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Truck Scheduling for Ground to Air Connectivity: Final Report

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University of Southern California

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Truck Scheduling for Ground to Air Connectivity

Final Report

October 27, 2002

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ABSTRACT

A critical link in the overnight package business is the on-time arrival of trucks at airport terminals. Truck delays can delay the package sorting and transfer process, which can in turn delay aircraft departures from the local terminal, as well as aircraft departures from hub terminals that depend on timely aircraft arrivals. This report models the airport terminal as a queueing process with random bulk arrivals. The models have been implemented in a web-based decision support tool (Truck to Air Dispatch, TAD, available at the website ger309-pc16.usc.edu), which provides real-time predictions for the status of the sort operation, and decision support for scheduling dispatches.

EXECUTIVE SUMMARY

This is the final report for the project “ATIS for Ground to Air Connectivity,” which investigated schedule coordination between ground transportation and aircraft departures at airport cargo terminals. UPS, Federal Express and other air express companies operate many local terminals within the Los Angeles region. At the end of each day, trucks depart from these terminals carrying express shipments, which are processed at Los Angeles International Airport, Ontario Airport and other local airports in Southern California. Aircraft depart from these airports according to a rigid schedule, so it is important for trucks to arrive on time and for shipments to be processed on time. Otherwise, aircraft cannot be fully loaded by their scheduled departure time, and they will either have to be held for late arrivals or depart without all of their shipments (thus creating late deliveries for the affected shipments).

This report models the sorting process at the terminal and the effects of truck arrival time on the completion of the sort. This paper also models the effects of sorting capacity and the start time for the sort. The model is implemented as a web-based decision support tool called Truck to Air Dispatch, or TAD (accessible at ger309-pc16.usc.edu). TAD is designed to assist terminal managers in creating truck schedules, both in real-time and for the future. For instance, it can predict whether a change in truck departure time (either planned or unplanned) will translate into delayed flights. When potential delays are revealed, managers can evaluate remedies, such as assigning more workers to the sorting line, starting sorting operations earlier than normal, expediting truck departures or adding truck departures. A dispatcher can also assess the impacts of holding a truck, beyond its normal departure time (e.g., to see whether it is possible to wait for a delayed incoming shipment). While TAD is not designed to re-route trucks (a decision typically left to drivers), it can evaluate the effects of the decisions that are typically at the command of terminal managers.

TAD provides real-time forecasting capability, utilizing data generated at the PEMS site maintained by PATH. TAD provides both tabular and graphical output, “what if” analysis capabilities, and the ability to analyze variability in travel times. The site also provides the capability for users to establish accounts and manage their own data. A user can also permit remote users to access data in a password protected environment, enabling them to exchange information through the website.

1. INTRODUCTION

In recent years the fastest growing segments of the goods movement industry in the United States have been small shipments and air shipments (Bearth, 2000). Federal Express, United Parcel Service and DHL have prospered in this environment by creating integrated ground/air networks. Air cargo terminals have also developed a capability to rapidly unload trucks, sort shipments, load these shipments into air containers, and load the air containers onto aircraft. These steps can sometimes be completed within a time span of 1 hour or less. At a destination airport the steps are reversed, allowing aircraft to be unloaded, and trucks to be loaded, within a short time span. High efficiency in sorting and loading has made it economical to send shipments across the country with next morning delivery (Analla and Helms, 1996; Chan and Ponder, 1979; Hansen and Kiesling, 1993; Jannah and Wilder, 1999; Larson, 1998; and Oster et al, 1995, examine the economic structure of the industry.)

Taken as a whole, express transportation can often be divided into the 11 steps listed in Table 1. To meet time commitments, it is desirable to make all of these steps as

Table 1. Express Transportation Phases

1. Pickup at shipper and transportation to local terminal
2. Processing shipment at local terminal (unload, sort, reload)
3. Truck transportation from local terminal to airport terminal
4. Processing shipment at airport terminal (unload, sort, load aircraft)
5. Air transportation to hub airport
6. Processing shipment at hub airport (unload, sort, load aircraft)
7. Air transportation to destination airport
8. Processing shipment at destination airport (unload, sort, load truck)
9. Truck transportation to local terminal
10. Processing shipment at local terminal (unload, sort, load truck)
11. Transportation to receiver and delivery

fast as possible. And it is also desirable to expedite some of the steps in order to provide more flexibility in others (e.g., to allow later pick-up times for shipments).

The sorting process at the origin airport is a particularly critical step, as it is susceptible to random delays in the arrival of work, and because it demands relatively large investments in facilities and labor. The facilities and labor are only needed within concentrated time periods, which sometimes makes it uneconomical to provide sufficient capacity to process shipments as quickly as they arrive. Unfortunately, late truck arrivals can also delay sorting, with significant repercussions. The issue is especially critical in Southern California for three reasons: (1) west coast shipments have a 3 hour time lag relative to east coast, due to the difference in time zones, (2) Southern California is the dominant population center on the west coast, and (3) congestion in Southern California has both elongated travel times and made them less predictable. The importance of these shipments is magnified by the fact that major hub terminals (such as Federal Express' Memphis hub) cannot release their outbound aircraft until all inbound flights have arrived and been processed. Thus a single delay to a Southern California flight (due to a few late trucks) can translate into systemwide delays.

From a customer service perspective, systemwide delays can force an airline to alter its delivery commitment and pickup cutoff times. Thus, airlines that are better at managing their ground operations can offer more competitive service to their customers, and capture a larger share of the express shipment market.

The fundamental unit of analysis in this report is a "sort" at an air cargo terminal. Some air cargo terminals schedule multiple sorts at different times, and some terminals have multiple lines that simultaneously complete sorts. Each sort ends when all the

packages have been processed for an individual aircraft, or for a group of aircraft that share a sort. Because different sorts process different inbound trucks, and because different sorts feed different aircraft, they can be analyzed independently of each other.

Background Research

Three categories of research are relevant to coordinating ground/air operations. First, the design of the network as a whole, including route structure and placement of terminals, has been studied by Hall (1989), Kim et al (1999), and Kuby and Gray (1993). Second, the operation and design of air terminal facilities, and the aircraft loading process, have been studied by Ashford and Fathers (1989), Cheung et al (1998), Cornett et al (1996), Geinzer and Meszaros (1990), Heidelberg et al (1998), Nobert and Roy (1998), Swip and Lee (1991) and Thomas et al (1998). A last area of research is the coordination of schedules for incoming and outgoing vehicles at a transfer terminal, which has been studied by Abkowitz et al (1987), Bookbinder and Desilets (1982), Hall (1985), and Lee and Schonfeld (1991). The focus of these papers was on ground-to-ground transfer, especially for mass transit systems.

Although many aspects of air freight operations have been examined, prior research has not addressed the interaction between the arrival of incoming trucks and the processing of shipments, as is the focus of this paper. Hall and Chong (1993) did investigate queueing interactions for banked arrivals of aircraft at a hub terminal, with focus on aircraft-to-aircraft transfers, rather than ground-to-air transfers. In this case queueing appeared as a consequence of runway capacity, rather than sortation capacity.

Report Organization

The remainder of the report is divided into three principle chapters. Chapter 2 summarizes prior work (Hall, 2001), in which models were developed for predicting the arrival of work at a central terminal. Chapter 3 also summarizes prior work, in which models were developed for predicting the completion of sorting operations at a central terminal. Chapter 4 presents new research, including the design for the Truck to Air Dispatch (TAD) website and instructions on how to use the site for analyzing truck schedules and their impacts on package sorting at air terminals. Conclusions are provided in Chapter 5.

2. MODELS FOR ARRIVAL OF WORK

The air freight terminal is modeled as a work conserving single server queueing system. Work arrives in the form of truckloads of shipments, and is processed by a conveyor sorting line. The amount of work on a truck depends on the number of shipments and their characteristics. By definition, one unit of work can be processed in one unit of time. Trucks are scheduled to arrive at a reasonably constant rate with the goals of keeping the conveyor line productive and minimizing the queue of shipments awaiting processing. This section models the arrival process; the service process is examined later.

Let:

n = number of trucks scheduled for a sort

X_i = amount of work on truck i

$I_i(t)$ = 1 if truck i has arrived by time t , 0 otherwise

X_i and $I_i(t)$ are random variables that depend on the characteristics of the terminal sending shipments, distances, roadway speeds and congestion.

Measures of cumulative arrival of work can be derived from X_i and $I_i(t)$. Let:

$W_i(t)$ = work arrived by time t on truck i .

$W(t)$ = cumulative work arrived by time t , among all trucks

Then:

$$W_i(t) = \sum_{i=1}^n I_i(t) X_i \quad (1a)$$

$$W(t) = \sum_{i=1}^n W_i(t) = \sum_{i=1}^n I_i(t) X_i \quad (1b)$$

We first wish to compute the expectation of $W(t)$:

$$E[W(t)] = \sum_{i=1}^n E[I_i(t)X_i] \quad (2)$$

In the special case where $I_i(t)$ and X_i are mutually independent (arrival time is independent of load size), Eq. 2 reduces to:

$$E[W(t)] = \sum_{i=1}^n p_i(t) E(X_i) \quad (3)$$

Where:

$$p_i(t) = \text{probability that truck } i \text{ has arrived by time } t$$

Examples of $E[W(t)]$ are shown in Figure 1. Each figure represents 12 trucks, scheduled at 5 minute intervals beginning at time 0 and ending at time 55 (an arrival period of 55 minutes). The mean load size is 5 in each case. The actual arrival time is assumed to be normally distributed, with standard deviation shown ($\sigma = 0, 5$ minutes or 20 minutes). As illustrated, small σ produces a step pattern, with each step representing one scheduled arrival. But when σ is large relative to the spacing between scheduled arrivals, random deviations in arrival times smooth $E[W(t)]$. It can also be seen that the slope is most nearly constant when σ is also small relative to the arrival period (55 minutes in the example). For large values of σ (e.g., when it equals 20 minutes in the figure), curvature in $E[W(t)]$ extends well beyond the end points (times 0 and 55). By comparison the slope is nearly constant at the mean arrival rate of 1 (5 units of work per 5 minute interval) when $\sigma = 5$.

Variance calculations can be more complicated. Let:

$$\sigma_{ij}^2(t) = \text{covariance between } [I_i(t)X_i] \text{ and } [I_j(t)X_j]$$

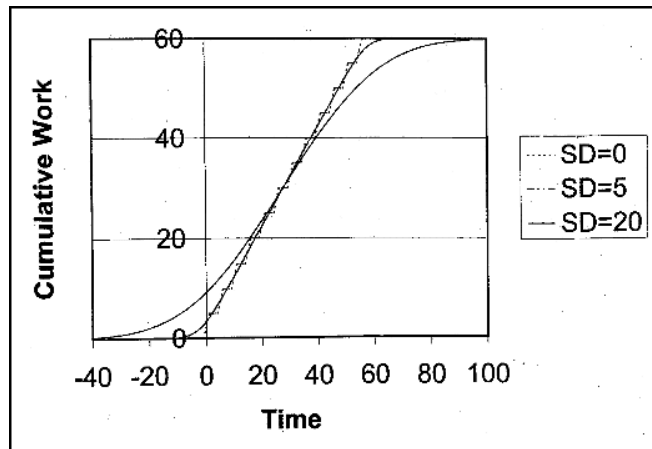


Figure 1. Effects of Arrival Time Standard Deviation on Expected Cumulative Arrival of Work

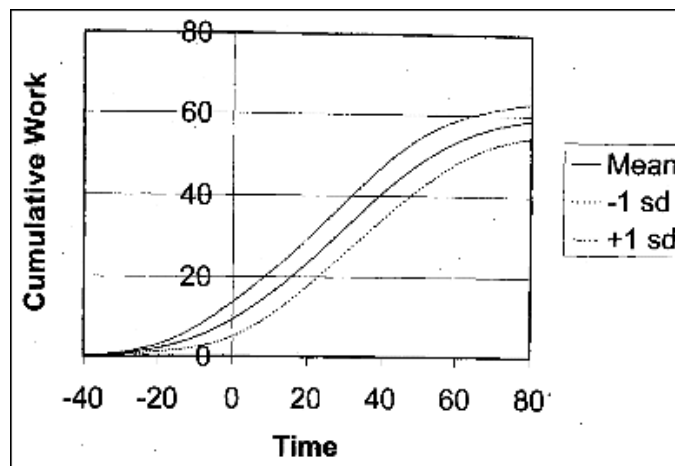


Figure 2. Expected Cumulative Arrival of Work ± 1 Standard Deviation ($\sigma_t = 5$; $\sigma_x = 0$)

