FREIGHT DATA VISUALIZATION: A 'PIVOTAL' POINT IN THE DEVELOPMENT OF VISUALIZATION APPLICATIONS IN TRANSPORTATION

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ABSTRACT

In transportation, a shift in from is taking place from the principle use of visualization (TRB 2006 International Symposium on Visualization in Transportation) to represent the ‘appearance’ of structures and facilities (Hixon, 2006) to the visualization of how major transportation ‘systems’ work or “operate “ (Hughes, 2006); as a case in point, TRB Research Need Statement, **“Applications of Data Visualization and Visual Analytics to Freight Operations and Logistics at the Sub-National Level”** (at: http://rns.trb.org/printview.asp?ids=23011|) as well as the earlier research need statement, **“The Visualization of System Operation: The Need to Integrate Modeling and Simulation”**(at: http://rns.trb.org/printview.asp?ids=13836|)**.** A 2010 SHRP2 C20 symposium on ‘Innovations’ in Freight Demand Modeling and Data identified data visualization as a potentially valuable tool for exploring the massive amounts of data currently generated by state, federal, and private stakeholders, and argued that data visualization should be incorporated into the SHRP2 future research ‘roadmap’ in this area. The present paper addresses, from a conceptual standpoint, how one might approach such an analysis requirement in the area of freight. The paper discusses the role of utilizing an eXtensible markup language such as XML for this purpose. The paper also acknowledges how traditional ‘input-output’ and ‘impedance’ notions common to traditional demand modeling approaches need, in the case of freight, to also address the quantifiable impacts of consumption, production, trade, and the impact of shifting global supply chain strategies (Grunzeback, 2007). Also discussed is the industry’s current use of ‘scorecards’ for tracking system performance data as well as the growing interest in the use of GPS tracking data (e.g., ATRI, 2009) for visualizing the spatial and temporal attributes of the surface transport of goods. Lastly, the paper points to the emergence and possible integration of ‘visual analytics’, a multi-disciplinary field which is the outgrowth of information visualization and scientific visualization.

PURPOSE OF PAPER

The purpose of the current paper is to address what is considered to be the need for a ‘pivotal’ alteration to what has been the traditional transportation community’s approach to ‘visualization.’ The paper briefly traces the evolution of what is presently TRB’s standing committee on transportation in visualization (ABJ95), the generation of TRB research need statements which have collectively defined the perception of the direction in applied visualization research to this point, and how requirements in the area of freight data visualization have prompted the need to establish a more concerted emphasis on ‘data visualization’ as opposed to a continuation of the ongoing focus on the generation of high resolution, photo-realistic imagery . . . largely for uses in the public involvement process.

This change in focus in no way implies that there are no longer research needs in the use of high resolution imagery in the public involvement process, or for benefit/cost data addressing the cost effectiveness of such applications. Neither should this modification of research and application focus suggest that there is no longer a need for the development of practitioner guidance for the use of visualization in the planning process, or for that matter, in the design and project development process.

The paper provides a preliminary discussion of data visualization considerations in the area of freight data. At this point, it remains premature to provide a detail, research-based overview of specific freight data visualization methods and techniques. We are at a point of establishing the necessary dialog and communication with practitioners in the freight data area, attempting to understand and better define what are the ‘stakeholders’ in this area, the decision support needs of stakeholders from state to regional to the federal level, as well as the massive-sometimes uncoordinated- nature of data sources in this area.

We believe that we are making process in this effort and are able make observations that have implication for what the next steps should be. In particular, we have established a working dialog with the SHRP2 project on freight data modeling and data. That dialogue has resulted in efforts to include data visualization into the project’s strategic research roadmap. In that roadmap we have emphasized work to both look at near term applications of data visualization as well as more longer term efforts to address the potential application of ‘visual analytics’ to freight data. The latter recommendation will hopefully serve to more closely align US and EU efforts in this area with the needs of transportation, and in so doing, result in the establishment of new ‘partnerships’ with the community science and data analysis communities that have traditionally been ‘outside’ the domain of transportation professionals.

BACKGROUND

The Emergency of Visualization within the Transportation Research Community

The Transportation Research Board (TRB) standing committee on Visualization in Transportation (ABJ95) is one of eighteen committees in the Data and information Technology Section. The scope or mission of the Visualization Committee is

> *to foster and disseminate collaborative exchange and research that enhances the usable knowledge of visualization methods and technologies for their potential in addressing critical transportation issues of today, as well as promoting innovative approaches to society's transportation needs of the future*
> *(From the committee's webpage at www.trbvis.org)*

Visualization is increasingly recognized as a 'cross cutting' discipline within the transportation field (1). Within TRB, the technical committees generate research need statements (2), the aim of which is to stimulate research that addresses concerns, issues, or problems facing the transportation community. Research needs identified by the Visualization Committee address both 'applications' of visualization as well as more basic concerns related to the further development of visualization as a tool.

