal freight flows. (see Figure 1.27).

However, the technical review of how freight systems were organized and how the FAF and CFS were structured, in relationship to the CTA’s enhancements for demand modeling, provided greater insights for technical staff consideration. FAF data for tonnage, commodities and trade value can be integrated into a GIS application for visualization purposes. This type of analysis does require expertise in multiple data sets in addition to FAF, as well as technical capabilities to compile, aggregate and integrate the information holistically within a particular geography. The broader global and national scope of these data sets which can be applied to state or regional geographies provides additional freight assessments, which can be visualized and used to define policy issues and needs.

Journal of the Transportation Research Board – Managing Performance and Assets; Freight Data and Visualization; Understanding Freight Trip-Chaining Behavior Using a Spatial Data-Mining Approach with GPS Data, 2016

This research study provided two primary components; first, the study developed a spatial data-mining approach to extract trip-chaining information from large GPS data sets. Second, the study used the generated trip-chaining data over multiple days to better understand freight travel behavior patterns with the goal of facilitating further development of freight demand models.

The study relied upon a GPS data set which was obtained under a contract with GPS fleet management device vendors, with each vendor providing GPS data from multiple trucking companies for the state of Washington. Data was retrieved via an automatic program developed to fetch raw files from vendors’ FTP servers on a daily basis. The GPS device identifier was scrambled for privacy protection, and the data set contained more than two million records.

The definition of a freight trip chain was established via a base depot origin, or anchor point, followed by a series of workday stops with an eventual return to the anchor point by the end of the day. Through algorithms, data was mined from the large data set. Over 12 percent of the two million records were determined to be trip origins or destinations. Algorithms included a three-minute dwell time threshold, engine status information and high travel speeds and travel times to rule out stops at signals, whether a truck was moving or not based on the engine being on or off and providing a zero value for high travel speeds.

The data did not provide for specific truck depot information, but based on the GPS data set, inferences were made regarding frequently visited locations serving as base depots, or anchor points. In order to better define these locations, GPS records falling on freeways were removed and rest areas and weigh stations were eliminated. These results led to nearly 68,000 GPS trip ends being eliminated and a 25 percent increase in processing speed performance.

Anchor points were identified through a spatial cluster algorithm. The intent of this process was to determine the frequency of trucks visiting the same locations within one week or one day. In addition to previous parameters, GPS records within 50 meters of each other would be counted as one cluster and the minimum time interval between two consecutive trip ends for each vehicle would not be greater than one hour.

A density-based spatial clustering of applications with noise (DBSCAN) algorithm was used for this process. A primary benefit for the use of this cluster was the ability to find arbitrarily shaped clusters and to determine the optimal number of clusters, versus traditional nonhierarchical clustering algorithms.

Results included the optimal parameter setting which was when Eps equaled 50 and minPts equaled five. Over 5,700 clusters container nearly 105,000 anchor points were generated based on one week of data. A visual inspection was performed using satellite imagery provided by Google Earth. Some cluster examples included depots adjacent to freeways, cargo ship terminals and a construction site. Failed results included two clusters being generated for one depot with multiple sided truck bays and a single cluster belonging to two clusters adjacent to one another with different land use types.
After estimated trip ends and anchor points were identified, individual trip chains were constructed. For each truck, the identified individual trip ends were ordered in a time sequence for each day. The trip chain construction algorithm ended when there were no more anchor stops for each truck. Truck GPS data from May 7 to 9, 2013 (Tuesday to Thursday) were used to generate individual truck daily trip-chaining information with the algorithms.

The distribution of the trip chains from these days was provided in a table including the number of trip chains, number of trucks, average stops per trip chain and percentage. More than 51 percent of all the trucks made at least one trip chain during the study week. Among those, more than 75 percent made one or two trip chains per day.

A question was then posed regarding the ability of GPS data to estimate truck trip purposes. A PAM clustering algorithm was used to group trucks with similar behavioral characteristics. Four trip-chaining features (average trip chains, average trip stops per trip chain, average dwell time, and average trip distance) were initially selected for clustering.

A table was created providing the results. Through this process, trucks falling with certain clusters displayed attributes which placed them into different categories including delivery trucks, drayage trucks, small package delivery trucks and local regional drivers. A similar validation method using satellite information was performed.

Using the GPS data set and developed algorithms, truck base depot, trip end, trip-chaining and categorization of truck types was achieved. A disadvantage of GPS data was mentioned regarding the fact that not all truck assets contained a GPS device, and that data sets would likely represent a nonrandomly selected subset of total truck activities within a spatial area. The study also concluded that a driver’s perception and route preference information could not be capture with GPS data, and that the combination of survey data and GPS data could provide stronger parameter improvement for models.

**Other Local Studies**

*Sol Price School of Public Policy, University of Southern California – Urban Spatial Structure, Employment Subcenters, and Freight Travel, March 2016*

This research study identified that there is a current gap between the amount of growing literature suggesting the importance of urban spatial structure for passenger travel, versus the relationship between employment subcenters and freight travel. The Los Angeles region was used to examine the relationship between urban spatial development patterns and freight travel. The National Employment Time Series (NETS) was used to identify employment subcenters in Los Angeles, and data for freight activities associated with subcenters was provided from SCAG. A regression model was used estimating freight activity as a function of whether a location is an employment subcenter, measures of nearby employment, access to the highway network and proximity to intermodal freight facilities.

Results indicated that employment is an important driver of freight activity, and that employment subcenters had an independent effect on freight activity. It was suggested that further research be performed, which could lead to more specific policy recommendations for urban goods movement.

An important driver factor mentioned in this work, relates to the changing dynamics of spatial patterns, most notably, the dispersion of manufacturing and warehousing to suburb and open areas as these functions seek lower land and transportation costs. The term employment subcenters is used to explain this phenomenon. The paper also highlights the notion that these employment subcenters are transforming from “business only” districts to multi-use areas which can include residential, office, retail, light industrial, and warehousing uses. For many metropolitan areas, this is an important highlight as it gets to the core of policy issues and needs including sprawl and conflicting adjacent land uses.
The second important highlight from the paper is the identification of a lack of focus on making connections to these changing spatial factors in relationship to freight activity. A clear example of this has been the recent development of fulfillment centers from Amazon in areas with proximity to major freeways and airports. This is due to the company’s need to maintain inventory at adequate levels and provide order deliveries with a day or even hours. In most cases, Amazon has opted for cheaper land and access to airports outside of major metropolitan urban centers. At the same time, these urban centers are strong drivers for fulfillment orders. Amazon’s breadth of service coverage has generated an increase in daily freight traffic to and from locations both outside of and within urban areas for supply and delivery needs.

Using Los Angeles as a focus, provided the research paper with a strong amount of freight activity defined by both employment and multimodal transport of goods between production, distribution and consumption spatial areas.

The defining characteristics of employment subcenters was developed by a cluster of contiguous zones having a minimum employment density of ten jobs per acre and total employment (for the sum of contiguous zones in the center) of at least 10,000 jobs in the Los Angeles region (10-10 criteria). Employment subcenter data was projected using one-square mile hexagons as the unit of analysis using the NETS data (see following Figures 1.28-1.30).

**Figure 1.28:**  Study area showing hexagons with employment data
It should be noted that 2005 NETS data was used to reflect pre-recession levels, due to the cyclical nature of economic cycles. As freight activity was still at a peak during 2008 (freight data used from 2008), there remains a stronger correlation versus the use of the 2010 NETS data.
Freight data from SCAG included the Heavy-Duty Truck (HDT) Model, which provided light, medium, and heavy duty truck vehicle classifications. TRANSEARCH was also used for the external model estimates from trip tables for interregional truck trips based on commodity flow patterns. Surveys and third-party truck GPS data was also incorporated into the internal model estimates. Validation was performed using the average daily truck traffic (AADT) 2010 data from Caltrans. Only freeways and highway SCAG data was compared to the Caltrans AADT data, and the results for the SCAG data were positively correlated. This suggested that the SCAG freight data were a reasonable data source for the study’s purposes focusing on regional freight activity.

Through regression analysis, summary tables and figures were provided for daily truck flow and density by link length, truck flow by classification, percentile distributions, and other factors. A hot spot analysis was also performed using truck density for the top 20 identified values.

For Los Angeles, these cluster areas focused on the seaports of Los Angeles and Long Beach, the City of Industry including warehousing and manufacturing, downtown Los Angeles including warehousing and intermodal terminals, the City of Commerce including manufacturing and intermodal terminals, and the Los Angeles Airport and I-210 major freight corridor.

**Figure 1.31: Heat map of freight flow**

![Heat map of freight flow](source)

An interpolation of daily freight flow was developed using the inverse distance weighting (IDW) method. This process was needed to visualize the freight flow data contained within the model. Additionally, employment subcenter locations were overlaid on top of the heat map (see Figure 1.31). This information clearly illustrates strong freight activities along freeway networks as well as high concentrations on the seaport and downtown Los Angeles areas. Overall, there was a strong correlation with the identified cluster areas. But there was not as strong of a correlation with the majority of employment subcenters.
These relationships and findings display that the types of employment including manufacturing, industrial and warehousing have a much greater correlation with freight activity than the broader identified employment subcenters. Additionally, highway corridors play an important role in connecting freight centers. The analysis also confirms the changing dynamics of more mixed-business and other land uses within a close proximity of one another.

As the information used within the study was collected prior to the recession, an update of the same methods for more recent data sets would provide for a more current analysis, but it is likely that similar results would be the outcome based upon static major freight land uses. Additionally, adjusting the extent to include both San Bernardino and Riverside counties would be of value and interest on this subject topic.

Identified research and policy implications included the need for planners and policymakers to assess how urban freight travel will be linked to changes in land use or infrastructure at both small geographic zone and larger metropolitan geographies. The inclusion of how zoning decisions and historic development patterns have been associated with freight activity was also mentioned. At the policy level, it was also highlighted that focusing on broader geographic areas for spatial development patterns outside of traditional intermodal facilities and highways was an area for future applied research.

