

A Simulation Modeling Methodology
for Analyzing Large Complex Rail Networks

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ABSTRACT

As the congestion in the nation's freeways increases, the reliance on rail freight shipments is increasing. For this reason, models are needed to analyze the increased traffic burden on the rail networks. Compound delays and ripple effects from conflicts at complex junctions, terminals, and railroad-railroad crossings at grade and other factors in some rail networks make it difficult to develop analytical models to study delays and capacity. Therefore, a simulation modeling methodology for analyzing complex rail networks is proposed. The methodology considers both double-track and single-track lines and is insensitive to the size of the rail network. The proposed simulation modeling methodology is then used to analyze train movement from Downtown Los Angeles to the San Pedro Bay Ports.

Keywords: Rail networks, process-oriented simulation, queueing models, train blockage, dispatching

1.0 INTRODUCTION

This paper presents a detailed computer simulation modeling methodology used to analyze the capacity of complex rail track networks and the congestion delay to the trains. Specifically, we model in detail the movement of trains over double-track and single-track rail lines, junctions, and terminals to determine the track configuration that minimizes congestion

delay to trains. Factors that are considered include the merging of multiple rail lines into a single rail line, rail tracks crossing one another, movement of trains in and out of sidings (passing tracks), and movement of trains in and out of their destination terminals. These models are then used to analyze a detailed rail network leading from transcontinental main line connections near Downtown Los Angeles to the Ports of Los Angeles and Long Beach (San Pedro Bay Ports).

Train movement on double-track is similar to car movement on a 2-lane freeway. Trains traveling in the same direction use the same track. The delay to the trains typically occurs at rail junctions which represent points where two or more rail lines merge or where railroad-railroad crossings exist. When a train experiences a delay, upstream trains can also be blocked from movement. Other factors causing track blockage are trains moving in or out of their destination points and train breakdowns. When a train is blocked or stopped, some additional time depending on the signal time and acceleration rate is required before it can again reach maximum speed.

All the above factors make the development of analytical models to analyze the congestion delay of trains traveling on a network of double-track extremely difficult. One analytical modeling approach is to model each rail track segment of the rail network as a separate **G/D/1** Queue. The problem with this approach is that each track segment is treated independently and the model does not capture the interaction between track segments (i.e., the delay caused by trains blocking one-another). The effect of the blockage delay is significant in cases when there is heavy traffic, high-speed tracks, and many junction points. Analytical models that consist of a network of queues that have general distributions for arrival and service time are difficult to solve (Wolff [1991]). A simulation model that considers all the above factors to represent movement of trains on a large double-track rail network is proposed.

Aside from double-track, a rail network can also contain lower-speed single-track segments. In single-track segments, trains moving in opposite directions cannot simultaneously occupy the track. Trains moving in the same direction may operate on close headways if the train tracks are low-speed. However, an arrival in the opposite direction must stop on a siding (passing track) and wait until the track is clear.

Previous analytical models which have been developed to study single-track rail operations include Frank [1966], Petersen [1974], Greenberg, Leachman, and Wolff [1988], and Chen and Harker [1990]. The model in Petersen assumes light traffic, uniformly distributed departure times, and equal spacing between sidings. Chen and Harker extend the work of Petersen by taking into account the train's scheduled departure and arrival time. They estimate both the mean and variance of the train delay by solving a system of nonlinear equations. The model in Frank is appropriate for heavy traffic situations but assumes that only one train can occupy the single-track line between sidings. Greenberg, Leachman, and Wolff's Model is intended for light traffic, low-speed rail lines. In addition, their model assumes that the train departure process is Poisson, the holding capacities at the sidings are not limiting, and train delays arising from following other movements in the same direction are negligible. These assumptions make it realistic to model each stretch of single-track as an independent queue with infinite capacity because it is unlikely that excessive train blockage can occur. However, if any of these assumptions do not hold, an integrated model that includes all track segments is necessary to realistically represent train movement. Another drawback with the analytical models is that they do not consider delay due to railroad-railroad crossings at grade in the single-track line segments.

