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SENSITIVITY STUDIES USING THE TRNSM 2 COMPUTERIZED MODEL FOR THE NRC PHYSICAL PROTECTION PROJECT FINAL REPORT

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ABSTRACT

A computerized model of the transportation system for shipment of nuclear fuel cycle materials is required to investigate the effects on fleet size, fleet composition and efficiency of fleet utilization resulting from changes in a variety of physical and regulatory factors, including shipping requirements, security regulations, work rules, maintenance requirements, and vehicle capacities. Such a model has been developed which provides a capability for complete sizing requirements studies of a combined aircraft and truck fleet. This report presents the results of a series of sensitivity studies performed using this model. These studies include the effects of the intinerary optimization criteria, work rules, and maintenance policies. These results demonstrate the effectiveness and versatility of the model for investigating the effects of a wide variety of physical and regulatory factors on the transportation fleet.

1.0 INTRODUCTION

A vital part of the system for safeguarding special nuclear material used in the nuclear fuel cycle is the system used to transport this material. This transportation system is affected by a variety of factors including the amount of material to be shipped, the carrying capacities of the transport vehicles, security regulations, personnel work rules, and vehicle maintenance policies. In order to analyze the effects of these and other factors on the size, composition and efficiency of the transportation system, a realistic computerized model of the system is required. This model must include all the major features of this transportation network, including the shipment schedule for the nuclear material, different transportation modes (e.g., trucks and aircraft), requirements for security escort vehicles, different maintenance requirements for trucks and escort vehicles, personnel assignment policies, and provisions for convoying trucks and escort vehicles.

Reference 1 outlines an overall plan for the development of this model. This development plan provides for a sequence of versions as described in Table 1.1. Each version is itself useful for a rational set of analyses. Furthermore, proceeding from one version to the next involves only refinements and/or additional modules rather than wholesale changes to previously developed code.

TRNSM 1 provides for complete sizing of all types of transport unit elements* for a single mode (trucking), using a fixed-fleet

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* The types of transport unit elements considered in this document include truck trailers, truck tractors, escort vehicles, aircraft, and crews to man these vehicles.

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Table 1.1 Sequential Model Development

☐ Indicates New Or Modified Feature				
COMPONENT FEATURES	TRNSM 1	TRNSM 2	TRNSM 3	TRNSM 4
Modes	One	Two	Several	Several
Transport Unit Elements	Several	Several	Several	Several
Convoying	No	No	Yes	Yes
Maintenance Policies	Nearest Base	Nearest Base	Home Base and Nearest Base	Home Base and Nearest Base
Sizing Options	Fixed-Fleet Only	Fixed-Fleet and Non-Fixed Fleet	Fixed-Fleet and Non-Fixed-Fleet	Fixed-Fleet and Non-Fixed-Fleet
Special Input/Output Options	None	None	None	Automated Sensitivity Analysis

oriented approach in which it is necessary to iterate on the fleet size to find the required number of each type of transport unit element.

TRNSM 2 incorporates a non-fixed-fleet approach to sizing in which no iterations on fleet size are required. The capability for considering an aircraft mode in addition to the trucking mode is included.

TRNSM 3 will extend the model to handle several modes (i.e., rail and water in addition to trucks and aircraft), convoying, and a home base maintenance policy.

TRNSM 4 will extend input and output options to simplify sensitivity analyses, i.e., provide for a succession of model runs and subsequent graphical displays.

Technical details of the TRNSM 2 model are presented in Reference 2. Other documents concerned with this model are the Programmer's Guide [3] and the User's Manual [4]. This report documents the results of sensitivity studies that have been made with the TRNSM 2 model. These studies demonstrate the effectiveness and versatility of the model for investigating the effects of a variety of physical and regulatory factors on the required fleet size, fleet composition and efficiency with which the transportation fleet is utilized.

Section 2 of this report presents a brief description of this TRNSM 2 model and summarizes its capabilities. Reference 2 contains a complete discussion of technical details on the algorithms used in this computerized model. The results of the sensitivity studies are then presented and discussed in Section 3. Appendix A summarizes the symbols which specify the base locations in the two sample shipment schedules used in the sensitivity studies. The sample schedules themselves are given in Appendices B and C.

2.0 DESCRIPTION OF THE TRNSM 2 MODEL

This section presents a general description of the TRNSM 2 model and a summary of its capabilities. The TRNSM 1 model is not discussed separately since all of its capabilities are included in TRNSM 2. The reader should consult Reference 2 for the complete technical details of this model.

2.1 General Description

A simplified flow diagram for the model of the transportation system is shown in Figure 2.1. The input which drives the model is the shipment schedule for the nuclear fuel cycle materials. Each individual shipment is specified by its origin base, destination base, earliest departure time, latest arrival time, material type, quantity of material, and any prespecified transportation requirements for that shipment (e.g., must be shipped in a specified truck-trailer type). There are two options available in TRNSM 2 for the generation of itineraries: fixed-fleet and non-fixed-fleet. The TRNSM 1 model used only the fixed-fleet approach in which the fleet size for a given transport unit element type is varied until the minimum fleet size is found which satisfies the service requirements. In order to provide a set of representative initial conditions, the shipment schedule is expanded to include a "warm-up" period at the beginning to establish these initial conditions. The non-fixed-fleet itinerary construction process, which is included in TRNSM 2, requires neither a warm-up period nor a search process on the fleet size. The resulting computer run times are about one-third those obtained with the fixed-fleet approach. For this reason, the preferred option is the non-fixed-fleet approach.

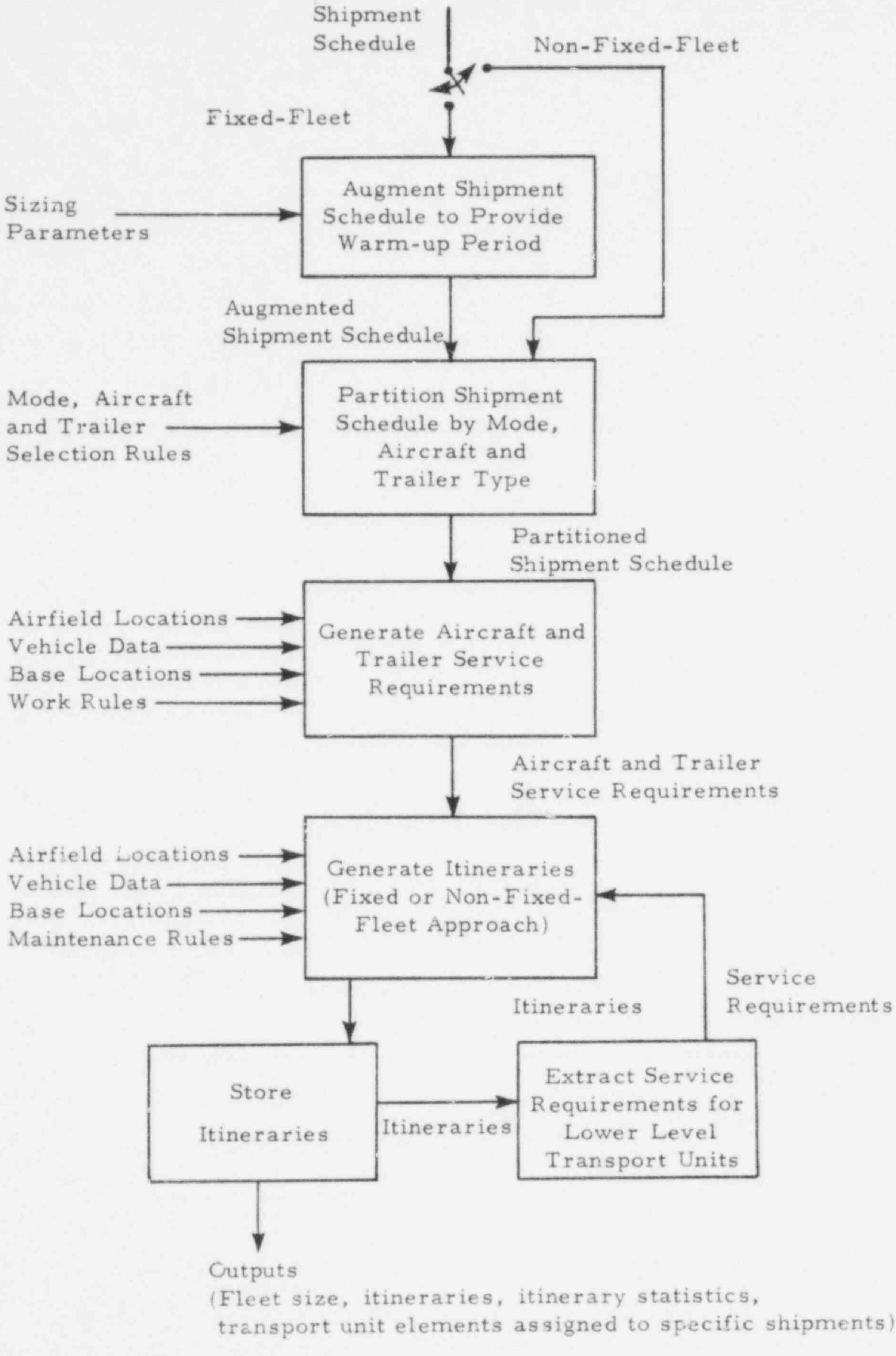

Figure 2. 1. Simplified flow diagram for TRNSM 2.