Eight of the fourteen current TRB Research Need Statements in visualization are from ABJ95, the visualization in transportation committee; the remainder are from other TRB standing committees: AHB70 (Access Management), ABJ60 (Geographic Information Science and Applications), ABJ20 (Statewide Transportation Data and Information Systems), AFH30 (Emerging Technology for Design and Construction), and AFB40 (Landscape and Environmental Design). The full text of each statement can be viewed online at:

http://rns.trb.org/advanced_project.asp?f1=k%3A%3AKeywords+%28Title+or+Description%29&ddlType=RNS&orgType=S&status=&date_params=&lower_date=1900&upper_date=2099&sb=&so=a%3A%3AAscending&sc=xx%3A%3AAll+Categories&t1=visualization

There have been two NCHRP 'state of the practice' reviews, or '*synthesis* studies,' of visualization since 1996 The first, published by Landphair and Larsen (3) focused on the emerging application of advanced computer image generation and computer graphics for generating photo-realistic images for use primarily in the public involvement process. Ten years later, Hixon (4) conducted a second 'synthesis' of the current state of practice where he indicated that, despite the continued absence of definitive guidance for practitioners and project management personnel, and despite the continued lack of benefit-cost data addressing the cost effectiveness of visualization, there was a growing use of visualization within state departments of transportation and the supporting engineering consulting community.

In 2007, the TRB publication TR News, devoted a special issue to visualization in Transportation (1). In 2008, three members of ABJ95 (Rhyne, Hughes, and Manore) conducted a 'class' on visualization in transportation at the IEEE ACM SIGGRAPH International Conference in Los Angeles, CA, further indicating the cross cutting aspects of visualization applications and the role of computer science in future efforts (5).

Visualization interest within TRB has grown from a sub-committee, to a task force, to the status of a standing committee. TRB has hosted international symposia on visualization in Minneapolis, MN, Orlando, FL, Houston, TX, and Salt Lake City, UT. In 2007, concurrent with achieving the status of a standing committee with TRB, the visualization committee published its first set of 'research need statements.'(6) It is the opinion of the ABJ95 Research Needs Sub Committee that these statements remain 'valid.'

- There is still a need for usable 'guidance' for visualization 'users' (from designers, to project managers, to senior executives)

- There is still an outstanding need for a clear benefit-cost template by which to evaluate the *effectiveness* of visualization across various applications;

- The remains the need for many organizations to develop and implement enterprise-level applications for the integrated collection, distribution, and application of spatial, geo-referenced data

- There remains a need for an education and training 'curriculum' to prepare users and practitioners at multiple entry levels;

- There remains a need for more specific guidance on 'planning' oriented applications of visualization;

- There remains a need for more applied research on the requirement to represent the underlying 'dynamics' of system operation (i.e., via modeling and simulation approaches).

- There is a pivotal need for research that seeks to integrate computational capabilities and visualization capabilities for solving problems and making decisions in areas (like freight) characterized by massive amounts of diverse data from multiple public and private sources.

DATA VISUALIZATION NEEDS IN TRANSPORTATION: A "PIVOTAL" POINT IN TIME FOR IDENTIFYING FUTURE RESEARCH DIRECTIONS AND NEW APPLICATION OPPORTUNITIES

Until now, the focus of visualization applications in transportation has been almost exclusively upon the means for generating, displaying, and interacting with (i.e., navigating) photo-realistic visual representations of ‘design’ data (4). Artist ‘renderings,’ with the help of advancements in computational and computer graphics capabilities, have been replaced by computer generated images. Improvements in computer processing now permit observers to navigate in real time through realistic computer generated environments. Computer generated visualizations, like artist renderings of the past are still, by and large, created at the ‘end’ of the design process, primarily for the purpose of public involvement.

As 2D design capabilities have evolved into 3D design, and as the graphics system capabilities associated with design tools have improved, visualization has become more an integral part of the design process itself. The emphasis, however, has remained on the visual representation of the spatial attributes (i.e., dimensions, etc.) and perceived ‘appearance’ of what is being designed.

Rarely is the expression, ‘*data visualization*,’ used by those involved in transportation applications of visualization although the ‘product’ produced by the visualization process is actually a t*ransformation* of the numerical (dimensional) attributes of the product of the design. CAD ‘data’ are *transformed* into visual representations of the design; and to the extent that those viewing these visual transformations (of design data) have a shared visual experience with the images that are produced, the observer’s ability to infer the eventual appearance of the design can be greatly facilitated (i.e., the basic premise underlying the effectiveness of visualization in the public involvement process).

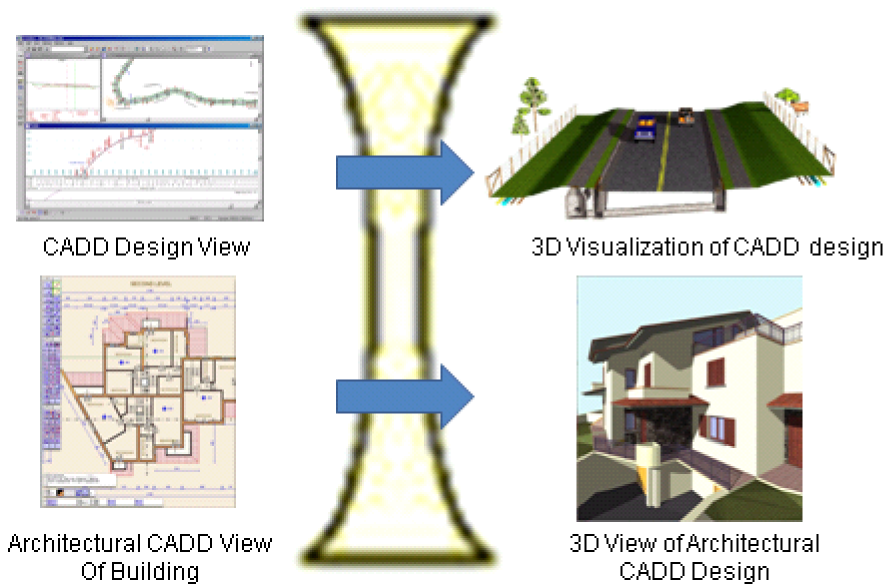


Figure 1. Visualization Transformation of Design ‘Data’ Into Images That Allow Us to Relate to the Data Via Our Shared, Common Visual Experience