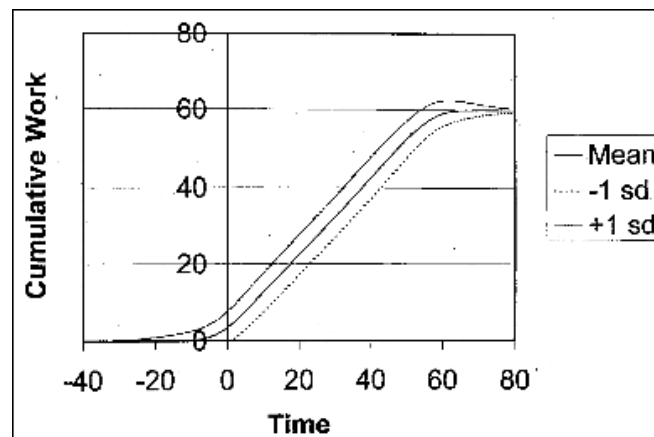


Figure 3. Expected Cumulative Arrival of Work ± 1 Standard Deviation ($\sigma_t = 20$; $\sigma_x = 1.25$)

Then:

$$V[W(t)] = \sum_{i,j=1}^n \sigma_{ij}^2(t) \quad (4)$$

Computation of the covariance terms can be difficult in this general case, as detailed data are frequently unavailable for estimation of parameters. Consider the special case where all random variables are mutually independent. Then the variance can be expressed as:

$$V[W(t)] = \sum_{i=1}^n p_i(t)[E(X_i^2) - p_i(t)E^2(X_i)] \quad (5a)$$

$$= \sum_{i=1}^n p_i(t)[V(X_i) + (1 - p_i(t))E^2(X_i)] \quad (5b)$$

Figures 2 and 3 illustrate two cases, again based on 12 trucks scheduled over a 55 minute interval, with normally distributed arrival times. Figure 2 is based on a standard deviation in arrival time (σ_t) of 5 minutes and a standard deviation in load size (σ_x) of zero. Figure 3 is based on a standard deviation in arrival time of 20 minutes, with a standard deviation in load size of 1.25. Each figure shows $E[W(t)]$, along with $E[W(t)] \pm$ one standard deviation. For very small values of t ($p_i(t) = 0$, for all i), $V[W(t)] = 0$, and for very large values of t ($p_i(t) = 1$, for all i), $V[W(t)]$ equals the sum of $V(X_i)$. The variance can be larger for intermediate values, and in some cases stays nearly constant in an intermediate range.

Model Extensions

The reality is that dependencies do exist among some of the variables $I_i(t)$. For instance, trucks that use the same route at similar times also experience similar travel

times as well as positively correlated arrival times (because they are exposed to similar levels of congestion). Accounting for these dependencies, but still assuming independence with respect to, and among, the X_i random variables:

$$\begin{aligned} V[W(t)] = & \left[\sum_{i=1}^n p_i(t) [E(X_i^2) - p_i(t) E^2(X_i)] \right. \\ & \left. + \left[\sum_{i \neq j} E(X_i) E(X_j) E\{I_i(t) I_j(t)\} - p_i(t) E(X_i) p_j(t) E(X_j) \right] \right] \end{aligned} \quad (6)$$

where

$$\begin{aligned} E\{I_i(t) I_j(t)\} &= P(T_i < t) P(T_j < t \mid T_i < t) \\ &= \int_0^t P(T_j < t \mid T_i) f(T_i) dT_i \end{aligned} \quad (7)$$

T_i and T_j are the arrival times of trucks i and j .

$f(T_i)$ is the probability density function for T_i .

If, for instance, travel times have a multivariate normal distribution, then

$$E\{I_i(t) I_j(t)\} = \int_{-\infty}^t \Phi \left[\frac{t - \mu_j - \rho(\sigma_j / \sigma_i)(T_i - \mu_i)}{\sigma_j \sqrt{1 - \rho^2}} \right] \Phi \left[\frac{T_i - \mu_i}{\sigma_i} \right] dT_i \quad (8)$$

where:

$$\mu_i = E(T_i)$$

$$\sigma_i = \text{standard deviation for arrival time of truck } i$$

$$\rho = \text{correlation coefficient between arrival times of truck } i \text{ and truck } j$$

As a practical matter, the usefulness of Eqs. 6-8 is limited by the availability of data to estimate model parameters. For this reason, the models provided in the following sections will be demonstrated with the simpler case of Eq. 5.

3. SORT STARVATION AND SCHEDULING

Shipments are processed on a belt sortation system, which operates at a constant rate (defined by the pre-determined belt speed). The sorting process is assumed to begin at a time τ , corresponding to the time employees arrive for work, and continue until all incoming work is processed. Without loss in generality, the maximum sort rate is assumed to be one unit of work per unit time, and the time of the first scheduled truck arrival equals zero. We assume that incoming loads arrive instantaneously, and that the sorting process continues at the rate 1 whenever work is queued, and the rate 0 otherwise. An example arrival and departure diagram is shown in Figure 4.

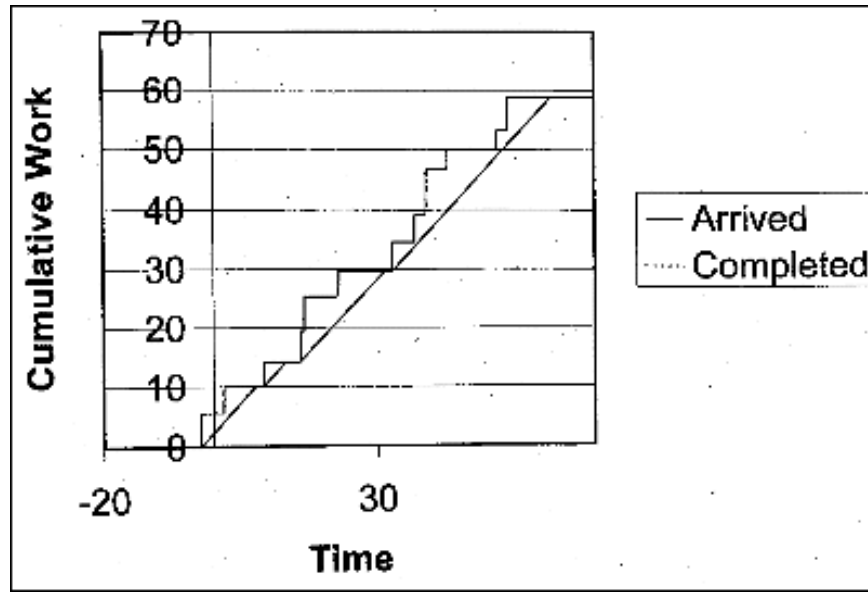


Figure 4. Example Realization of Sorting Process

Sort Completion Time

Let T represent a practical upper bound on the time when a truck could arrive at a given sort. Then the end time for the sort can be computed as:

$$\begin{aligned} \mathcal{A}(\tau) &= \text{end time of sort} \\ &= \tau + W(T) + S \end{aligned} \tag{9}$$

where S is the length of time that the sort is idled due to the absence of queued work. By making τ smaller, the expectation of $\mathcal{A}(\tau)$ can also be made smaller, thus allowing aircraft to depart earlier on average. However, because S is also a function of τ this effect is non-linear. In fact, as τ becomes small, $E[\mathcal{A}(\tau)]$ approaches a limiting value, which we denote by the sum $W(T) + S_0$. That is, when τ is sufficiently small, there is 0 likelihood that a truck will arrive earlier than τ , so reducing τ further has no effect on $E[\mathcal{A}(\tau)]$.

When τ is sufficiently large, $E(S)$ approaches 0, so $E[\mathcal{A}(\tau)]$ approaches $\tau + E[W(T)]$. Combining these two limiting cases, the following bound is created:

$$E[\mathcal{A}(\tau)] - E[W(T)] \geq \min\{S_0, \tau\} \tag{10}$$

The right-hand side of Eq. 10 can be viewed as the “excess end time,” meaning the amount that $E[\mathcal{A}(\tau)]$ exceeds the expected work, $E[W(T)]$. (For some distributions, it is possible for the excess end time to be negative.)

The performance of the sortation system depends on the rate at which work is scheduled to arrive, along with the start time of the sorting process. If work is scheduled

to arrive at a fast rate relative to the sort rate, then work is likely to queue, which has the benefit of minimizing idle time. But beyond a certain point there is little benefit in increasing the arrival rate, as the end time will be dictated by the sorting rate and start time (and not by arrivals). Thus, it may be acceptable to hold back some trucks, reducing pressure on processing shipments at origin terminals and possibly extending the cutoff time for pickup and drop-off of shipments. On the other hand, delaying the start time also reduces idle time (again, because work queues), but has the negative effect of extending the end time. Overall, a desirable design would be to pace the arrival of work to roughly match the sorting rate, and to schedule the start of the sort at a time that balances the objectives of maximizing productivity and minimizing the end time. System performance is further defined in the following.

Productivity: The productivity is represented by the amount of time that the sort is functioning (i.e., not idled due to the absence of work). To maximize productivity, it is desirable to schedule truck arrivals, and τ , such that S is made as small as possible. For instance, by increasing τ , a queue can be built prior to the start of the sort process, making idle time smaller. For a given realization of $W(t)$, the following relationship holds:

$$\frac{dS(\tau)}{d\tau} = \begin{cases} 1, & S(\tau) > 0 \\ 0, & S(\tau) = 0 \end{cases} \quad (11)$$

where $S(\tau)$ is the idle time for a random realization of the process with start time of τ .

That is, either there is idle time, in which case a change in τ causes slack to decrease by

an identical amount, or there is no idle time, in which case slack is unaffected by a delay in τ . It can also be concluded that:

$$dE[S(\tau)]/d\tau = -P[S(\tau)>0] \quad (12a)$$

$$E[S(\tau)] = \int_{-\infty}^{\tau} -P[S(\tau) > 0]dt \quad (12b)$$

where $P[S(\tau)>0]$ is the probability that the idle time (S) exceeds zero when the sort begins at time τ . It should be noted that for large τ , $dE[S(\tau)]/d\tau$ approaches 0 and for small τ , $dE[S(\tau)]/d\tau$ approaches -1 .

Expected Completion Time: The expected completion time is clearly a non-decreasing function of τ . For a given realization of $W(t)$, the following relationship holds:

$$\frac{d\varepsilon(\tau)}{d\tau} = \begin{cases} 0, & s(\tau) > 0 \\ 1, & s(\tau) = 1 \end{cases} \quad (13)$$

That is, either there is idle time, in which case a change in τ has no effect on the end time, or there is no idle time, in which case a delay in τ delays the end time by an identical amount. It can also be concluded that:

$$dE[\varepsilon(\tau)]/d\tau = 1 - P[S(\tau)>0] \quad (14a)$$

$$E[\varepsilon(\tau)] = \int_{-\infty}^{\tau} 1 - P[S(\tau) > 0]dt \quad (14b)$$

It can be noted that $dE[\varepsilon(\tau)]/d\tau$ equals $1+dE[S(\tau)]/d\tau$.

Percentile Completion Time: Aircraft are typically scheduled to depart at a set time that is held close to constant from day to day. To avoid unplanned schedule changes, the aircraft departure time must allow for a reasonable amount of slack, to cushion against random fluctuations in truck arrival times and truck load sizes. The performance can be measured from a percentile of the distribution for ε , which we denote ε_α , where α is the percentile. It should be noted that W and S tend to be negatively correlated (when work is large, slack tends to be small). Thus, an increase in τ may have a smaller effect on ε_α than on $E[\varepsilon(\tau)]$ (i.e., slack may be reduced on average, but reduced very little on the worst days, which define ε_α).