The augmented shipment schedule is partitioned by mode, i.e., each shipment is assigned to either the truck mode or aircraft mode. Then the schedule is further partitioned by aircraft type for the aircraft mode and by trailer type for the truck mode.

The partitioned shipment schedule is combined with work rules (e.g., no working at bases on weekends) to generate the service requirements for aircraft and truck trailers. One set of service requirements is generated for each aircraft and truck trailer type, e.g., if three trailer types are being considered, three separate sets of service requirements are generated.

The itineraries for the desired types of transport unit elements are then generated. The basic process used in itinerary construction is to first check to find all possible pairs of services which can be sequentially handled by one transport unit element (e.g., one truck). Temporal and maintenance feasibility tests are employed to find these candidate linkings which are then ranked according to an optimization criterion called the linking value function. This quantity is a linear combination of (1) added deadhead time in the linking, (2) added idle time in the linking, (3) loss of flexibility in the composite service compared to the flexibility in the two linked services, and (4) the lengths of the two services being linked. This linking value function is discussed in more detail in Section 2.2.4. The linking with the smallest linking value is then selected. This pair of linked services is now viewed as one composite service which is added to the list of required services while the two original services are deleted. This process is repeated until no further linkings are feasible.

In the fixed fleet option, the generation of these itineraries requires that iterations be performed on the fleet size until the minimum number is found which satisfies the service requirements. An efficient search technique [2] has been developed to speed this process of finding the minimum fleet size. In the non-fixed-fleet option, the fleet size is automatically determined by a self-linking process in which the required services toward the end of the planning horizon are linked to services at the beginning of the planning interval. This results in a set of closed chains of linked services which specifies the fleet size and the itineraries.

The process for the sequential generation of itineraries for the types of transport unit elements under consideration is illustrated by the example shown in Figure 2.2. Note that the itineraries for the aircraft are generated first. These aircraft itineraries then impose additional service requirements on the truck trailers because of the need to transport the shipments between the bases and airfields. Next the truck trailer itineraries are generated. The aircraft itineraries also levy requirements for the assignment of aircraft crews, while the truck trailer itineraries levy requirements on several lower level transport unit elements. For example, on both active and deadhead itinerary legs, each trailer must be pulled by a truck tractor. In addition, on active trailer itinerary legs, escort vehicles must be assigned. The service requirements imposed by the aircraft and trailer itineraries on lower level transport unit elements are extracted and the itineraries for these transport unit elements are generated. These new itineraries, in turn, levy service requirements on other lower level transport unit elements, e.g., crews. This process of sequentially generating itineraries and extracting services continues until the itineraries for all the desired transport unit element types have been considered. It is important to emphasize that the user of the model specifies what types of transport unit elements are to be considered and in what order the resulting itineraries are to be generated.

EXAMPLE OF SEQUENTIAL GENERATION OF ITINERARIES

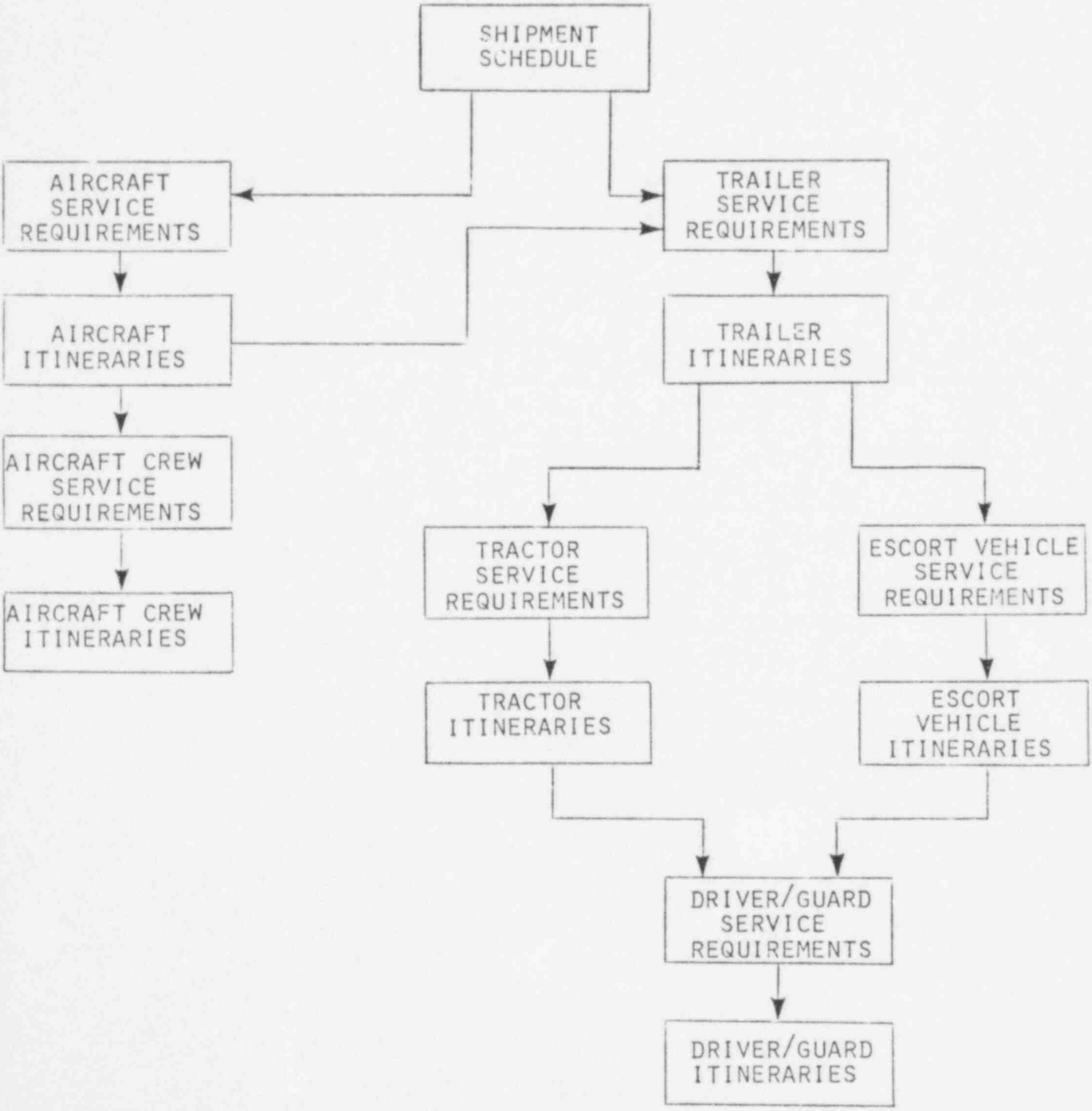

Figure 2.2 Example of sequential generation of itineraries and required services.

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Outputs provided by the model are the required number of each transport unit element type, detailed itineraries for each transport unit element, statistics on the itineraries (e.g., percent of total distance travelled in active service), and the assignments of specific transport unit elements to each shipment.

2.2 Capabilities of the TRNSM 2 Model

In this section, the general capabilities of the TRNSM 2 model are discussed.

2.2.1 Types of Transport Unit Elements

The TRNSM 2 model is designed to provide an effective sizing capability for combined aircraft and truck fleets to be used to transport material for the nuclear fuel cycle. Up to nine types of transport unit elements can be designated for each of the two available modes. For the truck mode, three of these designations are reserved for types of truck trailers, while the remainder can be used to designate specific types of truck tractors, escort vehicles and crews. Similarly, for the aircraft mode, three of the nine transport unit element designations are used for specific aircraft types. Table 2.1 summarizes the numerical designations currently assigned to the various types of transport unit elements.

As was discussed in Section 2.1, the user of TRNSM 2 specifies the order in which the different types of transport unit elements are to be considered. For example, a sequence might be aircraft type 1 (21), truck trailer type 1 (11), truck trailer type 2 (12), truck tractors (15), escort vehicles (16), and truck/escort crews (17). It is also possible to require that two or more types of transport unit elements (e.g., truck trailers and tractors) alwasys remain together as a unit. This is accomplished by specifying for the combined unit

Table 2.1 Numerical designations of transport unit elements.

NUMBER	TRANSPORT UNIT ELEMENT
11	Truck Trailer Type 1
12	Truck Trailer Type 2
13	Truck Trailer Type 3
14	(Unassigned)
15	Truck Tractors
16	Escort Vehicles
17	Truck/Escort Vehicle Crews
18	(Unassigned)
19	(Unassigned)
21	Aircraft Type 1
22	Aircraft Type 2
23	Aircraft Type 3
24	(Undesignated)
25	(Undesignated)
26	(Undesignated)
27	Aircraft Crews
28	Aircraft Guards
29	(Undesignated)

the m[illegible]ngent maintenance requirements from those of the individual units. [illegible]ample, consider the case in which truck tractors and trailers are required to remain together as a combined unit. Assume that an individual trailer requires a 4 day maintenance stop before 40,232 km (25,000 mi.) has been traveled since the last maintenance, whereas an individual tractor requires a 2 day maintenance stop before 12,824 km (8,000 mi.) has been traveled without maintenance. Thus, the combined trailer/tractor combination requires a 4 day maintenance stop (the trailer requirement) before 12,874 km has been exceeded (the tractor requirement).

