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Beyond Congestion Points; Freight Infrastructure System Investment Evaluation

TSHIPS:
Transportation Shipping Harmonization and Integration Planning System

by

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16. ABSTRACT

This report documents the development of the Transportation Shipping Harmonization and Integration Planning System (TSHIPS). The TSHIPS project was developed to advance the state of the art in transportation systems analysis. Existing approaches and methodologies are unable to assess the needs of the existing and future transportation systems for the world. Existing methodologies are unable to analyze the operation of an entire intermodal or multi-modal transportation network. In addition to this, they are not able to quantify the impacts that infrastructure changes or operational decisions will have on the system. The TSHIP project fills both of these voids and adds the ability to calculate fiscal impacts. The TSHIPS methodology can be applied to any transportation system at any level of development including undeveloped roads to the latest intelligent transportation technologies with defensible results.

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EXECUTIVE SUMMARY

This report documents the development of the Transportation Shipping Harmonization and Integration Planning System (TSHIPS). The TSHIPS project was developed to advance the state of the art in transportation systems analysis. Existing approaches and methodologies are unable to assess the needs of the existing and future transportation systems of the world. Existing methodologies are unable to analyze the operation of an entire intermodal or multi-modal transportation network. In addition to this, they are not able to quantify the impacts that infrastructure changes or operational decisions will have on the system. The TSHIP project fills both of these voids and adds the ability to calculate fiscal impacts. The TSHIPS methodology can be applied to any transportation system at any level of development including undeveloped roads to the latest intelligent transportation technologies with defensible results.

TSHIPS is an epic leap forward in the state of the art for transportation systems analysis and meets the needs of the transportation systems of today and the future.

TSHIPS

Background

In 1995, the Asia Pacific Economic Cooperation (APEC) Transportation Working Group (TPT) undertook an effort to address congestion issues in the region. The initial phases of this work focused on the identification of congestion areas and the promotion of transportation improvements to address them. A Congestion Points Study was commissioned to look at congestion issues and identify best practices throughout the region in solving them.

Phase I of the Congestion Points Study focused on identification of important trade corridors, international gateways, distribution points, and traffic congestion points. Phase II of this effort focused on congestion at seaports and airports and identified general problems common to several economies. Phase II also identified case studies and initiatives to resolve congestion problems.

The Congestion Points Study was a significant contribution to the critical transportation issues affecting the APEC region. It also provided very useful information about how these issues were being addressed in many areas through best practices identification.

Upon acceptance of the Congestion Points Study, the TPT looked for opportunities to bring these efforts closer to implementation. As a result, the Transportation Shipping Harmonization Integration and Planning System (TSHIPS) project was proposed to the TPT in April 1998. This report is the result of that effort.

TSHIP Project

The primary purpose of the TSHIP project was to develop and present a methodology for systems analysis specifically for freight transportation systems infrastructure. As part of the project a sample test of the proposed methodology was also conducted. The project also looked at institutional concepts associated with freight transportation and potential improvements they could have on increasing freight mobility.

The TSHIPS project was designed to address the concept of benchmarking and analysis needed for transportation improvement assessment. While the best mitigation and improvement practices were known, a tool was needed to evaluate the implementation of them. The TSHIP effort addresses this element of the improvement process.

A sensible approach to transportation system improvements is similar to the approach used for many other systems. The approach uses the fundamentals of a total Quality Management process where improvements are measured and evaluated before being implemented. This method has the following steps:

1. Clearly identify the problem to be solved or the desired accomplishment.

2. Determine the assumptions and constraints that form the boundary conditions for developing alternative solutions. The assumptions are clear statements used to describe the present and future environment upon which the analysis is based. Constraints are factors external to the environment that limit the quality and quantity of alternatives that can be developed.
3. List all of the alternative solutions for the defined problem including status quo.
4. Determine all of the costs and benefits for each alternative. Benchmarks are developed as a basis to compare alternatives.
5. Compare alternatives in terms of their costs and benefits in net present value terms.
6. Adjust alternative solutions for risk and sensitivity and implement the solution that best meets the desired accomplishment.

This approach provides the decision maker with a logical, defendable and cost effective solution to a stated problem, which is also the best fit to the identified resources and constraints. The Congestion Points Study clearly provided information on the causes and identification of congestion points as well as excellent information about the best practices that have been implemented and alternatives available. The TSHIPS project provides a mechanism for determining benefits as well as the measurement or benchmarking necessary to compare individual alternatives. It allows the user to conduce multiple "what if" scenarios to determine which improvement or solution will provide the best results.

In addition to providing necessary input to the improvement process, the TSHIP project also is able to analyze an entire transportation system. In the past, no tools or approaches were available to assess the operations of an entire system. This did not meet the needs of shippers, as they were interested in end-to-end movement of cargo, nor the interests of planners interested in movements of people.

Additionally, without conducting an analysis of the entire system, there is the great probability that improvements at one congestion point may simply create a new congestion point at another location. The elimination of congestion at one location in the transportation chain may increase flow through that point and result in a new congestion point upstream or downstream in the system. Another location may not have been designed to accommodate the increased volumes that it is receiving and a new congestion point is created. In this example, the initial solution may have solved one problem, but created another one with the net result being little improvement of the entire transportation system operations.

The TSHIPS project is able to determine benefits of a proposed improvement, provide benchmarking metrics all through a complete analysis of the entire transportation system. This report presents the methodology to do this based on a freight shipping container movement system.

This approach can be used on any transportation system including passengers and freight. It is applicable to all modes and systems including bulk transportation, container shipping, transit and buses, high speed rail, pedestrian facilities, freeways, urban street and elevated or subterranean systems, rural roads, seaports, airport terminals and toll facilities. It can be used in underdeveloped areas also.

Approach

A review of the literature found several approaches to conducting systems analysis of business operations as well as the use of systems analysis as a decision making tool. For transportation systems however, the use of systems analysis was rarely applied. The systems analysis theories however were applicable. Based on the theory and an understanding of freight transportation, the following six-step approach was developed for a systems analysis:

1. Choose parameters
2. Model the system
3. Conduct operational analysis
4. Conduct systems analysis
5. Value performance measures
6. Model scenarios

This paper will expand on these steps, present a sample application of this methodology and discuss the institutional issues associated with shipping improvements.

METHODOLOGY

Step 1 – Choose Parameters

Choosing the parameters for a systems analysis includes identification of the timeframes, constraints, and data to be modeled. In choosing these parameters, it is important to understand what goal is to be accomplished by the systems analysis. Specifically, choosing the time period to analyze is an important step. The time period chosen will directly affect the output of the process and the measurements used in the final results. For example, if an individual peak hour is chosen, your system performance will be based on that individual hour. However if a 24-hour time period is chosen, the analysis will be based on operations over an entire day. Daily operations may provide more useful information, but the data needed is much higher as well. Further, the time of year or season is an important determination to make upfront in the analysis. If the peak monthly time period is used, the system performance and proposed solutions will be evaluated on that data set. If another month is chosen the results could vary significantly. An example of this is seen in Chart 1 below.

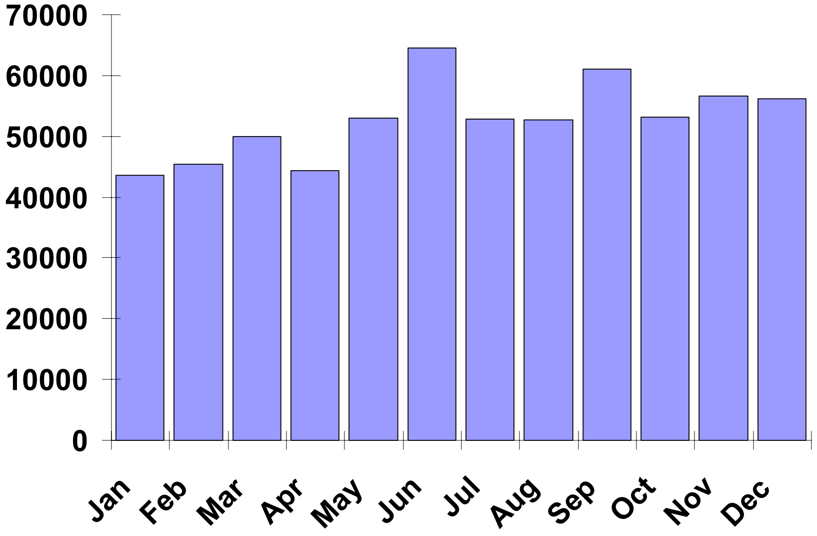


Chart 1 - Import TEUS Per Month

In this example, if the month of January is chosen for the analysis time period, the results will be significantly different than if the month of July is chosen. Here the difference is about 20%, which could drastically change the final systems analysis results.

Choosing the parameters is a very important step in the process. A common approach to choosing the time period is to determine existing and anticipated volume variations and a time period located between 85% and 90% of the highest unit flow. This will result in a solution that is expected to become constrained only 10 to 15% of the time. If the variations seasonally as well as throughout the day are small, it is reasonable to expect that the 100% value may be used.

The decision regarding which time periods to use in this analysis is up to the user, however this decision will have a significant impact on the outcome and careful consideration should be given to these parameters. These values will be the basis for the entire systems analysis and should be selected appropriately.

Step 2 - Model the System

After the parameters have been chosen, the next step is to model the system to be analyzed. In this step, modeling the system is defined as "determining and defining the processes and steps involved with the physical movement of freight though a system". Actual operational analysis of the system comes in a later step.

An important first step in this process is to determine the limits or boundaries of the system to be modeled. The geographic limitations of the study area as well as the level of detail in which freight movement will be modeled must be made at this point in the process.

There are several approaches available to define the limits of the system. The ultimate decision on the limits should be primarily decided based on the goals of the systems analysis users. For example, a shipper using this systems analysis approach may define the system as beginning at the manufacturer or warehouse and ending at the store, warehouse, or final destination of the goods being shipped. The goal for the shipper would be a systems analysis for the end-to-end movement of goods. This system inclusive of a large supply chain could also include several transportation modes over a large area.