California Department of Transportation – California Vehicle Inventory Use and Survey, 2016

The California Vehicle Inventory and Use Survey (CA-VIUS) is an effort sponsored by Caltrans and conducted by Cambridge Systematics to collect data on the physical and operational characteristics of the state’s commercial vehicle population. Data is being collected via surveys that focus on freight-related vehicles operating in California, with questions designated to obtain annual freight truck activities, operational characteristics, physical characteristics and the types of commodities carried at the state level.

The survey results are also expected to yield key insights on the inventory and flow of different types of commodities and commercial vehicle fleets that are critical for statewide freight travel demand modeling, the CFMP, as well as informing Caltrans about needed improvements to facilitate freight movement within California.

The survey instrument development and data collection efforts are being performed by a prime consultant with the assistance of sub-consultants, including third-party data providers.

Vendor Literature & Information

There are a large number of data vendors offering freight-based products and services. Many of these vendors rely upon their technical expertise at managing or distilling large data sets. Data mining is one primary method, which relies upon algorithms to extract such information. Data vendors may not necessarily generate the data but have access to it through contract agreements to provide their services.

The interest and potential benefits for using vendor data is predicated on the potential for consistent and timely data which can be updated as needed, integration capabilities for modeling needs, as well as better real-time information versus reliance upon survey data and/or other more static sources, whether annual, quarterly or monthly. The matrix below provides a listing of potential data vendors which provide products and services for public agency freight-based data needs. Each vendor listed in the table below (Figure 1.32) is briefly discussed in the following pages.
Other private freight industry service providers work directly with freight industry customers such as terminal operators, ocean, air, truck and rail carriers as well as freight forwarders and brokers, among others. These companies typically provide fleet management, payment management and visibility tools such as load tracking and matching. In some cases, similar technologies are relied upon including GPS and cellular data, among others. A listing of these types of companies is provided below.

- PeopleNet
- Omnitracs
- Nextraq
- Telogis
- TomTom
- Chainalytics
- Convoy
- Cargomatic
- Trucker Path
- Uber Technology
- Navistar
- Teradata

While there may be synergies related to these private sector focused companies, it is not anticipated that government agencies reflect a prospective customer at this time, therefore, no further review is included. Below, snapshots are provided for the potential vendors listed in the table above.

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</tr>
</tbody>
</table>
INRIX

INRIX Trips is a potential planning application product which provide organizations a comprehensive solution for understanding the movement of people and goods through the trips they take (see Figure 1.33). “Its power comes from industry leading geospatial data processing – enabling insights on population movements such as popular origin and destination zones, diversion routes during peak time incidents, corridor usage and more.” INRIX can provide trip matrices and records aggregated exclusively from freight carriers. The company has built its freight data from vehicle probe information through the growing trend of fleet telematics penetration. This has resulted in four-plus years with one trillion-plus records, nationwide. This type of data/information can be integrated into existing regional/state/federal models/networks and can improve insights into planning issues such as economy, international trade and data availability. It can also inform and support all levels of government grant applications and funding programs. Third-party vendor data typically protects against data privacy issues, depending on cost plans, this can lead to greater synergies and overall benefits.

Figure 1.33: XD Segments Supporting Queue Detection

Source: INRIX – How Freight Probe Data is Revolutionizing the Industry, March 2015
Streetlight

Streetlight’s mission is to seamlessly bring data to bear in transportation decisions. The company’s goal is to get all the data collection and processing work done in moments, instead of months, so that planners can focus on what the data all means and implementing the best plans and policies for their communities (see Figure 1.34).

Figure 1.34: Visualize Travel Projects

Source: Streetlight Website

Figure 1.35: Traffic peaks by hour of weekday by mode including freight

Source: Streetlight Website
Streetlight’s products, Streetlight InSight® and Metrics, can enable planners to answer questions that previously were not readily answerable, such as the interaction of personal and commercial vehicles (see Figure 1.35). In the past year or so, Streetlight InSight has been used to support nearly 100 transportation and community planning/design projects, many of which were interested in a clearer understanding of commercial vehicles. Streetlight licenses INRIX data, so many of the opportunities and benefits are similar. Streetlight’s focus is to provide value above and beyond the data it licenses, with a strong connection to provide services for planning and policy needs.

**HERE**

The HERE Traffic portfolio has been rigorously engineered to provide highly accurate time-saving traffic information. Precision mapping and real-time big data combine with deep historical insights to create an up-to-the-minute industry leading traffic service.

HERE collects billions of GPS data points every day and leverages over 100 different incident sources to provide a robust foundation for traffic services. The company uses information collected from a variety of devices across the globe including vehicle sensor data, smartphones, PNDs, road sensors and connected cars. Traffic experts also monitor incidents such as accidents and construction as they happen, 24 hours a day, seven days a week.

Once collected, data is processed through a traffic engine - continuously updating data every 60 seconds. By combining all these sources and analyzing the data in an incident management center, HERE regularly captures events that may not be offered by other services. HERE’s focus on GPS data also provides the ability to generate benefits for planning and policy issue needs, as they relate to the movement of people and goods.

**ATRI**

The American Transportation Research Institute (ATRI) has been engaged in critical transportation studies and operational tests since 1954. ATRI is part of the American Trucking Association’s (ATAs) Federation. The company’s primary mission is to conduct transportation research with an emphasis on the trucking industry’s essential role in safe, efficient, and viable transportation systems.

**Figure 1.36: Example of one random truck’s GPS records for the whole month of April 2011**

Source: MAG Truck Travel Model Update, Final Report, July 2013
ATRI's Research Advisory Committee (RAC) is comprised of government officials, independent scientists, labor union officials, academics and trucking company executives and suppliers from a diverse cross-section of the industry, all who understand the importance of sound science to an industry as complex as the trucking industry. ATRI has a very strong emphasis on truck GPS data (see Figure 1.36). The company's direct relationships with many of the country's largest carriers is highly unique. This provides very robust data from these carriers, but at the same time it does not reflect the full diversity of all truck classifications. Similar to the INRIX data, GPS data is highly useful for better informing truck flow issues associated with planning and policy including improved (not perfect) insights about truck origin and destination data.

**ITERIS**

**Figure 1.37: Illustration of Chicago area percentage of time each road segment is congested**

As a first step, Iteris reviews origin-destination data for vehicles arriving at or leaving from freight hubs to identify major origins and destinations. Freight hubs may include ports, industrial areas, major distribution centers or downtown areas.

Freight productivity is reviewed by monitoring the impacts of congestion on freight vehicles (see Figure 1.37). Datasets such as the National Performance Management Research Data Set (NPMRDS) include speed / travel time data for freight and passenger vehicles separately. Iteris ingests and processes this data to extract speed and travel times. ITERIS provides similar value-add services as Streetlight, in that it relies upon other third-party data to perform analysis. This allows for the company to focus directly on agency issues and needs, as well as an ability to provide its expertise in various data sets.
Panjiva

Panjiva focuses mostly on private sector freight customers, including shippers, distributors and major carriers (see Figure 1.38 below). The company provides comprehensive trade data; in each shipping record, you’ll find the declared value, as well as the harmonized system (HS) commodity classification, of the goods, including shipments, for shippers and consignees. Panjiva’s data and information is highly applicable for specific trade gateways including seaports and land ports of entry. This type of data set allows agency users to focus on the specific planning and policy issues for local areas, as well as larger regional and national implications.

Figure 1.38: Depiction of supply chain shipment flows between producers and suppliers

Source: Panjiva Website
**DESCARTES Datamyne**

Datamyne is very similar to Panjiva in that it is a service geared towards private sector freight customers, including shippers, distributors and major carriers. The company also provides comprehensive trade data with shipping records, and harmonized system (HS) commodity classifications of goods with shippers and consignees. Datamyne products provide further visual insights and granularity regarding origin and destination information, which adds another layer of analysis for smaller geographies (cities/communities) and this can be highly valuable for planning, policy, privacy and cost issues. These relationships at smaller localities can also be related to larger units of geography for regional, state and national implications.

**AVAIL**

AVAIL is the premier data science engineering group within the State University of New York at Albany. AVAIL is looking to empower a new generation of students to assimilate computer science knowledge and subject-matter expertise in the fields of data science and analytics. In doing so, AVAIL is formulating innovative solutions for private business and government.

AVAIL provides similar value-add services as Streetlight and ITERIS, which can be used for improving a variety of planning and policy issues, as well as providing expertise in multiple data sets.

**Air Sage**

Air Sage anonymously collects and analyzes wireless signaling data—processing more than 15 billion mobile device locations everyday—turning them into meaningful and actionable information.

Private businesses, government agencies and other organizations can use this aggregated information to model, evaluate and analyze the location, movement and flow of people and assets.

AirSage provides location data nationwide. The company is committed to becoming the world’s leading provider of comprehensive location and movement content—powering transportation modeling applications, driving smarter spending for out-of-home media, providing better site location insights to businesses, and more. Similar to other aforementioned providers, AirSage has unique access to cellular data, and is capable of providing insightful information for planning and policy needs. This extends to location-based information, thereby providing further information regarding how people and goods are moving.
Quetica provides consulting services to business clients as well as to state DOTs, MPOs and state and local economic development authorities to optimize statewide and regional freight transportation networks and key industry supply chains. In addition, Quetica provides transportation strategic sourcing, capacity/model decision optimization, managed inbound programs, supply chain network optimization and design, freight pre-/post-payment audit and opportunity analysis, as well as benchmark consulting for federal agencies and mid to large companies.

Quetica also provides Payment Management System (PMS), Transportation Management System (TMS) and Warehouse Management System (WMS) systems and process development, integration and implementation consulting. Quetica is an example of yet another approach of relying upon transactional data to distill origin and destination information applicable for goods movement industries (see case studies in Figure 1.40). The company’s expertise can provide technical synergies with agencies looking to focus on unique supply chain related events, impacting the flow of goods.
Section 4: Conclusions

A review of the relevant literature and case studies reveals that there are strong correlations with government agency planning transportation systems and research identifying freight land uses and freight travel demand characteristics. However, this relationship is not necessarily strongly linked together from a technical perspective, likely stemming from a large amount of historical observed and/or real-time information. Heretofore many government agencies have relied upon survey data, primarily for trip origin and destination information to perform this need on a project by project basis. This is evident at federal, state and local levels.