2.2.2 Maintenance Procedures

This section summarizes the maintenance procedures and options which are included in the model for both vehicles, including aircraft, and personnel.

2.2.2.1 Vehicle Maintenance Procedures

Vehicles require maintenance when either a specific time period has elapsed or the vehicle has traveled a specific distance since the last maintenance. The TRNSM 2 model allows both these time and distance maintenance criteria to be specified. The vehicle must return to a base for maintenance before either of these limits is exceeded.

TRNSM 2 provides for a nearest-base maintenance policy, i.e., each vehicle proceeds to the nearest maintenance base when maintenance is required. There are a number of difficulties in providing for a home-base maintenance policy in which each vehicle must return to its home base for maintenance. Because of these difficulties, which are discussed in Reference 2, an option for specifying a home-base maintenance policy is not included in TRNSM 2, but will be included in a later version of the model.

2.2.2.2 Personnel Maintenance Policies

Generally, there is an upper limit on the maximum amount of time that drivers, guards and aircraft crews can spend on duty without a rest break at home base. Thus the criterion on which crew rest breaks are determined in the TRNSM 2 model is the total time without such a break, which cannot exceed a specified amount.

It is mandatory that personnel be returned to their home bases for these rest breaks so that a home-base maintenance policy is required for the crews and guards. If there is only a single crew home base, no difficulties arise. With multiple home bases, however, many of the same difficulties arise as occur with a home-base maintenance policy for vehicles. In TRNSM 2, a home-base policy for crews is approximated by a nearest-base maintenance policy. This approximation seems reasonable because the time required for a crew to travel to and from the nearest crew home base should be representative of the time it takes to travel to and from the actual home base, possibly via commercial airline. The implications of a home-base maintenance policy are discussed in more detail in Reference 2.

2.2.3 Work Rules

Work rules for personnel located at bases and traveling on the road can affect the fleet size and the resultant itineraries, as is shown in the sensitivity studies discussed in Section 3.4.

Specific quantities that can be designated by the user of the TRNSM 2 computer model are the length of the working day in hours at bases and on the road.

The user is also able to specify whether or not loading and unloading trailers and aircraft is permitted on Saturdays, Sundays, and holidays. Similar restrictions can be imposed for traveling with a load on weekends and holidays. However, the model presently has no provision to prohibit an empty trailer or aircraft from traveling on weekends and holidays.

2.2.4 Itinerary Optimization Criteria

Itineraries are generated by linking together services to form composite services which are themselves then used in the linking process. At each step, the feasible linkings are ranked in a candidate linking list according to an optimization criterion which is called a "linking value function." The linking with the best linking value is selected, saved to be used as part of an itinerary, and then deleted from the candidate linking list.

The linking value function is a linear combination of:

(1) added idle time in the linking

(2) added deadhead time in the linking

(3) loss of flexibility in the composite service compared to the flexibility in the two linked services

(4) length (in time) of the first service to be linked

(5) length (in time) of the second service to be linked.

The first two criteria penalize added deadhead and idle time, both of which are undesirable from the viewpoint of efficient fleet utilization. The loss of flexibility penalty term is also very important in the generation of efficient itineraries. By retaining as much flexibility as possible in the composite services as the linking process proceeds, more feasible linkings are available for consideration toward the end of the linking process. This wider choice of feasible linkings potentially allows further reduction of idle and deadhead time, resulting in a more efficient set of itineraries. The importance of this penalty term on loss of flexibility is illustrated by the examples discussed in Section 3.1. The last two terms in the linking value function which penalize the length of the two individual services in the candidate linking are included to force balanced itineraries to be generated.

The user of the TRNSM 2 model is able to control the itinerary generation process by specifying the weightings to be placed on each of these penalty factors in the linking value function. The effects on the fleet size and resulting itineraries due to changes in these weightings are discussed in detail in Section 3.1.

2.2.5 Fleet Sizing Capabilities

The TRNSM 2 model is basically designed as a tool to study the fleet size required to handle shipments of the nuclear fuel cycle materials. The driving input which probably has the greatest effect on the fleet size is the shipment schedule. Within the shipment schedule itself, the flexibility in possible shipping dates has a major impact on the fleet size. The fleet size is also affected by the maintenance procedures, the work rules, and the linking value function, all of which are controlled by the user.

When the fixed-fleet option for fleet sizing is selected, the initial conditions for the transport unit elements must be specified. To reduce the effect of arbitrary selection of initial conditions on fleet size, provision is made for a warm-up period to be attached to the beginning of the schedule to establish reasonable initial conditions. The shipments in this warm-up period are obtained by taking all the shipments in a specified interval of the original schedule. The length of the warm-up period and the portion of the original schedule from which the warm-up shipments are extracted are under the control of the user. At the start of the warm-up period, the transport unit elements are randomly distributed among the maintenance bases with random amounts of accumulated use, i.e., distance traveled and time since last maintenance. The randomization of the initial values of the accumulative use variables is provided to avoid the situation in which all the individual transport unit elements require maintenance at about the same time. This, in turn, allows a shorter warm-up period to be used to generate representative initial conditions. Transport unit element usage statistics are not collected during the warm-up period, but only for the actual shipment schedule. This warm-up period is not required when the non-fixed fleet sizing option is selected.

The user is also able to specify the desired planning horizon. This option could be used when it is not necessary to use the complete shipment schedule for sizing studies. Specification of a planning horizon causes the model to ignore those shipments with earliest shipping dates after the planning horizon date.

3.0 EXAMPLE SENSITIVITY STUDIES

This section presents the results of a number of example sensitivity studies to demonstrate the effectiveness and versatility of the TRNSM 2 model. These studies, which are based on sample shipment schedules, examine the effects on fleet size and the characteristics of the resulting itineraries due to variations in the linking value penalties, the planning horizon, maintenance rules, vehicle speed, loading/unloading time, vehicle capacity, warm-up time in the fixed-fleet sizing mode, escort assignment rules, and rules for assignment of shipments to the aircraft mode. In addition, an example of sequentially scheduling all transport unit elements is presented.

In examining the results of these sensitivity studies, it should be remembered that the TRNSM 2 model does not minimize the fleet size. Because of the extremely high dimensionality of the problem, such a fleet size minimization routine based on optimization techniques is computationally not feasible. Instead the TRNSM 2 model attempts to compute the smallest adequate fleet size by choosing the best possible service linkings as measured by the linking value function. Experience has shown that there is a relatively large range of linking value penalties which results in efficient itineraries with either a minimum fleet size or one very close to minimum. Although it is not possible to definitely establish whether or not the minimum fleet size has been achieved, examination of the detailed itineraries often provides an indication of how close the fleet size is to the minimum.

Two sample shipment schedules are used in these studies. Schedule 1 is a relatively small schedule consisting of 152 shipments with starting dates distributed over a period of 90 days. Schedule 2 consists of 682 shipments with starting dates distributed over a period of 180 days. However, to conserve computer resources, most of the studies with this larger schedule were accomplished using a reduced planning horizon of 90 days. These sample shipment schedules are presented in Appendices B and C.

Since there are a large number of parameters used in the TRNSM 2 model, a set of baseline parameters were selected to be used in these studies. The sensitivity studies were carried out by varying one or two of these parameters at a time. These baseline parameters are summarized in Table 3.1. The linking value penalties of idle 10, deadhead 1, flexibility loss 0.1, and total time 0 were selected because previous experience in developing the model demonstrated that this choice tends to produce a set of efficient itineraries with a fleet size at or close to minimum.

Most of the sensitivity studies discussed below use the nonfixed fleet sizing mode and are based on trailers and tractors traveling together as a single unit. Such trailer/tractor combinations are assumed to require a four day maintenance stop before 12,874 km has been traveled since the previous maintenance stop. Figures 3.1 and 3.2 depict these baseline trailer/tractor itineraries and the resulting itinerary statistics for schedules 1 and 2, respectively. In these and subsequent figures which show itineraries, the various types of services are depicted as follows:

———— = Active or deadhead service

 = Maintenance stop

(BLANK) = Idle

Often part of one active, deadhead or maintenance leg appears at the end of one itinerary with the other part at the start of the next itinerary. In this case the data on this leg is included only in the statistics for the earlier itinerary.

Table 3.1

Baseline parameters for sensitivity studies (used for both Schedules 1 and 2)

Sizing mode - non fixed fleet

Planning horizon - 90 days

Road distance = 1.1 x great circle distance

Length of duty day (at base and on the road) - 24 hours

Weekend/holiday loading/unloading restrictions - none

Weekend/holiday travel restrictions - none

Average truck velocity - 55 kph

Truck loading time - 2 hours

Truck unloading time - 2 hours

Truck trailer capacities

Fuel type 1 - 12 containers

Fuel type 2 - 7 containers

Fuel type 3 - 16 containers

Truck maintenance policy - nearest maintenance base

Truck maintenance base location - Youngsville (HNC)

Maximum time between maintenance

Trailers 180 days, tractors 180 days

Trailers/tractors together 180 days

Maximum distance between maintenance

Trailers 40,232 km (25,000 mi.), Tractors 12,874 km (8,000 mi.)