Simulations

We now present the results from a series of simulations in which system performance is estimated as a function of τ . The analysis compares different methods for determining τ , as follows:

- 1) $\tau = S_0$
- 2) $\text{Min}(\tau)$ s.t. $E(W(t)) - \sqrt{V[W(t)]} \geq (t - \tau)$, for all $T \geq t \geq \tau$
- 3) $\text{Min}(\tau)$ s.t. $E(W(t)) - 3\sqrt{V[W(t)]} \geq (t - \tau)$, for all $T \geq t \geq \tau$

For each value of τ , $E[\varepsilon(\tau)]$, $E(S)$ and ε_{95} are estimated. In addition, Eq. (15) is evaluated for values of $\alpha = .1, 1$ and 10 . These comparisons help determine whether any of the heuristics is sufficiently robust to produce a near-optimal solution for a variety of cases.

The evaluations were completed for a series of cases in which 12 trucks are scheduled to arrive over a 55 to 70 minute period, with 2.5 to 5 minute intervals between scheduled times. The cases are further defined by: (1) the standard deviation in truck

arrival times ($\sigma_t = 5$ or 10 minutes), (2) standard deviation of the load size ($\sigma_x = 1.25$ or .25), (3) the length of the time interval over which trucks arrive ($T = 55, 61$ or 70 minutes), (4) whether or not the scheduled interarrival times are constant. In the case of non-constant interarrival times, we evaluated a bi-modal pattern, where trucks are scheduled to arrive in two periods, each of length .5. The two periods are separated by a gap g during which no trucks are scheduled to arrive ($g = 6$ or 15 minutes). 50 trials were completed for each case, producing standard errors on the order of .3 minutes.

Table 2 presents results for six cases. It should be noted that the three methods result in a fairly tight range of values for average idle time, with Method 1 producing values between 1.6 and 5.7 minutes, Method 2 producing values between 1.1 and 6.4 minutes and Method 3 producing values between 1.1 and 4.6 minutes. It can be seen that Methods 2 and 3 are most conservative (i.e., produce smallest idle time) for the case where $T = 25$ minutes. This is because $E[W(t)]$ has a much larger slope than the 1, meaning that beyond the first few minutes there is little chance of idle time. Methods 2 and 3 are least conservative when $\sigma_x = .25$ minutes (a small value), as the slopes of $E[W(t)] - k$ standard deviations is most nearly constant and most nearly equal to 1, meaning that the sort can be idled at almost any time. In most cases, it appears that the solutions produced by the three methods bracket around the optimum for different values of α . In all of the cases, the 95th percentile for the end time of the sort is substantially larger than average – varying from about 10 to 15 minutes later.

Table 2. Comparison of Performance Measures with Differing Start Times

$\sigma_t = 5, \sigma_x = 1.25, T = 55, g = 0$					Objective Function		
Method	τ	$E(\varepsilon)$	$E(S)$	$\varepsilon_{.95}$	0.1	0.5	0.9
1	6	67.8	3.2	72.0	10.0	37.1	64.2
2	11	69.8	1.7	76.0	8.6	36.6	64.5
3	7	68.9	2.7	74.0	9.6	37.2	64.7

$\sigma_t = 10, \sigma_x = 1.25, T = 55, g = 0$					Objective Function		
Method	τ	$E(\varepsilon)$	$E(S)$	$\varepsilon_{.95}$	0.1	0.5	0.9
1	9	71.6	2.8	83.0	9.9	38.6	67.2
2	14	75.4	1.3	87.0	8.9	39.0	69.2
3	9	71.6	2.8	83.0	9.9	38.6	67.2

$\sigma_t = 10, \sigma_x = .25, T = 55, g = 0$					Objective Function		
Method	τ	$E(\varepsilon)$	$E(S)$	$\varepsilon_{.95}$	0.1	0.5	0.9
1	4	68.6	5.7	79.0	12.5	39.9	67.4
2	6	69.6	4.6	83.0	11.6	39.4	67.2
3	8	69.9	3.1	82.2	10.1	38.0	66.0

$\sigma_t = 10, \sigma_x = 1.25, T = 27.5, g = 0$					Objective Function		
Method	τ	$E(\varepsilon)$	$E(S)$	$\varepsilon_{.95}$	0.1	0.5	0.9
1	2	62.2	1.1	76.0	7.4	32.2	57.1
2	3	62.7	1.1	77.0	7.4	32.4	57.5
3	-2	60.4	2.6	75.0	8.6	32.8	57.0

$\sigma_t = 10, \sigma_x = .25, T = 61, g = 6$					Objective Function		
Method	τ	$E(\varepsilon)$	$E(S)$	$\varepsilon_{.95}$	0.1	0.5	0.9
1	10	73.4	4.2	84.0	11.5	40.9	70.2
2	15	75.4	1.6	86.0	9.1	39.3	69.4
3	15	75.4	1.6	86.0	9.1	39.3	69.4

$\sigma_t = 10, \sigma_x = .25, T = 70, g = 15$					Objective Function		
Method	τ	$E(\varepsilon)$	$E(S)$	$\varepsilon_{.95}$	0.1	0.5	0.9
1	18	83.4	6.4	96.0	14.7	48.1	81.5
2	23	86.0	3.7	98.0	12.3	46.6	81.0
3	19	83.5	5.7	92.0	14.0	47.5	80.9

4. WEB-BASED DECISION SUPPORT TOOL

The models developed in this paper for evaluating performance have been implemented as a web-based tool called Truck to Air Dispatch, or TAD (<http://ger309-pc16.usc.edu>). TAD follows these design concepts:

- The site contains a public section and a member-only section. The public section provides links to a variety of data sources related to air/ground shipments, including:
 - Real-time traffic (freeway speeds, lane closures, traffic incidents, directions, traffic information from other regions).
 - Real-time weather.
 - Real-time aviation, including airport delays.
 - Associations and organizations that are involved in air and truck freight shipments.
 - Airports.
- The member section is open to any individual. The individual who establishes the account acts as the account manager and represents an airport terminal. The member can permit additional users to access and edit terminal data. These users may represent local terminals, from where trucks depart for the airport. In this manner, data can be communicated among participants.
- Data can be easily edited to represent “today’s schedule,” or to represent a planned, or “normal”, schedule.

- Real-time data are generated to predict the arrival of work (i.e., shipments needing sorting) at the airport terminal. Data are presented both in tabular and graphical formats.
- “What-if” capability is provided, so the user can easily evaluate the effects of changing the start time for a sort, or changing the processing rate for a sort.

A basic goal for the design is to provide a user-friendly interface, and a “one-stop-shopping” location to access a variety of information relevant to ground and air transportation.

Figure 5 diagrams the site organization, showing six basic functional areas, and an expanded view of the Member Area. Our focus has been on the Member Area, which is explained in the following sections.

Design Methodology – Member Area

The Member Area is limited to registered users as a means for protecting the confidentiality of user entered data. Immediately after a “New User” form is entered, a new user account is created and an email notification is sent to the user’s email address. This permits the user to enter the Member Area, which provides various functions. Figure 6 provides an overview of the workflow in the Member Area. We now explain how the functions are performed, beginning with the database.

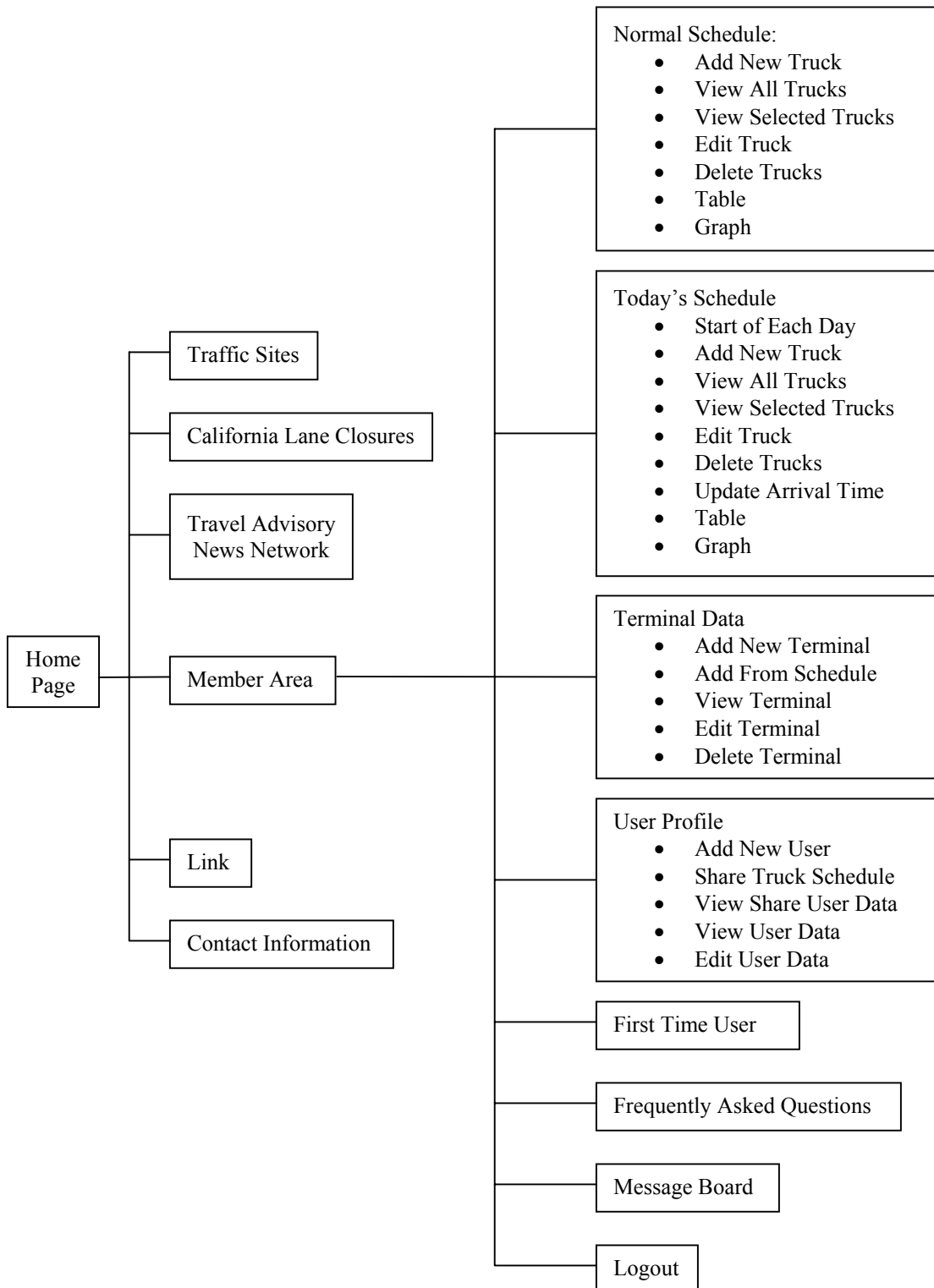


Figure 5. TAD Site Organization

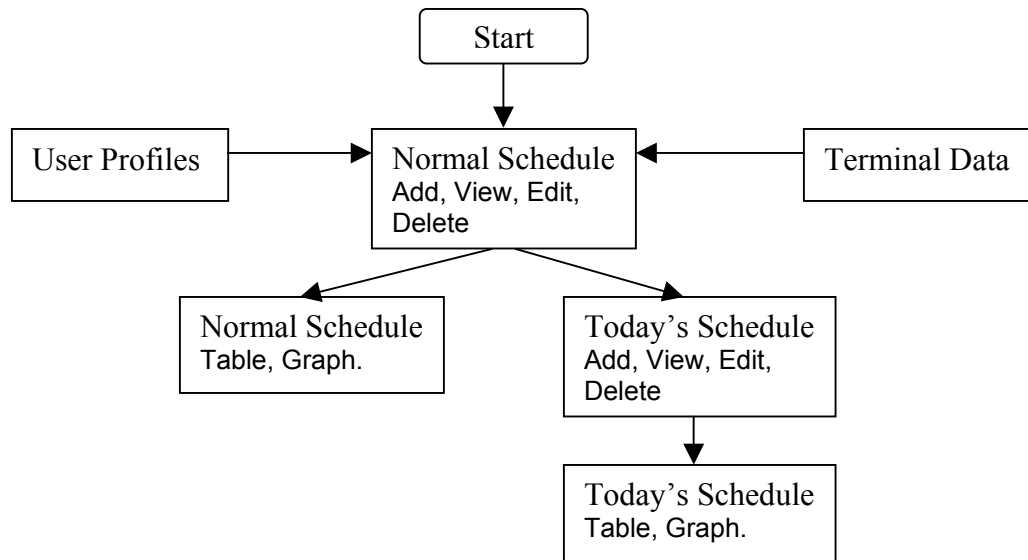


Figure 6. Member Area Workflow Diagram

Database Structures Within the Member Area, users can populate four databases; one database is automatically generated, and two are static, created by the developers. All databases are created in MS Access. The four user-populated databases are:

Normal truck schedule database for storing planned truck schedules.