From a technical methodological review, many government agencies have evolved and are now highly capable of utilizing and integrating multiple data sources including survey, GPS, vendor and other external data sets, which may have varying attributes not all common to one another. For any data source, whether internally developed or purchased from a third party, strong attention should be paid to data bias issues. At the same time, expectations and needs should be focused on how data granularity and representation are available and/or constructed. There is clearly no single approach which is utilized across the board for freight traffic demand data. Compared with passenger travel data, truck data sample sets and data sources appear to be more piecemeal incorporating much smaller sample sizes.

Clearly the truck mode creates highway impacts which require better understanding. Federal and state policies have had an effect in driving the need for better truck analytics in public agencies. A clear example of this stems to 2015 passage of the federal Fixing America’s Surface Transportation (FAST) Act which had several freight related provisions. Similarly, the 2016 passage of the California State Sustainable Freight Action Plan is another piece of legislation making truck visualization more important. These impacts have already been integrated into long-range planning documents as evidenced by the focus on truck bottleneck analysis and through the accompanying need to highlight relationships between freight and land uses.

Some agencies have already begun the incorporation of newer sources of data for their freight analysis. Recent federal guidance for National Performance Management Research Data Set (NPMRDS) has provided methods for monitoring freight travel demand. Federal data sets have integrated freight data through the inclusion of both HERE and ATRI sources. The state of Florida DOT, as well as other DOTs and MPOs have also begun using vendors including INRIX and Streetlight for traffic demand analysis.

Based upon these factors the following considerations are provided:

• Since truck traffic represents the largest amount of tonnage versus all other modes, there is a strong need to plan for future demand on freeway and highway and local roadway transportation infrastructure.

• Relationships between freight land uses and travel patterns should be included for any visual tool.

• The goal of the visualization tool should be to integrate data which provides a strong correlation through actual dynamics of shipments, tying together freight generators and attractors and travel demand.

• Based upon a region’s needs and/or priorities and the identified sources of freight data available, the type of freight demand should be clarified; specifically, whether traffic, tonnage, shipments, value, or commodities are the desired goal for visualization purposes.

• Federal and state guidelines should be considered for freight visualization tools.

• Other constraints should be identified for policy considerations including land use conflicts, costs of land development, as well as production, distribution and consumption trends within geographies.

• Consideration should be given for intermodal dynamics between truck shipments for any visual tool; especially in more complex global supply chain regions.

• Truck classification definitions should be clarified for any modeling and/or visualization purposes.
Works Cited


Using Truck Visualization as a Planning Tool

Technical Memorandum #2: Issue Identification

This technical memorandum identifies a preliminary list of issues associated with truck visualization data collection, integration and use as a tool as identified in the literature review. The memo consists of the following sections.

- Section 1: Regional Context and Research Need
- Section 2: Summary of Identified Potential Issues
- Section 3: Categorization of Truck Types

Section 1: Regional Context and Research Need

Regional Context

The San Diego region is one of the largest metropolitan regions in the State of California and one of the most geographically and culturally diverse areas in the country. Home to a population of more than three million people and covering over 4,199 square miles of land, it is the southernmost region in California, bounded to the south by Mexico, Riverside and Orange counties to the north, Imperial County to the east and spanning 70 miles of coastline to the west.

Situated between major production, trade and population centers, San Diego possesses a wide array of transportation and infrastructure assets. Goods movement in the San Diego region involves a complex system of interstate highways and state routes which link air cargo operations, two marine terminals (Port of San Diego), a major commercial international border crossing as well as the largest shipyard and largest Navy base on the West Coast. All of these regional assets are in place to meet the mobility needs of the region’s 3 million residents and to carry some 62 million tons of truck-borne freight.

Regional rail capacity is important, it is highly constrained and cannot match the flexibility and reliability of regional truck distribution. Trade and distribution in the region, therefore, is heavily dependent on truck movements. Additionally, the region’s roughly 300 miles of urban and rural freeways are not expected to significantly grow. This roadway network must simultaneously serve a growing population and growing levels of international trade. Furthermore, this same system must carry the goods that satisfy the local demand of the area’s residents and tourists (domestic truck flows). These domestic truck flows will continue to account for most of the region’s truck traffic. In addition, the Otay Mesa border crossing processes about 1.6 million trucks annually and accommodates more than $42 billion worth of goods, which makes it the busiest commercial crossing between California and Mexico and the third busiest along the entire United States-Mexico border. In short, truck traffic, a derived demand generated by personal consumption and inputs to the production process, will continue to grow, and trucks will place increasing pressure on the region’s highways.

The region’s southern border with Mexico is connected to the region’s northern border with Riverside and Orange counties via State Route 11 (SR 11), State Route 905 (SR 905), Interstate 805 (I-805), Interstate 5 (I-5) and Interstate 15 (I-15). The major east/west freeways include Interstate 8 (I-8), State Route 78 (SR 78), State Route 54 (SR 54) and State Route 52 (SR 52). All of these freeways are experiencing increasing peak period traffic congestion that is expected to grow commensurately with the steady population and job growth projected for the region (4.1 million residents, 1.9 million jobs and 1.5 million housing units by 2050). Increased congestion on the region’s highways leads to congestion on local streets, impacting communities and raising safety issues related to conflicts between trucks and passenger vehicles. Higher truck volumes also can contribute to truck-related crashes.
Research Need

The discussion below conceptualizes why this truck visualization research is needed and timely. The parameters of the study were informed by a literature review and were further refined based on feedback from the Project Study Team (PST).

In the San Diego region, trucks are the backbone of the goods movement system. Trucks carry more than 90% of freight volume in the San Diego region and travel nearly 2 million vehicle miles each day on the region’s freeways. Truck vehicle miles traveled (VMT) on freeways are expected to grow 1.5 million by 2035, reaching an estimated 7 percent of all freeway VMT and growing at a rate faster than that for personal vehicles. In 2015, over 62 million tons of goods, valued at nearly $150 billion were transported in the San Diego region by trucks.

Truck bottlenecks exist on freeways during peak periods and at freight gateways (e.g. land and sea ports of entry), straining the region’s multimodal goods movement network. Therefore, it is prudent to review and update truck visualization tools. This is important as an improved truck visualization tools can be applied to a broad spectrum of planning, policy and implementation strategies.

There is a shift occurring for truck data which is two-fold. First, greater amounts of truck data are being generated as truck cabs become more “computerized” driven by federal rules and mandates, simultaneously, billing and load-matching activities are increasingly being managed by third-parties via the Internet and through mobile devices. Other truck data collection sources to be considered include closed-circuit TV (CCTV), radio frequency identification (RFID) and other GPS and Internet-based collection methods. Second, technology companies have made the connection between these types of data and their utility for the planning profession. This has led to new approaches including data-mining through the development of algorithms in order to extract a larger number of records displaying relevant attributes for planning purposes.

Impacts from the fluidity of global supply chains have affected land use development as well as transportation networks and the different freight modes using them. As these changes have and continue to occur, it becomes more important for planning staff and policy makers to be able to visually understand these relationships in order to make informed decisions on the region's transportation infrastructure.

Based upon these issues and challenges, SANDAG in partnership with Caltrans, is undertaking the Project to enhance existing technical methods through the procurement of data sources with a stronger connection to truck movements. The truck visualization tool will provide a stronger user-friendly illustration of truck flows and goods moved within the San Diego region, using these data sets.

Section 2: Summary of Potential Issues for Analysis

The following section provides a list of the identified potential issues as part of this study. It should be noted that the primary purpose of this study is to develop a truck visualization tool (or tools), which can be used for a wide variety of analytical planning purposes. The planning issues below will provide the initial foundation for further development of approaches to collecting and/or procuring data as well as development of other tool applications. Given the dynamic nature of freight movements, these identified issues should be regularly re-assessed.

Planning

- **Economic Issues**: What are critical transportation infrastructure needs within the San Diego region impacting the trucking industry? How do transportation planning decisions impact the trucking industry from an operational standpoint? Is there a clear benefit from freeway/highway capital projects for the trucking industry? What improvements can be made for truck parking needs?

- **Border issues**: How will border issues and the projected growth in goods movement from Mexico affect truck mobility in the region? How will the implementation of intelligent transportation systems (ITS) at the border and the implementation of the new border crossing impact the trucking industry?
**Environment:** Can relationships be defined more clearly between truck traffic growth and the understanding of and better management or reduction of greenhouse gas emissions (GHG) for baseline and future land use/transportation modeling scenarios? What other relationships can be better understood regarding for particulate matter and other air quality impacts from trucking?

**Modeling:** What types of resources are needed to integrate and maintain truck visualization tools? What type of benefits can be gained through the addition of new data sources? Can new data sources for truck visualization be utilized to improve model validation/calibration and/or be used to illustrate performance measurement? Can new performance measures be associated from additional truck visualization tools?

**Data Availability:** What are the most important data sources needed to generate optimal truck visualization tools? What is the level of effort needed whether internal or external to gain access to the use of potential data sets?

**Data Reliability & Validation:** What biases should be considered based upon truck vendor data? How should vendor truck data be cross-checked and validated for data penetration/coverage?

**Policy**

**Federal:** How can truck visualization techniques be used to support grant applications for either Fixing America’s Surface Transportation (FAST) Act discretionary or formula funding programs? Can a truck visualization tool be utilized for the development of the National Multimodal Freight Network and future Primary Highway Freight System? Can truck visualizations be used to better inform federal policy development?

**State:** How can truck visualization techniques be used to support grant applications for Air Resources Board (ARB), Energy Commission (CEC) funding and the Senate Bill 1 Trade Corridor Enhancement Program (TCEP)? Can truck visualization techniques be incorporated into statewide freight plans? Can truck visualization tools illustrate the economic benefits of truck movements?

**Local:** How can truck visualization techniques be used to support local government freight planning activities including implementation of projects including highly traveled local roadway corridors near major gateways and industrial clusters? How can truck visualization techniques be used to clearly illustrate land use and freight transportation constraints? How can truck visualizations be used for community education?