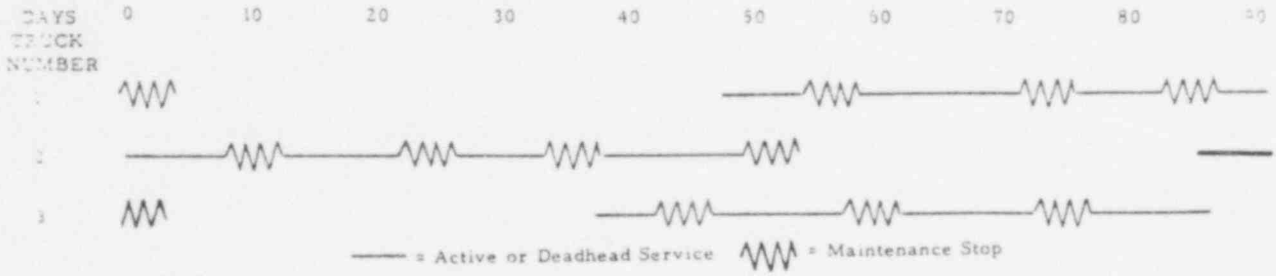
Trailers/tractors together 12,874 km (8,000 mi)

Length of maintenance stop

Trailer 4 days, tractors 2 days

Trailers/tractors together 4 days

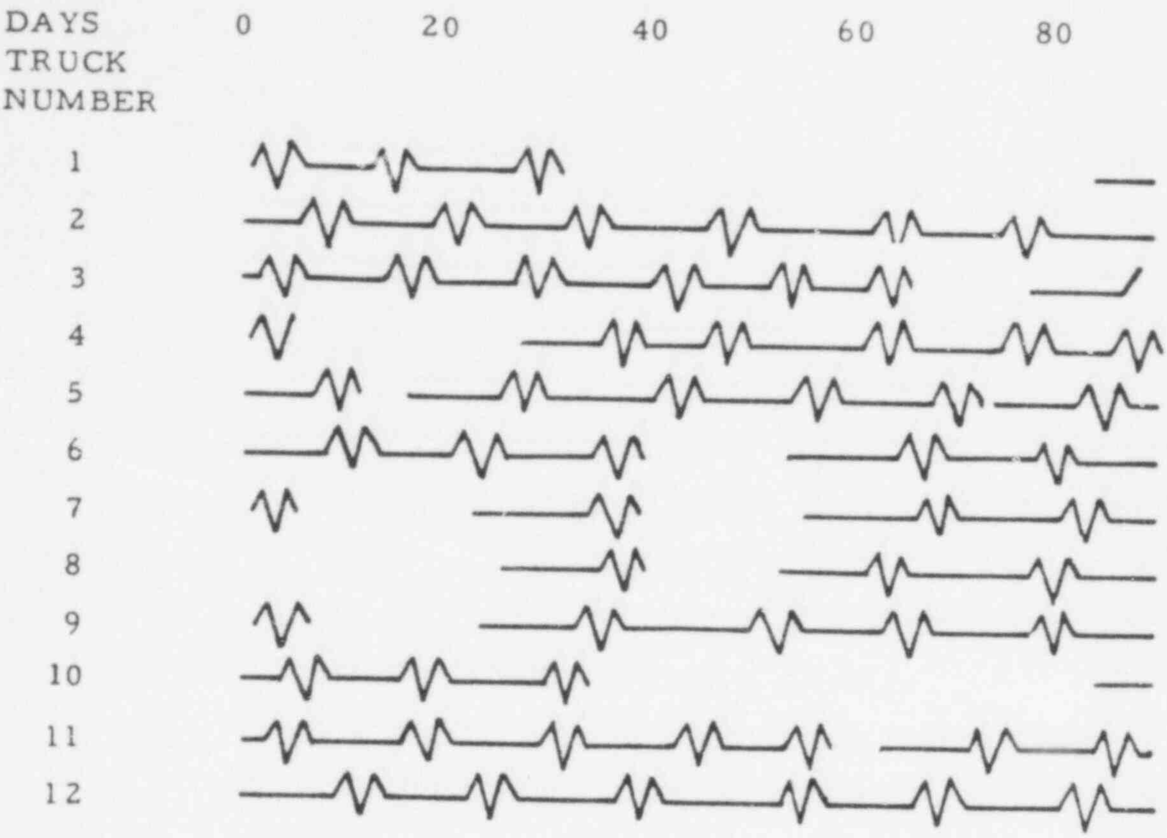
Linking value penalties: idle 10, deadhead 1, flexibility loss 0.1, total time 0.



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	33,468	13,411	20,057	16	43	40.1	47.8
2	41,550	13,710	27,840	16	31	33.0	34.4
3	41,832	17,127	24,705	16	33	40.9	36.7
TOTAL	116,851	44,249	72,602	48	108	-	-
AVE.	38,950	14,749	24,201	16	36	37.9	40.1

Figure 3.1. Schedule 1 trailer/tractor itineraries for baseline parameters. Linking value penalties: idle 10, deadhead 1, flexibility loss 0.1 and total time 0.

An important measure of efficiency of a set of itineraries is the percent of total distance traveled on active service, i.e., when the trailer/tractor is loaded. For Schedule 1, the small schedule, 37.9 percent of the total distance traveled is on active service, whereas with the larger schedule 2, 65.6 percent of this total distance is on active service. This dramatic difference is caused by the greater average density of 3.50 shipments per day during the first 90 days for schedule 2, as compared to 1.69 shipments per day for schedule 1. The greater density of shipments allows a larger choice of possible service linkings which, in turn, allows selection of those with relatively little deadhead travel required. In general, it can be expected that this percentage of total distance traveled on active service will increase as the average shipment density increases.



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	32,364	18,153	14,211	12	51	56.1	56.7
2	76,755	53,974	22,781	24	0	70.3	0
3	62,867	35,454	27,413	28	13	56.4	14.4
4	54,460	38,790	15,670	20	23	71.2	25.6
5	72,083	42,966	29,117	24	6	59.6	6.7
6	66,848	46,761	20,087	20	14	70.0	15.6
7	39,604	26,059	13,545	16	40	65.8	44.4
8	48,644	37,395	11,249	12	39	76.9	43.3
9	61,282	38,412	22,870	20	18	62.7	20.0
10	39,499	23,918	15,581	12	48	60.6	53.[illegible]
11	69,097	43,771	25,326	28	3	63.3	3.3
12	78,695	55,112	23,583	24	0	70.6	0
TOTAL	702,198	460,767	241,431	240	256	-	-
AVE.	58,516	38,397	20,119	20	21	65.6	23.7

Figure 3.2 Schedule 2 trailer-tractor itineraries with linking value penalty coefficients idle 10, deadhead 1, flexibility loss 0.1, and total time 0.

3.1 Effects of Linking Value Penalties

Since the linking value penalties are critical to the generation of good itineraries, an extensive number of runs were made to investigate the effects of variations in the linking value penalties. We first discuss the effects of the linking value penalties on trailer/tractor itineraries for both schedules 1 and 2. Then we briefly investigate the effects of linking value penalties for tractor itineraries when trailers and tractors are sequentially scheduled.

3.1.1 Trailer/Tractor Itineraries

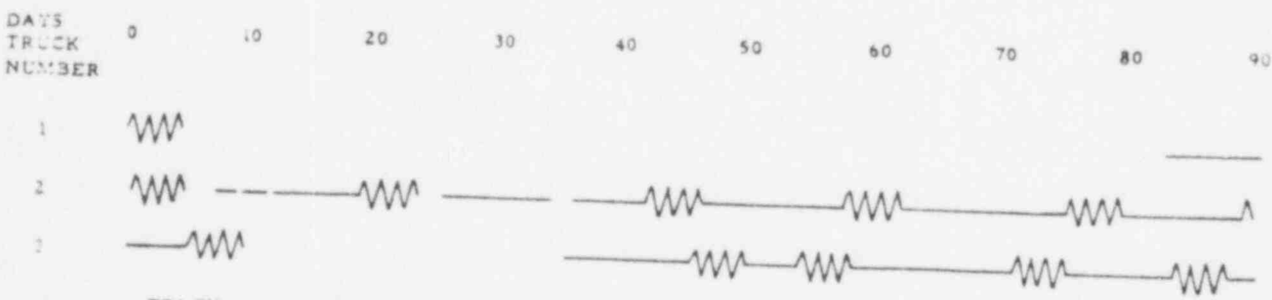
Table 3.2 summarizes the effects on fleet size and itinerary statistics for schedule 1 due to variations in the linking value penalties. The individual itineraries and their statistics are given in Figures 3.1 and 3.3 through 3.13.

Note that a fleet size of 3 is obtained in all but four situations: 1) when the flexibility loss penalty is small, but non-zero, relative to the idle and deadhead penalties, and the deadhead penalty is considerably larger than the idle; 2) when the flexibility loss penalty is about equal to the idle and deadhead penalties; 3) when there is no flexibility loss penalty; and 4) when a penalty for total time is included. The percent of total distance traveled on active service generally tends to increase as the deadhead penalty is increased relative to the idle penalty, as should be expected. An increase in the flexibility loss penalty tends to increase the deadhead distance traveled since now the linkings are chosen with more emphasis on flexibility loss. This, in turn, decreases the percent of total distance traveled on active service.