To the extent that the stakeholder has a great deal of 'shared' experience with the infrastructure elements of transportation systems (roads, bridges, interchanges, vehicles, etc.), these visual representations combined with the perceptual-behavioral process of perception and 'generalization' work well . . . except when there are questions about how something 'works.' Photo-realistic, but not necessarily numerically correct, visual representations of traffic and traffic operations reveal the importance of being able to correctly represent 'operations' to an equivalent (or sometimes greater) level of fidelity as that used to represent the physical fidelity of the more structural components of the system.

Figure 2. What people typically report they 'see' when asked to visualize 'freight'

And then there are those transportation system concepts, like 'freight,' whose visual correlates are of little help in understanding the actual operation of the system

What, for example, do most persons report when asked what they 'see' when they think of freight (8,9).. More often than not, they report they 'see' the different modalities by which goods (the actual freight) are transported (i.e., ships, trucks, trains, airplanes, etc.).

The analyst's conceptual model of freight is defined in terms of data attributes such as those contained in the types of data sources shown in the Table 1 (e.g., the Commodity Flow Survey (origins, destinations, commodities, weight, value, the Freight Analysis Framework or FAF, etc.). Other sources of data include Bills of Lading, Manifests, etc). The logistician is

- Commodity Flow Survey
- Freight Analysis Framework (FAF)
- GeoFreight
- Highway Statistics
- Maritime Statistics
- Motor Carrier Financial and Operating Statistics
- National Transportation Atlas Database
- Oil Pipeline Statistics
- Pipeline Safety Statistics
- Rail Waybill Data
- Transborder Freight Data
- Truck Transportation, Messenger Services and Warehousing
- U.S. Army Corps of Engineers Navigation Data Center
- Vehicle Inventory and Uses Survey (VIUS)
- Vehicle Travel Information System (VTRIS)

Table 1. The Most Common Data Sources Which Characterize 'Freight'

more likely to think in terms of ‘networks,’ links and nodes, and transfer points. For facility managers, one’s visual reference to freight is likely more driven by infrastructure, demand, capacity, and the like.

Freight is not synonymous with a single mode of transport although we often analyze freight system performance by modality (marine, air, surface/truck, etc.). Neither is the freight system defined solely in terms of the commodities transported, or the routes taken. Freight is an *operational, system-level concept*. And as such, it is a concept that requires a different sort of ‘visualization.’ The effective visualization of a ‘process’ is different from the visualization of a ‘thing.’

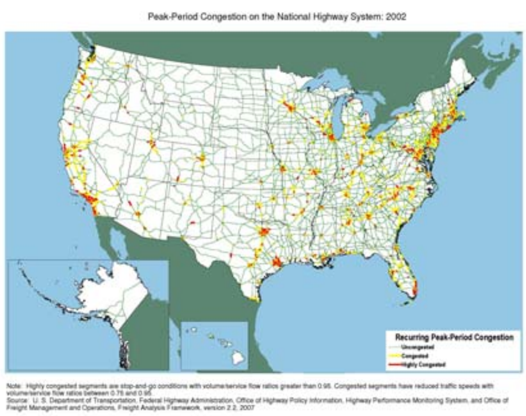
The items in Table 1 represent some of the most common data sources used to characterize freight activity. For the most part, they represent modal performance indicators in much the same way that body temperature, blood pressure, and body mass index represent ‘indicators’ of an individual’s overall ‘health.’ Each is obviously necessary to obtaining an overview description of the health of the (freight) system in this country. None, however, are ‘sufficient’ by themselves to provide an integrated, system-level view.

How Do We Currently Visualize Freight Data?

The Use of Map-Based Displays The concept of freight operations (as opposed to the concept of freight as the actual cargo being transported) has an inherent ‘spatial’ component. Freight is transported from point A to point B. It is not surprising then that efforts to visualize freight operations have relied on map-based displays to visualize routes, corridors, etc. The figures below, from the FHWA Office of Freight Management and Operations (http://ops.fhwa.dot.gov/freight/) provide good examples of efforts to portray major freight corridors and the use of graduated symbology to visualize the demand attributes associated with those corridors. The figures also show how this approach can/has been used to depict projected changes in demand over time.

Figures 3 and 4. Major Truck Routes on the National Highway System, 2002 and 2035

Figures 4 and 5 use similar map-based displays to depict major areas of congestion, again for 2002 and (as projected) for 2035. The figures provide a ‘national level’ snapshot. The user would need to have access to state and regional data, at a higher level of data resolution, to draw inferences about more ‘local’ levels of operation, or to explore in more explicit detail, the nature of the ‘congestion’ documented by these figures. Such visualizations are good for depicted national level ‘trends’ inferred from a variety of data sources. As ‘snapshots’, however, the visualization ‘stands along,’ and fail to provide the observer (e.g., an analyst) any ability to directly view or interact with the data from these figures were generated. They are typical of what would be called ‘presentation graphics.’