**Privacy**

**Data Privacy Challenges:** How will procured data from any potential vendor, which has access to specific vehicle locations, avoid privacy concerns? Do agencies seeking to use location-based data have a privacy assessment plan in place with sufficient documentation to ensure that there are no conflicts and/or risks? How will the private sector view advancements into truck visualization? How can truck visualization data be utilized to ensure anonymity?

**Costs/Funding**

**Project:** What are the staffing resources needs to continually update truck visualization tools and maintain required information, and are these costs justifiable on a cost benefit basis? What are the comparative benefits versus costs of incorporating new data sources versus existing ones?

**Other Issues:** We anticipate that the PDT will help inform us of other potential uses for truck visualization tools.
Section 3: Categorization of Truck Types

The trip purpose and type of truck are yet another important possible application to consider as part of the truck visualization tool development process. As identified in the literature review, different truck classifications can generate different trip types and have varying trip-chain tours and trip ends based upon truck purposes with different lands use attractor and generator relationships. It would be valuable to determine capabilities of the visualization tool in providing the different truck trip relationships between local, regional and long-haul trip types as well as providing insights for truck trip purposes and truck trip trend analysis.

For the purposes of this study, local, regional and long-haul trips are defined as follows:

- Local – Originates and terminates within San Diego County
- Regional – Originates or terminates within Southern California (defined as all bordering counties and Los Angeles County)
- Long haul – Starts or ends in San Diego County, but travels outside the region; OR both originates and terminates outside the region

In general, local trucks are likely to consist primarily of light and medium vehicles; regional trucks are likely to consist of an even distribution of light, medium and heavy vehicles; and long-haul trucks are likely to consist primarily of heavy vehicles.

The complexities of vehicle classifications and equipment as they relate to supply chains can pose some challenges. For example, most international trade is carried across the U.S./Mexico border and interchanged within Southern California. Many of these shipments are then distributed to other locations, some outside of California. Depending on the length of haul, as well as commodities, different types of trucks may provide different services. Domestically, the same can be said for production and consumption.

As this relates to truck visualization and potential vendor data, it is very important to consider truck fleet mix and the confidence in the accuracy of the information being provided. Additionally, acknowledging biases and/or limitations in truck data sources, will help define the value of the data, as well as create transparency for how the data is analyzed and presented.

The Federal Highway Administration truck weigh classifications based on Gross Vehicle Weight Rating are described below:

- Light vehicles (Class 1-4) – Up to 14,000 pounds
- Medium vehicles (Class 5-6) – 14,001 to 26,000 pounds
- Heavy vehicles (Class 7) – 26,001 to 33,000 pounds, and (Class 8) 33,001 and above

Note: Trucks less than 33,000 pounds are not required to adhere to some of California ARB requirements, but this is not to say that these truck moves are not of interest to local planning agencies.
Using Truck Visualization as a Planning Tool

Technical Memorandum #3: Methods for Understanding Truck Flow Generators and Attractors

This technical memorandum identifies existing methods used to analyze truck flows, including the San Diego Association of Governments (SANDAG) Truck Model (TM) and Commercial Vehicle Model (CVM). Additionally, it includes other factors such as land use relationships (population and employment), as well as distilling truck flow generators and attractors. A critical outcome of reviewing these methods is the identified limitations and gaps, suggesting the need for discovering new data sources and/or collection strategies. There is a consistent theme for greater benefits through enhanced truck data from both SANDAG existing methods and other studies, notably the Analysis of Freeway Operational Strategies Related to the Use of Managed Lanes by Trucks.

- Section 1: Overview of SANDAG Truck Flow Methods
- Section 2: Application of Truck Flow Methods
- Section 3: Truck Flow Generators and Attractors
- Section 4: Identified Data Limitations and Gaps

Section 1: Overview of SANDAG Truck Flow Methods

To appreciate the current SANDAG truck flow methods, a bit of background is in order, with an emphasis on the recent steps that the agency has taken. The truck flow analysis process has been based upon a continual focus of improving commercial vehicle flow information, with specific implications for freight truck flows. As mentioned in Technical Memorandum 1 (TM 1), there are various commercial vehicle and industry classifications that have distinct relationships. For the purposes of this report, heavy truck classifications, and industries generating and attracting these types of trips, serve as the focus.

The history of most recent progress for SANDAG truck flow information has largely related to two areas; the initial development of the TM and the CVM. Through development and enhancement of these models, the agency has had the opportunity to use external data sources, survey, and other sources of information to better understand the flow of trucks both within and outside of the region (County of San Diego). As a direct part of this process, land use information driven by population and employment growth, also has been a critical component for determining the number of truck trips by geographies within the region.

Figure 3.1: Truck model flow chart

Source: SANDAG External Truck Model
The intent of this memorandum is not to describe the technical intricacies of SANDAG models, but suffice it to say, there are very fundamental transportation modeling structures that inform how models will distill information related to truck flow dynamics. These structures are of interest as they correlate with the need for data and/or information. As such, it is important to highlight where data and information are needed, and where opportunities lie to further enhance technical capabilities, specifically, freight truck flows.

**SANDAG TM**

SANDAG has undergone two developments for the TM. The initial development was completed as a final report in December 2008, entitled, The Development of a Truck Model for the San Diego Region. The second was a report completed in June 2013, entitled SANDAG External Truck Model.

The 2008 SANDAG TM was created to serve as a foundational enhancement to the agency’s regional model tool. Development of an integrated TM was necessary to provide greater sensitivity to policies, project and program needs with direct relationships to truck flows for the region. The 2013 study served as an extension of the initial development process, with a strict focus on external truck model components.

The 2013 external TM focus was based on the transition from the December 2008 study’s internal model design to the CVM, as highlighted from the June 2013 study. This move was based upon the original bifurcation of internal versus external truck trips. As discussed in the 2008 study (pages 12 – 15), internal trips were organized by truck classification, trip generation and attraction rates, as well as special generator information. This data relied upon the Southern California Association of Governments’ already developed model information as produced by Cambridge Systematics in 2008. The primary distinguishing characteristic of growth for internal trips was predicated on household and employment data.

External trips are organized by external to external (EE), internal to external (IE) and external to internal (EI). The primary data source suggested during 2008 and relied upon through the 2013 study has been the Freight Analysis Framework (FAF) information for all external truck trip needs (see figure 3.1). FAF is published by the Federal Highway Administration (FHWA) of the U.S. Department of Transportation (US DOT). This data set, generated by the USDOT’s Commodity Flow Survey (CFS), provides both value and tonnage base year and forecast data for domestic and international trade, by freight modes.

The FAF data sets are valuable in that they provide global trade flows to the U.S., as well as domestic production and consumption information for a national truck model. The unique zone of SANDAG within FAF allows for both global and domestic relationships for external trip purposes, in unison with internal growth drivers. Tonnage information is convertible for flows in trucks and empty truck trips.

As such, the local level model component of internal trips has been replaced with the tour-based CVM. This is a very important positive step, as this was a key strategy and recommendation for improvement from the 2008 study for long-term model enhancement. External trip information is derived from commodity flow data provided by FAF, which has continued to be revised through each new FAF iteration.

**SANDAG CVM**

For the SANDAG CVM, there were two core documents produced including the December 2013 Work-Related Travel Survey Final Report and the July 2014 Final CVM Model Development and Calibration.

As stated in the SANDAG TM section, multiple improvements were incorporated into the CVM as recommendations were made in the 2008 initial TM. This included the establishment of work-related person and vehicle movement data, collected as part of the SANDAG Work-Related Travel Survey which was conducted between November 2012 to September 2013. Additionally, 2013 global positioning system (GPS) SANDAG area commercial vehicle movement data was purchased by SANDAG from the American Transportation Research Institute to upgrade and refine the existing SANDAG Interim CVM.

As a second step to the 2008 TM, the SANDAG Interim CVM was implemented in the SANDAG travel model system in the fall of 2012, using a model framework that HBA Specto Incorporated (HBA Specto) had successfully developed and applied in Calgary, Edmonton, the California Statewide Travel Demand Model (CSTDM) and the San Joaquin Valley Interregional Travel Model (SJVITM).
In August 2012, SANDAG identified possible upgrades to the Interim CVM model as suggested inputs for the Final CVM. The Final CVM has included upgrades to better refine model structure and overall applicability. Basics of the Final CVM include relationships between industries, vehicle types, and land use categories (see Figure 3.2). The fundamental difference of the Final CVM versus the initial TM is the tour-based microsimulation process, which provides further granularity for truck flows in the region.

**Section 2: Application of Truck Flow Methods**

The core application for truck flow methods is to provide regional model sensitivity to goods and service movement-related attributes. This information is utilized for the Regional Transportation Plan (RTP) update but also is valuable for providing analysis for other studies, projects, and programs. As an illustration of this, SANDAG is currently applying this information to the region’s project planning and implementation process for transportation infrastructure at the new border crossing in Otay Mesa, State Route 11 Otay Mesa East (SR 11 OME). Other examples include planning studies, such as corridor studies with a stronger relationship with goods movement, and federal and state grant funding opportunities.

As mentioned above, the tour-based microsimulation process is a strong feature for organizing and simulating truck flows. For the SANDAG CVM, truck flow attributes are broken down into three basic areas including industry classifications as defined by the North American Industry Classification System (NAICS), commercial vehicle classifications as defined by FHWA; and land use types by both population and employment.

Industry classifications are organized into seven establishment types, including:

- Industrial (IN)
- Wholesale (WH)
- Service (SE)
- Government/Office (GO)
- Retail (RE)
- Transport and Handling (TH)
Fleet Allocator (FA) – (all but military)

The FA establishment type is a specific type that uses a large, coordinated fleet that tends to service an area rather than specific demands, examples including mail and courier, garbage hauling, newspaper delivery, utility vehicles, and public works.

**Figure 3.3:** CVM vehicle classes by FHWA Classification/Caltrans Count Program

![CVM vehicle classes by FHWA Classification/Caltrans Count Program](image)

Source: FHWA CVM Classification

As exhibited above (Figure 3.3), four commercial vehicle classification types are defined, including light vehicles (FHWA classes 1-3), Medium trucks less than 8.8 short tons, or 17,640 pounds (FHWA classes 5-6), medium trucks greater than 8.8 short tons, or 17,640 pounds (FHWA classes 5-6), and heavy trucks (FHWA classes 7-13).