Today's truck schedule database for storing temporary changes in the truck schedule.

Terminal database for storing a terminal's physical address.

User profiles database stores user information.

The database structures for Normal Schedule and Today's Schedules are the same (Figure 7). Each record represents an individual truck that is scheduled to travel from a

particular terminal to a particular airport, for a particular sort, with given departure and arrival times. These data are represented in 14 fields:

ID:	an automatically generated ordered record number
USER:	user ID
AIRPORT:	name of destination airport
SORTNAME:	name of the terminal sort
DAY:	days of week
TRUCKNO:	truck number
TERMINAL:	name of the origin terminal for the truck
DEPTIME:	scheduled departure time for the truck
ARRTIME:	scheduled arrival time for the truck
LOADSIZE:	load size for the truck
R1:	the first freeway where the truck enters the highway
R2:	entrance where the truck enters the highway
ODTIME	convert departure time from natural time into a time line system, from 1 to 1440 minutes (24 hours).
OATIME	convert arrival time from natural time into a time line system, from 1 to 1440 minutes (24 hours).

The terminal database is simpler (Figure 8). Each record represents an individual terminal, and there are nine data fields: ID, USERNAME, TERMINALNAME, ADDRESS, CITY, STATE, ZIP, PHONE, and REMARK, which are self explanatory. “REMARK” is used at the discretion of the user to enter comments on a terminal. When a new terminal is entered in the normal schedule database, a record is automatically generated in the terminal database, which the user can later populate with supplemental information (address, phone number, etc.).

The user profile database is also simple (Figure 9), and contains the fields: ID, NAME, ADDRESS, PHONENUMBER, EMAIL, AIRLINE, USERNAME, PASSWORD and SUPERIOR. The last field, SUPERIOR, is used to store the relationship between this user and other users. If the user is the root in the group, then a “0” is assigned to this field. Otherwise, this field is assigned a user ID that created the user account and that can share his/her truck schedules with this user.

The automatically generated database maintains information on real-time traffic. Each record represents the state of an individual loop detector, and the database contains three fields (Figure 10):

ID:	ordered number from 1 to 1510
VDS_ID	Caltrans detector identification number
SPEED:	Latest speed acquired for the loop detector

routetable : Table													
ID	USER	AIRPORT	SORTNAME	DAY	TRUCKNO	TERMINAL	DEPTIME	ARRTIME	LOADSIZE	R1	R2	ODTIME	OATIME
214	demo	LAX	Memphis	Monday-Friday	1	Olympic	1730	1800	1000	14	5395	1050	1080
215	demo	LAX	Memphis	Monday-Friday	2	Burbank	1720	1810	1250	2	665	1040	1090
216	demo	LAX	Memphis	Monday-Friday	3	Norwalk	1725	1805	1500	2	635	1045	1085
217	demo	LAX	Memphis	Monday-Friday	4	Cerritos	1740	1810	750	21	7974	1060	1090

Record: 1 of 93

Figure 7. Normal Schedule Database in DB View

terminaltable : Table									
ID	USERNAME	TERMINALNAME	ADDRESS	CITY	STATE	ZIP	PHONE	REMARK	
106	demo	Olympic	Olympic	Los Angeles	CA	90015	N/A		
107	demo	Burbank	Burbank	Los Angeles	CA	90015	N/A		
108	demo	Norwalk	Norwalk	Los Angeles	CA	90015	N/A		
109	demo	Cerritos	Cerritos	Los Angeles	CA	90015	N/A		

Record: 30 of 40

Figure 8. Terminal Database in DB View

usertable : Table									
ID	NAME	ADDRESS	PHONENUMBER	EMAIL	AIRLINE	USERNAME	PASSWORD	SUPERIOR	
41	DEMO	DEMO	DEMO	shihchel@hotmail.com	DEMO	demo	demo	0	

Record: 1 of 17

Figure 9. User Profile Database in DB View

Realtime : Table			
	ID	VDS_ID	SPEED
	1	715898	65.38
	2	715915	48.79
	3	715918	54.91
	4	715921	63.19
	5	715922	69.51
	6	715929	71.74
	7	715930	52.6
	8	715933	66.41
	9	715938	75.53
	10	715944	71.99
	11	715947	61.8
	12	716010	60.96
	13	716016	60.89
	14	716017	62.02
	15	716028	58.02
	16	716032	55.96
	17	716036	56.42

Record: 1 of 1510

Figure 10. Real-time Database in DB View

The static databases provides information on loop detectors, highway entrances and routes. Figure 11 shows the database structure for the freeway entrance in Los Angeles area. There are six fields in this database:

ID: an automatically generated ordered record number

ENTRANCE: a unique number assigned to the entrance

NAME: name of the freeway entrance

DISTANCE: distance from freeway entrance to nearest Single Loop Detector (VDS) in the direction to LAX

VDS_ID: ID for nearest Single Loop Detector

ROUTE: freeway ID for the entrance

Figure 12 shows the database structure for VDS, which gives the locations of single loop detectors in freeway in Los Angeles area, and the routes to the airport. There are eight fields in this database:

ID: an automatically generated ordered record number

VDS_ID: ID the Single Loop Detector

FREEWAY_ID: ID for the freeway

DIRECTION: flow directions for Single Loop Detector in freeway

CAL_POSTMILE: California post mile for Single Loop Detector

ABS_POSTMILE: Absolute post mile for Single Loop Detector

DISTANCE: distance from this Single Loop Detector to next Single Loop Detector in the direction to LAX

NEXT_VDS: next Single Loop Detector ID in the direction to LAX, which defines the route

LAXEXIT : Table						
	ID	ENTRANCE	NAME	DISTANCE	VDS_ID	ROUTE
	450	675	PANORAMA CITY, OSBORNE STREET	0.11	715996	5
	451	676	PAICOMA, TERRA BELLA STREET	0.12	717006	5
	452	677	PAICOMA, VAN NUYS BOULEVARD	0.16	759228	5
	454	679	MISSION HILLS, BRAND BOULEVARD	0.2	759822	5
	455	680	MISSION HILLS, MISSION BOULEVARD	0.07	759835	5
	457	682	SYLMAR, ROXFORD STREET	0.23	759858	5
	461	686	ROUTE 5 S. SYLMAR,	0.32	718405	5
	469	694	SANTA CLARITA, CALGROVE BOULEVARD	0.23	759870	5
	470	695	SANTA CLARITA, LYONS AVENUE	0.17	759888	5
	471	696	SANTA CLARITA, MC BEAN PARKWAY	1.34	759888	5
	472	697	SANTA CLARITA, VALENCIA BOULEVARD	2.33	759888	5
	474	699	SANTA CLARITA, RYE CANYON ROAD	0.76	759914	5
	476	701	HASLEY CANYON ROAD	2.4	716017	5
	477	702	PARKER ROAD	2.25	759927	5
	478	703	VIOLIN CANYON/LAKE HUGHES ROADS	2.73	759927	5
	479	704	TEMPLIN HIGHWAY	0.27	759942	5
	481	706	SMOKEY BEAR ROAD	0.26	763636	5

Record: 1 of 498

Figure 11. Freeway Exit Database in DB View

LAXML : Table								
	ID	VDS_ID	FREEWAY_ID	DIRECTION	CAL_POSTMIL	ABS_POSTMIL	DISTANCE	NEXT_VDS
	5	716409	105	W	2.6	2.6	0.8	716407
	6	760426	105	W	3.3	3.3	0.7	716409
	7	716413	105	W	4	4	0.7	760426
	8	760440	105	W	4.5	4.5	0.5	716413
	9	760452	105	W	4.8	4.8	0.3	760440
	10	716420	105	W	5.5	5.5	0.7	760452
	11	716422	105	W	6	6	0.5	716420
	12	760473	105	W	6.5	6.5	0.5	716422
	13	760481	105	W	6.81	6.81	0.31	760473
	14	716426	105	W	7.1	7.1	0.39	760481
	15	716428	105	W	7.8	7.8	0.7	716426
	16	760496	105	W	8.2	8.2	0.4	716428
	17	716434	105	W	8.4	8.4	0.2	760496
	18	760512	105	W	8.8	8.8	0.4	716434
	19	716437	105	W	9.5	9.5	0.7	760512
	20	760535	105	W	10.1	10.1	0.6	716437
	21	716441	105	W	10.5	10.5	0.4	760535

Record: 1 of 691

Figure 12. VDS Database in DB View

Retrieving Real-time Data The PATH Performance Measurement System (PEMS) FTP site is the source for real-time traffic data. (PEMS independently acquires data from Caltrans). When requested by the user, data are transferred to the TAD website with an FTP client, which was created for our web server using Borland C++ Builder. Next, the PEMS file is decompressed. We used a standard gzip program to decompress the file from UNIX (PEMS) to our Windows operation system environment. After the decompress process is complete, we obtain an ASCII text file that contains the real-time information. Then, we extract relevant data from the ASCII text file (e.g., data from outside the region are discarded), and store the data in our Access database, writing over old data. The total time to complete those steps is about 30 seconds.

Real-time Performance To calculate the real-time performance of the airport terminal, truck arrival times must first be estimated. While PEMS is being designed to provide real-time predictions through its website, this capability will not be available through the PEMS FTP site. Therefore, TAD must product its own estimates.

For each highway origin, a normal route is stored in the TAD system, which corresponds to a sequence of loop detectors. Each detector represents a highway segment, with a given length and a current speed. The travel time over the segment is simply the ratio of segment length to speed. In the event of missing data (i.e., a non-functioning detector), the length of an adjacent detector's segment is increased to cover the missing data segment. The estimated travel time equals the sum of the segment travel

times, plus a nominal off-freeway travel time (for which real-time data are unavailable). The arrival time is the sum of the planned departure time and the calculated travel time.

The Ph.D. student working on this project will, in the future, develop improved algorithms for arrival time estimation, accounting for historical trends and current system state. As part of his thesis, he will incorporate methods based on fuzzy logic in TAD.

In addition to these calculations, users are permitted to alter “today’s schedule”, which also affects the real-time calculations. For instance, users can delete trucks, add trucks, change truck departure times or change truck load sizes. These changes could represent unpredictable delays (e.g., delays in feeder truck arriving at a local terminal, or delays in sorting) or represent planned changes (e.g., a truck that is deliberately released early or late). These real-time updates, entered by users, are all reflected in predictions for terminal performance.

Output Generation Program output is generated in both tabular and graphical forms. Both show when trucks are predicted to arrive for a given sort at a given airport, the cumulative arrival of shipments and cumulative processed shipments. They also provide predictions for when the sort will be completed, and provide “what-if” capabilities, with respect to sort rate and sort start time. The calculations are based on the methods presented in Chapter 2.