An important observation from these results is that the itineraries are relatively insensitive to rather large changes in the

Table 3.2 Results of sensitivity study on linking value penalties for Schedule 1, trailers/tractors together.

IDLE PENALTY	DEADHEAD PENALTY	FLEX LOSS PENALTY	TIME PENALTY	FLEET SIZE	TOTAL KM	PERCENT KM ACTIVE	PERCENT DAYS IDLE
10	1	0.1	0	3	116,851	37.9	40.1
5	1	0.1	0	3	116,851	37.9	40.1
2	1	0.1	0	3	116,851	37.9	40.1
1	1	0.1	0	3	114,965	38.5	42.1
1	2	0.1	0	3	110,688	40.0	44.8
1	10	0.1	0	4	105,310	42.0	59.7
2	2	0.1	0	3	110,588	40.0	44.8
10	1	1	0	3	154,920	28.6	23.5
2	1	1	0	3	155,474	28.5	23.3
1	1	1	0	4	155,125	28.5	42.5
1	2	1	0	3	143,503	30.8	31.1
2	1	0	0	4	114,100	38.8	55.6
1	2	0	0	4	111,703	39.6	57.2
10	1	0.1	10	4	143,963	30.7	44.9



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	6,276	2,286	3,990	0	81	36.4	90.0
2	62,252	24,159	38,093	24	7	38.8	7.8
3	46,436	17,803	28,633	20	26	38.3	28.9
TOTAL	114,965	44,249	70,716	44	114	-	-
AVE.	38,321	14,749	23,572	15	38	38.5	42.1

Figure 3.3 Schedule 1 trailer/tractor itineraries with linking value penalty coefficients idle 10, deadhead 10, flexibility loss 1, and total time 0; and idle 1, deadhead 1, flexibility loss 0.1 and total time 0.

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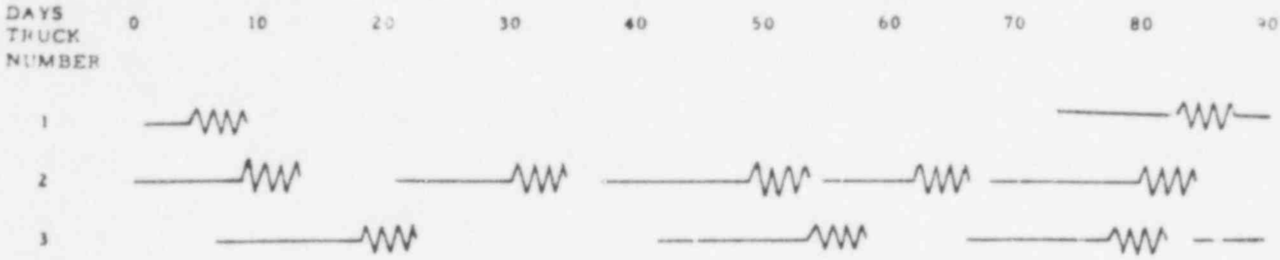
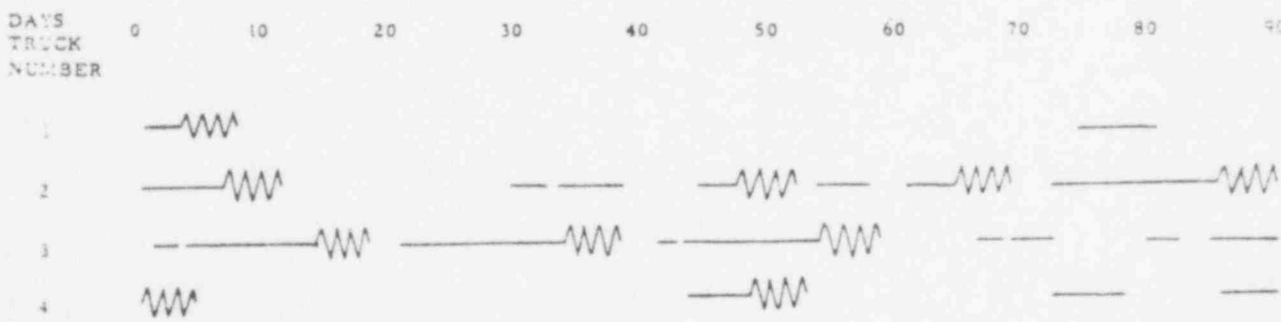


TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	17,204	5,418	11,786	8	65	31.5	72.2
2	51,211	20,023	31,188	20	20	39.1	22.2
3	42,273	18,808	23,465	12	36	44.5	40.0
TOTAL	110,688	44,249	66,439	40	121	-	-
AVE.	36,896	14,750	22,146	13	40	40.0	44.8

Figure 3.4 Schedule 1 trailer/tractor itineraries with linking value penalty coefficients idle 1, deadhead 2, flexibility loss 0.1, and total time 0.



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	9,913	3,942	5,971	4	77	39.8	85.6
2	35,576	13,884	21,692	16	38	39.0	42.2
3	44,595	18,986	25.609	12	32	42.0	35.6
4	15,226	7,437	7,789	8	68	40.8	75.6
TOTAL	105,310	44,248	61,062	40	215	-	-
AVG.	26,327	11,062	15,265	10	54	42.0	59.7

Figure 3.5 Schedule 1 trailer/tractor itineraries with linking value penalty coefficients idle 1, deadhead 10, flexibility loss 0.1 and total time 0.

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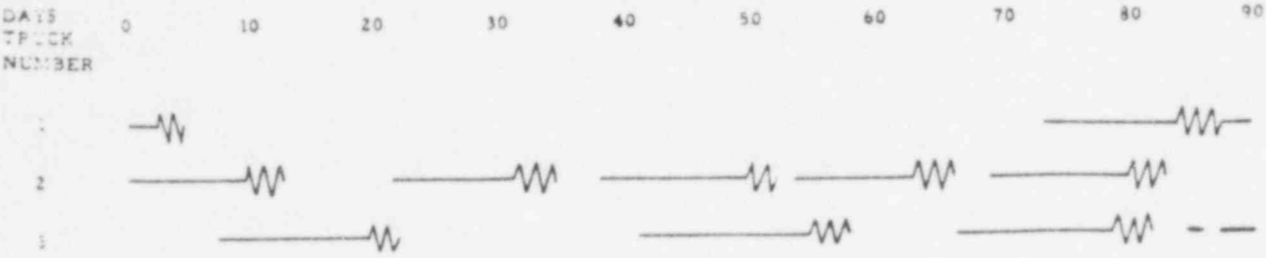
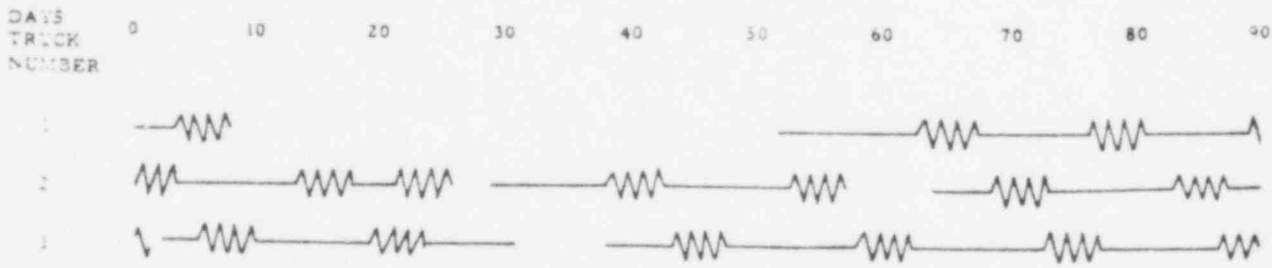


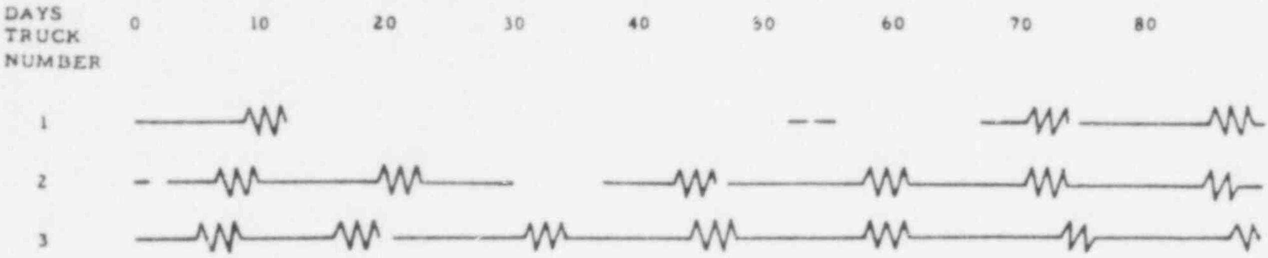
TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	17,204	5,418	11,786	8	65	31.5	72.2
2	51,211	20,023	31,188	20	20	39.1	22.2
3	42,273	18,808	23,465	12	36	44.5	43.0
TOTAL	110,688	44,249	66,439	40	121	-	-
AVE.	36,896	14,750	22,146	13	40	40.0	44.4

Figure 3.6 Schedule 1 trailer/tractor itineraries with linking value penalty coefficients idle 2. deadhead 2, flexibility loss 0.1, and total time 0.