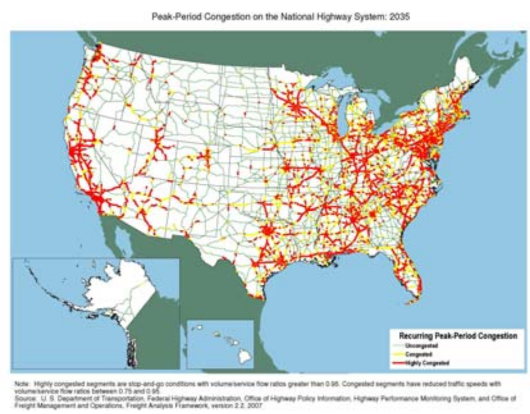


Figure 4 and 5. Peak Period Congestion on the National Highway System, 2002 and 2035

The Use of ‘Score Cards’ It is popular in many areas (for example, in the business arena’) to visually track critical key performance indicators (KPI) of system-level performance by what are called ‘scorecards.’ (refer to http://en.wikipedia.org/wiki/Performance_indicator for a discussion of KPIs and ‘balanced scorecards’).

Performance Measure	10 Year Trend	Analysis	20 Year Forecast
Freight Safety Measures			
Truck Injury and Fatal Crashes		Between 1983 and 2007, the large truck injury crash rate decreased from 67.9 to 31.8 per million miles traveled. The 2007 rate is the lowest on record. The large truck fatal crash rate has also declined. In 2007, this rate was 1.85, down from a peak of 5.21 in 1979. The 2007 rate is the lowest rate on record.	
Highway/Rail At-Grade Crashes		Between 1993 and 2008 the number of incidents at RR crossings involving both vehicles and pedestrians declined 32 percent. Nearly 2400 annual incidents still occur with 289 deaths in 2008.	
System Investment Measures			
Estimated Investment in NHS to Sustain Conditions		The 2004 FHWA Condition and Performance Report indicated that then-current investment levels were adequate to sustain most NHS conditions. However, since then construction costs increased significantly and funding for the federal highway program remains undecided.	
Rail Freight Industry Earning Cost of Capital		The Cost of Capital for the Class I railroads has steadily declined, which is a positive economic trend for them. Lower Cost of Capital reflects lower costs to acquire capital to improve the rail network.	
Estimated Rail Capital Investment to Sustain Market Share		A rail industry analysis concluded that the Class I RRs need to increase capital investment in expansion to sustain market share. The inability to raise sufficient investment capital is not definite and may not be sufficient to sustain market share.	
Inland Waterway Investment to Sustain Lock and Dam Average Age at Less than 50 Years		The average age of locks on the inland waterways system is estimated to be in excess of 51 years. Current expenditure levels do not appear to be sufficient to improve that average age.	

Figure 6. Typical 'Scorecard'

The scorecard shown above lists key performance indicators in the left column and provides a visual assessment of 10 and 20 year 'trends' shown by color coded arrows and their direction. The performance indicators are grouped into 'system safety measures' and 'system investment measures.' The column labeled 'analysis' provides some level of meta data as well as guidance on interpreting the data.

The figure below is an example currently being used by the Motor Carrier Enforcement Administration of the North Carolina State Highway Patrol to track key performance indicators of its Commercial Vehicle Safety Plan (required by the Motor Carrier Safety Assistance Program grant from FMCSA) as well as key performance indicators for its Truck Weight Enforcement grant from FHWA (10).