Petersen and Taylor [1982] present a structured model for rail line simulation. They divide the line into track segments representing the stretches of track between adjacent switches and develop algebraic relationships to represent the model logic. Their model is

implemented in FORTRAN containing 1800 lines of code. The simulation model presented in this paper is a process-oriented model implemented using the SLAM II Simulation Language (Pritsker [1986]). The advantage of using a process-oriented language to model rail operations is that a small generic network which has the flexibility to test many different train dispatching rules can be used to represent detailed rail movement. The methodology used in this paper also divides the rail network into track segments, but in this case each track segment is assumed to be equal to the maximum train length providing for a more detailed representation of the rail network. The representation of movements through multiple crossover junctions in a track segment is modeled by defining separate resources for junction switches and crossovers within the track segments. In particular for a crossover track contained in the middle of a track segment, the crossover track resource can be released as the rear of the train passes the intersection allowing trains waiting at the intersection to take possession of the crossover resource and continue moving. Finally, by using the built-in functionality in SLAM II such as activities, queues, and resources, complicated logic at the source and destination terminals for train movement can be easily integrated with the rail network simulation model.

2.0 SIMULATION MODELING METHODOLOGY

This section presents a simulation modeling methodology used to analyze single and double-track rail networks. The methodology is developed for a generic double-track network, and a separate model is developed to represent train movement on a generic single-track rail network. The simulation models are developed in the SLAM II Simulation Language (Pritsker [1986]), but may be implemented using any general-purpose simulation language. The modeling methodology does not depend on the size of the rail network and is insensitive to the trackage configuration. Thus, changes to the trackage configuration require changes only to the input data files.

2.1 Double-track Rail Network

Train movement on double-track is similar to car movement on a 2-lane freeway. Trains traveling in the same direction use the same tracks. The characteristics and the assumptions of the double-track rail network model are as follows:

1. Each train has a unique route that uses only a certain portion of the rail network.
2. The headway from the front of one train to the rear of a leading train is one train length.
3. Trains traveling on the rail network have varying train lengths and acceleration rates.
4. The maximum speed of the trains depends on the particular track segment.

The main idea behind the modeling approach is to divide the rail network into track segments. Within each track segment may exist several junctions which represent points where two or more rail lines merge or where railroad-railroad crossing exist. Each track segment and junction is represented as a unique resource in the simulation model. It is assumed that only one train at a time can occupy any portion of a track segment because the minimum headway from the front of one train to the rear of a leading train is one train length. Thus, the minimum length of a track segment should be the maximum train length size. The move time on a track segment is based on the time the head of the train travels the entire track segment. When a train moves to the next track segment in the rail network, the previous track segment resource is not freed (released so that another train can travel on it) until the time the rear of the train is completely in the next track segment. Hence, the overall distance the head of the train travels holding a track segment resource is the length of the track segment plus a train length.

Figure 1 diagrams a small 4 track segment rail network that shows the merger of two rail lines into one rail line. Note that each track segment has a northbound and southbound portion (the diagram only labels the southbound sections.). Included in the rail network are crossover rail tracks with the northbound and southbound junctions separately identified. For example, trains traveling on track segment **T5S** also occupy junctions **J1S** and **J2S**.

Southbound trains enter the rail network from either track segment **T5S** (area 1) or **T6S**

(area 2) and depart from the network using track segment **T8S** (area 3). Northbound trains enter the rail network from track segment **T8N** (area 3) and depart from the network from either track segment **T5N** (area 1) or **T6N** (area 2). Table 1 shows the 4 possible routes of the example rail network. The route defines the track segments that the train will move on including the junctions that the train will pass. Also included in the route definition is the length of the track segment, the maximum speed of the track segment, and the location of any junctions in the track segment as measured in distance to the end of the track segment. For example, the route for trains entering from area 2 is **T6S**, **T7S**, and **T8S**. Since the crossover track intersects track segments **T5S** and **T6S**, the trains traveling on track segment **T6S** also require resources **J1N**, **J1S** and **J2S** before they can move on segment **T6S**. Thus, a train on track segment **T6S** blocks any northbound or southbound train requiring track segment **T5S** or **T5N** since they require use of the same junctions. Once the train passes a junction, the junction resource is freed so that a train requiring track segment **T5N** or **T5S** can continue moving.