Output graphs are generating by Java Applet, using Java 2 as our programming environment. The size of the applet is 600×400 dots. The actual size of the graph is 450×300 dots. A white line represents the cumulative arrival of loads and a green line represents cumulative processed loads. The sort start time, finish time, rate and total

shipments processed are also displayed numerically at the top of the page. Users can alter the start time and processing rate by entering the “Reschedule Parameters” at the bottom of the page. A new graph is then created with these parameters.

Identical display formats are provided for the normal schedule and the today schedule. An additional option provides an alternative format, showing expected arrival of work $\pm$ one standard deviation, and expected completion of work for each of these arrival patterns. This graph accounts for variability in truck arrival times at the airport, and is based on Equation 5, with a normal arrival time distribution, identical standard deviations for truck arrival times, and a standard deviation in truck load size equal to 10% of the mean.

TAD Usage

Before entering the member portion of TAD, users must first create their user profile, entering their name, password, email address, airline, address, and phone number. The initial user for an account is automatically the account administrator. Only the administrator can add users to an account, using TAD’s Add New User function. For instance, the account administrator may represent the airport terminal, and additional users may represent local terminals. By adding users, TAD can enable local terminal operators to communicate current information on truck departure times and load sizes to other users and the airport.

Populating and Managing the Normal Schedule Before engaging the analysis features of TAD, users must first create their normal truck schedule. The normal schedule is the

planned schedule for a truck, as applied to a particular day of week or group of days (e.g., Monday to Friday or Monday to Thursday). The planned schedule should stay fairly constant over extended periods, so these data only need to be altered when the planned schedule is updated.

Users can view all truck schedules at the same time (in one page) or they can set search conditions to view only selected trucks in the View Selected Trucks page. Once entered, data can be edited through the Edit Truck page, or deleted through the Delete Trucks page.

Management of Today's Schedule The Today's Schedule represents one-day changes to schedules, for instance if an additional truck is needed, a departure time is delayed or expedited, or load size differs from normal. Changes to Today's Schedule do not affect the Normal Schedule.

At the start of each day, the administrator (initial user) should click Start of Each Day to reset Today's Schedule to the Normal Schedule. The program automatically determines which trucks are scheduled to operate each day, so it only duplicates relevant trucks from the normal truck schedule. At the same time, TAD calculates the estimated travel time for each truck based on current traffic conditions.

Users can view all truck schedules at the same time (in one page) or users can set search conditions to view selected trucks. Users can then edit Today's Schedule through the Edit Truck page or Delete Trucks page without altering the normal schedule. These changes are automatically erased when the user selects Start of Each Day, mentioned earlier.

Management of Terminal Data Terminal Data are stored in the Terminal Database.

These data do not directly affect calculations. They are used to provide a record of where terminals are located, and how to contact the terminal, so that information can be shared more effectively among users on a given account. When a terminal is entered in the normal schedule, a record is automatically added to the terminal database, but the user must later enter supplemental information to completely populate the record.

Output: Graphs and Tables Tables and graphs are used to evaluate the schedule performance at the airport. The output table shows detailed truck schedules, sequenced in order of arrival at the airport. The table is most useful in tracking the arrival of individual trucks. Arrival Time, Truck Number, Terminal Name, Load Size, Cumulative Load Size, and Processed Load Size are all listed. Start Time, Finish Time, Rate, and Total Processed are shown at the top of the page. Users can change the Start Time and Processing Rate by filling the Reschedule Parameters at the bottom of the page, and a new table will be created with the parameters. A graph can also be generated to obtain a high-level view of terminal performance. The graph shows whether the terminal is likely to starve for lack of work, and when the accumulation of work is likely to be largest.

Example Showing How to Use TAD

The TAD website can be accessed from the address:

<http://128.125.27.141/> or

<http://ger309-pc16.usc.edu/>

In the top frame of the home page, you will see a set of links to TAD's basic functions:

Home	home page
Traffic Sites	page linking to a variety of sources for real-time traffic information
Member Area	management and analysis of member-specific data
California Lane Closures	current lane closures in California, as reported by Caltrans
Traveler Advisory News Network	real-time traffic conditions map for Southern California
Links	links page, connecting to: airports, general information and magazines, transportation research sites, real-time aviation information, real-time weather, governmental agencies and transportation associations.
Contact Information	contact to the TAD site administrator

Select "Member Area" at the top of the content window, and then select "Register" to create a new account. The Register New Account window (Figure 13) will then appear.

TAD: Truck-to-Air-Dispatch - Microsoft Internet Explorer provided by University of Southern California

File Edit View Favorites Tools Help

Back Forward Stop Search Favorites History Links Yahoo! Google

Address http://ger309-pc16.usc.edu/ Go

Truck to Air Dispatch

Home | Traffic Sites | Member Area | California Lane Closures

Travel Advisory News Network | Links | Contact Information

Register New Account

UserName* demo

Password* AAAAA

Confirm Password* AAAAA

Email* demo@ger309-pc16.us

Company DEMO

Name DEMO

Address DEMO

Phone Number DEMO

(Fields with * are required!)

Submit Reset

Figure 13. Register New Account Window

Fill in the data and click the “Submit” button, and the account will be created immediately. Also, an email notification will be sent to the registered email address for confirmation. Be sure to remember both your user name and password for future access.

Alternatively, for demonstration purposes, login under the user name “demo” and password “demo.” This will enable you to access sample data, for the purpose of learning how to use TAD. Note that users are automatically logged out after 20 minutes if no actions are taken.

Options Menu After entering the Member Area, you will see three frames (Figure 14).

The top frame is our open gallery, which appear on all TAD pages and provides links to

all of TAD's basic functions. The left frame is our Options Menu that links to all functions in the Member Area. The options menu will always appear in the Member Area of the site, but cannot be viewed outside of the Member Area. The right frame is our content window. After clicking any link in the left frame, the results will appear in the right frame.

There are four major categories in our Options Menu: Normal Schedule, Today's Schedule, Terminal Data, and User Profile. Click the "cross" icon to expand any category and click the "minus" icon to compact a category. In addition to the major categories: First Time User provides information for the first time users; FAQs contains several frequently asked questions in Q & A format; Message Board is a place to leave messages and report bugs; Logout is the means for leaving the member area.

If you have not yet entered data, and are not using the "demo" option, several of the option links will be disabled (e.g., edit truck or delete truck). Once data are entered, all options will appear and can be selected.

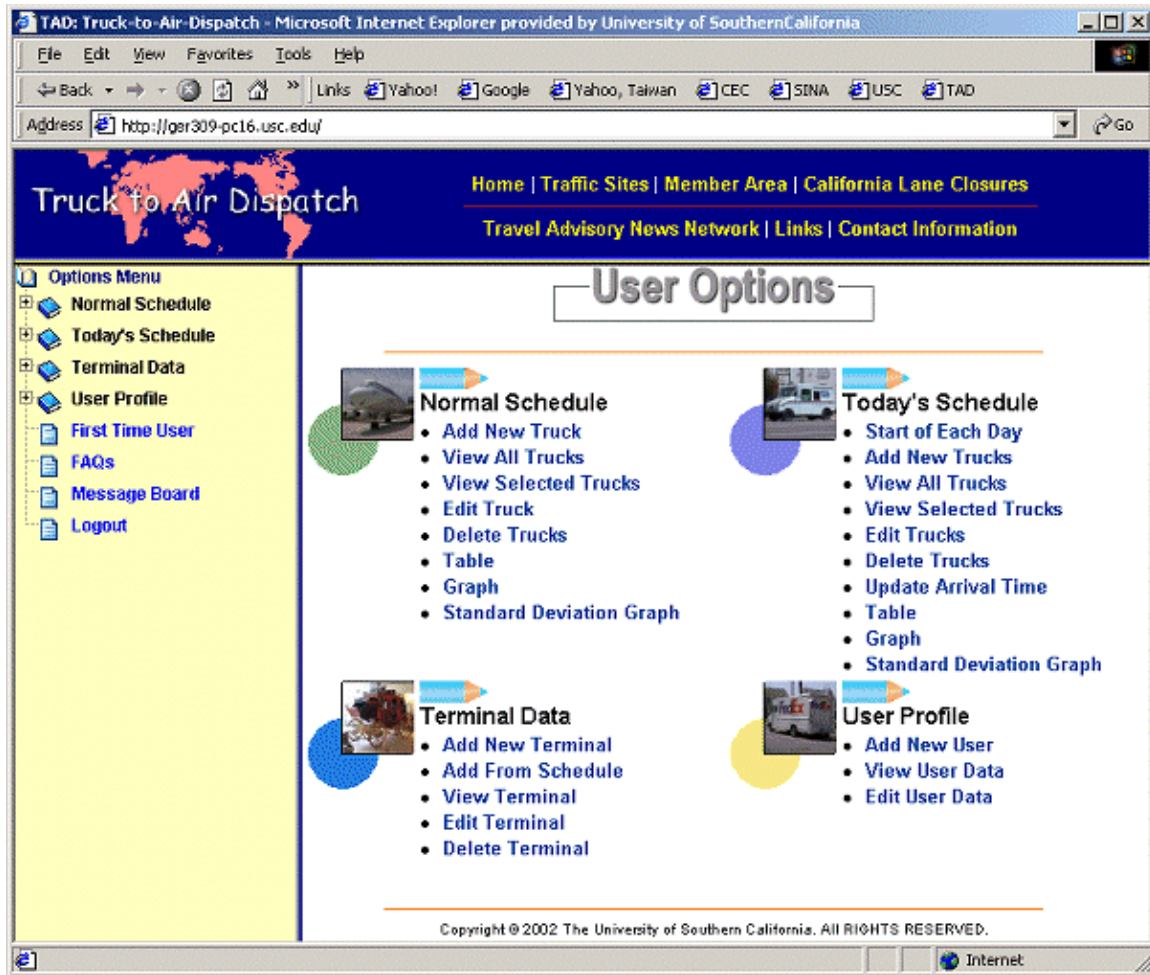


Figure 14. Options Menu

Normal Schedule Entry Click the “cross” icon in front of Normal Schedule to expand the links for Normal Schedule. Then click Add New Truck to access the data entry page (Figure 15). Data are entered in the following order, as explained for the example below:

1. Destination airport is shown first, and LAX is selected from a pull-down menu.
2. Memphis is selected from a pull-down menu as the truck’s sort (alternatively, a new sort name can be entered). When a new sort name is entered, it will be added automatically to the pull-down menu for future trucks.

3. “Monday-Friday” is selected from a pull-down menu as the “Day of Week” for the truck’s operation (either individual days or groups of days can be selected).
4. Truck number is entered (“1”), which corresponds to the carrier’s internal truck numbering system.
5. “Olympic” is entered as the departure terminal name, which is copied to both the Normal Schedule Database and the Terminal Database. Once a terminal name is entered, it will appear in the future on a pull-down menu when a new truck is added to the schedule.
6. 17:30 is selected as the departure time for the truck (note: use military time)
7. 18:00 is selected as the planned arrival time for the truck.
8. 1000 is entered as the load size. TAD can use any units of measurement for shipments, as long as they are consistent for all trucks.
9. I-110 is selected as the beginning freeway from a pull down menu. This is the first freeway visited on the route to the airport.
10. “Los Angeles Olympic Blvd” is selected as the location where the truck enters the freeway.

After completing these steps, click on Save Data to save the data in the Normal Schedule Database. Repeat these steps for each truck until all trucks have been stored in the database. At any point, go to View All Trucks (Figure 16) to review the entire truck schedule or use View Selected Trucks to display specific truck schedules. To correct errors, select the Edit Truck page to make any changes. Operations for editing are shown in the following section.

Add New Truck

Airport Name LAX (All fields are required.)