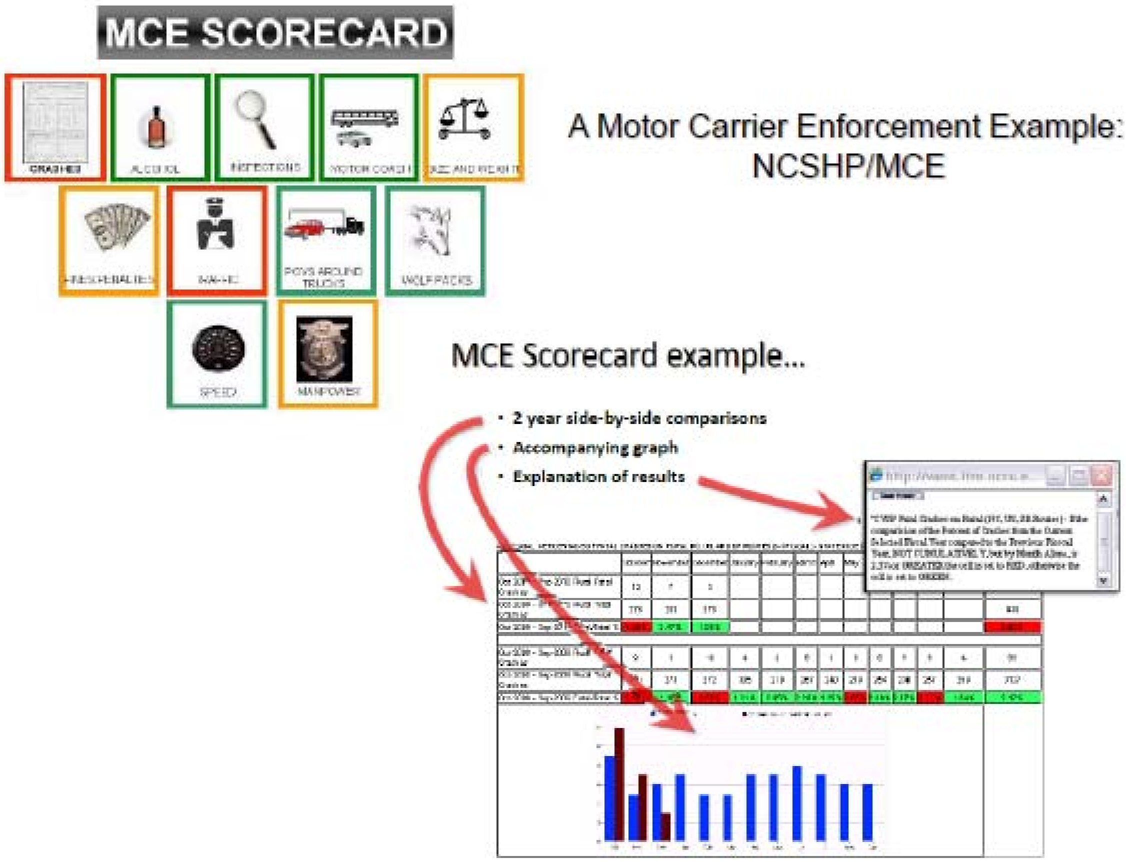


Figure 7. Example of NCSHP MCE 'Scorecard' for tracking MCSAP and Weight Enforcement Program Goals

The upper left portion of the figure illustrates the simple graphic user interface used to access data either at the statewide level or the individual 'troop' level. Once selected the score card provides the user with month-by-month data that are color coded with respect to the goal established in the CVSP or weight enforcement plan. The data are also shown in a simple bar chart comparing the current period with a reference period.

Scorecards and cash boards require an agreed upon understanding of the underlying variables of which the KPIs are a function. It is important that these types of data visualization enable their user to track not just the 'outcomes' but the 'strategies' of which the outcomes are a logical function. What such visualizations often lack is the ability for the user to effectively interrogate the underlying data to more fully 'explore' the relationship between strategies (actions taken) and program level outcomes (goals).

Similar types of data visualization may be referred to as 'dash boards' depending upon the nature of their application. A typical state DOT dashboard, in this case for the NCDOT, is shown below. Clicking on the dashboard display at this level typically takes the user to more detailed data presented in table and/or graphic form.

Figure 8. Example of NCDOT 'Dashboard,' in this case, for tracking organizational performance with respect to 'fatality rate'

From a freight standpoint, scorecards and dash boards can be used to track such system level variables as tonnage and value, in the aggregate or by specific commodity. More operational users may want to track key performance indicators of gate (in/out) functions, storage parameters (dwell time), or the effectiveness of the intermodal freight transfer facility in off loading cargo (e.g., from a container ship) and loading onto either rail or truck.

Scorecards and dash boards can be helpful when they track the behaviors/performances/activities of which system level goals are a function. Too often however they are used to track system level goals where there is inadequate understanding of the variables (strategies) of which of which system level performance is a function (e.g., where an enforcement function tracks driver/vehicle inspections as a contributor to crash reduction without having a logical connection between inspections and the likelihood of crashes. In the freight area, we can track tonnage by mode and by commodity; we can likewise track the stated 'value' of the commodity; and we can do so without a thorough understanding of the variables can influence weight and value. Likewise, we can 'track' capacity of the system (e.g., number of lane miles, miles of track, numbers of ports, etc.) only to find that variation in ‘utilization’ is not solely a function of capacity (i.e., build it and they will come).

Where Do Our Current Freight Data Systems ‘Fall Short’?

To begin to solve complex, system-level freight data problems, we need to move beyond our current desktop analysis tools (Excel, Access, etc.), and beyond useful, but simplistic, dash boards and scorecards, neither of which are designed to

- effectively organize our data for the type of robust ,investigative analysis required
- to permit “sharing‟ between different applications, or
- to go beyond serving as an “aid‟ to the conduct of simple “arithmetic operations‟ and off-the-shelf “production graphics‟

One could not describe the freight community as being ‘without data.’ If anything, it is ‘adrift in data.’ From a ‘measurement’ standpoint, there is a great deal of focus on identifying and standardizing freight performance measures (11, 12, 13, 14). Part of the ‘problem’ instead is that current measures focus on the performance attributes of the system, but fail in large part in providing measurable concepts of system-level performance (15). And to the extent that measures of system level performance are lacking, our ‘visualization’ efforts remain at the level of ‘presentation graphics.’

Before we can effectively pursue data visualization capabilities that are responsive to the needs of freight data stake holders, the freight data community needs to develop a more ‘functional’ understanding of the variables of which freight system level operation is a function. A more precise, more informed notion of system level operations is required before work can be done to address the community’s need for models and simulations – capabilities by which more robust forecasts of future system demands can be derived.

The freight data community needs to first develop a ‘conceptual’ model of freight operations that has application for the unique needs of stakeholders (state, regional, federal) as multiple levels. It needs to develop a clearer understanding of the data needs (in terms of data elements) and data processing requirements associated with the types of decisions stakeholders at different levels are attempting to make.

An Example of Where Visualization Becomes a “Part of” the Analysis Rather than Solely a Means to Convey the “Outcome” of the Analysis

Consider the problem described in the box below. It is a problem that requires logical thinking (versus a purely statistical approach) to its solution. As you try to solve the problem, observe how you may use ‘visualization’ (a simple sketch if you will) to aid you in reaching the solution.

