APPENDIX (II) DETAILS OF MODELING OF CARRIER OPERATIONS

Definition of Regions

As one of the user-defined assumptions, the model can simulate one or more of four continental U.S. regions: Northeast, Midwest, West, and South. The Northeast region includes Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. The Midwest region includes Illinois, Indiana, and Ohio. The West region includes Arizona, Arkansas, California, Colorado, Iowa, Idaho, Kansas, Louisiana, Minnesota, Missouri, Montana, Nebraska, New Mexico, Nevada, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming. The rest of the states constitute the South region.

Default Assumptions

In addition to the assumptions that can be revised by the user, the model has a number of default assumptions, detailed here:

- *Loading and Unloading Time* The time required for loading and unloading the vehicle is based on a random draw from a normal distribution with a mean of 2 hours and a standard deviation of 30 minutes. Further, we have assumed for computational ease a minimum loading and unloading time of 30 minutes, with the concurrence of industry expert opinion for reasonableness.

- *Pick-up Day of Week* The distribution of the day of the week for shipment pick-ups is based on a report by Reebie Associates[63], which determined the following patterns from data available from truckload carriers:

Exhibit (II)-1: Day of Week Patterns

Day of Week	Percentage
Sunday	0.8%
Monday	17.8%
Tuesday	19.7%
Wednesday	19.9%
Thursday	19.0%
Friday	19.5%
Saturday	3.3%

Exhibit (II)-1 shows that pick-up days are basically evenly distributed for the weekdays while the weekends are rarely used. The simulation of the pick-up day for a given shipment in the model is based on the percentages shown above. However, we have limited the alternatives so that the available possibilities for the next shipment pick-up are the same day as the just-completed drop-off and the two days immediately subsequent. For example, if the truck has arrived on Tuesday,

[63] "Day-of-Week Motor Carrier Demand Patterns," Reebie Associates, June 12, 2002.

the pick-up day choices for the next shipment would be based on the relative distributions for Tuesday, Wednesday, and Thursday.

- *Delivery Day of Week* The scheduled delivery day of the week depends on the pick-up day of week and the travel time required to the delivery destination. The model calculates a simplified transit time from the origin to the destination as equal to the distance between the origin and destination divided by the average driving speed (default of 50 mph), and then doubled to allow for non-driving time (for breaks, etc.). Effectively, this makes trips feasible if the CMV operator spends at least 50 percent of the time after pick-up driving.

- *Pick-up and Delivery Windows* The pick-up and delivery windows represent the interval of time in which a pick-up or interval needs to be made. Based on research and input from industry experts, they are assumed to have the distributions shown in Exhibit (II)-2:

Exhibit (II)-**2**
Distribution of Pick-up and Delivery Windows

Window size	Pick-up Window	Delivery Window
15 or 30 Minutes	11%	44%
AM or PM	37%	33%
Whole Day	53%	22%

If the whole day is noted as the pick-up/delivery window, the CMV operator is able to pick-up/drop off any time during the day. Similarly, we assumed that the AM window is from 12 midnight to 12 noon while the PM window is from 12 noon to 12 midnight. For the shorter 15 minute and 30 minute windows, we assigned the distribution of pick-up/delivery windows as suggested by the industry experts following the distribution of all actual pick-up and delivery times. The pick-up and delivery window distributions for the 15 and 30 minute windows are shown in Exhibits (II)-3 and (II)-4. Within each of these ranges, the actual window was randomly assigned (using a uniform distribution) to a time increment commencing within the range.

Exhibit (II)-**3**
Distribution of Pick-up Hours for 15 or 30 Minute Windows

Pick-up Hour	% of Shipments
22:00-10:00	60%
10:00-14:00	30%
14:00-22:00	10%

Exhibit (II)-**4**
Distribution of Delivery Hours for 15 or 30 Minute Windows

Delivery Hour	% of Shipments
05:00-08:00	40%
08:00-14:00	40%
14:00-21:00	10%
21:00-05:00	10%

Model Operation Note

In a few cases, none of the 20 origin-destination pairs that the CMV operator faces are feasible. For example, if a CMV operator arrives at the destination on late Friday, then all 20 pairs presented to the operator may be infeasible since the model draws very few Saturday and Sunday pick-ups (and may pick all 20 pickups for earlier in the day on Friday than the driver is available). In such cases where no origin-destination pair is feasible, the model allows the driver to have an extra day of pick-up (Monday) so the driver can choose from a feasible set of choices. Then, the model simulates all 20 O-D pairs instead of only the top seven, to ensure that the CMV operator chooses the shipment with the highest utility.