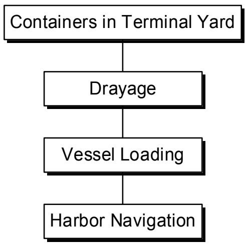
In other cases, the definition of the system may be set by geographic boundaries, borders, or current infrastructure limits. A possible goal in this case could be an efficient system for goods movement based on an area of influence. In this case it is realized that this is only a subset of a larger end to end system, however the model is limited to the area that a municipality, for example, has influence over. While limits such as these will still allow for a limited systems analysis to be completed, it is important to clearly identify that this is one section of a larger system. Often these limitations will restrict the overall benefits of an improvement by limiting the proposed improvement boundaries. Clearly, constraints such as these placed on defining the limits of a system may not provide the highest level of efficiency for goods movement, however they can provide substantial benefits and information on operations.

Once boundaries or limits have been placed to determine the ends of a system, the next step is to determine the individual operational elements of the system. The operational elements can include the following:

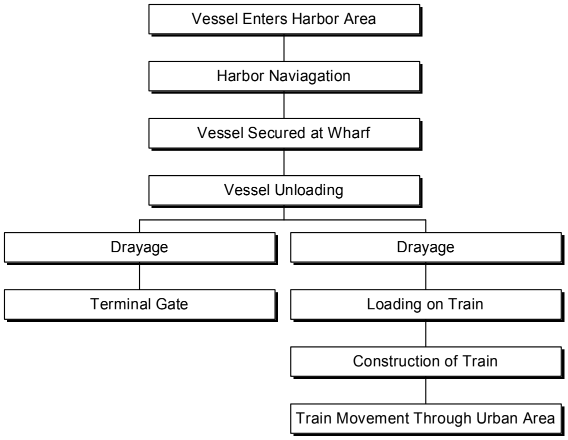
- Warehouse loading of goods
- Trucking and roadway movement
- Border crossing points
- Railroad car loading, unloading, movement
- Ship and harbor operations

In port environments alone, several potential operational elements exist. Beyond the individual elements, separate ports may also have different associations between the elements. As an example of this, Diagram 1 shows different elements and associations of three ports in the APEC region.

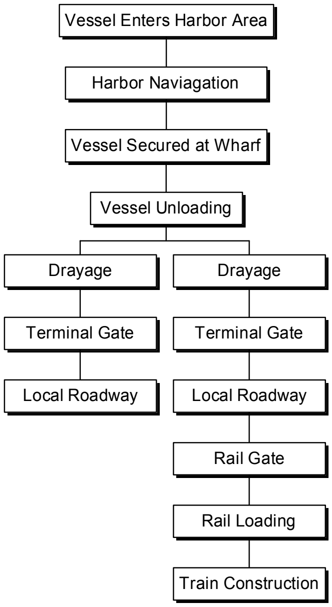
Port of Kaohsiung Container Movement



Port of Tacoma Container Movement



Port of Seattle Container Movement



The ports of Kaohsiung, Seattle, and Tacoma above are all container ports on the Pacific Ocean, however they each have different operational elements and connections.

For the Port of Kaohsiung, a significant movement of containers is between the vessel, terminal, and truck. In fact, a majority of containers that move from vessel to terminal, are consolidated with other containers, and then are loaded onto another vessel. This is significantly different from the Port of Seattle where imported containers move from vessel to terminal, and then by truck or truck and rail to the final destination. Yet another set of operational movements is used at the Port of Tacoma where after the terminal, containers can move directly onto rail.

As this example illustrates, the specific elements of a transportation system may vary. It is important to fully understand these interactions within the study area and develop a model similar to Diagram 1 before proceeding to the operational analysis step, next.

Step 3 – Operational Analysis

This step of the process simply conducts an operational analysis of the individual elements and transfer points identified in Step 2, above.

In conducting an operational analysis, individual elements are modeled using conventions that are appropriate to each element. Since each geographic area has unique characteristics and individual analytical groups prefer the use of certain models to others, the choice of which model to use for individual elements is left up to the user.

The following section discusses some options for modeling these elements. It is important to note that these are only examples of some common approaches and any model may be used in this phase.

It is important, however, in the selection of a model that it has metrics or measurements that are consistent from step to step. Since the output from each individual model is used as an input for others, there must either be consistency in the calculations or the ability convert an output from one step to an appropriate input for another. Following the example above, using the Port of Kaohsiung, the output from the vessel modeling step must be compatible as an input to the port terminal modeling step, and then the port terminal modeling output must be compatible as an input to the yard operations step, and so on. In another example, a model, which has an output of only 'daily TEU's', will not work well with a model that requires hourly TEU volume as an input.

The choice of which model to employ will be determined by the models currently used or available, the level of process detail desired, and the quality of data available. The level of detail desired as mentioned in step 1 will also be a factor in which model is used. If the final systems analysis outcome only requires general operational parameters for each mode, then the effort required to conduct detailed modeling and the high level of data needed to support that model may not be justified.

Using the Ports of Kaohsiung, Tacoma, and Seattle again as an example, the following elements would need to be modeled:

Element	Modeling Element
Ocean Transit	Travel Time
Port and Harbor Operations	Dwell Time and Transit Time
Unloading/Loading	Cranes/Equipment Operations-Capacity
Yard Movement	Equipment Capacity and Distance
Terminal Gates	Gate Capacity
Truck Movement - Roadway	Highway Capacity
Train Movement	Yard Operations-Regional Capacity

This report will discuss the operational characteristics and some common analytical approaches for each of these elements. Note that individual Ports and facilities with similar characteristics may use different measures and modeling approaches than the ones presented.

Ocean Transit

The ocean transit time can be one of the easier calculations to perform. The transit time is simply the standard or mean travel time for a typical container ship to traverse between the offshore areas of the origin port and the destination port. While the transit times on a particular route will vary depending on the vessel in service, these times can be easily determined. In addition to the transit time for a vessel, the carrying capacity is also important. The total TEU's that a vessel can accommodate factored with the transit time will yield a capacity for that phase of operations.

A simple example would show that from origin port to destination port not including harbor operations, the total travel time is 230 hours. For this route a vessel has a 2,200 TEU carrying capacity. The measurement would then be 2,200 TEU's in 230 hours.

This level of calculation will often meet the needs of a systems analysis. However, if necessary, a detailed analysis of vessel operating characteristics, fuel consumption and detailed operational parameters may be made in this phase. The decision to conduct this detailed analysis will depend upon user requirements. Since these can be time consuming efforts, are highly dependent on the shipping line decisions, and primarily impact the shipping line economics as opposed to the system performance, the details of these analyses are not included in this report. If this information is required, it could serve as an input to the overall ocean transit time calculations.

Port and Harbor Operations

Port and harbor operations are frequently modeled by empirical data. The amount of time a ship sits idle in a harbor waiting for an available berth added to the amount of time to moor and secure the vessel is the most common measurement. The factors limiting these movements or capacity restrictions could then be vessel traffic in the port area, number and size of berths, individual characteristics of the berths, tug equipment availability, and complexity of maneuvering required for berthing (such as use of turning basins, etc). While some of the capacity restrictions for this element are physical limitations, much of it is based on operational issues.

For operational constraints, vessel tracking and harbor management technologies for high volume port areas could significantly reduce the total time for this phase. Systems such as those in place at Keelung Harbor in Taiwan are good examples of technology applications intended to improve operations. While reductions associated with implementation of advanced harbor management tools can be significant, benchmarking is important to determine benefits as they relate to operations and timesavings. Approximations based on benchmarks, detailed review of procedures, and experience in other ports can be used to determine savings by implementing these tools or approaches.

The likely final measurements for this element would be total time to complete the operations and the capacity to accommodate additional vessels of defined type and capacity.

Loading and Unloading

The loading and unloading of containers can be modeled based the capacity and availability of equipment used for this task, along with details of the physical environment they work in. The number of cranes available and the operating characteristics of them are major factors in determining the amount of time it takes to load or unload a ship. For example, if two cranes capable of 20 lifts per hour are available, it will take approximately 31 hours to unload a 2,200 TEU vessel as shown below.

2200TEU's on ship
20Lifts per hour per crane
2Cranes available
1.75TEU container equivalent*

31.4Hours to unload

* average container length assumed to be 35 feet.

While the crane capacities are important factors in the loading and unloading elements, there are several other issues to consider. In the above example, the number of lifts per hour can only be achieved if trucks or trains are available to accept the containers from the crane. If they are unable to accept 20 containers per hour per crane, the capacity of this movement would then be constrained by the number of TEUs the vehicles are able to receive.

Another important factor is the design of the vessel to be unloaded and the corresponding design of the terminal. The number and location of holds in the ship and compatibility with the available cranes will limit the transfer time. Again, using the above example, the 31.4 hours needed to unload a vessel assumes that all the cranes are able to readily access the containers on the ship and proximity of the hold access areas to each other are far enough apart to allow the two cranes to operated independently and not synchronized. The terminal and ship designs may facilitate or limit the loading and unloading process.

Some modern terminals are designed so that cranes can access both sides of a vessel, which can potentially double the cargo transfer time and related capacity of a traditional ‘single side’ operation.

Advanced computer models are often used to simulate the loading and unloading of vessels. These tools provide more detail than the method presented above and can be used in this phase of the operational analysis. The availability of the model, user experience, and desired outcomes for this phase of the operational analysis may dictate whether advanced techniques such as this are used.

Yard Movements

Models of yard movements may vary widely. The location of the yard, or port area where containers are stored, the equipment available to service that yard, and destination of containers may all be key factors in the modeling and operations of this phase. In addition to these parameters, the inventory management and storage of containers is also important.