Sort Name or Memphis

Day of Week Monday-Friday

Truck Number 1

Terminal Olympic or

Departure Time HH: 17 MM: 30

Arrival Time HH: 18 MM: 00

Load Size 1000

Beginning Freeway 110

Freeway Entrance LOS ANGELES, OLYMPIC BOULEVARD



Figure 15: Add New Truck Page

View All Trucks

AIRPORT	SORTNAME	DAY	TRUCKNO	TERMINAL	DEPTIME	ARRTIME	LOADSIZE	Freeway	Entrance
LAX	Memphis	Monday-Friday	1	Olympic	1730	1800	1000	110	LOS ANGELES, OLYMPIC BOULEVARD
LAX	Memphis	Monday-Friday	2	Burbank	1720	1810	1250	5	BURBANK, BURBANK BOULEVARD
LAX	Memphis	Monday-Friday	3	Norwalk	1725	1805	1500	5	NORWALK, NORWALK BOULE= VARD/SAN ANTONIO DRIVE
LAX	Memphis	Monday-Friday	4	Cerritos	1740	1810	750	605	CERRITOS, DEL AMO BOULEVARD

Figure 16. View All Trucks Page

Normal Schedule Editing It is easy to update the normal schedule. Go to the Edit Truck page and all truck schedules will be shown. Click the circle in the Check column, and then select Edit. An edit page will then appear in the same format as the Add New

Truck page. Make any needed changes, then click Save Data and the data will be updated in the database.

Editing Today's Schedule To make changes in the schedule for today only (not saved for the future), select the Today's Schedule option. If this is the start of the day (i.e., no changes have already been entered for today), click Start of Each Day to transfer normal schedule data to today's database. A warning page will be displayed in the right frame indicating that all data from the previous day will be replaced by the normal schedule. Click OK, then wait several seconds for the data to be updated, as real-time arrival times will also be estimated. A message will appear when the process is finished.

You can now use the add, view, edit, and delete functions in the same manner as for the Normal Schedule. At any time, click Update Arrival Time to retrieve the latest real-time data and recalculate arrival time for every truck. There is a warning page first, then a message will show that the operation is complete.

Predicting Terminal Performance Both a table and a graph are provided for evaluating schedule performance. All estimates in Today's Schedule are based on current traffic conditions. Here we show how the changes will affect the output table in Normal Schedule.

After clicking Table under Normal Schedule, a three-row selection will appear in the right frame (Figure 17). Select an airport, sort name, and day of week, and then click See Schedule to view the table (Figure 18). When viewing the Today's Schedule table, the day of week is automatically assumed to be today.

Click Graph to view a cumulative graph of truck arrivals and work completion (Figure 19). The truck arrivals appear as a step curve, with each step representing the arrival time and load size of one or more trucks. The work completion is also shown, based on the user entered processing rate, the start time for the sort, and the cumulative truck arrivals. The separation between the two curves represents the queue of shipments waiting to be processed. When the queue drops to zero, the sorting process must slow down or shut down, for lack of work. Thus, if truck arrivals are delayed sufficiently, the sort finish time will also be delayed.

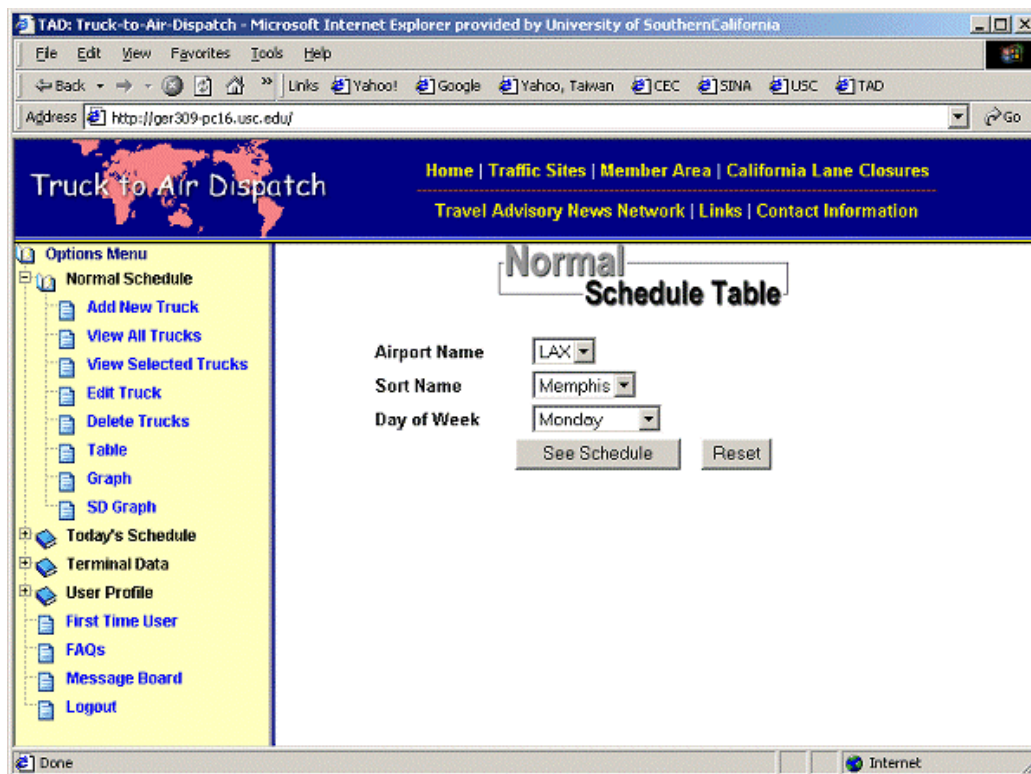


Figure 17. Window for Selecting Normal Schedule Output Table

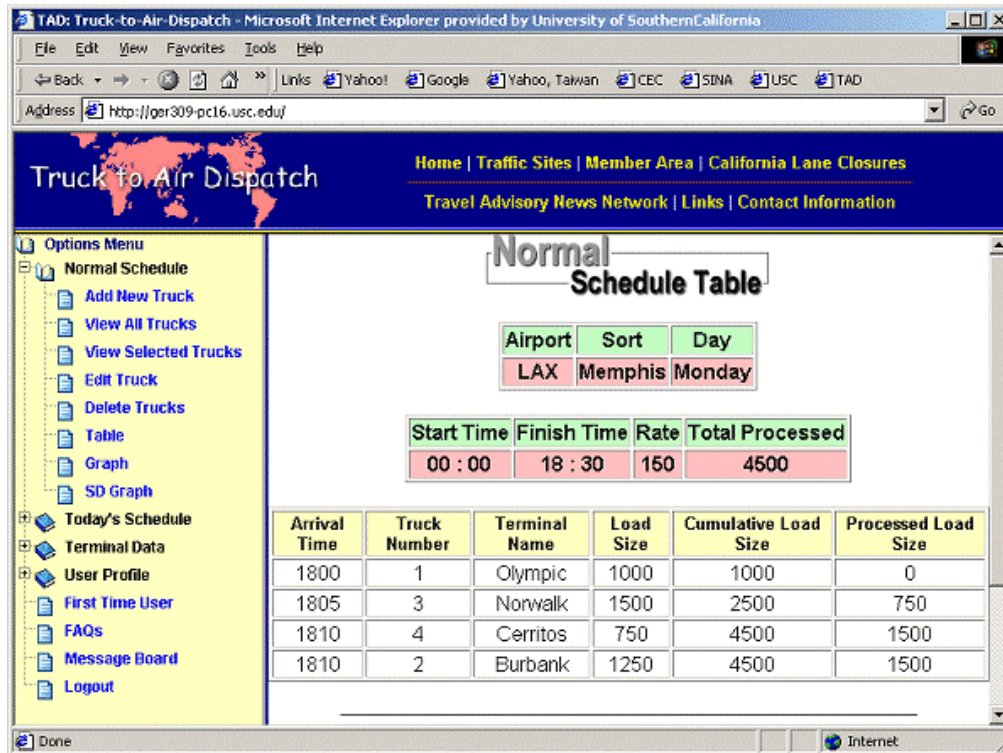


Figure 18. Output Table for Normal Schedule

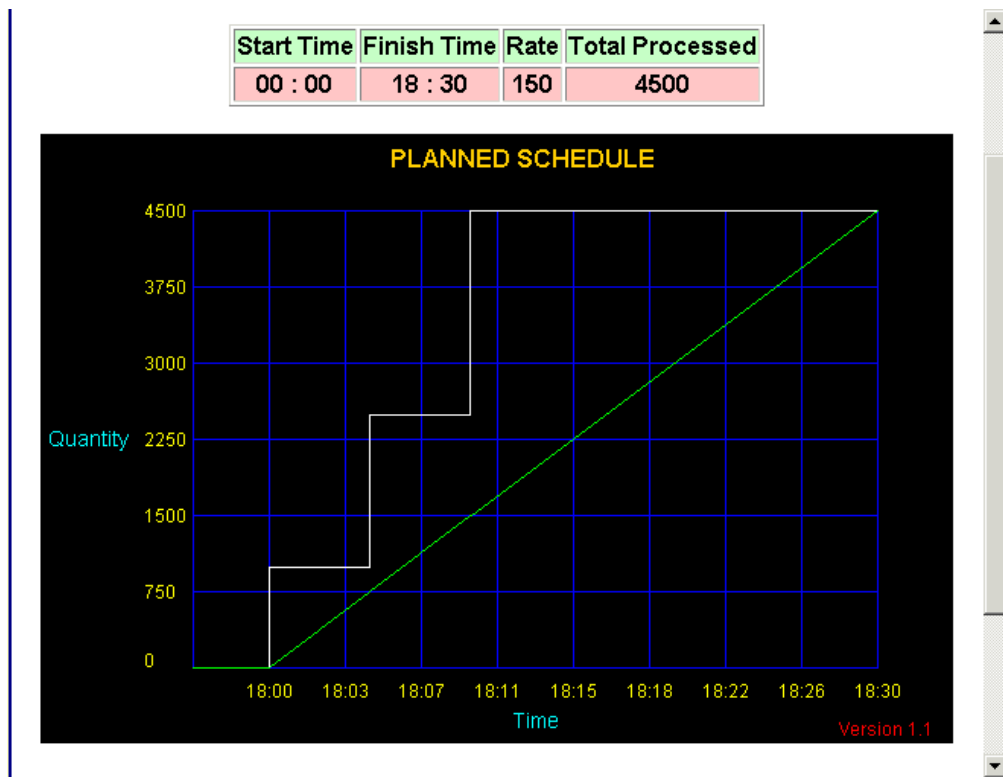


Figure 19. Output Graph for Normal Schedule

Now click SD Graph to view the standard deviation graph, which accounts for the variability in truck arrival times and load sizes (Figure 20). Six curves are shown, representing:

$A_{+\sigma}(t)$ = expected arrival of shipments, plus one standard deviation

$A(t)$ = expected arrival of shipments

$A_{-\sigma}(t)$ = expected arrival of shipments, minus one standard deviation

$P_{+\sigma}(t)$ = expected processed shipments, based on $A_{+\sigma}(t)$

$P(t)$ = expected processed shipments

$P_{-\sigma}(t)$ = expected processed shipments, based on $A_{-\sigma}(t)$

These curves do not exhibit a step pattern, as the precise truck arrival times are not known with certainty. As a default, the standard deviation in truck arrival time is set at 8 minutes, but this value is easily changed with the slide bar located below the graph (see what-if analysis section).

The graph shows a 10 minute range for the completion of the sort, varying from 6:30 to 6:40 p.m., based on the $\pm$ one standard deviation variation (by contrast, the prior prediction was that work would be completed at 6:30). This result is typical in that the deterministic (non-variable) prediction is optimistic.