Order Sets

The process of obtaining a representative sample of the US truck transportation industry's movements began by obtaining data sets containing the total tons shipped to and from every county in the country, sorted by FIPS code[64]. It was decided to base the sample on the total tons shipped to and from each county to best represent the number of truckload moves. The shipments to and from each county were combined to create a table relating each county to the total tons shipped associated with it. This data set provided 3,141 data points from which to create a sample. First, a sample size of 1,000 was established, to speed model computation time and assuming that quantity to be more than sufficient to represent industry movements for the purposes of the model. Next, those counties and areas located outside the lower 48 states were removed from the potential sample, as their geographic circumstances would not permit modeling within this framework. This step reduced the number of FIPS codes used as potential data points to 3,109. Then, counties were sorted by total tonnage, and the 194 counties whose movements made up 60 percent of total goods shipped were placed in the sample. The remaining 2,915 counties were assigned random values between 0 and 1, and those with the 806 largest random numbers were included in the sample to complete the set of 1,000.

Treating the sample set as a closed system, statistical software was then used to calculate the probability of a shipment going from each FIPS origin to each separate FIPS destination, ignoring the probabilities associated with the FIPS areas outside the sample. Because the 2,915 smaller counties were now under-represented in the sample, an imbalance was present in the O-D probabilities. In order to correct this imbalance, the proportion of total tonnage of low-volume counties in the data set relative to the tonnage of those low-volume counties used in the sample

[64] FIPS codes generally represent counties, parishes or districts. The term county is used interchangeably herein to also represent FIPS code areas, parishes and districts.

was calculated, which was roughly equal to 3.76. The origin-destination probabilities in cases where the destination was a low-volume county were then multiplied by that proportion.[65] This step effectively made the low-volume counties that were randomly selected for the sample stand in for all low-volume counties in the data set.

After this rebalancing of the sample's representation, the sum of the destination county probabilities for each individual origin county did not precisely equal one. In order to recalibrate the probabilities to achieve a workable model, each origin-destination combination's initial value was divided by the initial sum of the origin county's values. These new probability values were then summed to result in a total probability for each origin county of one.

Utility Function

The specific formulation and assumptions for the utility function are as follows:

Total Utility = Revenue - Cost – AwayFromHome Penalty + HOSStatusPremium

where

Revenue = Fixed shipment revenue + RevenueMiles from shipment pick-up to shipment drop-off * Revenue/mile) + ServicePremium revenue

where

Fixed shipment revenue = $120
RevenueMiles = Miles from shipment pick-up to shipment drop-off
Revenue/mile = $1.18
ServicePremium revenue = $25 per pick-up or drop-off with a15-minute or 30-minute time window

and

Cost = (OperatingCost/mile * VehicleMiles) + (Cost/clock-hour * ClockHours)

where

OperatingCost/mile = $1.13/mile for employee drivers paid per mile
VehicleMiles = Miles from previous drop-off to next destination drop-off (i.e., includes "deadhead" miles to shipment's pick-up)
Cost/clock-hour = $5.40/hour for employee drivers paid per mile
ClockHours = Total hours (duty and non-duty) from previous drop-off to next destination drop-off (i.e., includes "deadhead" time to shipment's pick-up time)

and

[65] Shipments to high-volume counties did not need adjustment as they were fully represented in the sample.

AwayFromHome Penalty = $V * (max (0 , 1 - ((DaysAway/W)^X * (DestDistAway/Y)^Z))

where

V = $10.00
W = 14 days
X = 2 (exponential parameter for time away from home)
Y = 500 miles
Z = 1.25 (exponential parameter for destination's distance away from home)

and

HOSStatusPremium = HoursBeforeRestart * Net revenue per duty hour

where

HoursBeforeRestart = Expected hours drivers will have remaining in 70-hour HOS work period before the 34 or 58 hour "restart" rest period

Net revenue per duty hour = $2.00 (based on expert opinion derived from revenue data presented in the *Blue Book*).

Algorithms

The details of the algorithms used to carry out some of the specific model components. are detailed below:

Destination Algorithm

The shipments' origins and destinations are based on recent empirical data regarding the actual probabilities of commercial truck movement from county to county in the continental United States. As explained in the order sets section (3.2.3), the available data provides the probabilities of shipment movements among the representative counties. Thus, the destination county is drawn based on the distribution of shipment movements from the origin county to potential destination counties. Specifically, when the destination algorithm is initiated, the model generates a random number between 0 and 1 and the model sequentially adds up each of the individual shipment probabilities associated with the origin county to potential destination counties until the cumulative sum is greater than the randomly generated number. Once the cumulative sum exceeds the randomly generated number, the model chooses the particular destination county that marginally increases the cumulative sum to be greater than the randomly generated number as one of the 20 origin-destination pairs.

Load Choice Algorithm

As explained in the operation section of Chapter 3 (3.2.2), the model simulates the top seven origin-destination pairs among the 20 pairs. The choice algorithm allows the user to see actual behavioral pattern of the driver in each of 15 or 30 minute time slots as the vehicle hypothetically would "move" from the origin terminal to the destination terminal. The algorithm also ensures the driver complies with all of the HOS regulations.