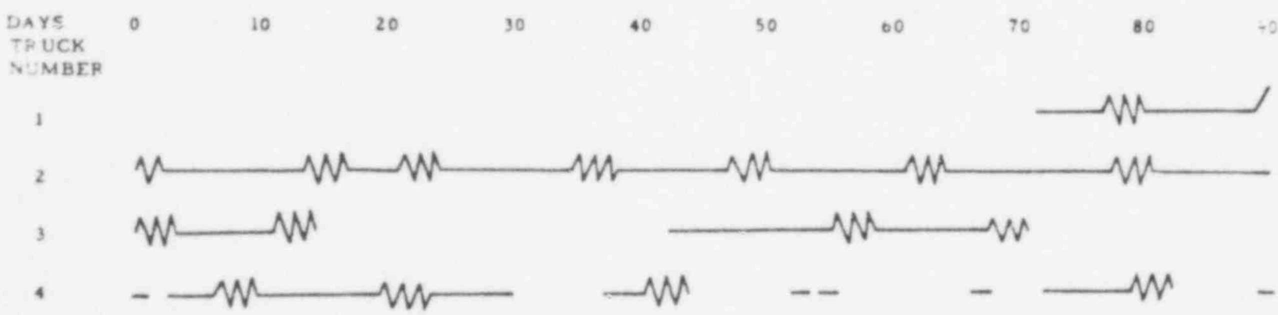
TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	36,642	11,235	25,407	16	43	30.7	47.8
2	55,430	14,773	40,657	24	12	26.7	13.4
3	62,848	18,240	44,608	24	8	29.0	8.9
TOTAL	154,920	44,249	110,672	64	63	-	-
AVE.	51,640	14,750	36,891	21	21	28.6	23.5

Figure 3.7. Schedule 1 trailer/tractor itineraries with linking value penalty coefficients idle 10, deadhead 1, flexibility loss 1 and total time 0.



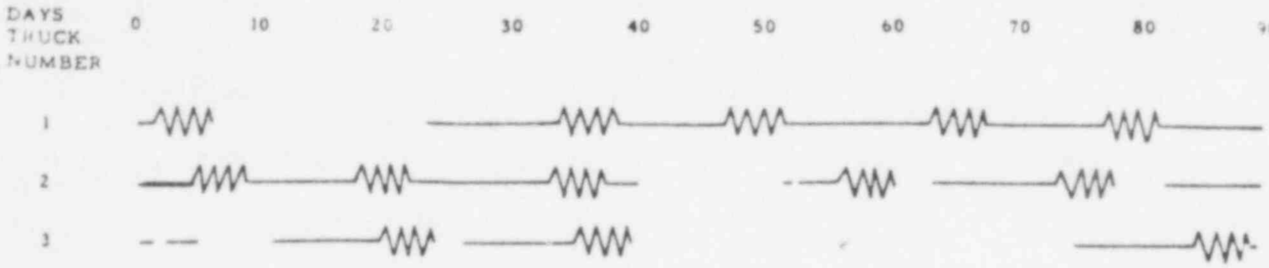
TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	25,869	5,169	20,700	12	52	20.0	57.8
2	60,207	17,165	43,042	24	9	28.5	10.0
3	69,397	21,914	47,483	28	2	31.6	2.2
TOTAL	155,474	44,249	111,225	64	63	-	-
AVE.	51,825	14,750	37,075	21	21	28.5	23.3

Figure 3.8. Schedule 1 trailer/tractor itineraries with linking value penalty coefficients idle 2, deadhead 1, flexibility loss 1 and total time 0.



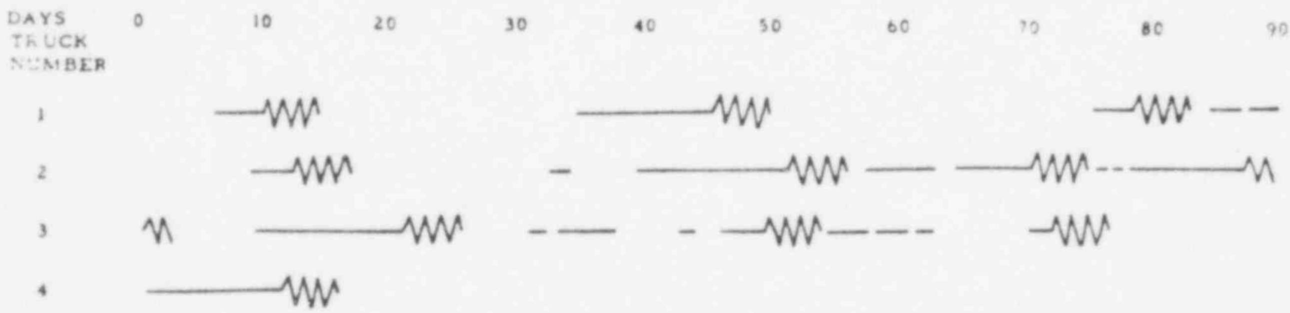
TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	15,977	5,804	10,173	8	71	36.3	78.9
2	70,651	22,523	48,128	24	0	31.9	0
3	30,791	10,600	20,191	16	46	34.4	51.1
4	37,705	5,321	32,384	16	36	14.1	40.1
TOTAL	155,125	44,249	110,876	64	153	-	-
AVE.	38,781	11,062	27,719	16	38	28.5	42.5

Figure 3.9. Schedule 1 trailer/tractor itineraries with linking value penalty coefficients idle 1, deadhead 1, flexibility loss 1, and total time 0.



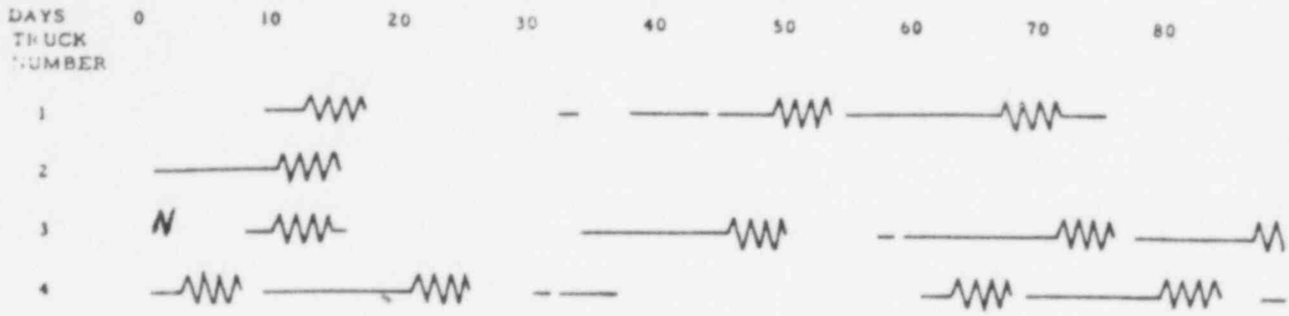
TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	56,985	20,521	36,464	20	13	36.0	20.0
2	53,231	15,576	37,705	20	19	29.2	21.1
3	33,237	8,152	25,085	12	47	24.5	52.2
TOTAL	143,503	44,249	99,254	52	84	-	-
AVE.	47,834	14,749	33,085	17	28	30.8	31.1

Figure 3.10. Schedule 1 trailer/tractor itineraries with linking value penalty coefficients idle 1, deadhead 2, flexibility loss 1, and total time 0.



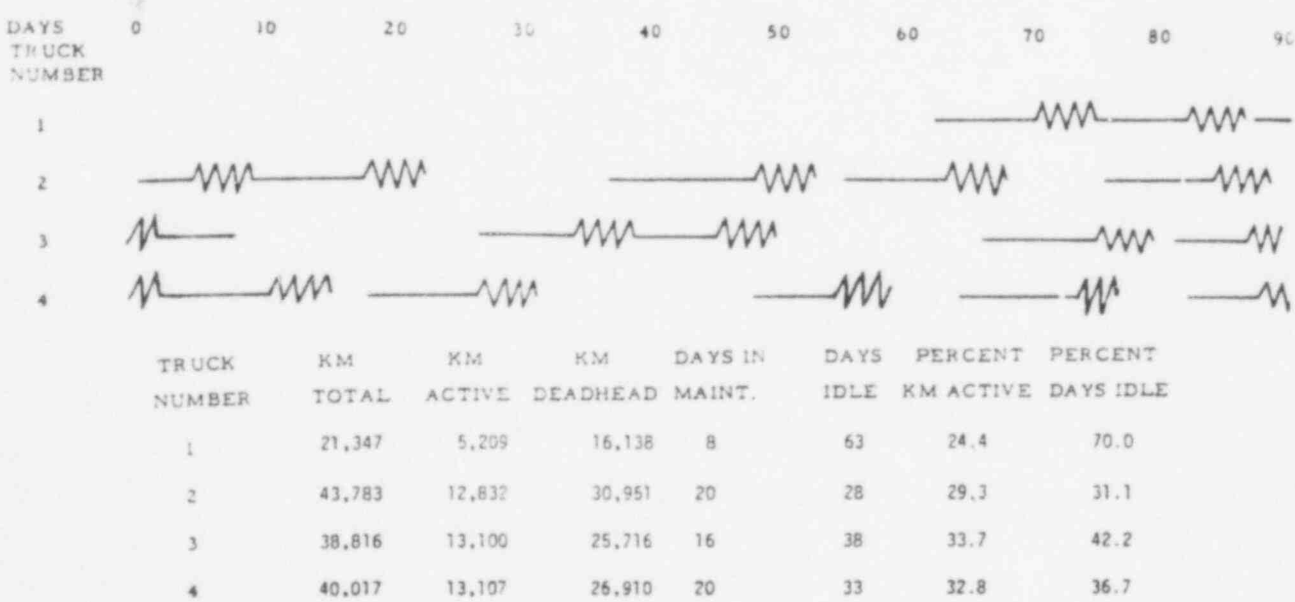
TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	29,777	11,388	18,389	12	50	38.2	55.6
2	40,015	16,352	23,662	16	37	40.9	41.1
3	30,216	11,520	18,696	12	44	38.1	48.9
4	11,694	4,988	6,706	4	75	42.7	83.3
TOTAL	111,703	44,249	67,454	44	206	-	-
AVE.	27,926	11,062	16,864	11	52	39.6	57.2