Truck trip start and end times are forecasted to the nearest minute. Time is organized into five-time periods including Early, AM Peak, Midday, PM Peak, and Late. In addition, 40-time periods are identified as truck trip list output time periods.
Five traffic analysis zones (TAZ) land use types also are incorporated into the CVM including low density, residential, commercial, industrial and employment node (see Figure 3.4). Definition criteria are applied to correlate TAZ land use types to NAICS industry classifications. If a TAZ does not meet the criteria for any of the first four land use types, it is allocated to the employment node type.

Accessibility to TAZ level employment and population for light, medium and heavy vehicles types has been determined to provide vehicle classification utility based upon travel time, distance, and tolls between varying time periods.

Source: SANDAG Commercial Vehicle Model
Collectively, this model structure is used to aggregate TAZ tour generation, by the number of tours generated for a given zone, vehicle type, purpose, and time period through relevant total employment in each zone and by calculation order (see Figure 3.5).

Survey data from the Work-Place Survey, and Interim CVM survey data for Edmonton and Calgary urban regions in Alberta, Canada adjusted for San Diego conditions were underpinning data and information for the Final CVM.

Additionally, it should be noted that the FAF data has been incorporated to provide the necessary external information for EE, EI and IE truck trips. In contrast to CVM truck classifications, two truck types are distinguished for the external model including single-unit trucks (FHWA vehicles classes 5-7) and multi-unit trucks (FHWA vehicles classes 8-14).

Having a general understanding of how the CVM incorporates this information and processes and simulates tours of truck flows is valuable in getting a sense of how data and information can have an impact on improving methods for visualizing truck flows.
Section 3: Truck Flow Generators and Attractors

Upon the review of SANDAG truck flow methods, there is a clear focus and need to organize the relationship of truck flows to generators and attractors. At the technical level, this has been framed by FAF for external national truck flows to the SANDAG region; and by the CVM for land use types industry classifications.

For the purposes of this study’s focus on heavy truck classifications, revisiting TM and CVM generator and attractor information and other studies is valuable in distinguishing further between truck flows and land uses.

FAF Truck Origin and Destination Flows

FAF data is an important component in interpreting truck flows because of the information’s distinction between domestic and international movement. For the SANDAG region’s unique location to the U.S.-Mexico border, the FAF data is further strengthened by additional data sets from the Bureau of Transportation Statistics (BTS), the U.S. Department of Agriculture (USDA) and the U.S. Army Corps of Engineers, among others.

The FAF data provides origin and destination information for the truck mode, both to/from San Diego County and the rest of the U.S.FAF zones (see Figure 3.6). In addition, origin and destination information is provided through the U.S.-Mexico border crossings in San Diego County to/from the rest of the U.S. FAF zones, as well as to/from San Diego County itself.

Figure 3.6: U.S.-wide assignment of truck flows

Source: FHWA FAF website

There is an important technical process to disaggregate truck commodity flows to smaller geographies across the U.S., as well as to convert short tons to loaded and empty trucks. These steps are critical in providing needed information that can be incorporated into the region’s CVM, especially as there is no further disaggregation below San Diego County, and the CVM structure is relied upon for internal local trips.
Through the process of commodity flow disaggregation, TAZ matrices are developed within the county, linking external truck trips between TAZ and external stations by two truck types (single-unit and multi-unit) and 6 commodity groups plus loaded and empty trucks, adding up to 14 vehicle types.

Flows to and from the two internal centroids in San Diego County are disaggregated to 4,998 TAZ. As truck flows are provided by 6 commodity groups, truck flows can be allocated to zones with employment categories that consume or produce a given commodity group. Empty trucks are allocated to the sum of productions and attractions of all employment types (see Figure 3.7).
As shown above in Figure 3.8, the CVM includes both industry classification and land use type attributes. Through the Work-Place Survey and Interim CVM Survey Data, information was obtained to provide travel survey data via travel logs (set up to be entered as a trip was undertaken).

The result for vehicle type in San Diego was a very light mix. According to the survey results, 63 percent of overall trips were made by light vehicles. This proportion was as high as 85 percent when considering certain industry sectors.

This is an important note as it relates to generators and attractors, when thinking about internal local trips within the county. For the purposes of this study, the emphasis is on heavy truck classifications. A substantial light vehicle mix for commercial trips suggests that there is a high number of trips serving both residential and employment areas throughout the county, whereas heavy truck classifications are likely to be serving fewer residential and more industrial and larger retail locations.

There is also an interesting factor for companies including FedEx and United Parcel Service (UPS), which rely upon consolidation centers for heavy truck shipments, yet also utilize smaller classification vehicles for package deliveries. The intent of this study is to better understand truck flows which generate substantial tonnage, but relationships which drive changes in vehicle classification and equipment based upon consolidation centers is also of interest.

There is a clear distinction between the CVM underpinning data and the FAF external information as it relates to both vehicle classification and trip tours within the county. Commercial vehicle trips to residential areas for landscaping, utility services, contracted home improvement work, and many other services are not the focal point for this study.
Similarly, there are a wide variety of services for employment centers and locations that are focused on daily deliveries which may be provided by smaller commercial vehicles as mentioned above. There are services of interest for internal trips including package delivery and other distribution needs, especially for the restaurant industry. In certain cases, some distribution is provided directly from centers within San Diego for foodservice and restocking of inventory.

One unique example of an area of interest that relates to consolidation centers and residential services is waste collection. There is a strong amount of tonnage that is collected within the county for both residential and employment locations by garbage trucks. Waste is placed in landfills within the county, as well as distributed to locations outside of the county. Recycled goods are consolidated at specific locations and distributed outside of the region as well. Construction projects are another area of interest where larger commercial vehicle classifications may be locally relied upon.

There may be other industries with similar relationships to the ones identified above. Based on the strong proportion of light vehicles making commercial trips within the county, it would help freight planners if they were to deconstruct the truck classification mix and build associations to generators and attractors. This will help planners understand interrelationships with external and internal trips. Additionally, this will improve their understanding of production zones, distribution zones, and consumer consumption, and how those zones relate to truck demand and truck tonnages.
Based upon the assessment of the SANDAG technical methods, it is important to reiterate the distinction between the external FAF method and internal CVM. For an exercise such as this one with a strong focus on heavy truck classifications, but also an interest in consolidation relationships to other vehicle classifications, there may be an opportunity to make stronger connections to FAF information and CVM data through additional data sources.

As highlighted in the SANDAG Analysis of Freeway Operational Strategies Related to the Use of Managed Lanes by Trucks (Managed Lanes Study), previous work has included emphasized trucking gateways and distribution hubs, with direct connections to truck flow generators and attractors (see Figure 3.9).
There are just over ten general documented locations from the Managed Lanes Study, which can be related to both FAF and CVM information.

Other SANDAG projects such as the SR 11 OME project, also have contributed an abundance of information over the last several years. This has included analysis of many different commodity types, with connections to domestic production and consumption within and outside of the SANDAG region.

Information distilled by commodity types, vehicle classifications and/or equipment, as well as the ability to make relationships to loaded/empty trucks are critical components for improving technical base year data, namely validation and calibration. Clearly, the stronger the confidence in the data inputs, the better the tools will be for planning, programming and project development purposes.

Partner agencies involved directly with projects or operations at key gateway locations, including the border land ports of entry and seaport terminals, can provide truck count information as inputs and have a role to play. Agencies including the Port of San Diego, Caltrans, District 11, California Highway Patrol (CHP), and U.S. Customs and Border Protection (CBP) are some of the important partner agencies with a stake in truck flows within and through the region.

Depending on available resources, there is value in further developing the groundwork generated from the Managed Lanes Study. There are static locations for specific industries that will continue to provide truck flows between distribution and retail physical locations. Industries include grocery, foodservice, waste collection and big-box retail, to a larger degree, as well as many others at varying scales.

Another large-scale area of focus is the U.S.-Mexico border. The binational manufacturing of goods and distribution facilities within San Diego County will continue to grow over time. Developing stronger data sets for this dynamic will be complimentary for both FAF and CVM needs. Other industrial, manufacturing and distribution areas throughout the region offer unique prospects as well. Finding opportunities to improve data sources and integration between FAF and CVM technical methods where possible is a step in the right direction to further enhance these truck flow tools.

Section 4: Identified Data Limitations and Gaps

The primary benefit of this review of the SANDAG technical methods for truck flows, is the critical aspect of having base year information that is as up to date and realistic as possible. The core way of determining this is through model calibration and validation. A reoccurring theme from the review of the FAF external truck flow process, CVM and Managed Lanes Study is that there are significant limitations and gaps as part of the calibration and validation processes. We will be revisiting this observation in the “Conclusion” section of this study, Visualization techniques are dynamic and require constant updating and refinement.

The complexities of heavy vehicle classification truck flows are significant, as supply chain facilities are globally distributed on multiple continents throughout the world. Competition and natural economic cycles foster constant fluidity as supply chains are adjusted to reflect shippers’ needs on a daily basis. This leads to various dynamics including mode shifts when expedited shipment needs arise, as well as longer term changes in logistics relationships and arrangements as companies grow or look to diversify risk.

Incorporating technical methods to capture these dynamics is no easy task. The SANDAG model development since 2008 has been very robust in transitioning to an activity-based model (ABM) and enhancing the truck flow components for both internal and external trips. Despite recent progress, each of the documentations from SANDAG core truck flow methods and other studies have identified limitations and gaps which remain for data and information, especially for model calibration and validation.

For FAF truck flows, the model has been calibrated to match truck count data provided by SANDAG. This has included Cordon counts, Caltrans Performance Measurement System (PeMS) counts, as well as Caltrans and Port of San Diego counts. For the CVM calibration included developed targets for model components based on the Work-Place Survey, by industry sector, previous data collection in Alberta and adjustments based on validation results.
While calibration and validation methods used have consistently been highly sound, issues have related to underlying data sources and bias as part of the process. Issues have related to truck count data, vehicle classification information, origin/destination data, lack of trip purpose and use of regional data outside of San Diego.