Models of complexity varying from simple spreadsheets tracking container information to complex computer models of cataloging, transferring and logistics optimization are used for the management of containers in the yard.

Whether containers are inbound, outbound or already available in the yard, the details of access to the yard, along with container handling equipment limitations are all factors that may yard impact operations. The complexity in which containers are stacked and sorted, equipment type, and distances between storage areas and the loading dock are also all potential constraints in this element. Complex models and inventory management practices are often in place to manage container location and placement. Typically the work associated with yard container space, container location, and stacking is determined prior to a vessel loading or unloading. As a result, it is assumed that this element has been addressed and the operational analysis is simple a factor of equipment capacities and the distances associated with moving containers.

The yard movements can be modeled through the computer simulation programs or simply based on time-space calculations using distances, travel time, yard design parameters, and loading and unloading equipment capacities. The decision of which approach to use will again depend on the users specific needs.

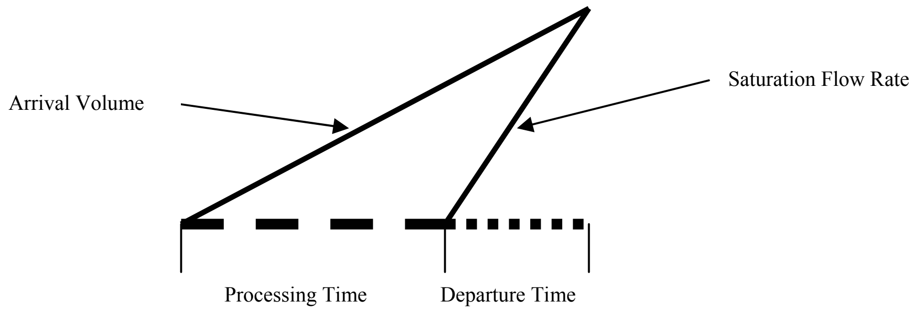
Terminal Gates

Terminal gate operations are essentially the interactions between trucks carrying containers and the processing of these vehicles at the entrance or exit to the port facility. The amount of time it takes to process these vehicles determines the capacity of a terminal gate.

Terminal gates also may be modeled based on empirical volume and capacity values, queuing formulas, or as part of a computer simulation model for the port. Modeling based on empirical data is simply based on an understanding of the total number of vehicles per hour per gate that can be accommodated at a facility. Once this value is known, the total throughput for a set of gates can be determined and compared to actual or projected demand.

Since gate operations are often a constraint in container movement, more detailed operational information of the terminal gates is often needed. If the truck demand exceeds the capacity of the gates, significant vehicle queuing can result which may impede operations of the port or external roadway functions. To provide this information, queuing models and formulas are often used.

Queuing models such as the one shown below can be used to calculate vehicle queue backups as well as determining the amount of time vehicles have to wait to get through a gate.



In this diagram, the slope of the left side is the arrival rate in vehicles per hour at the gate. The slope of the right side is the saturated flow rate in vehicles per hour. The height of the triangle is the maximum back-up queue in vehicles. This diagram can also be represented by the following formula.

$$Q = \frac{v}{3600} \times R \times \left[1 + \frac{1}{s/v - 1} \right] \times \frac{L}{n \times Fu}$$

Where:

Q= Queue length in feet
R = Red time (s)
s = Saturation Flow Rate (trucks per hour)
v = Arrival Rate (trucks per hour)
L = Length of vehicles including space between (ft)
n = Number of Lanes (gates)
Fu = Lane Utilization Factor

In many terminal gate operations, the lane utilization factor would be 1.0. This would represent the trucks being equally dispersed among all available lanes. Computer programs are available and often used to conduct the gate terminal queuing analysis. The computer modeling, queuing diagram and formula approaches are very useful in determining the queue lengths and can predict 50, 85, and 90th percentile queues which are very useful in operational analysis.

It is possible that the terminal gate operations can be modeled as part of the terminal operations modeling program as well. The computer simulation models used in terminal operations often model the gates as well as the internal operations.

Whichever model is used, the modeling of gate operations is an important element in conducting a systems analysis. In many cases, the terminal gate separates the internal port operations that are dedicated to freight movement from the external operations that often include roadways that are used for passenger as well as freight movement.

Roadway

There are several approaches to modeling roadway operations. The analysis of roadway operations has been conducted for several years and several methodologies are currently available. As a result, detailed calculations and approaches are available today.

All of the models presented above are unique from the roadway operations. In the other elements of the system the operations and movement of containers were under the control of the shipping line, the terminal operator, port authority or similar group. Roadway operations however are often on public roads and the movement (trucking) must interact with other transportation modes such as cars and transit vehicles. Not only must trucks interact with these other modes, the other modes often have significant impacts on truck operations. For example, roadway congestion due to passenger vehicles or increases in passenger vehicle volumes will limit the ability of trucks to move throughout the roadway network.

As a result of these interactions and constraints, the modeling of roadway operations often warrants a detailed modeling effort. While the decision of which approach to use is up to the user, the following methods are commonly employed.

The operational analysis of roadway facilities is typically divided into two types: free flow facilities and facilities with interrupted flow. Examples of free flow would include freeways, arterials or two lane roads without intersections. Interrupted flow types would typically include signalized or unsignalized intersections or other area where free flow cannot exist, including toll facilities.

Analysis of free flow facilities is commonly based on speed-flow curves. These curves have been developed over several years using empirical data and actual observations. The curves simply show the change in speed on a roadway based on changes in volumes.

Chart 2 is a series of speed vs. flow curves demonstrating how freeway speeds change as volumes increase. The chart is based on empirical data calculations for a 120-kilometer per hour design speed facility. The X-Axis is volume to capacity ratio of the roadway facility. The Y-Axis is the freeway speed in kilometers per hour.

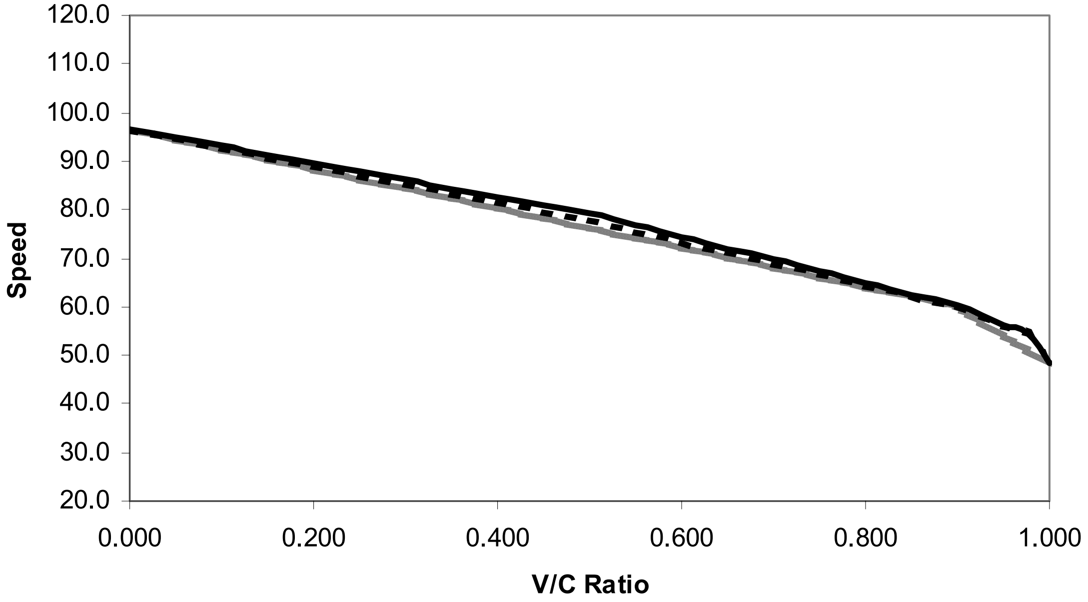


Chart 2 Sample Speed – Flow Curve

As the volumes increase and they approach the roadway capacity (V/C=1.000), the speeds decrease. This is a common and well-documented phenomena for free flow facilities.

Based on empirical data similar to that shown in Chart 2, formulas have been developed to model speed – flow relationships as well. The following formula is from the 2000 Highway Capacity Manual for freeway sections. The Highway Capacity Manual is a common tool used for operational analysis.

$$R = R_0 + 0.25 \bullet T\left[(x-1) + \sqrt{(x-1)^2 + \frac{16J \bullet L^2 \bullet x}{T^2}}\right]$$

where:

R = segment traversal time (hr)
R_0 = segment traversal time at free-flow speed (hr)
T = expected duration of the demand, typically one hour (hr)
x = segment demand/capacity ratio (v/c)
L = segment length (mi)
J = calibration parameter

Free-flow Speed (mph)	Speed (mph) at Capacity	J"
55	50	1.29E-06
60	51	3.38E-06
65	52	5.78E-06
70	53	8.20E-06
75	54	1.05E-05

Using calculations such as these provide the user with a good tool for modeling the operations of a freeway segment. It allows for the calculation of operations based on the total number of vehicles on a facility including both passenger vehicles and trucks.

In addition to these basic calculations, operational analysis of free flow facilities should take into account such issues as grades and lane widths as they can significantly affect truck operations.

Other approaches are also available to model freeway operations, but they are largely based on the speed-flow approach presented above. Many software packages have been developed to automate these calculations, as well.

The operation of interrupted flow facilities such as signalized or unsignalized intersections, roundabouts, or toll facilities on a roadway are largely based on the type of traffic control needed at each location.

For basic intersections without active traffic control, where one direction of traffic must stop while the other direction of traffic does not, the operations are based on gaps in traffic. The spacing between the vehicles that do not have to stop, and their speed, determine the capacity or ability of the other vehicles to traverse the intersection. Both the size and the distribution of the gaps will have an affect on the intersection operations. Local and regional empirical data is commonly available to determine roadway vehicle spacing and volumes as well the minimum acceptable critical gap values. With this information, delay calculations as well as vehicle queuing estimates can be made.