Table 1. Route File

<u>Route Name</u>	<u>Track Segment</u>	<u>Junction Name</u>	<u>Track Length</u>	<u>Distance To End</u>	<u>Maximum Speed</u>
A1-A3	T5S		11000		15
A1-A3		J1S		1500	
A1-A3		J2S		1000	
A1-A3	T7S		10000		30
A1-A3	T8S		10000		30
A2-A3	T6S		10050		15
A2-A3		J1N		1500	
A2-A3		J1S		1500	
A2-A3		J2S		1000	
A2-A3	T7S		10000		30
A2-A3	T8S		10000		30
A3-A1	T8N		10000		30

A3-A1	T7N		10000	30
A3-A1	T5N		11000	15
A3-A1		J2N		10000
A3-A1		J1N		9500
A3-A2	T8N		10000	30
A3-A2	T7N		10000	30
A3-A2	T6N		10050	15
A3-A2		J2N	9050	

The SLAM II Network Model representing train movement on double-track is shown in Figure 2. The entities in the simulation model are the trains while the resources are the track segments and junctions. Associated with each entity in the network is a set of attributes which represent basic characteristics of the train. Table 2 lists the attributes of the trains.

Table 2. List of Attributes

<u>Attribute</u>	<u>Description</u>
Accel	the acceleration rate of the train
TrnLgth	the length of the train
RteNme	the route name of the train
TrkSgNm	the current track segment that the train is moving on
TrnNme	the name of the train

As the diagram shows, the movement of trains on double-track can be represented by a 3 node network. The size of the SLAM II network is independent of the number of trains to simulate or the number of track segments. The overall logic is for the train to move from one track segment to the next. Before the train can move on a track segment, the train has to seize all the resources on the track segment including any junction resources. The trains wait for the track and junction resources at **AWAIT NODE 1**. The seizing of the resources is performed by a user-written routine, **ALLOC(1)**. This

routine searches to see if all the track and junction resources that the train needs for the current track segment are currently available. If any of the resources are currently being utilized by another train, none of the resources are seized and the train continues waiting at the **AWAIT NODE**. Train priority is typically based on a first-come-first-service basis. However, later arriving trains (on a different track) can supersede other waiting trains if all the track and junction resources that the later arriving trains require are currently available.

EVENT NODE 1 schedules the freeing of the track segment resource of the previously utilized track segment and junction resources. This event is discussed in more detail below.

USERF(1) calculates the move time on the track segment. The move time on a track segment is based on the time the head of the train travels the entire track segment. The following calculations determine the move time on the segment:

1) Parameters

d_i length of track segment i
 mv_i maximum speed on track segment i
 $rect$ time to signal train and to begin moving if stopped (reaction time)

2) Computed Variables

tc time for the train to reach maximum speed after it stops
 sc distance the train travels before it reaches maximum speed after it stops

3) Move Time Calculations

$$tc = mv_i / Accel$$

$$sc = .5 * Accel * (tc) ** 2$$

If train did not stop then

$$USERF(1) = d_i / mv_i$$

If train stopped and sc is greater than d_i then

$$USERF(I) = \text{sqrt}(2*d_i / \text{Accel}) + \text{rect}$$

If train stopped and sc is less than or equal to d_i then

$$USERF(I) = tc + (d_i - sc)/mv_i + \text{rect}$$

The parameter rect is a global variable while parameters d_i and mv_i are stored in the route data file and are accessed using the attributes **RteNme** and **TrkSgNm**. If the train did not have to wait for the track segment (i.e., the train did not stop), the move time is simply the distance of the track segment divided by the maximum speed. If the train stopped to wait and the distance it travels while accelerating is greater than the length of the track segment, the move time is the time the train spent accelerating plus the time it takes to signal the train to begin moving again (the reaction time). If the train did stop and the distance it travels while accelerating is less than the track segment, the move time is the accelerating time plus the time spent traveling at maximum speed plus the reaction time.

After the train travels on the track segment, **EVENT NODE 2** determines where the train goes next and updates the attribute **TrkSgNm** (the next track segment becomes the current track segment). If the train reached its destination, the train stops moving on the rail network and the simulation logic of the destination terminal is performed. This depends on the activities of the destination location and is briefly discussed in the Case Study. Otherwise, the train goes to **AWAIT NODE 1** to wait for the track and junction resources of the current track segment.

After the train seizes all the track and junction resources of the current track segment, **EVENT NODE 1** signals (schedules an event) to free the previous track segment resource. The previous track segment cannot be immediately released because the move time calculations only account for the time the head of the train travels the entire track segment and some additional time is required to clear the rear of the train from the previous track segment. The lag time to

free the track segment resource is based on the head of the train traveling the length of the train because the train has to completely clear the previous track segment before it can release the previous track segment resource.

The calculation of the lag time to free the track segment resource is similar to the move time calculations except the distance the head of the train has to travel is equal to the length of a train instead of the length of the track segment.