For FAF, count data issues related to weigh-in-motion (WiM) station, the Managed Lanes Study stated, “With limited active WiM sites, the region lacks historical and on-going truck volumes on key corridors throughout the County.” The study went on to mention that despite temporary solutions through manual counts, that efforts were infrequent, resource constrained and reflected narrow snapshots in time.

As mentioned the Work-Place Survey was an important improvement from the initial developed TM. However, in certain cases, insufficient data was collected, and a comparison was required to be made with results obtained from the Interim CVM (based on a model calibrated initially to survey data for the Edmonton and Calgary urban regions in Alberta, Canada, and adjusted for San Diego conditions). Comparisons with the Interim CVM were made, and targets were set through a combination of averaging the Work-Place Survey and Interim CVM results and in a few cases, using the Interim CVM results directly.

The CVM also provided a substantial focus on light vehicle classifications, leading to bias regarding both different regional information used for calibration and survey information, more heavily skewed to a light vehicle mix.

For origin and destination data for heavy truck classifications, the Managed Lanes Study concluded that commercial employment surveys were not comprehensive, and that the data shortfall stems from this classification representing only a subset of overall commercial trips. Additionally, data sets were not easily accessible due to trucking companies viewing the information as proprietary.

Lastly, having further information for trip purpose for heavy truck classifications was listed as being sparse. There is a breakdown of the number of trucks crossing the border (including laden and empty trailers), but the data is limited to the northbound direction only, focused solely on the international border crossing trip component and only provided monthly and annually. For domestic truck flows, the information is widely incomplete other than the availability from the subset of commercial survey data.

There are clear limitations and gaps associated with commercial vehicle flows, as well as the subset of heavy classification truck flows. Despite these challenges, there are clear foundational structures in place that have been developed over the past decade, which can be enhanced through the addition of new data sources. The primary objective is to find data sources which can provide the level of granularity necessary to fit into these existing structures.
Using Truck Visualization as a Planning Tool

Technical Memorandum #4: Summary Framework Methodology for Developing a Freight Web-Based Tool

This technical memorandum provides an overview of the PhillyFreightFinder web application, which was used as a template to develop the San Diego Association of Governments (SANDAG) freight visualization web-based tool. The overview includes the assessment of the PhillyFreightFinder from the State of the Practice research, a summation of the public work shop on vendor freight visualization data, how SANDAG technical applications were considered, and the subsequent development and installation process.

- Section 1: State of the Practice Research
- Section 2: Freight Visualization Data Vendor Workshop
- Section 3: SANDAG Technical Applications and Skills
- Section 4: Freight Web-Based Tool Development Process

Section 1: State of the Practice Research

As part of the State of the Practice research, the Delaware Valley Regional Planning Commission’s (DVRPC) PhillyFreightFinder was reviewed. The DVRPC received funding through the second Strategic Highway Research Program (SHRP2) for its Local Freight Data Improvement project. As stated in Technical Memorandum 1 (TM 1), this was a unique project versus other case studies, in that it was focused on using a web-based interactive platform as a communicative and sharing framework, with the specific goal of creating a visualization tool.
The *PhillyFreightFinder* provides a holistic visualization tool for the assessment of freight-based data within the DVRPC region (see Figure 4.1). The SANDAG truck visualization project is directly focused on truck flows but being able to substantially replicate DVRPC’s web-tool in the San Diego region was a value-added opportunity to tie in other freight modes and land use relationships, with strong connections to both domestic and international truck demand.

Through the process of transplanting the *PhillyFreightFinder* to a San Diego context, improvement opportunities for existing San Diego data sources were discovered, with a specific focus on truck count data and collection needs. This type of freight data gap has already been identified through the review of the SANDAG technical data reviews. Through the transplanting and adaptation of the *PhillyFreightFinder*, SANDAG was able to methodically consider its own unique freight facilities, generators, attractors, international gateways, etc.; and the various ways to measure performance through data sources, and further needs to enhance these objectives. In short, the *PhillyFreightFinder* was deemed to be a great freight tool that SANDAG wanted to replicate.

SANDAG was able to reach out to DVRPC staff directly regarding the *PhillyFreightFinder*, as well as getting guidance on from various Transportation Research Board (TRB) freight events to develop a relationship in transferring information and establish a collaborative dialogue. Once both planning and technical staff were able to assess the level of effort required to replicate the DVRPC web-tool, it was determined that existing project resources could be utilized to tailor a similar product for the San Diego region.

Administratively, an amendment to the project’s scope of work was required and the grant deadline from the Caltrans District 11 was extended to garner additional time required for development.

Ultimately, new relationships have been established by regional agencies nationally, and funding from the SHRP2 has indirectly translated to another region’s visualization interests. Through the State of the Practice research, and federal funding programs, this unique freight visualization opportunity has arisen and been taken advantage of, as multiple agencies which are striving toward improving freight data and visualization tools across the country.
Section 2: Freight Visualization Data Public Work Shop

As part of the truck visualization project, a Project Study Team (PST) was created to participate in the overall process of developing a truck visualization tool. The primary intent of having a PST was to organize a peer group capable of providing feedback and insights throughout the entire project process. Agencies included in the PST include federal, state and local Metropolitan Planning Organization (MPO) peers and partner agencies. As an added benefit for the PST and public, a public workshop was held late in 2017 with a strong focus on freight visualization data tools. Information was presented by three invited vendors with strong expertise in visualization applications and products to highlight freight visualization techniques and opportunities.

The three vendors attending the public workshop included INRIX, Streetlight and the American Transportation Research Institute (ATRI). Aside from other MPOs and regional planning agencies across California, Caltrans District 11, federal partners, other agencies, including the Port of San Diego, and researchers and industry experts, attended for the presentations and discussion.

All three vendors were reviewed as part of TM 1 – the public workshop session was an opportunity for additional highlights, especially as they related to the San Diego region. Each presenter was allotted a 45-minute presentation and discussion period, with an additional amount of time at the end for a wrap-up session.

As highlighted from TM 1, there has been a substantial increase in interest in visualizing freight data. This has been directly related to the truck mode, as many planning agencies at all levels continue to look for more information regarding truck travel patterns. Due to complexities of global supply chains, having precise data inputs regarding truck flows has been challenging, especially as most information tends to be of a proprietary nature. Interestingly, all three vendors have looked to enhance freight data by utilizing information from global positioning system (GPS) applications.

Both ATRI and INRIX have direct access to GPS data. Streetlight is a licensor of INRIX data and has developed its proprietary user-friendly suite of products that can be used by planning organizations to synthesize freight data through its value-add analysis of large data sets. However, not all GPS data sets are alike, as primary data sources differ.

In ATRI’s case, GPS data is attained through its strong direct connection to the private sector from its board of directors and research advisory committee. The board and research advisory committee are comprised of industry leaders for both motor carriers and industry suppliers, with a strong emphasis on improving safety and efficiency for the trucking industry. This includes major companies such as FedEx Corporation, Cummins Inc., C.H. Robinson Worldwide, and many others, as well as government officials, scientists, academics and others.

In the INRIX application, the firm aggregates GPS probe data from a wide variety of commercial vehicle fleets, with varying vehicle classifications. Challenges to the accuracy of this GPS data include certain biases and limitations related to smaller and unrelated random sources of GPS data. Users of these evolving GPS based datasets need to understand the primary sources of GPS signals so as to be able to determine the efficacy for selected planning purposes. An additional caveat for users of these evolving GPS sources includes knowing whether there is sufficient data to validate against GPS data sets as a proof of concept, to justify resource investments.

In the case of the SANDAG truck visualization project, the focal point is with heavy truck classifications, moving the largest amounts of freight tonnage. For the San Diego region, this is applicable for both domestic and international truck flows, as both the seaport and land ports have significant demand for goods moved by truck.

Based on the vendor information presented and the makeup of the San Diego region, there is a clear justifiable need for heavy truck classification flows, distinguished between domestic and international access points and gateways. Additionally, as noted in Technical Memorandum 3 (TM 3), there is an additional interest in the consolidation of freight from heavy to medium and/or light truck classifications.
Section 3: SANDAG Technical Applications and Skills

The review of SANDAG applications of truck flow methods in TM 3 was undertaken to clarify technical considerations including transportation model applications and land use generators and attractors, as they related to truck flows. For the purposes of the development of the freight web-based tool, additional specific applications and expertise have been identified and highlighted as an overview of the resources necessary to successfully implement such a tool.

Through the coordination with the DVRPC, it was determined that the SANDAG Data Solutions (DS) team would be instrumental in developing and delivering the freight web-based tool. This would not be accomplished however, without including other critical teams for economic and demographic analysis, transportation applications, and eventually web-based application needs.

To mirror the utility and applicability of the PhillyFreightFinder, a combination of Geographic Information System (GIS) analysts, programmers, and economic and transportation analysts were added to the team to provide both data and information, and web-tool integration expertise. At the planning level, the SANDAG goods movement team was required to frame the objectives of the tool, as well as the different components which were originally included.

The SANDAG DS team includes GIS and applied research analysts, as well as researchers and modelers. This group is heavily involved in maintaining and improving both land use and transportation networks for a wide variety of transportation project needs. With a strong focus on land use and industry classifications, economic researchers and modelers from the Economic and Demographic Analysis and Modeling (EDAM) team provide population, housing and employment information for regional planning needs. The Transportation Analysis and Applications (TAM) team is comprised of researchers and modelers tasked with developing, enhancing, and validating and calibrating long-range models for planning purposes. Software Development Solutions (SDS) includes programmer analysts who provide services for website application needs.

For the DVRPC, the agency was dependent upon fewer staff who were able to provide all the necessary technical expertise to fulfill all aspects of developing the PhillyFreightFinder. In either case, the point is that it is highly important for any agency looking to undertake an effort to develop a freight tool or application to assess internal resources and capabilities, as well as external availability based on funding capacity.
Section 4: Freight Web-Based Tool Development Process

Figure 4.2:  PhillyFreightFinder tool

Source: The PhillyFreightFinder

The PhillyFreightFinder tool is organized into four primary website categories including the main page, county freight profiles, performance indicators and network exploration (see Figure 4.2). As highlighted in the section above, there is a multi-disciplinary team of staff involved at SANDAG, which has contributed resources to the development of the SANDAG e-freight web-based tool. To simplify the development process, each of the four website categories will have an overview detailing the components of this process.