For more complex intersections including those with signalized control, the analysis is much more involved. Operational parameters such as the phasing of movements and timing must be determined and calculated. Modeling of these facilities can be fairly complicated and computer software is often used in this analysis. Several methodologies and computer programs exist and are used to determine these values.

As part of the operational analysis for all interrupted flow facilities, it is important to look at geometric issues also. Often, the turning radii at intersections do not meet the needs of large trucks and impede their operations.

Regardless of the type of approach used for analyzing roadway operations, it must be compatible with the other model segments in terms of data type and output. Using the example presented in Step 2, the roadway operations model must be consistent with both the gate operations and rail operations models.

Train Movement - Loading

The operations of train movements and loading or unloading are modeled using several approaches. Two primary approaches are used in transferring containers from vessel to train. One transfers the containers from the vessel to railcars on the wharf. The second transfers containers from vessel to truck and then from truck to railcars. The transfer of containers from vessel to train can be modeled with the following approach.

The actual loading of containers in an unconstrained area such as on-wharf rail areas has two major elements. First the operational capacity of the equipment available and distance the containers need to be moved is modeled. Empirical data on the operational characteristics of the lifting equipment is easily determined and can be calculated. Once this is known, the distance required to move the container is factored in to determine a total movement time and capacity for the loading process.

The second element of train loading involves the movement or repositioning of the rail cars. Commonly, containers are loaded onto rail cars and the cars are joined to make small train sections and ultimately these sections are combined to make a final long train. This process of building a train requires several movements of the cars in each stage.

The organization of containers on the cars and the actual linking of the rail cars are highly variable and dependent upon the final destination of the containers. Because this is not predictable, an appropriate approach would model this element based on the average number of rail car moves needed to complete a final train.

Modeling would also include the master schedule for that train as well. Often trains operate on a daily basis. If this is the case, segments of rail cars may be built and waiting idle until the scheduled departure time. This dwell time should be included in the operational analysis.

Transferring containers from vessel to truck to rail car uses several of the conventions presented earlier. In this process, the terminal gate operations, roadway operations, and often rail yard gate operations are modeled before the actual loading onto rail cars.

As trucks enter the rail yard, they are often processed through gates similar to those at the terminal. Operationally, these gates work the same, and modeling of them can follow the same approach as terminal gates. As with the terminal gates, it is recommended that modeling such as queue analysis be used because of the potential for trucks queuing from the rail yard gates back onto the roadway system. Once inside the rail yard, the actual transfer of containers from truck to rail is modeled based on the equipment loading characteristics, and the rail car linking approach presented above.

Once these elements have been modeled it is important to also model train operations after the final train has been assembled. The travel time and speed of a train towards its destination is used as the measurement for this. These operations are typically controlled by the physical design of the rail line and the number of at-grade vehicle crossings on the line.

Physical design limitations such as grades and substandard curves can limit speeds and overall travel time for a train. Additionally, it is common that train speeds are lowered if a high number of vehicle crossings are present. Grade separation of these crossings or physical control through gates can mitigate these and allow for higher speeds. All of these limitations, however, should be included in the mainline train operations and travel time calculations.

The above is one approach to modeling the loading of trains and their operations. Often advanced large-scale computer models are used for this task. If this approach is used and the operational data is available, it can be used also.

Once all of the individual elements of the transportation system are modeled, the next step is to link them and conduct a systems analysis.

Step 4 - Conduct Systems Analysis

Once the individual elements are modeled, they are linked through an input-output process. Following the model developed in step 2 of this process, each of the individual elements are linked and system operations are measured.

For existing conditions, the individual elements are modeled separately as presented in step 3. For modeling of different scenarios, these models need to be linked. Both the existing conditions and the scenario analyses will have two types of result.

The first result will be the operational parameters for each individual element. The second result will be the overall system performance. This information is useful in determining where delays exist in the overall system and also provide information on the location of individual bottlenecks or constraints. This measure gives the user information on how the entire system is operating and can be used as a benchmark for comparing different scenarios.

For existing conditions, the systems analysis simply shows the operations of each individual element and a cumulative measurement of the system. There is no need to specifically link inputs and outputs in the existing conditions scenario. This scenario is a reflection of present operations, and therefor, volume linkages between the models which already exist. The volume of containers passing through the system already reflects any bottlenecks or constraints that exist and therefor modeling of the linkages is not necessary.

An example of an existing conditions systems analysis is shown below. In this example, the travel time is used as the system performance measure.

Element	**Time (hrs)**	**Containers* per hour**	**Time per Container***	**Cumulative Time**
Ocean to Harbor	120			120.0000
Harbor to Dock	6.4			126.4000
Vessel Pick to Crane Drop		40	1.5 min	126.4250
Transit to Terminal Gate			3.2 min	126.4783
Terminal Gate		40	1.5 min	126.5033
Roadway to Warehouse			82.8 min	127.8833

* assumes 35 foot average container size

This example shows the transit time for each unit as well as the cumulative time for the entire system. Note that the ocean and harbor times have a significant percentage of the total time. These vessel-related elements however are often difficult and expensive to change. Ship operations and performance for example are difficult elements to change and changes are often impractical to implement. As a result, alternate scenario analyses often look to other elements for improvements. The alternate scenario systems analysis, such as the one below, often look at improvements on the landside area because of ease of implementation and lower capital costs.

In the scenario analyses, the individual elements must be linked to each other. Outputs (volumes) from each element are used as inputs to the next element identified in the system. It is important that these linkages are made to determine capacities, constraints and overall system performance.

In addition to linking the elements, the actual volumes are important variables in the systems analysis and operations. Changes in transit time or delay should also account for volume impacts as well. The following example illustrates this.

Element	**Time (hrs)**	**Containers* per hour**	**Time per Container***	**Cumulative Time**
Ocean to Harbor	120			120.0000
Harbor to Dock	6.4			126.4000
Vessel Pick to Crane Drop		45	1.33 min	126.4222
Transit to Terminal Gate			3.2 min	126.4756
Terminal Gate Including Time in Queue		40	1.71 min	126.5041
Roadway to Warehouse			82.8 min	127.8841

* assumes 35 foot average container size

In this scenario the cranes increased their number of container lifts per hour from 40 to 45. The result was a savings of 0.1667 minutes per container in this phase. This appears to be a direct benefit on the system. However, since the gate capacity remained constant at 40 containers per hour these additional volumes cannot be moved outside the terminal area. The result is trucks queued at the gate and a net loss in the overall system performance is realized. The net loss is due to the fact that the queued trucks have a longer average delay from the queue than if they were processed at a rate of 40 per hour and no queue.

Although gains were realized in the crane operations, the additional volumes queuing up at the terminal gate eliminated these benefits. This clearly illustrates the importance of linking individual elements when conducting scenario analyses.

As mentioned before, volumes should also be factored into the performance of the system. When volumes are factored into this scenario, other results can be seen.

If it is assumed that the crane unloading process was operating for 8 hours, the existing conditions would have unloaded 320 containers. Under the alternate scenario, a total of 360 containers are unloaded during that same time period. While the gate constraints limit these additional 40 containers from leaving the terminal during the during the 8 hour period they were unloaded sooner. There may be benefits to be realized by increasing this unloading time even if it negatively impacted the system performance. The benefits of allowing the vessel to be unloaded and depart sooner and creating more berth space may be more valuable than the time lost in the system operations. Without including volumes, the systems analysis would not have calculated this result.

The examples presented above are simplified for demonstration purposes. In conducting a systems analysis, time, volumes, and other variables may be used in the system performance measurement. It is important to clearly identify these values early in Step 3 to insure that the operational analysis methods selected are able to provide the needed measurement statistics.

Once this systems analysis is completed, values are placed on the performance measures used.

Step 5 - Value Performance Measures

Once the systems analysis has been conducted, a value of the measurement unit is chosen. This value is the assignment of a monetary worth to the measurement unit used in the operational and systems analyses. When determining the values to assign to performance measures it is important to take into account how it will be used. Since the ultimate result of this systems analysis is to evaluate the transportation system operations and changes that may result from potential improvements to it, the value assigned should reflect that.

This decision must be made in concert with the operational analysis decision of which measurement units will be used. For example, if the measurement unit used in the operations analysis is total number of containers moved through the system, the performance value would be the monetary value per container transiting the system. If the operational analysis used delay or travel time, the performance measure would be monetary value of time associated with containers in the system.

Once values have been applied, it is possible to evaluate the fiscal function of the system and individual elements. This is very useful in assessing congestion points within the system. If a congestion point exists and a solution is proposed to address it, the fiscal performance can be compared against the fiscal cost of implementing the solution. This provides practical information on benefit-cost ratios for proposed improvements.

The ability to evaluate the fiscal function of the system also enables the user to compare different investment alternatives. This approach allows the user to look at issues such as staging of improvements over time as well. The anticipated most common use however would be conducting benefit-cost scenario calculations.

There are several approaches to benefit-cost calculations. Factors such as monetary depreciation rates and project life cycles should be taken into account. The following approach is recommended.

Benefit-Cost Determination

A benefit-cost ratio calculation is used to compare the cost of a particular improvement against the benefit received through implementation. The costs of improvements are most often incurred at the beginning or implementation phase. The benefits however are realized over time, often over the entire life of the project. As a result, an equitable benefit-cost comparison should convert the all benefits, both present and future to a present day value.

The following information is used to determine benefits:

- project life cycle
- annual discount rate
- benefits realized in existing year
- benefits realized in future year

The project life cycle is used to determine the number of years the benefits will be in place. This can be the design year or design life of the improvements. For physical infrastructure this is commonly 20 to 30 years. For operational improvements, the time period may be much smaller. Since external influences often affect operations, the projected life cycle for operational improvements may be as low as 2-3 years.