You immediately recognize that the solution to the problem is not dependent upon the application of ‘statistics.’ It is a problem that, while simple, requires more than most persons can do ‘in their head.’ Most find that it is helpful is begin with a simple (visual) representation of the two boats. From there you explore your initial hypothesis of how the individuals from the two groups might be allocated in the two boats in a way that satisfies the criteria laid out in the problem. As you proceed, you immediately recognize whether or not your initial hypothesis is correct. You proceed to your next hypothesis until successful at which point your solution is now correlated the attributes of your visual sketch; i.e., two boats with an allocation of representatives from each class that effectively satisfies the constraints of the problem.

Four men (A,B,C,D) and four women (W,X,Y,Z) are going rafting in two rafts. Each raft holds exactly four people, and the groups of people in the two rafts follow these conditions.	Data Attributes
(1) There are exactly two men and two women in each raft (2) Either A or B, but not both, must be in the first raft (3) If W is in the first raft, then C must also be in the first raft (4) If Y is in the first raft, then B cannot be in the first raft	Solution Constraints
If B is in the first raft, which of the following can be the other three people in the first raft?	Desired Outcome
Your choices: (A) A,X,Z (B) C,D,W (C) C,W,X (D) C,X,Y (E) D,W,Z	Consider the ‘visual’ component of the strategy used to reach a solution. Was your ability to reach a solution based upon any numeric ‘computations’?

Table 2. A Simple Problem Requiring “Logical Thinking” for its Solution

The problem illustrated above is also important in a discussion of how data are used to reach a solution to a problem. In the above problem, we start with a definition of the desired outcome (i.e., the ‘constraints’ that define the desired solution). In our efforts to create a ‘national vision for freight analysis’ the problem is made more difficult by the absence of a clear statement of the factors that constrain an effective solution. It seems rather obvious that if we are to develop an effective analysis approach to the freight data problem (regardless of whether it be for state, regional, or national level application), we must begin with some notion of the actual problems to be solved and the actual decisions that have to be made, Without a notion of what the solution looks like, our analyses will continue to little more than summary statistics of the available data elements.

As We Move Toward a Data-Driven Description of Freight Operations at the "Systems" Level, What Should Data Visualization Research Agenda Focus On?

I think it is fair to say that we are exhausting our ability to apply traditional data analysis and data visualization methods (as those in the field currently know and understand them) to the problem of freight data. In a presentation to the SHRP2 C20 project in September 2009, we characterized the problem as shown in the figure to the right (9).

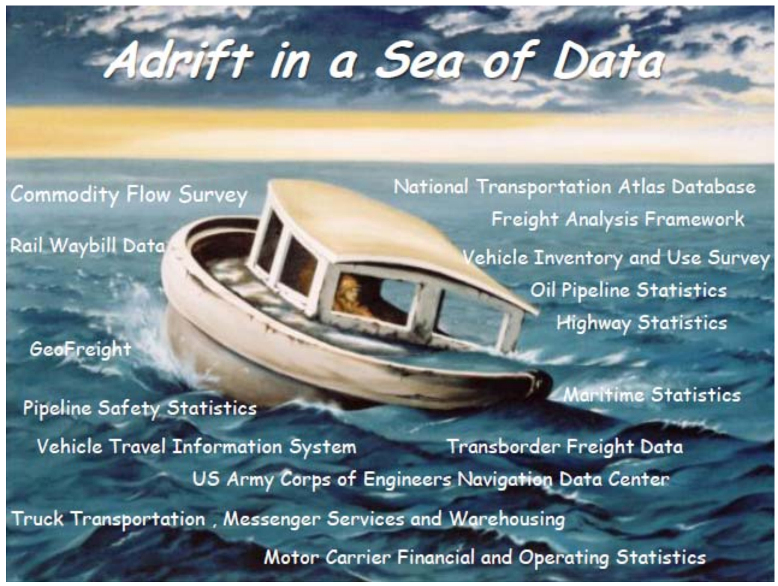


Figure 9. Adrift in a Sea of Data

In the SHRP2 C20 presentation, the TRB Visualization in Transportation Committee (ABJ95) recommended that the project's strategic research roadmap (see Figure 10) for travel demand modeling and data contain an element for data visualization, at two levels:

> (1) Efforts that would utilize <u>current</u> data visualization methods and techniques to improve the ability of stakeholders in the field to better orient to existing data and to communicate freight data to non-technical as well as technical decision makers, and
>
> (2) Efforts to 'explore' the feasibility of <u>new and emerging methods</u> for more tightly coupling automated computation capabilities and visualization capabilities. Work toward this goal currently comes under the general heading of Visual Analytics.

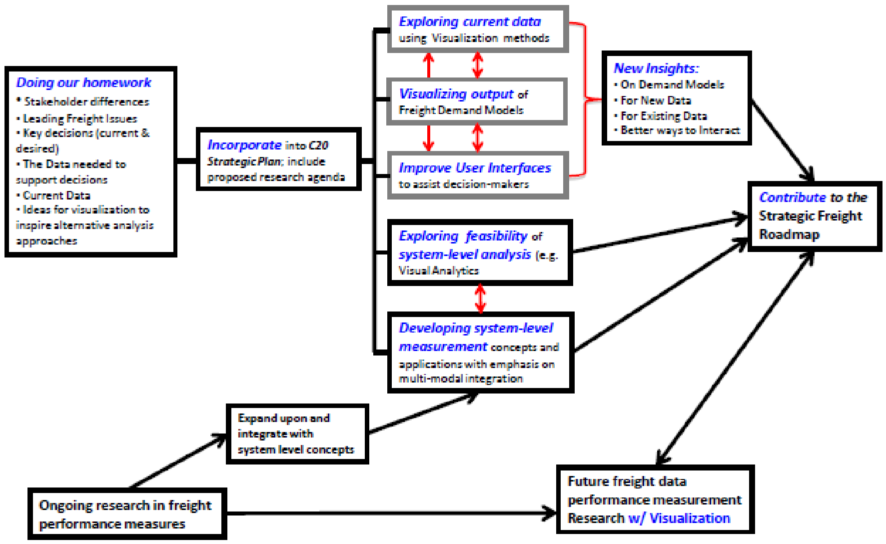


Figure 10. A Recommended SHRP2 Roadway for Applied Freight Data Visualization Research

So What is Visual Analytics?