EVENT 1 also signals to release any junction resources that the train passes. These junction resources are (1) any junction located in the current track segment that has distance to end greater than the train length and (2) any junction located in the previous track segment that has distance to end less than the train length. If the distance to the end of the track segment for the junction is greater than the length of the train, the junction resource can be released after the train immediately passes the junction. In this case the lag time is based on the head of the train traveling the length of the train plus the distance to the junction. If the distance to the end of the track segment for the junction is less than the length of the train, the junction resource cannot be released until the next track segment is seized because if the train stops to wait for the next track segment the rail crossing will be blocked. Thus, **EVENT 1** also signals to free any junction resources in the previous track segment that had distance to the end less than the length of the train.

2.2 Single-track Rail Network

In the single-track simulation model, the rail network is also divided into track segments. In this case, the track segments represent stretches of single-track between sidings or yards (locations where trains may pass). It is assumed that train movements in the same direction may follow each other on relatively close headways; in particular, more than one train moving in the same direction is allowed on a segment of single-track between sidings. Running times

over single-track stretches are deterministic, but with an added random component if there exists an intervening railroad-railroad crossing at grade. (The distribution describing the random component is an input to the model.) When the simulated train movement must take siding or is starting from a siding, an additional fixed time to signal the train is added to the running time.

The dispatching logic resolves conflicts on the basis of a least-track-time-requirements-first rule. For example, if a northbound train is waiting at a siding for a southbound train to move over the adjacent single-track segment, and another southbound train arrives at the opposite end of the single-track segment, that train will be given priority over the northbound train since it can clear the single-track segment sooner.

Passing locations are assumed in the model to have infinite storage capacity, i.e., multiple trains are allowed to pull into the clear in a siding. If any passing locations are frequently occupied by a greater number of trains than the actual capacity of the location, this is an indication that fluid operations cannot be maintained and capacity is insufficient. In such a case, the trackage configuration is changed (i.e., additional sidings or stretches of double-track are inserted), and the simulation is re-run. Beginning with an assumed trackage configuration, iterative simulation runs are made until delays and siding utilizations are judged to be acceptable.

Figure 3 shows the SLAM II Network Model for a sample single-track segment. The northbound and southbound trains requiring the same single-track segment wait in separate **AWAIT NODES**. Southbound trains wait in **AWAIT NODE 1** while northbound trains wait in **AWAIT NODE 2**. The single-track segment is modeled as two separate gates with each gate representing the direction of movement of the train. When the gate is opened, trains requiring the gate do not have to wait. Southbound trains wait for **GATE S1** to be opened while northbound trains wait for **GATE N1**.

When a train arrives to an **AWAIT NODE** and the gate is opened, the train does not move into the siding and continues moving. However, it closes the gate for the opposing direction of movement. The time in the track segment is calculated in **USERF(1)**. As previously stated, this time has a deterministic and random component. After completing the train movement, the train moves to the next single-track segment in the simulation model. If there are no more trains moving in the same direction, the gate representing the opposing direction train movement is opened *rect* time units from now.

3.0 CASE STUDY

The Ports of Long Beach and Los Angeles (San Pedro Bay Ports) are the busiest ports on the West Coast (TMS [1988]). However, much of the demand can be serviced by other ports if the lack of availability of transportation from/to the ports raises costs and reduces the quality of service at the San Pedro Bay Ports. The ports have a significant influence on the local economy and losing business would affect it.

Recently, port growth has averaged 8 to 15 percent annually [TMS (1988)]. Even at lower growth forecasts, the increased port demand will severely strain the current transportation service from Downtown Los Angeles to the ports. The only feasible mode of transportation that can handle the increased demand is rail because the highway system is too saturated. Unfortunately, the present rail system cannot handle the increased port demand without unacceptable increases in traffic congestion and noise. For this reason, a re-evaluation of the transportation service from/to the ports is needed.

Three railroads, Santa Fe (ATSF), Southern Pacific (SP), and Union Pacific (UP), operate service from downtown to the ports. Each railroad operates their own slow-speed, low-capacity single tracks which is insufficient to meet the expected increase in traffic. As outlined by Leachman [1984], one method of handling the projected rail traffic growth while

minimizing the environmental impact is to develop a Consolidated Rail Corridor. The proposed Corridor combines the operations of the three rail carriers into a common line from downtown to the ports. The envisioned Rail Corridor will be a high-capacity double-track rail line that is grade-separated. Near Downtown Los Angeles the consolidated corridor would connect with transcontinental main lines for rail service east of Southern California.