The discount rate is the depreciation value assigned to money over time. This is included in considering that inflation, or the depreciation of money over time, will result in future benefits which will be worth less than present day values.

Benefits realized in existing and future years are determined through the steps presented above. Similar to the example used demonstrating how changes in crane operations affect the system performance, future year analyses would show how volume increases impact the system operations. The future year analyses are conducted the same as the existing year, but include growth rates or growth factors.

Once these values have been determined, the financial benefits of the system can be calculated. To determine these benefits, four scenarios of operational analysis need to be conducted. These are:

- Year 1 system analysis with no improvements
- Year 1 system analysis with proposed improvements
- Future year system analysis with no improvements
- Future year system analysis with proposed improvements.

These four scenarios allow for the comparison of operations with and without the improvements. The difference between these is the benefit of the improvement. Year 1 and future years are used so benefits can be calculated over the entire life of the project. Year 1 is defined as the time at which improvements will be completed and operating. For an infrastructure project, this would be the year of opening. For operational improvements, this would be the year that full improvements are implemented and in use.

The future year is equal to Year 1 plus the project life cycle in years.

In this benefit-cost approach, the benefits are determined based on the difference between the ‘with and without improvement’ scenarios for year 1 and future year using the following methodology and formula.

$$PVF = \frac{e^{\left[\frac{LN\left(\frac{FB}{YB}\right)}{n} - i \times n\right]} - 1}{\left[\frac{LN\left(\frac{FB}{YB}\right)}{n}\right] - i}$$

where:

PVF=present value factor
FB=future year benefits
YB=year 1 benefits
n=number of years
i=discount rate

Since the costs of an improvement are incurred in the present, the benefits must be converted to present time values as well. The present value factor calculation is used to convert future benefits to present day values. Once the present value factor is calculated, it is multiplied by the year 1 benefits to determine the present value of all future benefits.

The present value of future benefits can then be compared against cost of implementing the proposed improvement. This will provide the user with a benefit to cost ratio. This ratio is useful in determining the merits of individual projects. The ratio can be used to evaluate yields of the system as well as of the individual elements. It is possible that an individual element in the system may have a poor benefit to cost ratio, while in the system as a whole it creates a high ratio.

It is also useful in comparing different improvement strategies or scenarios to determine which has the best benefits compared to costs.

Step 6 – Model Scenarios

The final step in the systems analysis process is to model alternative scenarios. These can include changes in growth rates or projections, changes in operations, infrastructure, hours of operation, or any other functional change to the system.

In this phase any scenario can be modeled and the impacts of proposed changes can be fully seen, both on the individual level as well as on the entire system. The modeling of scenarios is simply an extension of the alternate scenario analysis presented in Step 4. In this step, however, the scenario analysis includes monetary benefits as well as benefit to cost ratios.

A matrix such as the example below can be created to evaluate alternatives.

Scenario	Total Benefits	Costs	Benefit-Cost Ratio
New Cranes and One New Gate			
Ocean to Harbor	$0	$0	
Harbor to Dock	$0	$0	
Vessel Pick to Crane Drop	$978,000	$871,000	1.12
Transit to Terminal Gate	$0	$0	
Terminal Gate Including Time in Queue	-$543,000	$150,000	-3.62
Roadway to Warehouse	$0		
System	$435,000	$1,021,000	0.43
New Cranes and Three New Gates			
Ocean to Harbor	$0	$0	
Harbor to Dock	$0	$0	
Vessel Pick to Crane Drop	$978,000	$871,000	1.12
Transit to Terminal Gate	$0	$0	
Terminal Gate Including Time in Queue	$696,000	$450,000	1.55
Roadway to Warehouse	$0		
System	$1,674,000	$1,321,000	1.27

In this matrix, two scenarios are presented. The first scenario has the upgrade of three gantry cranes and the addition of one new processing lane at the terminal gates. The second scenario has the crane upgrades as well as three new processing lanes at the terminal gates.

In the first scenario, there are significant benefits realized as containers are moved through the crane element. The upgraded cranes have a higher capacity and are able to process more volume and at a higher rate per unit of time. The cost of this improvement is $871,000, and the benefits at that point are $978,000. The result is a benefit to cost ratio of 1.12 for this element. This is a good ratio.

These increased volumes however have a negative effect on the terminal gate operations. This scenario has the addition of one terminal gate. This addition, however, is not adequate to handle all the additional volumes and higher rate of container volumes from the cranes. The result is significant queuing and a negative benefit of $543,000. With the cost of terminal gate at $150,000, the benefit to cost ratio for this element is –3.62.

The system performance reflects both of these values. The benefits realized by the crane operations are significantly reduced by the terminal gates and the overall benefit to cost ratio is 0.43. Typically ratios less than 1.0 are not desirable.

The second scenario has the same crane improvement, but instead of one new terminal gate lane, it has three. The individual benefits for the crane element remain the same as the previous scenario. The terminal gate benefits and costs are both higher.

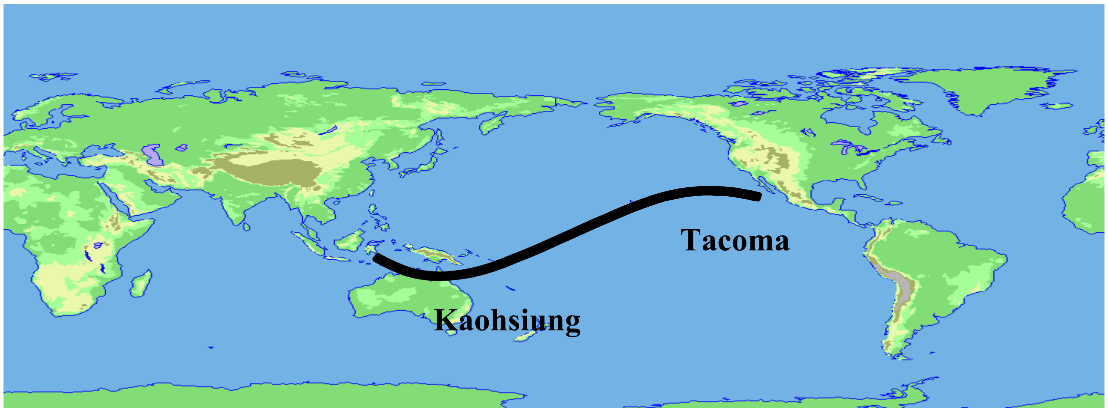
The addition of three terminal gates costs $450,000. These gates are able to process the increased volumes and rates from the crane operations. The result is a significant benefit to this element of the system. The benefit to cost ratio for this element is 1.55. Overall, the system benefit to cost ratio is 1.27.

The second scenario had higher total costs than the first. The total cost increased 0.97% from $1,021,000 to $1,031,000. The benefits of the second scenario increased over 384% from $435,000 to $1,674,000. Clearly, the additional costs appear to be justified. Additionally, it is also evident that the first scenario would be a poor investment due to the low benefit to cost ratio 0.43.

This example illustrates the importance of conducting a systems analysis and evaluating both the individual elements and the entire system. The next section will demonstrate application of this methodology.

SAMPLE TSHIPS APPLICATION

This section will step through the process of conducting a systems analysis for container movement between the Port of Kaohsiung in Chinese Taipei and the Port of Tacoma in the United States. The systems analysis will also include inland operations in the US as well as container movement across the United States and Canada border.



Step 1 Choose Parameters

For this study, 1999 was chosen as the base year for analysis. Volumes, and data from the month of May were collected. This month represents an average level of volume for the ports and will provide results based on these conditions.

The actual analysis periods were based on single hour time periods. All 24 hours of a day were analyzed as appropriate for each element. The use of single hours allowed the modeling to account for variations in volumes and identification of capacity and operational constraints throughout each day. This also allowed for a high level of confidence in the results as the analysis reflects actual operations as opposed to general capacity values.

The daily operational parameters were converted to a yearly value based on the anticipated numbers of day per year the system would be operating. For all elements of this study, 260 operating days per year were used. This was a conservative value that assumed that operations were generally functioning five days per week. The value of 260 days was multiplied by the daily totals to calculated annual operations.

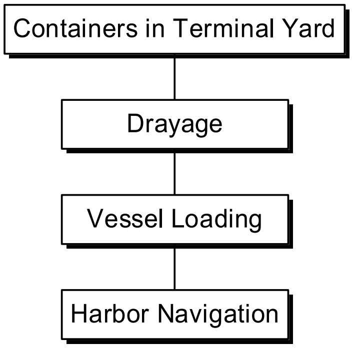
All measurements of systems performance will be in container hour of travel time. This will be evaluated only for the time that the individual containers are moved in the system. As a result, this modeling will document the movements of containers through all elements of the system, however the harbor operations and ocean transit times will not be included in the operational analysis. These can be included in a systems analysis, however this analysis assumed them to be constant and did not model their travel time.

Step 2 Model the System

A review of the system was conducted through direct work with the ports of Kaohsiung and Tacoma, shipping lines, railroads, and ground transportation agencies. The following models were developed based on the flow of container volumes through the system. One defined endpoint of the system is the Port of Kaohsiung in Chinese Taipei. Containers from this port are shipped to the Port of Tacoma in the United States. From the United States, the containers are shipped to final destinations domestically and to destinations in Canada.

The Port of Kaohsiung container movement is represented below.