Figure 3.11. Schedule 1 trailer/tractor itineraries with linking value penalty coefficients idle 1, deadhead 2, flexibility loss 0, and total time 0.



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	27,698	10,176	17,522	12	49	36.7	54.4
2	11,725	4,988	6,737	4	75	42.5	83.3
3	38,824	15,934	22,890	16	37	41.0	41.1
4	35,853	13,151	22,702	16	38	36.7	42.2
TOTAL	114,100	44,249	69,851	48	200	-	-
AVE.	28,525	11,062	17,463	12	50	38.8	55.6

Figure 3.12. Schedule 1 trailer/tractor itineraries with linking value penalty coefficients idle 2, deadhead 1, flexibility loss 0, and total time 0.



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	21,347	5,209	16,138	8	63	24.4	70.0
2	43,783	12,832	30,951	20	28	29.3	31.1
3	38,816	13,100	25,716	16	38	33.7	42.2
4	40,017	13,107	26,910	20	33	32.8	36.7
TOTAL	143,963	44,249	99,714	64	161	-	-
AVE.	35,991	11,062	24,929	16	40	30.7	44.9

Figure 3.13. Schedule 1 trailer/tractor itineraries with linking value penalty coefficients idle 10, deadhead 1, flexibility loss 0.1 and total time 0.

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idle linking value penalty. For example, with a deadhead penalty of 1 and a flexibility loss penalty of 0.1 identical itineraries are generated with idle penalties of 10, 5 and 2. The reason for this is that, due to the large amount of flexibility in the shipment schedule, there are a large number of possible linkings with zero idle time. These linkings, which are generally the first to be selected, are independent of the idle penalty. There is, however, greater sensitivity to changes in the deadhead and flexibility loss penalties.

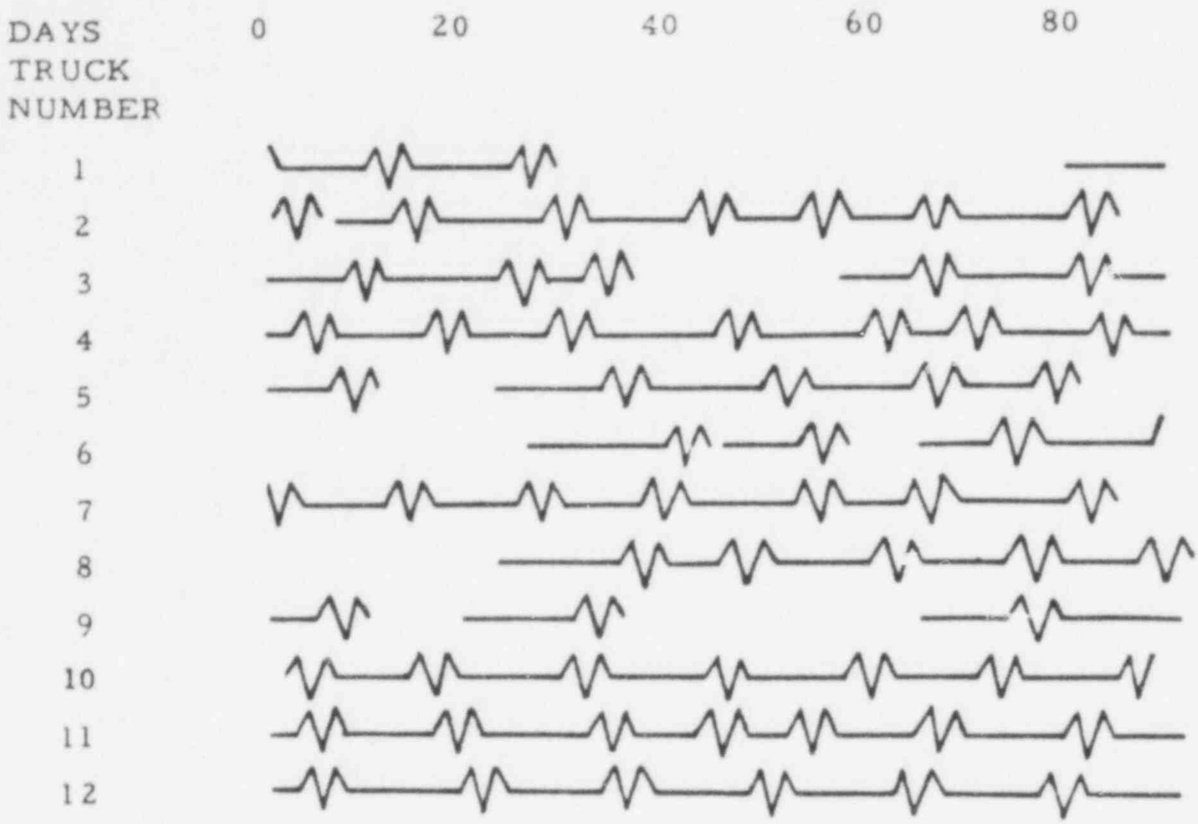
Table 3.3 summarizes the statistics of the study of the effect of the linking value penalties on the itineraries for schedule 2. The detailed itineraries and their statistics are given by Figures 3.2 and 3.14 through 3.24. The results are very similar to those obtained with schedule 1. A fleet size of 12 is generally obtained (13 in one case) for a flexibility loss penalty of 0.1 as long as the deadhead penalty does not exceed 5 with the idle penalty set at 1.

3.1.2 Tractor Itineraries to Cover Trailer Service Requirements

When trailer itineraries are generated to cover the shipping service requirements, these itineraries levy service requirements for truck tractors to pull the trailers. In the resulting trailer service requirements for tractors there is no flexibility since all the original flexibility in the shipment schedule was used in the generation of the trailer itineraries. In the development of the model, preliminary runs indicated that in this situation a tractor tends to be assigned to one trailer itinerary until either the tractor or the trailer goes to maintenance. This assignment of tractors to cover trailer itineraries is relatively insensitive to the linking value penalties on idle and deadhead time.

Table 3.3. Results of sensitivity study on linking value penalties for Schedule 2, trailers/tractors together, 90 days planning horizon.