Visual Analytics is an emerging, multi-disciplinary approach to data visualization that has its roots in the areas of Information Visualization (ref) and Scientific Visualization (ref). In the US, Visual Analytics gained prominence following the 9-11 terrorist attacks and criticisms of the US intelligence agencies for their apparent inability to 'connect the dots.' One of the most frequently cited definitions or descriptions of Visual Analytics is

> "the science of analytical reasoning supported by the interactive visual interface (16)

Elsewhere, visual analytics has been described as

. . . a 'process' that involves a tight coupling of automated analysis methods and interactive visual representations to enable people to synthesize information and to derive insights from massive, dynamic, ambiguous, and often conflicting data sets.

. . . Visual Analytics combines automated analysis techniques with interactive visualizations interactive visualizations for effective understanding, reasoning, and decision making on the basis of very large and complex datasets.

It is a multi-disciplinary research area, combining information visualization science, data mining, mathematical and statistical methods, data management, user interface techniques, human perception and cognition research as suggested by the figure below.

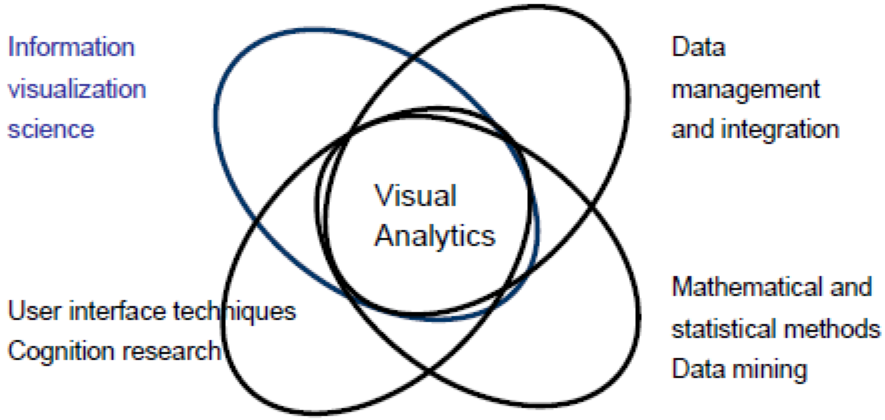


Figure 11. Building Blocks of Visual Analytics (17)

In the US, visual analytics – as a program of research – is described in the publication "Illuminating the Path: The Research and Development Agenda for Visual Analytics" (16). In the European community, a similar research agenda for visual analytics has been published as "VisMaster. Visual Analytics: Mastering the Information Age (2010).

Information visualization has been around since the early 1990s. The special issue of Computer Graphics on Visualization in Scientific Computing in 1987 is considered as the starting point. Since then there have been several conferences and workshops, co-sponsored by the IEEE Computer Society and ACM SIGGRAPH, devoted to the general topic, and special areas in the field.

In 2008, Manore, Hughes, and Rhyne from the TRB Visualization in Transportation committee presented a *class* on visualization applications in transportation to the ACM SIGGRAPH conference in Los Angeles, CA. Applications of visual analytics to transportation to date have, so far as we can determine, been limited (see Xiaoyu Wang[1], Wenwen Dou[1], Shen-En Chen[2], William Ribarsky[1], and Chang (2010), entitled: . *An Interactive Visual Analytics System for Bridge Management* (18).

The authors' assessment of the dialog that transpired at the meeting was that the transportation domain represented an appropriate and potentially valuable area for future exploratory work in visual analytics, contrary to remarks made , in private, by a program official of the National Science Foundation (NSF) to one of the speakers from TRB to the effect that, "Why would NSF be interested in t transportation ? Transportation lies at the 'other end' of science."

It is the opinion of the current author that transportation, more specifically – freight system performance – has significant computational and data visualization requirements to merit serious efforts to seek a transfer of visual analytics research knowledge and results from the NSF/DHS program (as well as the EU VisMaster program) to the USDOT. The Federal investment in visual analytics research should 'require' that its potential value to the transportation domain (in particular freight demand modeling) be fully exploited. The value in doing so is a potential order of magnitude improvement in freight data modeling and simulation capabilities- the result of which would be more informed investment in freight system infrastructure and more effective management of the capacity produced by that investment.

Visual Analytics is not the antithesis of conventional analysis and visualization methods. It is distinguished from our more conventional notions of analysis and visualization by its emphasis on a tight coupling of automated computation and visualization. To the extent that visual analytics represents a potentially more effective approach to deriving knowledge from “massive, dynamic, ambiguous, and often conflicting data sets, there is a data management component involved as well (i.e., how to first ‘organize’ the data for this type of analysis). There are those who point to the utility of eXtensible data languages such as XML which serves to ‘tag’ data elements according to standardized data definitions (19).