In addition to analyzing the proposed Rail Corridor, the current trackage configuration (each railroad independently operating its own tracks) is analyzed and modifications to the current design that can handle the increased demand are proposed. This design is referred to as the "Status Quo". The purpose of this study is to compare the total train delay using the trackage configuration for the proposed Consolidated Rail Corridor with the total train delay using the proposed Status Quo trackage configuration for rail traffic forecasts in years 2010 and 2020.

3.1 Port Area Description

There are 22 different rail terminals proposed to be located in the San Pedro Bay Ports by the year 2020. Each terminal is used to load a particular container or product type (i.e., carload, coal, white bulk, oil, and intermodal). For most terminals, there is a limited capacity of tracks for trains to wait for loading or unloading. The carload terminals are not capacity constrained.

Trains arriving to a carload terminal have a fixed layover time then travel back to downtown. The layover time depends on the terminal. The layover times range from 3 to 7 hours.

The coal and white bulk terminals have track capacity for two trains. One train track is reserved for unloading the train while the other is used for storage. The unload time is 2.5 hours, and the unloader has a 10% probability of failure. The repair time is 1 hour. The unloader can only fail during the unloading operation.

The train movement into and out of the intermodal terminals, as well as the train dwell

times at terminals, vary according to the terminal configuration. The track capacity at the intermodal terminals used for loading and unloading a train ranges from 2-4 trains for year 2010 and from 2-8 trains for year 2020. Some of the intermodal terminals have additional track capacity used only for train storage. The loading and unloading tracks also can be used for train storage. The load and unload times also vary depending on the terminal ranging from 2.5-6 hours. Between the unloading and reloading operations at the intermodal terminals, the trains have a possibility of being placed in storage (a probability of .75 for small terminals and .50 for large terminals). The storage time is an exponential random variable with the mean equal to 1 day. In addition, the train at an intermodal terminal experiences a delay due to inspection (30 minutes), and is subject to random delays for repair of mechanical defects (uniformly distributed between 45 and 75 minutes with the probability of a defect being 5%), as well as switching out the defective cars (50-90 minutes depending on the particular terminal with the probability of switching being 8%).

3.2 Rail System Description

Various train types travel from downtown to the San Pedro Bay Ports. The trains can be classified as unit intermodal, solid waste, bulk, and oil trains plus general carload trains. The total daily forecasted through train movement from/to the ports area for year 2010 is 72.9, and for year 2020 is 96.7. Such high density of heavy through freight train movements are unprecedented, and there were questions in the minds of some planners of whether or not the Consolidated Corridor and its connections could cope with such traffic levels.

The majority of the through trains are intermodal. The arrival process of unit intermodal, unit bulk, and carload trains is assumed to be Poisson due to random ocean transport connections and delays occurring on main lines outside the study area. The arrival times for unit oil and unit solid waste trains are predetermined and assumed to be known.

Maximum speed for the Corridor is assumed to be 30 MPH. Over downtown connections, sharp curvatures at junctions, and near the port area the maximum speed is 15 MPH. The acceleration rates depend on the train type and vary from .10 MPHPS to .30 MPHPS. The length of the train depends on the train type and the terminal the train will be visiting. The train length ranges from 4000-8000 feet.

The proposed trackage for the Status Quo routing alternative is shown in Figure 4. Each railroad (ATSF, UP, SP) has separate low-speed (15-20 mph) single-track lines from downtown to the San Pedro Bay Ports. Note that the SP railroad has two routes to the port area, the SP Wilmington Branch and the SP San Pedro Branch, which may be paired to obtain double-track operation. The same is true of the SP La Habra and Santa Ana Branches.

The proposed trackage for the Consolidated Corridor routing alternative is shown in Figure 5. Note that the three railroads share one high-speed double-track line from the downtown junctions to the ports area that is grade-separated. The train trackage in the port area for both routing alternatives is double-track.

3.3 Results and Comparison of Routing Alternatives

Starting with a trial or initial trackage configuration, iterative simulations are performed until the results indicate that the assumed track configuration is appropriate for the traffic demand. For example, too many trains waiting at sidings between single-track indicates that an additional siding is needed. The final trackage configuration for both routing alternatives is shown in Figures 4 and 5. In this section, the results of only the final trackage configuration are presented. Leachman [1991] presents a detailed discussion of the analysis to determine the final trackage configuration. The models were validated by simulating and tracing the movement of a single train on numerous possible routes. Personnel from all the railroads and ports then validated the resulting trace and run times.