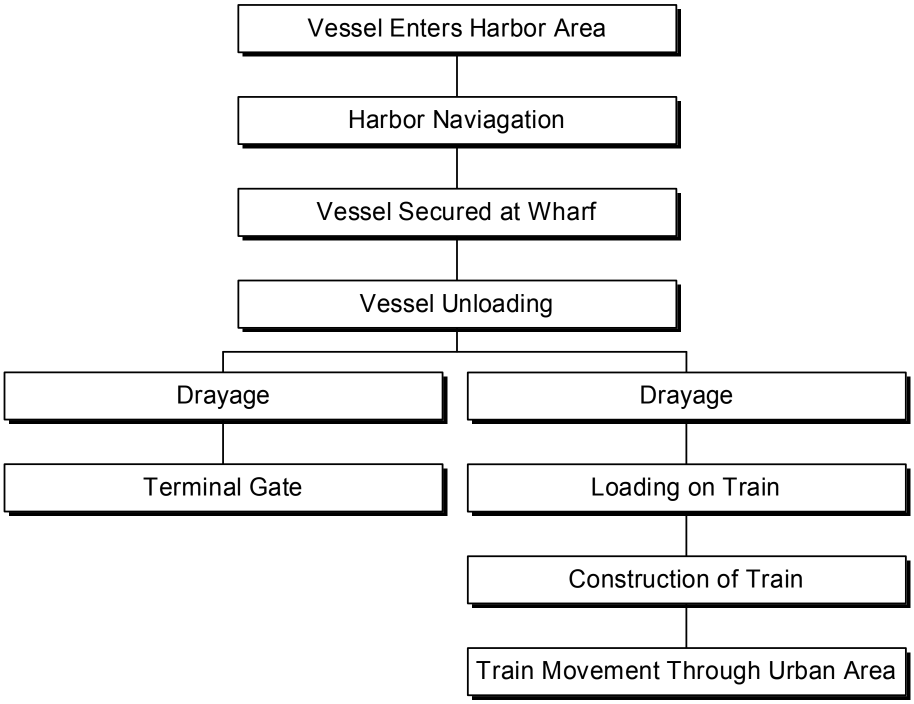
Port of Kaohsiung Container Movement



Within the Kaohsiung port area, containers are located on the terminal. They are loaded onto trucks and drayed to the wharf. From here, cranes pick the containers from the truck and load the vessel. The final step in this process is the movement of the loaded vessel out of the harbor and across the Pacific Ocean to the United States.

As the vessel approaches the United States, it enters the inland waters of the State of Washington. The container movement approaching and internal to the Port of Tacoma area is shown below:

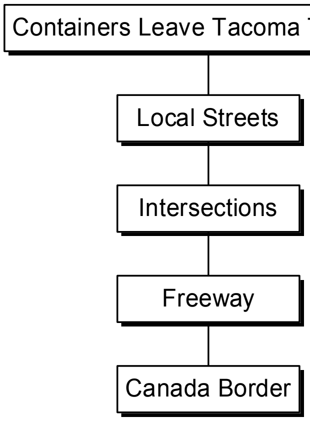
Port of Tacoma Container Movement



The vessel traverses the waters and is secured at the Port of Tacoma wharf. From here, the vessel is unloaded and containers are either moved by truck or rail through the port area. The containers moved solely by truck leave the port area through the terminal gates. Containers moving by rail are drayed over to the rail area. Once loaded onto the rail cars, the trains are fully assembled and travel through the urban area. For these containers, the movement outside of the urban area is the endpoint of analysis for this system. The rail transportation system beyond this area directly connects to final destinations in the eastern United States.

The containers moved by truck have local destinations as well as destinations in Canada. The movement of containers through this final part of the system is shown below.

State of Washington Container Movement



As the trucks and containers leave the port, they travel through the local street system and onto the freeway network. From the freeway network, containers destine for Canada stay on the system up to the border.

For the remainder of this systems analysis, the model of traffic flows presented above will direct what will be analyzed.

Step 3 – Operational Analysis

An operational analysis is conducted on all the elements identified in Step 2.

This begins in the Port of Kaohsiung area. For this analysis, the Yang Ming Line container terminal at the Port of Kaohsiung is used. Yang Ming Line provided the operating information and details presented below. For all the analysis elements, TEU's have been converted into actual containers. A factor of 1.75 TEU per actual container is used which results in an average container length of 35 feet. This is consistent with averages between Asia and North America.

The first element is the movement of the containers from the terminal yard to the crane for loading. All of the containers are located within the Yang Ming Line area so there are no terminal gate issues in this movement. The distance is 1.5 kilometers between the yard and crane. An average speed for this element including initial pickup of the container through lifting of the container by the vessel-loading crane is 20 kilometers per hour. A total of 1027 actual containers will be loaded onto the vessel. This equates to 77.07 container hours of travel time for this element.

Drayage		
	Distance (K one way)	1.5
	Speed (average kph)	20
	Travel time per actual container (hrs)	0.075
	Actual containers	1027
	Container hours	77.03

The next element is the lifting of the containers from the drayage trucks and placing them on the vessel. Based on Yang Ming Line facilities and operations, three cranes are used to load the vessel. Each of these operates at 28 lifts per hour. The 28 lifts per hour equates to 0.0357 hours of travel time for each container to be loaded. Using the same number of containers as above, a total of 36.69 containers hours of travel take place in this element. The total loading time assuming constant operation will be 12.23 hours.

Cranes		
	Lifts per hour per crane	28
	Hours per lift	0.0357
	Container hours	36.69

These two elements provide the beginning metrics for evaluation of the system performance. The next element is the harbor operations.

As mentioned in the earlier section of the report, operational analysis will not be conducted for the harbor and ocean transit elements of this system. For the systems analysis results, the operational parameters for these values are assumed to be constant.

The next element in the system to be modeled is the unloading procedure at the Port of Tacoma. Three gantry cranes will unload the vessel at a rate of 25 lifts per hour per crane. This results in 41.08 container hours to complete this element of the system.

Cranes		
	Lifts per hour per crane	25
	Hours per lift	0.0400
	Container hours	41.08

Once the containers have been unloaded from the vessel, they take one of two routes. The first route is that they are placed on truck and leave the terminal. The second route is to be loaded onto double stack rail cars. 60% of the containers are placed on truck and leave the terminal.

For containers moving by truck directly to the gate, the drayage distance is .32 miles. An average speed for this movement is 18 miles per hour.

Drayage		
	Distance (miles one way)	0.32
	Speed (average mph)	18
	Travel time per actual container (hrs)	0.018
	Actual containers	616
	Container hours	10.95

Based on these values, this element of the system involves 18.26 container hours.

These trucks and containers must exit through the port terminal gates. For this movement, two gates operate at a rate of 23 trucks processes per hour each. The gate operations are modeled using the Dqueue gate operations computer program. This program uses queuing theory formulas to evaluate how the gates will operate. The results of this program show an average delay per truck is 0.044 hours.

Gate Operations		
	Average delay per truck (hrs)	0.044
	Actual trucks	616
	Container hours	27.15

The gate operations element results in 27.15 container hours.

As the vehicles leave the terminal gate, they travel over a roadway for a distance of 2.12 miles. This segment of road moves 15,000 vehicles per day. Of this total number, 70% are trucks. Analysis of this roadway segment using speed flow curves and analysis of each hour of operation results in a total of 363 vehicle hours of travel time. The table below summarized the results of the travel time calculation by hour of the day.

Hour	Vehicle Hours of Delay
1	4.27
2	2.73
3	2.44
4	1.75
5	2.30
6	6.08
7	12.94
8	19.75
9	18.65
10	18.98
11	19.17
12	20.43
13	21.08
14	21.33
15	23.49
16	28.68
17	30.96
18	29.88
19	22.24
20	15.99
21	12.94
22	11.38
23	8.75
24	7.23
Total	363.44

Near the end of this roadway element there are two traffic intersections. These elements are modeled using modeling techniques developed to calculate the 24-hour operations at signalized intersections. The intersection analysis resulted in 108.35 and 56.83 vehicle hours of delay for each intersection respectively as shown below.

Hour	Vehicle Hours of Delay	
	Intersection 2	Intersection 2
1	0.61	0.3
2	0.55	0.2
3	0.53	0.2
4	0.52	0.2
5	0.57	0.2
6	1.10	0.5
7	4.22	2.1
8	9.82	5.3
9	6.12	3.2
10	4.09	2.0
11	3.27	1.6
12	3.97	2.0
13	4.40	2.2
14	4.86	2.5
15	7.88	4.2
16	10.14	5.5
17	13.91	7.8
18	13.37	7.4
19	9.08	4.9
20	3.85	1.9
21	2.18	1.0
22	1.68	0.8
23	0.93	0.4
24	0.71	0.3
Total	108.35	56.83

The next element in the system is the freeway. The freeway segments were analyzed for the PM peak hour using the Corsim analysis software. This covered only one hour of the analysis period. To calculate the other 23 hours of a day, speed-flow curves were used. These curves were based on the capacity values and operating characteristics calculated in the Corsim model. The following tables summarize the freeway elements of the system including volumes and vehicle hours of travel time per section.