The algorithm starts each time increment with the decision of whether to rest or not. The CMV operator always decides to rest upon reaching the limit on driving hours or duty hours per day or the limit on cumulative duty hours in the last 8 days.

When the CMV operator decides not to take a rest, it has to decide whether to drive, load, unload, or just wait. The CMV operator waits[66] if it has driven four consecutive hours and still has more than one hour of driving left until the destination. If it has not reached the limit on driving hours and has not arrived at the destination, it chooses to drive. Once it arrives at the destination and is not resting, it either unloads or waits. To wait is counted as duty time, even though the truck is not moving, since the CMV operator is not fulfilling the HOS criteria for rest time. In these cases, the driver waits until it is within the delivery window and then unloads. Similarly, when it arrives at the pick-up terminal and is not resting, it waits until the time is within the pick-up time window and then loads the shipment.

The decision to drive, load, or unload is overridden when the CMV operator reaches the limit on the cumulative duty hours in the last 8 days. Then, the CMV operator automatically rests until its restart rest hours are met, or until the last 8 days included less than 70 hours on duty.

Schedule Algorithm

The schedule algorithm includes all the decision-making procedures within the choice algorithm. The schedule algorithm writes the selected origin-destination pair to the output table.

Feasibility Algorithm

In order to reduce the computing time for the model, we simulate seven origin-destination pairs among the 20 pairs that the CMV operator is presented with. The feasibility algorithm screened out the 13 pairs that would lead to the lowest utility. The algorithm calculates the travel time it takes to get to each pick-up terminal. Then it compares the travel time with the pick-up time and pick-up window of each origin-destination pair to check feasibility. Because the CMV operator is constrained by the limits on driving hours per day, a 4 hour drive to the next destination may take more than 4 hours. For example, it takes only 4 hours if the operator has at least 4 hours left on its daily limit on driving hours, but it would take 14 hours if the operator already had reached the limit on the driving hours per day and has to rest for 10 hours. Thus, the feasibility algorithm eliminates infeasible O-D pairs.

Longer Restart Rest Period Algorithm

When the CMV operator reaches the limit on cumulative duty hours in the last 8 days, the operator takes a restart rest of the required minimum hours (see user-defined inputs). This rest also re-set the cumulative count toward the limits. In other words, if the cumulative driving hours are at 5 hours, taking the restart rest hours re-sets the cumulative driving hours to 0 hours. In actuality, many commercial truck drivers take longer restart periods than are actually required, presumably in order to start their next working period in the morning or at a convenient or

[66] Effectively, this represents the driver taking a break without fulfilling criteria for HOS "rest", and thus counts as duty time but not driving time.

accustomed time. Therefore, the model reflects the longer restart rests by imposing the following pattern of restart rests:

Long – Short – Short – Long – Short – Long – Short – Long

The “Long” restart period means that the CMV operator takes longer restart rests by resting until 7 AM of the next day in addition to the regular restart rest of 34 or 58 hours. The “Short” restart period means that the CMV operator takes regular restart rest of 34 or 58 hours. The first restart period is “Long” so the CMV operator takes extra rest until 7 AM the next day. The second and third restart periods are regular restart rests, so it starts working as soon as the restart hours are up. Similar to the first restart, in the 4^{th}, 6^{th} and 8^{th} restarts, the CMV operator takes extra rest until 7 AM the next day in addition to the 34 or 58 restart rest hours. The fifth and seventh restart periods are regular restart periods. This pattern of restart periods gets repeated so the driver takes two consecutive long rests as it turns from the 8^{th} restart to the 9^{th} restart.

Break Time Algorithm

In order to make the model more closely reflect the driving patterns of actual truck drivers, a break period of either 30 minutes or one hour is imposed whenever the CMV operator drives four straight hours with more than one hour left until the destination. If the CMV operator hs equal to or less than one hour of driving left until the destination, the break period is not imposed since actual truck drivers would skip the break and continue driving.

The decision to break for 30 minutes or one hour is based on a random number generation with a 50 percent chance of each. According to DFACS survey, commercial truck drivers typically stopped for a break after 4 to 5 hours, and typically rested 30 to 60 minutes, with a median of 45.

Split Sleeper Berth

The model initiates the split sleeper berth algorithm whenever the CMV operator arrives at the pick-up or destination terminal and still has some time until the pick-up/delivery hour window. Specifically, if the minimum split sleeper berth is 2 hours and the daily rest is 10 hours, then the CMV operator takes a split sleeper rest if its waiting time at the pick-up or destination terminal is between 2 and 8 hours. If it needs to wait less than 2 hours, then it uses its duty time to wait for the shipment and if the wait is more than 8 hours, it uses its 10-hour rest to wait for the shipment.