In the simulations, many consecutive days of train operations are simulated. Delays ensuing during a simulated period of operation long enough to gauge the long-run or "steady-state" distributions of delays are tabulated by the computer program. Because the simulations are typically started with an unrealistic simulated status (e.g., no trains currently en route), it is necessary to discard early portions of the simulation results in order to obtain steady-state statistics. 10 days of simulated time starting with an "empty" railroad is used to initialize the simulation, followed by additional 190 days of simulated operations during which delay statistics are tabulated. To get independent sample means, each experiment is replicated 10 times.

Table 3 shows the resulting total train delay per day for each routing alternative and railroad in each year. In both 2010 and 2020, the Corridor Alternative requires about 38% less total train delay per day. The Status Quo Alternative has higher total train delays because it has substantial stretches of single-track operation as well as a relatively large number of railroad-railroad crossings at grade when compared to the Consolidated Corridor Alternative. For a statistical comparison of two-means, Law and Kelton [1991] recommend the Welch confidence interval. Table 4 shows the 99.0% confidence interval on the difference between the mean total delay of the routing alternatives for each railroad. As the confidence intervals show, the ATSF railroad would benefit the greatest with the Corridor Alternative, but all railroads will experience improved efficiency in terms of train delay with the Corridor Alternative.

Table 3. Total Train Delay (hours) per Day

	2010		2020	
Status Quo	Corridor	Status Quo	Corridor	
UP	4.71	2.94	10.88	6.47
ATSF	4.74	2.22	9.55	4.71
SP	5.94	4.42	13.19	9.66
Total	15.39	9.58	33.62	20.84

Table 4. Welch 99.0% Confidence Interval on Total Train Delay

	2010	2020
UP	(1.61, 1.92)	(4.16, 4.66)
ATSF	(2.35, 2.69)	(4.61, 5.06)
SP	(1.29, 1.74)	(3.32, 3.73)

It should be noted that this analysis only provides a relative comparison of the train delay between the routing alternatives. Other factors such as environmental impact, impact to local traffic, and capital outlay for each alternative need to be considered when selecting the final routing alternative. The trackage configuration of both the Status Quo and the Consolidated Corridor routing alternatives require major modifications to the current trackage. Moreover, both alternatives require grade separation of street crossings to mitigate impacts on vehicular traffic. These modifications are extremely capital intensive. A major benefit of the Consolidated Corridor alternative is that grade separation expenditures may be concentrated on a single line. An additional benefit of the proposed Rail Corridor is the closing of branch rail lines that are not part of the Corridor. Many of these branch rail lines travel through residential neighborhoods. Hence, the closing of these lines will reduce congestion and noise pollution in these neighborhoods.

4.0 CONCLUSIONS

Compound delays and ripple effects from conflicts at complex junctions, terminals, and railroad-railroad crossings at grade and other factors in some rail networks make it difficult to develop analytical models to study delays and capacity. Hence, a simulation modeling methodology used to analyze in detail the movement of trains on double-track and single-track lines is proposed. Factors that are considered include the merging of multiple rail lines into a

single rail line, rail tracks crossing one another, movement of trains in and out of sidings (passing tracks), and movement of trains in and out of their destination terminals.

The advantage of the methodology is that large complex rail networks may be analyzed using a small network simulation model which has the flexibility to test many different train dispatching rules and can be used to represent detailed rail movement. Furthermore, the size of the simulation network model is independent of the number of trains to simulate or the number of track segments. Thus, changes to the trackage configuration require only changes to the input data. The primary disadvantage of the methodology is that the accuracy of the model is dependent on how the rail network is decomposed into track segments and junction resources. Decomposing the rail network into small track segments provides for a more detailed representation of train movement. However, too small of a decomposition may increase computer run-times without much gain in accuracy. Thus, the simulation analyst must work closely with transportation engineers to determine the appropriate level of detail to include in the model.

The proposed simulation modeling methodology was used to analyze rail service from Downtown Los Angeles to the San Pedro Bay Ports. Currently, rail service to the San Pedro Bay Ports consists of rail lines that are slow-speed single track crossing numerous city streets. The expected increase in demand at the Ports will severely strain the current rail service, necessitating the need to make modifications in the current trackage configuration. A simulation analysis of several alternative trackage configurations showed the relative difference in total train delay between a proposed Rail Corridor alternative and a proposed Status Quo alternative.

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Biographical Sketch

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