Hour	Section 1		Section 2		Section 3		Section 4		Section 5	
	Volume	Time	Volume	Time	Volume	Time	Volume	Time	Volume	Time
1	1,720	137.05	1,863	131.02	1,856	143.90	2,116	215.12	2,486	319.14
2	1,169	85.93	1,197	75.70	1,267	83.14	1,457	124.26	1,713	184.28
3	1,010	76.70	918	55.07	1,097	60.48	1,273	90.39	1,496	132.80
4	1,003	54.62	962	42.13	1,180	46.27	1,389	68.51	1,633	100.66
5	1,984	72.57	1,986	61.12	2,964	67.75	3,543	100.31	4,165	148.76
6	5,208	199.10	4,988	139.75	8,778	154.96	10,548	229.45	12,398	343.74
7	8,230	457.75	7,845	310.25	10,578	344.26	12,573	520.51	14,778	789.74
8	10,642	786.53	9,942	469.73	11,201	521.57	13,195	808.56	15,509	1267.28
9	9,809	718.20	9,200	444.72	9,991	499.19	11,739	761.94	13,798	1192.99
10	8,910	731.10	8,123	428.14	9,084	480.47	10,645	730.19	12,512	1142.14
11	8,718	750.62	7,980	443.84	8,333	498.20	9,718	760.42	11,422	1190.61
12	9,047	803.01	8,254	470.06	8,392	521.95	9,769	809.14	11,482	1268.19
13	9,484	842.57	9,064	546.93	9,149	619.48	10,630	962.47	12,494	1540.57
14	9,804	867.70	9,975	657.31	10,216	758.07	11,854	1181.67	13,932	1903.41
15	10,366	995.30	12,012	1074.83	12,393	1267.52	14,280	2413.52	16,784	6566.98
16	11,541	1681.59	12,548	1152.46	12,452	1428.04	14,310	2923.12	16,819	6908.14
17	12,000	2269.41	12,516	1139.62	12,379	1412.13	14,230	2890.55	16,726	6831.16
18	11,637	2011.06	12,314	1128.09	12,381	1349.92	14,242	2660.03	16,739	6762.05
19	9,370	920.71	10,454	887.57	10,463	1029.06	12,020	1667.06	14,128	3626.26
20	7,139	592.90	7,733	545.78	7,540	618.18	8,668	960.44	10,188	1510.30
21	5,946	457.75	6,251	400.74	6,039	449.62	6,954	680.43	8,173	1063.27
22	5,306	392.73	5,687	366.08	5,698	410.64	6,571	614.59	7,723	951.31
23	4,034	292.02	4,474	292.23	4,551	327.58	5,238	490.12	6,156	743.38
24	2,922	238.84	3,443	258.91	3,540	287.24	4,039	429.66	4,747	651.26
Total		16436		11522		13380		23092		47138

Hour				Section 6				Section 7		
	Volume	Time	Volume	Time	Volume	Time	Volume	Time	Volume	Time
1	1,531	237.32	667	64.82	426	124.51	356	47.12	59	0.87
2	1,018	169.11	396	52.31	280	70.84	234	27.10	16	0.08
3	903	208.44	338	56.59	196	48.76	164	18.65	28	0.16
4	1,064	378.60	434	93.11	187	58.52	156	22.15	71	0.87
5	2,811	1323.11	1,099	320.08	303	119.06	254	45.06	134	1.67
6	6,620	4184.70	2,299	752.42	790	274.34	661	103.80	217	2.15
7	7,879	3949.80	2,982	949.07	1,913	728.40	1,601	272.18	375	3.38
8	8,931	4161.16	3,347	999.93	3,039	1424.09	2,543	517.34	639	6.92
9	8,840	3974.42	3,244	762.10	2,684	1115.49	2,246	411.18	717	7.66
10	8,141	3537.37	3,290	746.08	2,531	1060.98	2,118	391.27	725	7.91
11	8,174	3204.59	3,897	709.77	2,672	1055.56	2,236	389.27	911	9.86
12	8,243	2982.86	4,130	681.73	2,920	1066.40	2,444	398.03	938	10.45
13	8,714	3199.71	4,136	685.42	3,025	1067.31	2,531	398.37	1,029	11.12
14	9,598	3428.71	4,460	820.04	3,064	1051.04	2,564	387.60	1,057	12.36
15	11,330	3565.46	4,433	809.12	3,280	1042.00	2,744	384.27	962	10.45
16	11,265	3402.51	4,317	769.19	3,528	1139.29	2,952	419.95	954	10.87
17	11,328	3770.03	4,565	882.98	3,993	1373.16	3,341	499.17	911	11.12
18	10,591	3372.77	4,037	730.43	4,183	1338.92	3,500	486.72	792	9.25
19	9,342	2504.13	3,564	578.56	3,077	911.83	2,575	340.53	520	5.54
20	6,856	1550.71	3,015	386.08	2,035	566.06	1,703	211.63	406	3.95
21	5,458	1157.32	2,460	302.85	1,770	373.14	1,481	141.15	185	1.67
22	5,043	1133.07	2,098	252.58	1,447	315.95	1,211	119.54	142	1.59
23	3,884	1050.42	1,732	213.04	972	260.82	813	98.69	102	1.18
24	3,436	412.82	1,058	107.57	684	153.30	573	58.64	110	1.02
Total		56859		12726		16740		6189		132

The freeway vehicle hours total is 204,214. This total includes the trucks on the freeway system as well as other vehicles. Since all vehicle types use the freeway and others impact specific vehicle operations, it is appropriate that this measurement includes all types.

One endpoint of the systems analysis is the border crossing between the US and Canada. The border-crossing element is modeled using the Dqueue computer program. The number of border crossing gates varies from hour to hour as shown below.

Hour	Number of Gates Open
1	1
2	1
3	1
4	1
5	1
6	1
7	3
8	3
9	3
10	4
11	4
12	4
13	5
14	5
15	5
16	5
17	4
18	4
19	4
20	1
21	1
22	1
23	1
24	1

Each gate can process 95 vehicles per hour on average. The traffic volumes at the gates during certain hours of the day are very high. These volumes result in significant queuing and delay for the vehicles crossing the border, as shown below.

Hour	Volume	Dqueue delay (sec)	Vehicle Hours
1	16	2.50	0.18
2	12	2.00	1.31
3	20	3.75	2.28
4	28	4.25	3.23
5	51	11.75	7.07
6	110	342.00	116.48
7	209	199.67	137.88
8	307	108.00	124.61
9	351	681.00	700.63
10	347	278.75	305.13
11	449	265.75	379.06
12	449	1096.50	1416.13
13	509	1185.50	1728.19
14	485	1272.50	1764.99
15	473	1261.00	1706.83
16	445	1046.50	1341.84
17	390	1283.25	1432.25
18	355	1050.50	1072.66
19	252	294.50	232.95
20	213	831.00	513.80
21	102	1268.33	371.90
22	63	490.75	92.62
23	43	5.50	5.23
24	59	15.75	8.81
		Total	13466

The border crossing creates 13,466 vehicle hours of delay on the transportation system.

The final elements of this system are the movement of container by rail after being unloaded at the port terminal.

For the containers that move by rail, the operational analysis first models the movement after unloading by the cranes. This involves drayage of the containers to a holding area. Based on empirical data, the average time to complete this movement including actual placement of the container is 145 seconds.

Drayage for Rail		
	Average time to move (hrs)	0.040
	Actual Containers	411
	Container hours	16.55

The 411 containers that move by rail have 16.55 container hours in the drayage element of the system.

The next element involves movement of the containers from the yard onto rail cars. For efficiency reasons in unloading the vessel, the containers are all placed directly in the yard after being unloaded. At the same time, the containers begin to be individually moved from the yard to be loaded onto the rail cars. This process is simultaneous with the unloading.

The average time to load an individual container is 170 seconds. This results in 19.41 container hours for this movement.

Drayage for Rail		
	Average time to move (hrs)	0.047
	Actual Containers	411
	Container hours	19.41

After segments of rail cars are loaded, they are moved and positioned to construct a complete train. Based on empirical data and normal operating conditions, this involves .31 hours of actual movement time for all 411 containers. This value includes the movements necessary to bring the completed train onto the mainline tracks and up to operating speed. This results in 127.4 container hours in this element of the rail movement.

The final element in this system is the movement of the completed rail car through the urban area. The maximum speed for trains in the urban area is 35 miles per hour. The total corridor that this speed is adhered to is 62 miles long. This results in 728.06 containers to traverse this distance.

Similar to the roadway operations analysis, the rail operations should account for other uses of the facility during the 24-hour time period. This individual train represents 19.6% of the total daily train volume on this rail segment. As a result, the container hours are factored up to reflect the total container movement in the rail operations element.

Rail Operations		
	Average speed (mph)	35
	Actual Containers	411
	Distance (miles)	62
	Container hours	3713.09

All of the operational elements of the defined transportation system have been analyzed. The total vehicle and container hours can be calculated for the system analysis phase.

Step 4 - Conduct Systems Analysis

A systems analysis of the operations can now be conducted. All elements of the system inputs and outputs are equal for the existing conditions scenario. This is due to the fact that the system is fully operational today. The following table summarized all elements of the system.

Kaohsiung	
Drayage	77.03
Loading	36.68
Tacoma	
Unloading	41.08
Truck drayage	10.95
Terminal gate	27.15
Local Roadway	363.44
Intersections	165.19
Freeway sections	204214.64
Border crossing	13466.05
Rail drayage	16.55
Rail loading	19.41
Train construction	127.41
Urban rail travel	3713.09
System Total	222,279

Under current conditions, the system as defined in the previous sections has a total of 222,279 vehicle and container hours of operation per day. As the earlier section pointed out, this total includes roadway element vehicle hours as well as total container volumes in the rail operations element. Once this information is calculated, the performance measures can be applied to the system.

Step 5 - Value Performance Measures

For this system, specific values have been assigned for the times of container and vehicle movement. For the containers moving in the system, a value of $50.00 per hour has been used. For the other vehicles on the roadway system, a value of $10.00 per vehicle hour has been used. The table below shows the annual totals based on 260 days of operation per year.

		Daily Hours	Annual Container Value	Annual Vehicle Value
Kaohsiung				
	Drayage	77.03	$ 1,001,325	
	Loading	36.68	$ 476,821	
Tacoma				
	Unloading	41.08	$ 534,040	
	Truck drayage	10.95	$ 142,364	
	Terminal gate	27.15	$ 352,945	
	Local Roadway	363.44	$ 3,307,327	$ 283,485
	Intersections	165.19	$ 1,288,446	$ 171,793
	Freeway sections	204214.64	$ 238,931,133	$ 483,171,847
	Border crossing	13466.05	$ 54,268,198	$ 24,158,101
	Rail drayage	16.55	$ 215,204	
	Rail loading	19.41	$ 252,308	
	Train construction	127.41	$ 1,656,330	
	Urban rail travel	3713.09	$ 9,464,743	
System Total		222,279	$ 350,696,632	$ 507,785,226
				$ 858,481,858

The system with these values currently during the operational parameters provided has a value of $819,676,412.