Main Page

The main page of the PhillyFreightFinder is the landing/home page for DVRPC’s freight data portal. The structure and functionality of the website serves as the template by which SANDAG (or any other regional organization) was able to customize all aspects of information for the San Diego region. This has been accomplished through editing/re-writing all of the programming code that is underlying construct for the website’s layout, appearance, and intractability.

The primary orientation of the main page is to provide users with access to the three key freight data portal options: county freight profiles, performance indicators and a browsable freight network map. In addition to these interactive freight areas, information is provided for both freight planning and data in the DVRPC region, as well as other external link options for accessing freight data portal interactive information.

From a development standpoint, the main page is needed to provide the initial context for a region’s freight data portal. For SANDAG, the goods movement planning staff needed to review and update all text-related information to frame the San Diego region’s unique characteristics, including freight funding programs, regional infrastructure and international gateways, planning studies, projects, etc., as well as staff contact information.
The county freight profiles section is structured to provide a snapshot of a region at the county level (see Figure 4.3). Within the snapshot is information for freight network statistics by modes and facilities. Additional graphics including pictures and maps also are provided to give users additional context. For the DVRPC planning region, nine counties had to be profiled within the greater Philadelphia region. In the case of SANDAG, there is only one county (San Diego), but for important regional context, both Imperial County and Baja California, Mexico are included in the initial county freight profile overview page, with the potential for comparable information to be provided at a later iteration. Depending on a county’s freight modes and facilities, the freight network statistics are capable of being expanded. This is an important point that applies to all regions across the U.S.; each region must understand and depict its unique domestic and international freight transportation infrastructure and facilities. For the San Diego region, all major freight modes are incorporated including trucking, rail, and maritime (air cargo must be integrated at a later date). As stated earlier, there are both domestic and international freight flow dynamics.
Another point of consideration for agencies looking to replicate a freight web-based tool, is the level of granularity desired (and available) reflecting domestic trade patterns. The PhillyFreightFinder included domestic information for top domestic trading partners, by commodities and by volume, reflecting both inbound and outbound shipments, as well as all freight modes of transportation (see Figure 4.4).

This information was developed by DVRPC, utilizing proprietary IHS Global Transearch databases. SANDAG has reviewed this process and has determined that its’ initial version of its web-tool will not include such an analysis, or graphic illustrations (see figure 4.5). However, there are other approaches including customized depictions from the Freight Analysis Framework (FAF), as well as consideration of additional purchased data, which could allow for similar analysis. SANDAG will consider inclusion of domestic trade patterns in future iterations.
From the SANDAG development perspective, much of the information required for county profile level freight network statistics is available from in-house GIS analysts. Certain land use adjustments for freight facilities and/or external data for volume or trade value were coordinated with and provided from goods-movement planning staff. Planning staff was directly responsible for providing all narrative information, as well as freight-related pictures.

**Performance Indicators**

The performance indicators section is meant to provide users with transparency in evaluating performance of facilities supporting freight in the region. For the DVRPC, this was limited to highway performance and maritime indicators, based upon each county’s respective freight facilities (see Figure 4.6). For the SANDAG region, both highway and maritime indicators were included, as well as land ports of entry (POE) indicators. This is regionally important to reflect, as the Otay Mesa POE reflected the second largest border crossing between the U.S. and Mexico by the number of northbound truck crossings, second only to Laredo, Texas.
The highway performance was developed using DVRPC’s analysis of National Performance Management Research Data Set (NPMRDS) truck probe data. This included both a travel time index and average speeds during a typical weekday. Similarly, SANDAG has recently obtained upgraded licenses for the NPMRDS and will be capable of replicating average daily travel time index and average speeds for our region’s highway system.

**Figure 4.7:** DVRPC maritime indicators

DVRPC’s maritime indicators were focused on the number of annual ship calls, total trade by value and tonnage, as well as the exported foreign trade by volume (see Figure 4.7). Additionally, maritime activity was depicted by containers as expressed by 20-foot equivalent units.

The Unified Port of San Diego (UPSD) only has two terminals and is much smaller than the Philadelphia port system and does not contain exact commodity mixes. Regardless, the similar maritime cargo information is available through both public data sources as well as directly from the UPSD. Goods-movement staff has been responsible for coordinating with the UPSD and providing data formats as necessary.

As stated above, the San Diego region will also be including a land POE performance indicator section, with similar value and volume information as depicted in the maritime section. There will be a strong focus on import and export trade value, as well as some tonnage information, and the number of northbound trucks crossing the border.

Development of the land POE indicators section will rely on similar programming language to that which was used to develop the other sections. Throughout development process, there has been flexibility in the open source code provided by the DVRPC, thus enabling SANDAG to adjust information as necessary to tailor to our region’s specific needs.
It should be noted that for the maritime and land POE indicator sections, there was a large amount of descriptive information that goods movement staff was required to edit and adjust to the San Diego region’s context, as well as specific data sources relied upon.

**Browse the Network Map**

The network map is the most interactive component of the entire *PhillyFreightFinder* data portal tool (see Figure 4.8). As depicted on the above diagram, on the left side is a table of contents, which mirrors the overall region’s county profiles and to some extent, regional performance indicators. The value of the interactive mapping tool, is for users to be able to toggle specific categories and to zoom in/out with a background map geography as a reference point.
In relation to county profiles, the information in the interactive map is disaggregated, where users can scan over whichever location they desire, versus the county profile aggregating freight statistics within each county. For the SANDAG development process, all categories were incorporated with adjustments made based on the characteristics of the region. A San Diego regional background map was provided for each category’s attributes to overlay into the region’s geography reference point.

An important note during this process was the need to consider how employment was represented by the DVRPC. Freight centers were classified as either mega, major, or intermediate centers, and employment was solely based on the manufacturing industry. Employment classifications were organized by even proportional breaks for each category.

For SANDAG, industrial classifications utilized the North American Industry Classification System (NAICS) looking at manufacturing, wholesale trade, transportation, and warehousing, and portions within other areas such as retail trade, etc. Employment information was not broken down by relative numbers of employees, but rather by the NAICS codes. Employment data sets were organized within analysis zones and aggregated into sub-regional geographies.

Much of the upfront work for SANDAG relied upon the DVRPC county freight profile format and regional performance indicators were researched and applied into a customized interactive freight map for San Diego. The multi-disciplinary skills and personnel needed to successfully edit and implement the Open Freight App for the San Diego region should not be underestimated. In the case of both the DVRPC and SANDAG, strong expertise was required in both goods movement and technical backgrounds to develop and replicate this freight tool.

Now that two nationally significant MPOs have successfully accomplished this task, there is more information available for other MPO to replicate such a customized interactive freight visualization tool. The PhillyFreightFinder project has been highly successful in completing its two objectives – developing a freight visualization tool as funded and defined by SHRP2 and enabling another MPO to leverage this Philadelphia-centric framework to be successfully replicated and customized in San Diego, proving that freight transportation data can be accessible to interested members of the general public.

SANDAG staff is deeply grateful to the ever professional and ever generous staff of DVRPC; Ted Dahlberg, Manager of the Office of Freight and Aviation Planning; and Michael Ruane, Senior Freight Transportation Planner.
Conclusion: Assessment of a Truck Visualization Tool

Introduction

The preceding Technical Memoranda have covered:

- State of the Practice for Truck Data Collection and Truck Flows
- Summary of Prioritized Policy Issues
- Methods for Understanding Generators and Attractors
- Summary of Data Collection Needs and Strategies

As comprehensive as the authors tried to be in writing these tech memos, they are truly snapshots of the state-of-the practice that could be updated almost weekly. The field of truck visualization is evolving rapidly due to the proliferation of new locational data. This project study report concludes that the future of freight visualization, especially the truck mode, will require on-going fusion of data sources where many datasets will be combined and regularly updated. This is not a negative conclusion; in fact, it is a very positive conclusion. The explosion of data sources will enable so many opportunities for visualization of persistent freight planning challenges such as last mile tracking, mapping of urban congestion, truck parking location selection, as well as land use threats and opportunities. Agencies now have options for sensing and acquiring data, storing the data without expensive IT systems and employing new techniques to display freight congestion and freight flow situations.

In this final Technical memorandum, SANDAG will offer some basic assessments of the overall project and next steps for future truck visualization work.

Section 1: Summary of Findings

The truck visualization project study provided two direct benefits to SANDAG and members of the PDT. First, SANDAG could develop a specialized interactive freight web-tool for the San Diego region; second it was able to procure new truck data to provide further insights into freight flows.