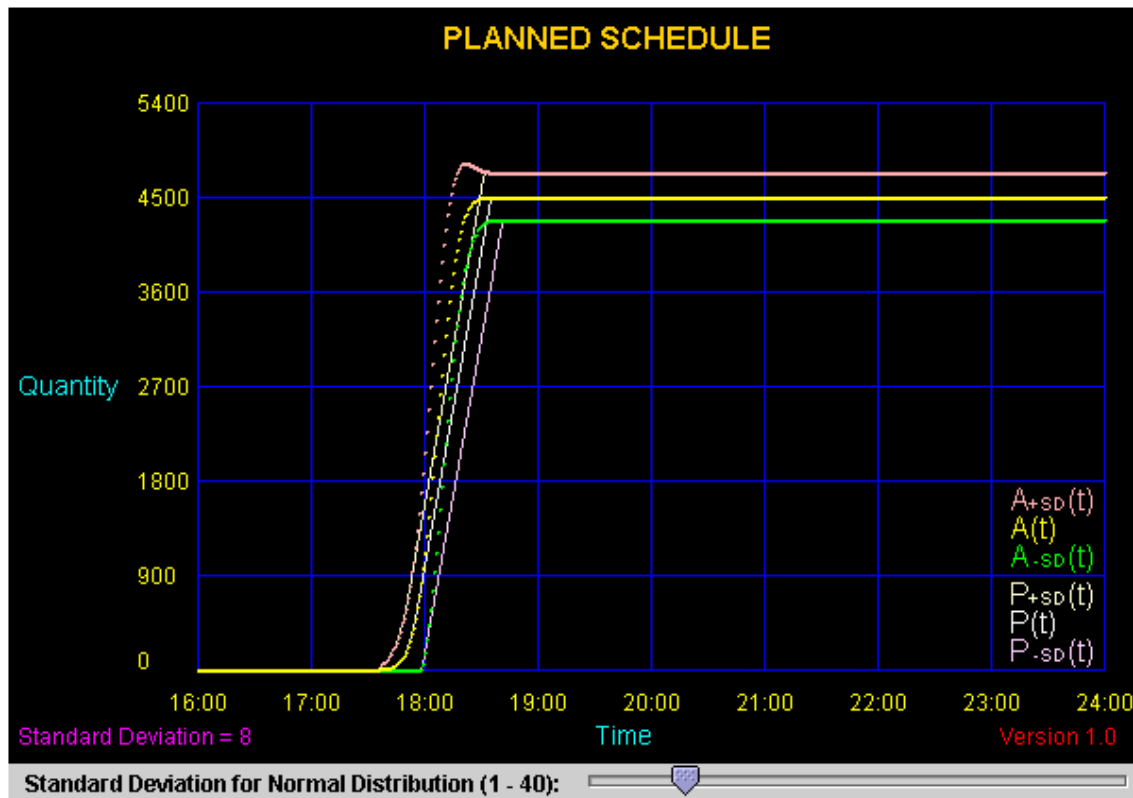


Figure 20. Standard Deviation Graph

What-if Analysis

Different types of what-if analyses are possible. Data may be changed for individual trucks, or data may be changed for the terminal sorting rate and start time. This section demonstrates these capabilities using the data found under the “demo” user name.

Editing Truck Data_Editing is illustrated by example. First, click Edit Truck, then select truck number 4, and then click Edit (Figure 21).

Edit Truck

Select One Truck to Edit:

Check	AIRPORT	SORTNAME	DAY	TRUCKNO	TERMINAL	DEPTIME	ARRTIME	LOADSIZE	Freeway	Entrance
☐	LAX	Memphis	Monday-Friday	1	Olympic	1730	1758	1000	110	LOS ANGELES, OLYMPIC BOULEVARD
☐	LAX	Memphis	Monday-Friday	2	Burbank	1720	1842	1250	5	BURBANK, BURBANK BOULEVARD
☐	LAX	Memphis	Monday-Friday	3	Norwalk	1725	1755	1500	5	NORWALK, NORWALK BOULEVARD/SAN ANTONIO DRIVE
☒	LAX	Memphis	Monday-Friday	4	Cerritos	1750	1812	750	605	CERRITOS, DEL AMO BOULEVARD

Internet

Figure 21: Edit Truck Schedule, with Truck 4 Selected

Suppose that, based on real-time data, we have discovered that the truck will arrive late at the airport. To avoid delays in completing the sort, we would like to instruct the terminal to dispatch the truck earlier than normal. To determine when the truck should be dispatched, we test a new departure time, changing the initial value from 17:50 to 17:40 (Figure 22). Next, Update Arrival Time is clicked to acquire the latest real-time traffic conditions. Last, a new graph is generated (Figure 23). By comparing this new graph to the old graph, we can now see that starvation has been eliminated and the sort is completed two minutes earlier.

Edit Truck

Airport Name

LAX (All fields are required.)

Sort Name

or Memphis

Day of Week

Monday-Friday

Truck Number

4

Terminal

or Cerritos

Departure Time

HH: 17 MM: 40

Arrival Time

HH: 18 MM: 12

Load Size

750

Beginning Freeway

605

Freeway Entrance

CERRITOS, DEL AMO BOULEVARD

Save Data

Reset

Internet

Figure 22. Edit Truck Page, with New Departure Time

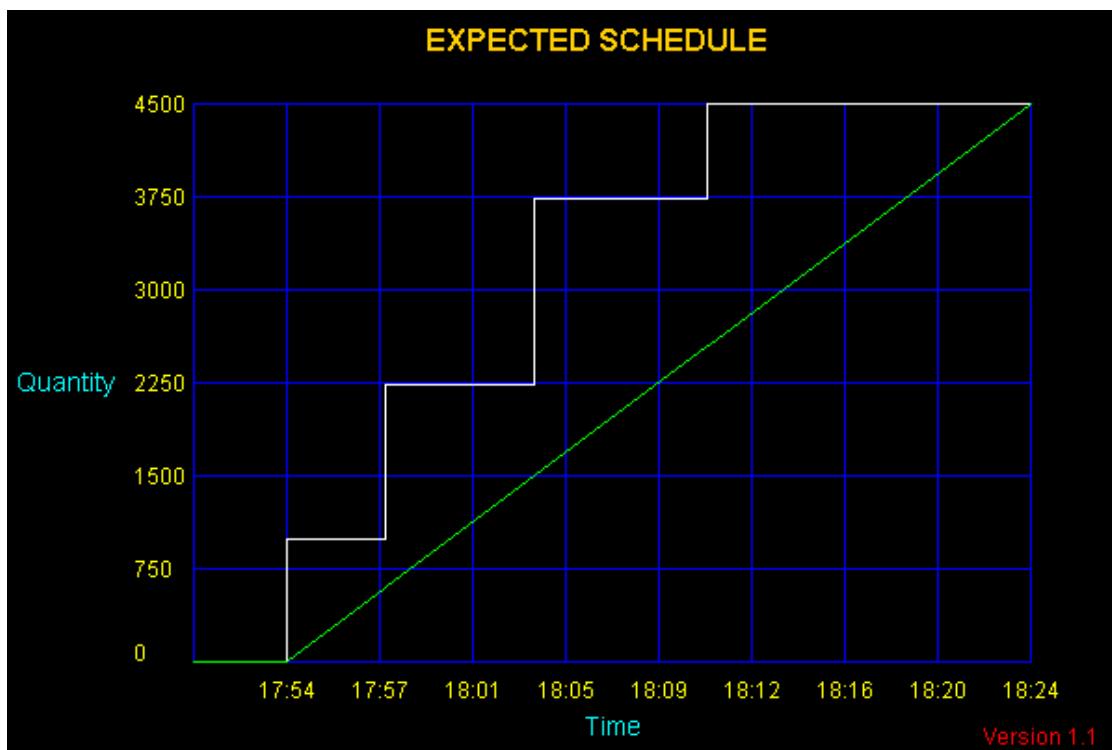
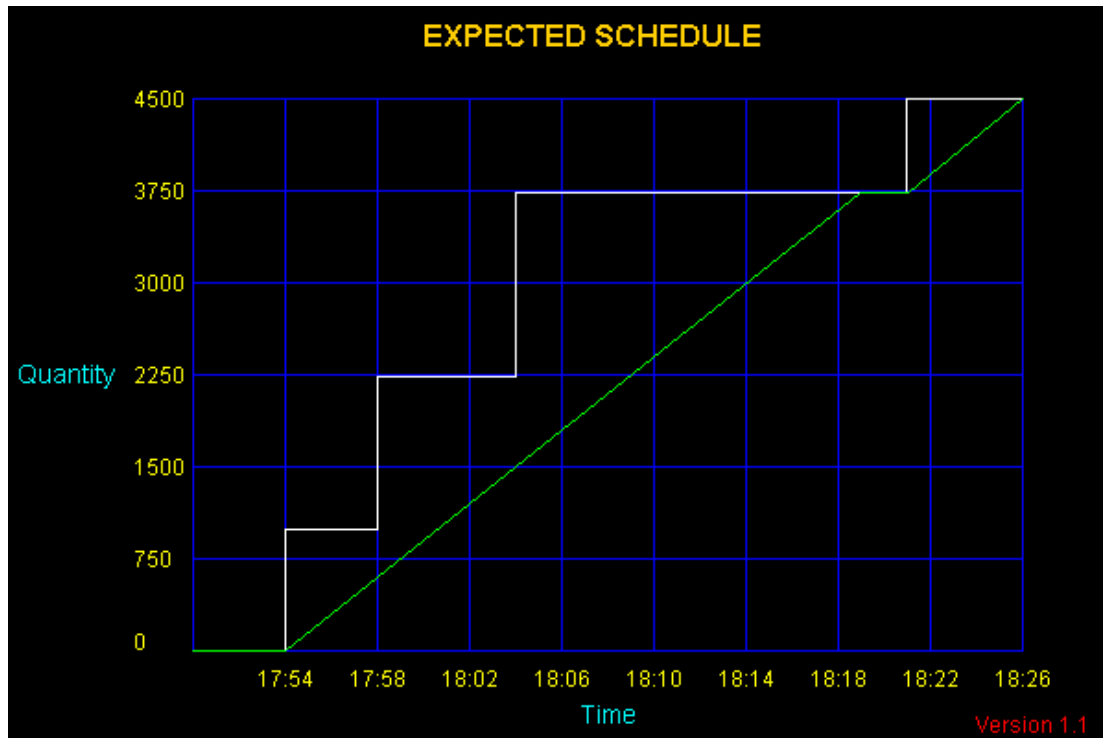


Figure 23. Cumulative Graphs, Before and After Change in Departure Time

Changing Start Time and Processing Rate for Airport In both the output table and graph, we can change the start time and processing rate for airport operation. Here, we show how the changes affect the output graph in Today's Schedule. The same principles apply to the Normal Schedule.

We begin with a default start time of 17:00 and default processing rate of 100 (Figure 24). Under the current condition, the sort is predicted to finish at 18:41. Suppose that this time is too late to meet the plane's schedule. Go to the bottom of the page, and select start time from the pull down menu. Here we select the initial start time, 17:00. Then we enter "110" in the processing rate box for a new larger processing rate. After clicking the "Reschedule" button, a new graph shows the result (Figure 25). It indicates that we will now finish at 18:37. From the graph, it is also evident that further increases in processing rate will not greatly reduce the finish time, as the terminal will likely starve for lack of shipments.

Changing Standard Deviation in Arrival Time For the SD Graph, it is easy to change the standard deviation in truck arrival times, to reflect more or less variability due to traffic conditions. Simply click on the slide bar, and move to the left for less variability, or to the right for more variability. The SD Graph is continuously redrawn as the bar is moved. Note that an increase in variability leads to a smoother and wider arrival pattern, which reduces queueing but causes the sort to be completed at a later time (Figure 26). In this graph, the P curves cannot be distinguished from the A curves, due to the absence of queueing at the airport.