The key words (with respect to the current freight data requirement) in these different descriptions of visual analytics are, “massive, dynamic, ambiguous, and often conflicting data sets;” also the terms “tight coupling of *automated analysis* methods and *interactive visual representations.”*

Conclusions and Recommendations

Part 2 of AASHTO’s 2010 ‘Transportation Reboot’ report (14) deals with the need to develop a *National Multimodal Strategic Freight Plan.* The urgency for such a plan is based upon the following:

- The nation’s freight transportation system directly affects economic development, current and future jobs, and the quality of life in our communities.

- The need to move significantly more freight across the country and the world will increase substantially in the 21st century.

- The current capacity of our nation’s roads, rails, and seaports is not keeping pace with demand.

- Greater investment, better planning and more highway and rail capacity are needed to address these problems.

Development of a strategic, multimodal freight plan requires, at a minimum, consensus on a conceptual model of what constitutes not only the modal components of the system and their associated infrastructure, but a solid, data-driven model of integrated system operation and performance based upon a data-driven understanding of the variables of which ‘system level’ performance is a function.

While there is agreement on the need for expanding our current infrastructure, there is also an emerging need, similar to that expressed by the ITS community with respect to roadway infrastructure, that perhaps we ‘can’t *build* our way out of this.’

As we pointed out earlier, simplistic input/output notions of system performance, especially in the case of freight, require an in-depth, functional understanding of the factors of (a) consumption – not only what we in the US consume internally, but the consumption that is fed by the products we produce and export, (b) productivity – not just a matter of more ‘widgets’ produced, but the demand (for consumption) that drives the need to produce, (c) trade – recognizing that the freight system does not only meet the internal transport needs ‘within’ the US but also the transportation needs to import and export products as well, and lastly (d) the changing nature of global logistics strategies.

It has been our position that ‘visualization’ can help in both the development and implementation of a national (as well as local, state, and regional) strategic freight plan – but not so much in the ‘traditional’ sense of generating photo-realistic images . The visualization research community in transportation (characterized by the Visualization in Transportation Committee of the Transportation Research Board (TRB) is at a ‘pivotal’ point in terms of future research direction.

The ‘freight’ visualization problem presents the opportunity to develop a new thrust in the area of data visualization. We have argued that data visualization needs to be seen as the broader theme, a theme that focuses on visualization as the transformation of ‘data’ into forms that are more useful by analysts. Whereas the conversion of CADD design data into photo-realistic images that were readily recognizable by stakeholders based upon their shared visual experience resulted in marked improvements in the ability to communicate complicated design ‘data’ to a non-technical stakeholder, freight data visualization affords us the same opportunity . . . with the exception that the resulting data transformation may or may not resemble a ‘picture’ as has been the case to this point.

The resulting product of this ‘transformation’ will depend in large part upon ones conceptual model of ‘freight’ and the extent to which users, analysts, stakeholder, and the like are able to relate to the product based upon a high degree of shared experience. Given the freight data community's current dependency upon map-based displays, it is likely that freight data visualization will continue to rely heavily upon such map-based displays – but with more of an ability (as an inherent part of new freight models and simulations) to provide for automated computation and interactive visualization.

We have not addressed the growing interest and use of GPS data to track freight shipments (20), or the use of technologies like RFID (21), and automated/electronic manifests and bills of lading to track the freight content itself during movement. While map-based displays of GPS track data will continue to be the norm, advancements will be made only when 'location data' are combined with commodity data to permit a more in-depth analysis of freight movements.

While at one level (ala the recommended visualization research 'roadmap' for SHRP2 C20) we can expect to continue to see an evolution of new ways of 'plotting'/presenting data, we can expect on the other hand, to see visualization as a means of improving the analyst's interface to the model itself.

In essence, we predict that the development of visualization methods for freight data will result in incremental, yet significant, 'improvements' to current methods for plotting data and analysis results; for that data to increasingly represent system-level performance; and where our analysis systems and methods increasingly permit a high level of 'automatic (embedded) computation' combined with interactive (versus passive) visualization.

We have provided a simple example of embedded computation and interactive visualization in an example (from GE Healthymagination) where the analyst or data user is able, through use of a simple 'slider,' to manipulate one variable while observing its (calculated) effects upon a number of different estimates of one's probability of being diagnosed with a given disease.

We concluded the paper with a discussion of the emerging area of 'visual analytics' and the extent to which its goal of bringing to bear a tight coupling of automated computation and interactive visualization on the task of discovering knowledge in dynamic, massive, ambiguous, and often conflicting data sets (which seemed to be a good characterization of freight data).

We mentioned that visual analytics research and application is a very multi-disciplinary area currently lying outside the domain of the traditional transportation data analysis community. We identified two national/international efforts, one in the US and the other funded by the EU community, both of which have generated research roadmaps for visual analytics research. We feel it is imperative for transportation to be included as one of the major domains for the development of visual analytics applications and methods.

It is our prediction that those of us in the transportation community cannot be successful in developing a robust, data-driven, strategic plan for f freight 'system' operation without an analysis capability of the type being sought by the visual analytics research community. To make this happen in the US, the transportation community (i.e., USDOT, RITA, BTS, and TRB) need to impress upon the National Science Foundation (NSF), the consortium of national and regional visual analytics 'laboratories', and their research 'partners' to include transportation (specifically, freight) as one of their primary research domains.

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