A Freight Visualization Web Tool: The San Diego Freight Viewer

During our research on the best practices in freight visualization, we came across the work of the Delaware Valley Regional Planning Commission (DVRPC), serving the great Philadelphia region. This sister MPO had already developed a widely praised Philly Freight Finder Tool which was a national prototype, and intentionally built for replication by other region planning agencies. SANDAG saw the value and utility of the Philly Freight Finder and assigned technical staff to utilize their “open Freight Application Framework,” and customize for the San Diego Region. The DVRPC stated their intention as follows:

…”[to] share with regional and national transportation planning partners the framework that is the basis for the PhillyFreightFinder web mapping and data application. Through this effort, DVRPC hopes that county planning agencies, metropolitan planning organizations and state departments of transportation, and economic development agencies can leverage this framework to further their efforts in making freight transportation data public. By utilizing the Open Freight App framework, rather than building from scratch, planning agencies can focus their time and resources on the development of data sets that can serve to improve the access to information on freight facilities and their role in economic development and transportation across the country. Open Freight App would serve as a self-hosted solution to offer these datasets to other planners, economic developers, public officials, decision-makers and the public.”
SANDAG readily adapted their Open Freight App, because it is a white-label, open source version of the DVRPC PhillyFreightFinder application. The adapted SANDAG application includes the following features:

- Map functionality for layers and features
- Creation of info windows for feature data
- Creation of and ability to modify legend and layer controls
- Populating search criteria
- Converting ArcGIS Shapefiles to lightweight GeoJSONs for use in the map and more!
- Fully commented versions of all necessary HTML, JavaScript and CSS files
- A starter set of freight facility icons

The SANDAG Freight Viewer can be accessed via the homepage icon below:

![View Project on GitHub](View_Project_on_GitHub)

**SANDAG Data Procurement Goals**

As part of the Caltrans planning Grant, SANDAG would procure and process GPS-based commercial vehicle data that would be used in visualizing: truck volumes on freeways, highways and major roadways as well as origin and destination relationships within and outside of San Diego County. SANDAG has targeted the key areas where the agency has a need to visually depict truck activity, which include:

**Truck Volume Snapshots**

The current data SANDAG relies upon for truck count/volume information is primarily derived from the Caltrans Traffic Census Program for interstates and state routes, and from local jurisdictions for arterials; survey data is also utilized intermittently. While these data collection programs have well-developed methods, maintenance of collection equipment and/or limited resources have constrained the consistency and accuracy of collection. To augment existing truck information, the goal of SANDAG is to obtain truck volume data for the San Diego region for interstate, state route and prime arterial roadways. This information is expected to provide accurate truck volume data for the region’s freight flows across the network. The following was considered for processing this part of the data request:

- 2017/2018 weekday truck information. This should include data obtained from primary sources such as GPS, cellular, etc.
- Weekday truck information should include at a minimum, information for each month of a calendar year (seasonality), and one week’s worth of data within each month.
- All interstates and state routes are required to be included; prime arterial roadways in total are desired, but negotiable.
- Processed information should be delivered in a SANDAG approved electronic file format or database. In addition to the acceptable electronic format, SANDAG is looking for unique and illustrative product applications as well.
- Data should be delivered within four weeks of the notice to proceed and include an accompanying methodology memo.

**Truck Origin & Destination Snapshots:**

At the commercial vehicle unit level, origin and destination information is much sparser, especially for domestic flows. Current data relied upon is primarily derived from survey instruments and other international
trade-related data sources. To augment existing truck information, SANDAG sought to procure truck origin and destination data reflecting multiple relationships across the San Diego region, including binational trade. This information is expected to provide a comprehensive snapshot of the region’s freight flows for external relationships. The following was considered for processing this part of the data request:

- 2017/2018 weekday truck information. This should include data obtained from primary sources such as GPS, cellular, etc.

- Weekday truck information should include at a minimum, information for each month of a calendar year (seasonality), and one week’s worth of data within each month.

- San Diego County will be broken into multiple zones including the entire county, the entire county excluding sub-zones and 10 sub-zones. Additional zones will include the ports of Los Angeles and Long Beach, 30 SCAG sub-zones, 10 U.S. state zones and 10 Tijuana, Mexico sub-zones.
  - A sample of Mexico cross border data should be distilled and compared with Bureau of Transportation Statistics (BTS) monthly data to provide SANDAG with the level of data penetration for the Otay Mesa Port of Entry.
  - Origin and destination pairs will include all San Diego County zones (including sub-zones) to all the zones outside of the region.
  - Other origin and destination zone pairs will include the following:
    - Tijuana and the ports of Los Angeles and Long Beach, all San Diego zones and sub-zones and outside of San Diego County zones
    - San Diego County and the ports of Los Angeles and Long Beach, 30 SCAG sub-zones and other areas outside of listed zones.
    - Select San Diego County sub-zones and three sub-zones for California and 10 state zones.
      - A sample of San Diego port terminal truck data should be distilled and compared with truck gate data to provide SANDAG with the level of data penetration for these terminals.

- Processed information should be delivered in a SANDAG approved electronic file format or database. In addition to the acceptable electronic format, SANDAG is looking for unique and illustrative product applications as well.

In addition to the above data, there will be an accompanying methodology memo.

**SANDAG Procurement of StreetLight Data**

SANDAG requested bids from qualified vendors with the goal of assessing the utility of this type of data for the above stated purposes, as well to investigate whether the data would useful for other regional planning activities, including model validation/calibration, and integration into a web-based freight application. Two vendors submitted bids on the procurement, and while both were highly qualified, the selection team found that Streetlight Data, best conformed to the SANDAG bid specifications, and the firm has an established track record with SANDAG as well as other MPOs. StreetLight Data was selected due to easy access, and user-friendly big data and analytics that featured easy to use software that enables interactive visualizations. Moreover, their customized data product also was within the modest data procurement budget.

**SANDAG Application of StreetLight Data**

SANDAG will assess the truck volume data provided by StreetLight Data for 250 count locations in the southern California and northern Baja California region for interstate, state route and prime arterial roadways. The 250 locations were selected from existing screen line locations used for SANDAG and SCAG modeling purposes, and locations in Baja California for major highways and arterials from Ensenada northward through the San Diego County ports of entry. This initial assessment will determine whether this
new data source provides a baseline level of accuracy, comparability, and consistency needed to support SANDAG planning and modeling data needs.

SANDAG will assess the origin and destination data provided by StreetLight Data to determine the utility of the data to help visualize the multiple business and operational relationships throughout southern California, with a specific focus on binational trade within the San Diego region. Analysis will be performed for 60 zones developed by SANDAG staff to determine the level of accuracy for key origin/destination relationships when compared with existing data sources and information provided through stakeholder relationships. This information is expected to provide a comprehensive snapshot of the region’s freight flows for external relationships, as well as develop a baseline utility determination for GPS-based origin/destination data.

The assessment of this initial acquisition of StreetLight Data GPS-based truck volume and origin/destination data is a first step in determining the utility of such data to meet freight visualization goals. Further, this limited sample size should provide initial insights for both SANDAG and StreetLight Data into the accuracy and utility of the data to support other regional planning and modeling data needs. SANDAG is in the early stages of adapting data for visualization purposes for large scale regional planning, and we anticipate that it will take MPOs such as SANDAG years of collegial work with vendors such as StreetLight Data, their Parent Company, INRIX Data, Air Sage Data, and American Transportation Institute Data (ATRI) to refine and calibrate their evolving products. As stated elsewhere in this report, the future of truck visualization data will be characterized by data fusion where existing data will be combined with these new locational data sources and will be routinely updated and refined.

Section 2: Importance of Partner Agency Collaboration

The original belief of SANDAG that public agencies will be well served by exploring big data visualization tools in partnership with like agencies, was validated through the Truck Visualization Study. There are several observations that further validate this original hypothesis:

- Many agencies such as Caltrans District 11, SCAG, ICTC, and the Port of San Diego, have similar needs to understand truck flows, it only makes sense to share experiences and exchange technical information.

- As noted under the StreetLight Data discussion, big data can be expensive, and long-term use with customized applications may as well serve both the vendor and the data using customers. In the case of StreetLight Data, there were discussions about SANDAG buying a master subscription, and then creating partnership agreement so that Caltrans District 11 and the Port of San Diego, and perhaps the City of San Diego could be satellite subscribers to the SANDAG master subscription. This option presents some compelling logic for future consideration, with a multi-agency RFP which could attract the best data vendors.

- It was also mentioned earlier that the fusion of many data sources, would be the way of the future. Our experience through this Project indicates, that there are various existing datasets that could be fused with new big data, for better technical applications. For example, Caltrans has the PEMS Data and the WIM datasets, fusing that information with truck GPS data, would likely provide very rich information. SANDAG has heavy duty truck data, and the evolving Activity based Model (ABM) as well as the PECAS model. These datasets could be enriched with vendor data about real time truck movements. This is just a thumbnail sketch of options for the future, but there is real merit on local agencies collaborating on future data fusion opportunities.
Section 3: Other Opportunities and Next Steps

There is a reoccurring theme throughout the Truck Visualization research which is the importance of clearly identifying areas of need for data and information, as well as developing a strategy for having adequate and consistent resources to both purchase and then refine fulfill these needs. Clearly SANDAG will be re-assessing the StreetLight Data (as well as other data products) and combining it with existing data to determine additional gaps in the data we have and need for answering new planning questions. Additionally, SANDAG will be requesting user feedback on the SANDAG Freight Viewer website to determine ongoing data update and website refresh needs. We also have a long-term goal of adding near real-time truck flow and wait time conditions. For example, we aspire over time to be able to visualize real-time truck flow data at the border and show traffic condition in both Mexico and in Otay Mesa. Finally, as noted, the StreetLight Data, is but a sample acquisition, and SANDAG plans to move toward a full year subscription for truck locational data, after further field testing.

Finally, SANDAG and the PDT found many freight visualization applications that present opportunities for further research and development. This is the first Freight Visualization Study that we and the PDT found to be useful as a compass for the future. We clearly found that this does not create a defined roadmap, therefore we look forward to further collegial work in this area. Our identified next iteration opportunities include:

- Consider how procured data from vendor(s) could be incorporated into the tool as an addition to NPMRDS and other performance indicator information – this could relate to either domestic and/or international information. May be a standalone new page (could supply the Philly Freight Finder’s domestic trade patterns page).
- Consider how the web tool may be better incorporated into the Goods Movement website, once SANDAG website revamp occurs.
- Consider including the San Diego International Airport freight activities at some point in the performance indicators section. Need better information for domestic air cargo data than what was previously discussed.
- Consider expanding the international trade value and tonnage information for both land port and seaport, by top 5-10 commodities, or major commodity trends/finished products.
- Consider including more information for Imperial County and/or Baja California within the county profiles and performance indicator sections. Given more time, there is comparable trade value and unit information for Imperial County/Mexicali. There are also relationships and data for the Port of Ensenada.
- Consider adding a screen that visualizes real-time truck processing activities at the border
- Consider further customizing the web tool with the following:
  - More graphics/pictures – enhancing maps or graphics in a more custom fashion as SANDAG would prefer.
  - Other layout options depending upon information/opportunities for more content.
  - Aerial imagery possibilities.
  - More information about land use patterns and associating those patterns to truck attractors and generators.

More context/descriptive information and connections with operational facilities (Port of San Diego, Otay Mesa POE, Airport, other consolidation/major interchange locations).