Start Time	Finish Time	Rate	Total Processed
17 : 00	18 : 41	100	4500

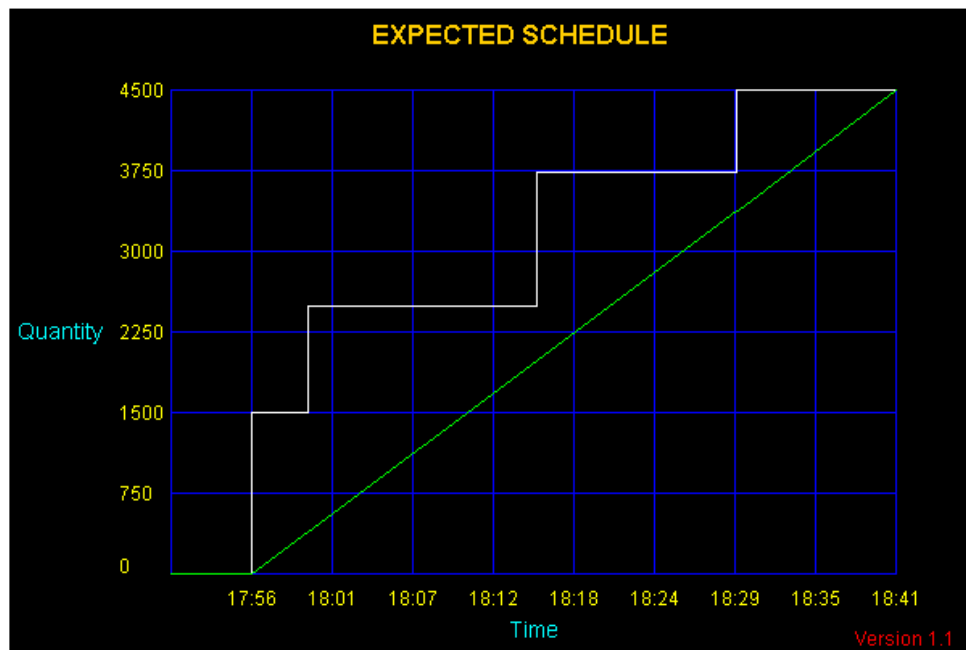


Figure 24. Cumulative Graph Before Changing Processing Rate

Start Time	Finish Time	Rate	Total Processed
17 : 00	18 : 37	110	4500

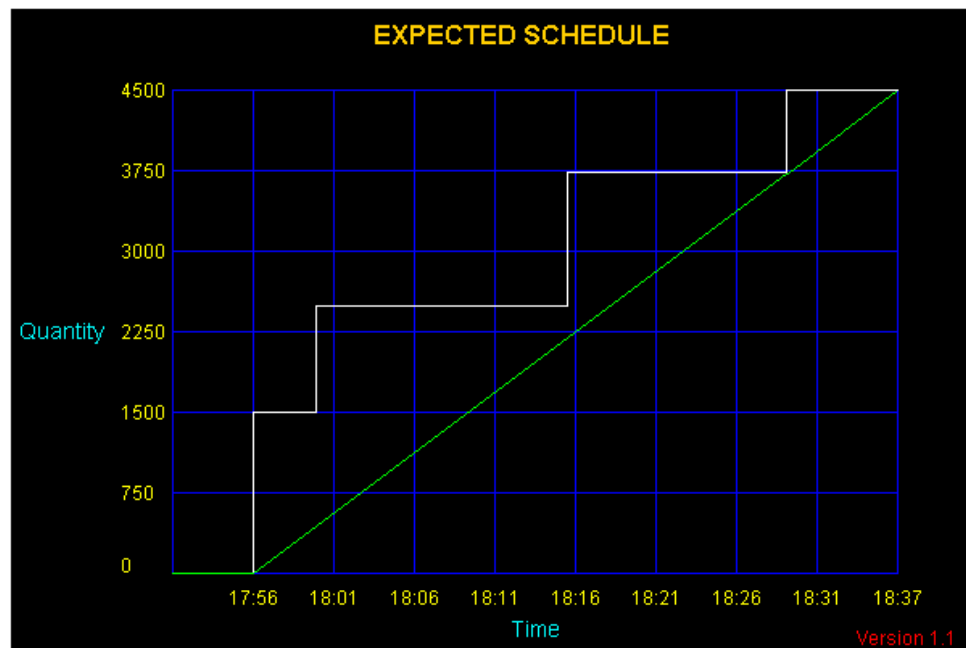


Figure 25. Cumulative Graph After Changing Rate

Airport	Sort	Day	Start Time	Processing Rate
LAX	Memphis	Monday	16:00	100

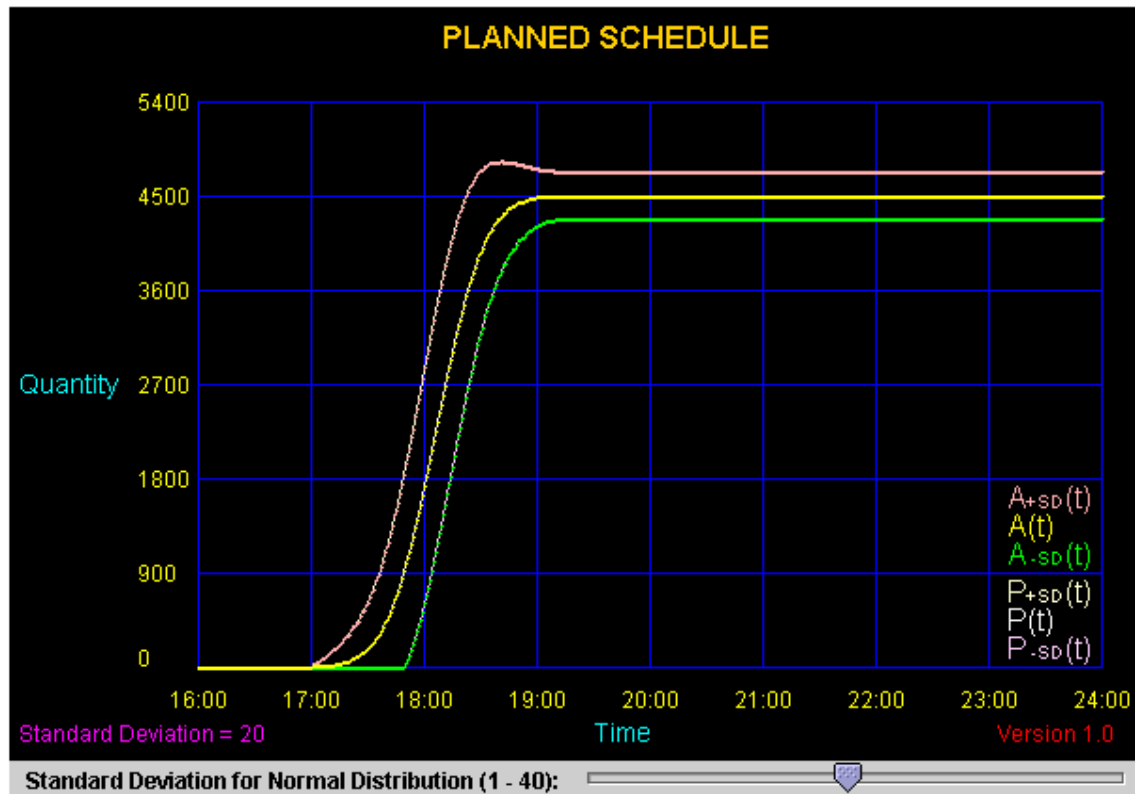


Figure 26. SD Graph with Increased Standard Deviation in Truck Arrival Times

5. CONCLUSIONS

This paper has developed a methodology and tool for predicting the arrival of shipments at a central terminal, based on scheduled departures from a set of remote terminals and travel time information. The application is focused on ground to air shipments, and assurance that outbound aircraft can depart on schedule. The tool predicts the completion time of sorting operations, which determines the earliest departure time for the aircraft.

A web-based tool (TAD) was created, which both provides access to a range of information sources, and analyzes truck arrival patterns at the airport terminal. The tool incorporates real-time traffic information, through transfer of data from the PEMS FTP site. The tool provides a variety of features for data entry and data editing, and for what-if analysis. It is particularly designed to assess alternative truck schedules and the impacts of these schedules on sorting operations.

The tool demonstrates the possibilities for incorporating real-time traffic measurements in truck scheduling. Unlike personal travel, trucking companies are concerned with the effect of traffic delays on entire fleets. Therefore, it is essential to have tools that enable sets of vehicles to be analyzed, as was accomplished in TAD.

In the future, new methods will be introduced to produce more accurate forecasts for truck arrival times at airports, accounting for both historical data and current state of the network.

6. REFERENCES

- Abkowitz, M., R. Josef, J. Tozzi and M.K. Driscoll (1987). "Operational Feasibility of Timed Transfer in Transit Systems," *Journal of Transportation Engineering*, **113**, 168-177.
- Analla, B.P. and Helms, M.M. (1996). Worldwide express small package industry. *Transportation Quarterly*, **50**, 51-64.
- Ashford, N., and Fathers, S. (1989). An approach to level of service design of air freight terminals for small express parcels. *Transportation Planning and Technology*, **14**, 171-180.
- Bearth, D.P. (2000). The sky's the limit, growth in air cargo opens windows of opportunity for trucking companies. *Transport Topics*, December 4, 1,10,12.
- Bookbinder, J.H. and Desilets, A. (1982). Transfer optimization in a transit network. *Transportation Science*, **26**, 106-118.
- Chan, Y. and Ponder, R.J. (1979). The small package air freight industry in the United States: a review of the Federal Express experience. *Transportation Research*, **13A**, 221-229.
- Chestler, L. (1985). Overnight air express: spatial pattern, competition and the future in small package delivery services. *Transportation Quarterly*, **39**, 59-71.
- Cornett, K.K., Ottman, W.S., and Miller, S.A. (1996). An aircraft operations simulation model for the United Parcel Service Louisville Air Park. *Proceedings of the 1996 Winter Simulation Conference*, J.M. Charnes, D.J. Morrice, D.T. Brunner and J.J. Swain (eds.), 1341-1346.

- Cheung, R.K., Liu, J., Tong, J.H., Wan, Y.-W. (1998). Warehouse location problems for air freight forwarders: a challenge created by the airport relocation. *Journal of Air Transport Management*, **4**, 201-207.
- Geinzer, C.M. and Meszaros, C.M. (1990). Modeling high volume conveyor sorting systems. *Proceedings of the 1990 Winter Simulation Conference*, O. Balci, R.P. Sadowski and R.E. Nance (eds.). 714-719.
- Hall, R.W. (1985). "Vehicle Scheduling at a Transportation Terminal with Random Delay en Route," *Transportation Science*, **19**, 308-320.
- Hall, R.W. (1989). "Configuration of an Overnight Package Air Network," *Transportation Research*, **23A**, 39-149.
- Hall, R.W. (2001). "Truck Scheduling for Ground to Air Connectivity," PATH Working Paper, 2001-8.
- Hall, R.W. and Chong, C. (1993). Scheduling timed transfers at hub terminals. *Proceedings of 12th International Symposium on Transportation and Traffic Flow Theory*, C.F. Daganzo (ed.), 217-236.
- Hansen, M.M. and Kiesling, M.K. (1993). Integrated air freight cost structure: the case of Federal Express. UCTC Report # 400, Berkeley, California.
- Heidelberg, K.R., Parnell, G.s. and Ames, J.E. (1998). Automated air load planning. *Naval Research Logistics*, **45**, 751-768.
- Janah, M. and Wilder, C. (1999). Special Delivery. *Infoweeek*, October 27, 42-60.
- Kim, D., Barnhart, C. and Reinhardt, G. (1999) "Multimodal Express Package Delivery: A Service Network Design Application," *Transportation Science*, **33**, 391-407.

- Kuby, M.J. and Gray, G.R. (1993). The hub network design problem with stopovers and feeders: the case of Federal Express. *Transportation Research*, **27A**, 1-12.
- Larson, P.D. (1998). Air cargo deregulation and JIT: Two 20th anniversaries in American logistics. *Transportation Quarterly*, **52**, 49-60.
- Lee, K.K.T. and P. Schonfeld (1991). "Optimal Slack Times for Timed Transfers at a Transit Terminal," *Journal of Advanced Transportation*, **25**, pp. 281-308.
- Nobert, Y. and Roy, J. (1998). Freight Handling personnel scheduling at air cargo terminals. *Transportation Science*, **32**, 295-301.
- Oster, C.V., Rubin, B.M. and Strong, J.S. (1995). Economic impacts of transportation investments: the case of Federal Express. Transportation Research Forum, 37th Annual Conference, 627-638, Chicago.
- Swip, T.M. and Lee, H.F. (1991). Application of an integrated modeling tool: United Parcel Service. *Proceedings of the 1991 Winter Simulation Conference*, B.L. Nelson, W.D. Kelton and G.M. Clark (eds.), 786-791.