From this base value, changes or improvements to the system can be made. Several scenario analyses can be conducted to determine impacts on the system performance.

Step 6 – Model Scenarios

In the scenario analysis provided here, traditional benefit-cost calculations will be used. Several scenarios will be considered. For all scenarios, a future year of 2005 will be analyzed. The roadway traffic volumes will be increased between 2% and 10% depending on local projections for all scenarios for year 2005.

From this future year basis, the following specific scenarios will be evaluated.

- One additional gate at the border crossing for hours 6 through 22
- Shift 75% of containers to rail transportation system
- Shift 75% of containers to rail transportation system and increase rail speed to 60 mph.

There are costs associated with the improvements noted in each scenario. These costs are included in the following benefit-cost analysis calculations. The benefit values are the net present benefit of improvements over the 5-year time period.

Scenario 1: One additional gate at the border crossing for hours 6 through 22
The cost of adding one addition gate to the crossing is $1,380,000. For the border-crossing element, the net present value of future benefits over five years is $249,885,525. The benefit to cost ratio for this element is 181.08. Since this is the only improvement in the system, it is also the system wide benefit to cost ratio.

Scenario 2: Shift 75% of containers to rail system
The shift to a system that has 75% of the containers on the rail system significantly impacts the performance of the system. For the rail elements, the estimated cost of this container shift is $1,650,000 in additional equipment necessary to maintain the same operational performance. The increases in volumes results in the container hour values to increase and consequently an increases cost. The benefits for these elements are negative.

This shift to rail however reduces the container volumes on the roadway and other elements of the system. These reductions result in an increase in performance for the individual impacted elements. The result of this 75% shift is an increase in rail costs, but a decrease in other costs. The net result is a positive impact on the system. The table below shows the values.

		Daily Hours	Future Benefits
Kaohsiung			
	Drayage	77.03	
	Loading	36.68	
Tacoma			
	Unloading	41.08	
	Truck drayage	4.57	$ 160,160
	Terminal gate	11.33	$ 397,063
	Local Roadway	305.29	$ 1,261,751
	Intersections	156.83	$ 165,682
	Freeway sections	185835.33	$ 144,734,604
	Border crossing	13331.39	$ 1,772,144
	Rail drayage	31.01	$ (470,906)
	Rail loading	36.36	$ (552,096)
	Train construction	238.70	$ (3,624,350)
	Urban rail travel	4349.03	$ (137,615,839)
System Total		204,455	
			$ 6,228,213

Scenario 3: Shift 75% of containers to rail system and increase speed to 60 mph
The shift of containers to the rail system has a net positive benefit on the system. Improvements to railroad and street grade crossings can increase the speed of trains along the corridor to 60 mph. The cost of improving 11 of these crossing is $268,000,000. Using the information calculated above and the increased speeds, the system benefit is $79,512,826. This results is a benefit to cost ratio of 0.0297.

		Daily Hours	Future Benefits
Kaohsiung			
	Drayage	77.03	
	Loading	36.68	
Tacoma			
	Unloading	41.08	
	Truck drayage	4.57	$ 160,160
	Terminal gate	11.33	$ 397,063
	Local Roadway	305.29	$ 1,261,751
	Intersections	156.83	$ 165,682
	Freeway sections	185835.33	$ 144,734,604
	Border crossing	13331.39	$ 1,772,144
	Rail drayage	31.01	$ (470,906)
	Rail loading	36.36	$ (552,096)
	Train construction	238.70	$ (3,624,350)
	Urban rail travel	2536.93	$ (64,331,226)
System Total		202,643	
			$ 79,512,826

For the time period of 5 years, this is a poor ratio. Considering the benefits will be realized for 20 years, the benefits could reach $318,000,000 depending on other volume projections. This would result in a positive benefit to cost ratio of 1.19.

These scenarios evaluating individual improvements clearly demonstrate the need for a systems analysis approach. The benefits realized at the US-Canada border crossing for example improve the performance of the entire system. While the improvements are isolated elements of the system, the benefits can be realized in the entire system. The increased efficiency of moving these containers can be direct benefit for all three economies.

The rail improvements scenario may have negative benefit to cost ratios for individual elements, however the system impact is positive. Again, the system benefits are realized throughout the system.

Finally, improvements to the rail system operating speeds in the urban area will benefit this transportation system as well as others. The Port of Seattle uses many of the same rail lines identified in this study. Although the Port of Seattle and Port of Tacoma are competitors, these improvements can provide mutual benefits to both interests.

This example demonstrates the need for conducting systems analysis. If the individual elements of this system were evaluated separately, improvements such as the movement of more containers to the rail element would not be justified. A systems analysis approach however demonstrates that there are significant benefits gained from this move.

Application of the TSHIPS approach will increase the efficiency of transportation systems, provide direct benefits to the global economy and allow economic gain by supporting sound decision making practices.

The fundamental approaches used in the TSHIPS systems analysis can be applied to the non-physical elements of the transportation system. The six steps used in the analysis can be followed to address issues such as documentation, customs regulation, communication deficiencies and other non-physical elements that affect the operation of transportation systems.

1. Choose parameters
2. Model the system
3. Conduct operational analysis
4. Conduct systems analysis
5. Value performance measures
6. Model scenarios

The following section discusses emergent areas in the non-physical elements.

A SUMMARY OF NON-PHYSICAL INSTITUTIONAL BARRIERS TO COMMERCIAL TRANSPORTATION

As all students of the shipping world are thoroughly aware, modeling the movement of cargo in any form from an end user in one country to another end user in a different country is not as simple as a single point-to-point calculation. Barriers to the simplest case of the free-flow of goods are many, and mostly of historic endurance. Out of necessity, the TSHIPS project has examined and catalogued many of the major, identifiable non-physical barriers that impact scheduling and larger fractions of the total cost of cargo handling. Those items, which have been considered in current and past modeling efforts, include the following:

Inadequate communication between modes
Poor tracking of container movements
Incomplete paperwork
Communication systems not compatible
Differing labor work issues in the same transportation system
Terminal operation times not matching warehouse operational times
Limited hours of service at delivery points
Individual modes in system not working with others
Missing documents at transfer points
Local policies inconsistent with transportation system objectives
No advance communication of shipments or delivery times
Lack of funding in needed areas
Taxing policies act as deterrents
System not responsive to Just-In-Time delivery needs

An additional category of non-physical impact causes to containerized cargo movement may be referred to as ‘emergent impacts’, and includes specific constraints, which are of a non-historical nature. These impact areas are of interest for several reasons.

- They are too new to be included in any current or past models
- The impacts are so broad that they’re hard to localize or quantify
- The impacts are not often predictable in scope or degree
- These areas are too flexible to model in a static manner
- These areas have impacts which differ based on perspective
- These areas have dependencies on other non-modeled processes
- These impacts are non-linear
- This set of impact areas is expected to change rapidly with time, making modeling challenging
- It is too often not clear who owns the controlling process of these impact areas

Possible impact areas in this set include:

1. IT and telecommunication concepts; integration of real-time data streams on portable equipment. Examples of this include the current ability to monitor WWW data, wireless telecommunications and secure, proprietary business-critical data, interactively, from mobile platforms anywhere on the planet.

2. EU issues; borders, tariffs, etc. The colors of the map of Europe are running, again, but this time due to international political and commercial agreements, rather than military conflict. The expansion of NATO and the EU, east and southeastward, will continue to have unanticipated global impacts on commerce.

3. WTO like trade agreements and lack of same. Only several months, ago, there existed an entirely different predictive model of international trade for the future than the one used, today. The failure of the Seattle-round of trade talks to produce binding agreements was just as significant in impacts as the generation of new constraints would have been, coupled with the uncertainty of when and where new agreements will be made.

4. Environmental constraints and mitigation measures. Restrictions on ballast-water dumping are only the beginning.

5. UN and other ‘world government’ owned processes. The use of commerce as a political tool is not new, but the tools to manage and change these decisions in real time are new. The impacts of approvals of new trade routes, re-flagging whole fleets of vessels, and the possibilities of worldwide tariff structures have yet to be successfully calculated.

Conclusion;

As with much in life, modeling is both a blessing and a curse. The blessings to be reaped from being able to predict future results of present business decisions and processes are clear and have always been sought. A large fraction of all of our time is spent in attempts to know or predict or control these very outcomes. The curse in this context comes from working in the modern world of today. We take for granted, and fundamentally expect, to know details of what’s transpiring on the other side of the world in near-real time; data ranging from international stock and currency market conditions to business-related actions of individual people. The common element between all of these areas may be generalized as ‘predictability’.

When the British-East India Tea Company started expanding the reach of the British Empire in the last century, the major variable in scheduling clipper arrivals and departures was port and en-route weather. Even that was semi-predictable centuries ago. With the advent of powered vessels carrying containerized cargo between highly mechanized and automated ports, the system variables have been dramatically reduced, to the point, today, where schedules are considered fixed and are published far in advance. This predictability of trade has had un-anticipated impacts on business, resulting in declining profitability of historically sound businesses. Any modern trans-shipment firm or consolidator can testify to the vast increase in work required to keep a business viable today, compared with only a decade, ago.

Just imagine what these businesses and models will have to look like in 10 to 50 years; a border agreement involving Indonesia may well have a pronounced effect on a single aspect of currency or shoe trade in Europe. The result of an election in France or Italy with environmental impact will dramatically influence trade with Australia, and the like.

The modeling of emergent and un-stable parameters will become just as significant in the next quarter century as all of the historic trends were in the last century. The TSHIP project team has commenced the inclusion of these emergent factors into developmental models, in anticipation of their need for future work. We expect to be able to address the next generation of APEC needs in these areas of transportation modeling before the needs become critical, and will remain available to support APEC and other trade groups in addressing many aspects of infrastructure investment and process analysis, upon request.