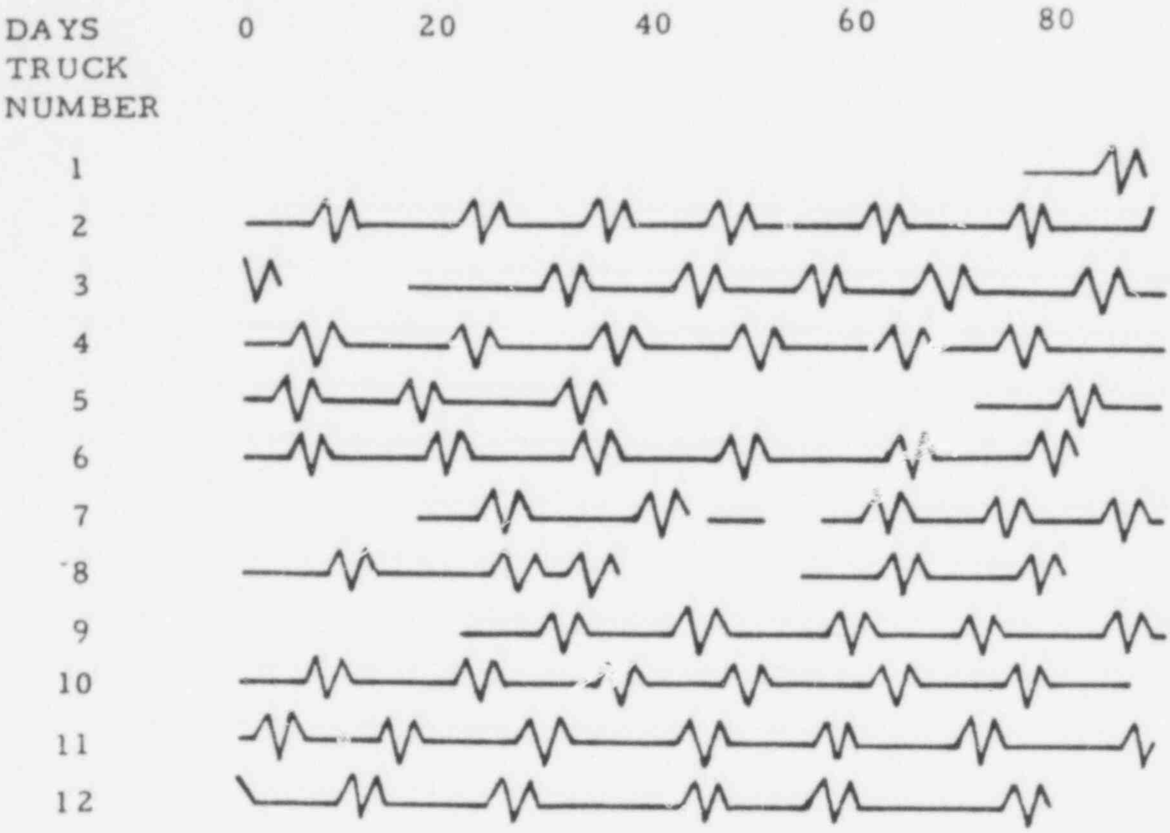
IDLE PENALTY	DEADHEAD PENALTY	FLEX LOSS PENALTY	TIME PENALTY	FLEET SIZE	TOTAL KM	PERCENT KM ACTIVE	PERCENT DAYS IDLE
20	1	0.1	0	12	733,416	62.8	20.0
10	1	0.1	0	12	702,198	65.6	23.7
5	1	0.1	0	12	725,698	63.5	21.3
2	1	0.1	0	13	710,804	64.8	28.6
1	1	0.1	0	12	742,962	62.0	19.3
1	2	0.1	0	12	698,399	66.0	23.9
1	5	0.1	0	16	667,342	69.1	45.7
1	10	0.1	0	15	651,954	70.7	43.2
10	1	1	0	13	820,746	56.1	16.4
2	1	0	0	15	711,479	64.8	36.9
10	1	0.1	10	16	883,816	52.1	25.7
1	2	0	0	13	700,616	65.8	28.3



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	38,230	23,335	14,895	12	49	61.0	54.4
2	66,870	38,440	28,430	24	8	57.5	8.9
3	63,639	36,232	27,408	20	20	56.9	22.2
4	72,452	43,676	28,776	28	0	60.3	0
5	55,833	35,420	20,413	20	24	63.4	27.8
6	47,333	29,801	17,532	16	38	63.0	42.2
7	67,344	44,189	23,155	24	6	65.6	6.7
8	54,116	36,625	17,491	20	25	67.7	27.8
9	42,775	27,600	15,175	12	42	64.5	46.7
10	74,759	48,151	26,608	28	0	64.4	0
11	77,084	47,730	29,354	28	1	61.9	1.1
12	72,979	49,568	23,411	24	1	67.9	1.1
TOTAL	733,416	460,767	272,649	256	216	-	-
AVE.	61,118	38,397	22,721	21.3	18.0	62.8	20.0

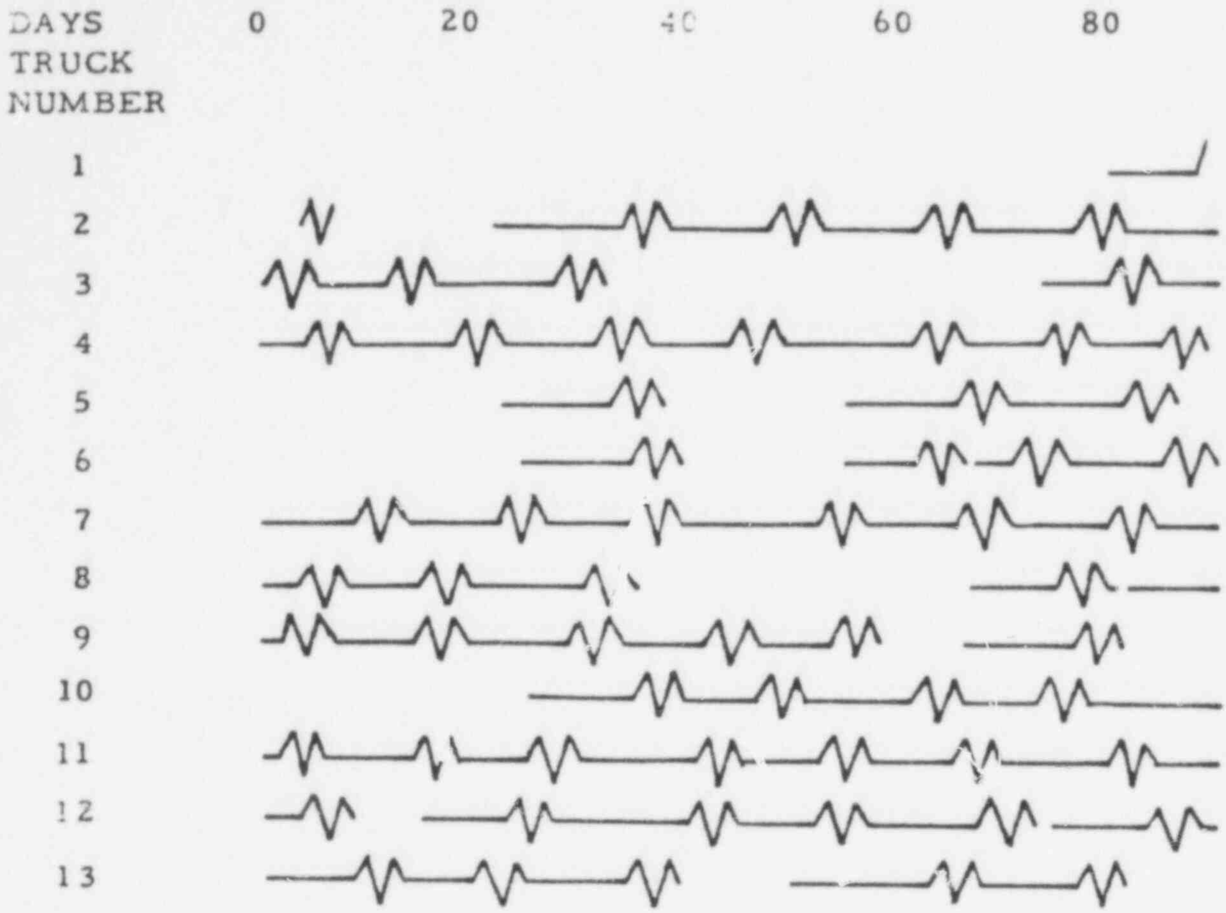
Figure 3.14. Schedule 2 trailer/tractor itineraries with linking value penalty coefficients idle 20, deadhead 1, flexibility loss 0.1, and total time 0.

779 165



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	14,378	10,149	4,229	4	74	70.6	82.2
2	78,973	46,148	32,825	28	0	58.4	0
3	67,538	42,562	24,976	20	15	63.0	16.7
4	75,874	51,040	24,834	24	0	67.3	0
5	49,777	33,815	15,962	16	34	67.9	37.8
6	62,997	44,243	18,754	24	10	70.2	11.1
7	55,400	35,346	20,054	20	26	63.8	28.9
8	50,560	27,835	22,725	20	27	55.1	30.0
9	56,235	33,348	22,887	20	23	59.3	25.6
10	79,924	54,837	25,087	24	0	68.6	0
11	74,759	48,151	26,608	28	1	64.4	1.1
12	59,282	33,292	25,990	20	19	56.1	21.1
TOTAL	725,698	460,767	264,931	248	230	-	-
AVE.	60,475	38,397	22,078	21	19	63.5	21.3

Figure 3.15. Schedule 2 trailer/tractor itineraries with linking value penalty coefficients idle 5, deadhead 1, flexibility loss 0.1, and total time 0.



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	12,351	8,434	3,917	4	79	68.3	87.8
2	60,188	38,412	21,776	16	19	63.8	21.1
3	40,369	21,165	19,204	16	41	52.4	45.6
4	74,591	52,173	22,418	28	0	69.4	0
5	38,296	26,059	12,237	12	45	68.0	50.0
6	40,006	24,797	15,209	16	42	62.0	46.7
7	78,695	55,112	23,553	24	0	70.0	0
8	52,895	30,688	22,207	16	33	58.0	36.7
9	56,388	36,944	19,444	24	18	65.5	20.0
10	55,593	38,884	16,709	16	26	70.0	28.9
11	75,2[illegible]	40,009	35,232	28	2	53.2	2.2
12	68,[illegible]	42,966	25,218	24	9	63.0	10.0
13	58,007	45,123	12,884	20	21	77.8	23.3
TOTAL	710,804	460,767	250,037	244	335	-	-
AVE.	54,677	35,443	19,734	19	26	64.8	28.6

Figure 3.16. Schedule 2 trailer/tractor itineraries with linking value penalty coefficients idle 2, deadhead 1, flexibility loss 0.1, and total time 0.

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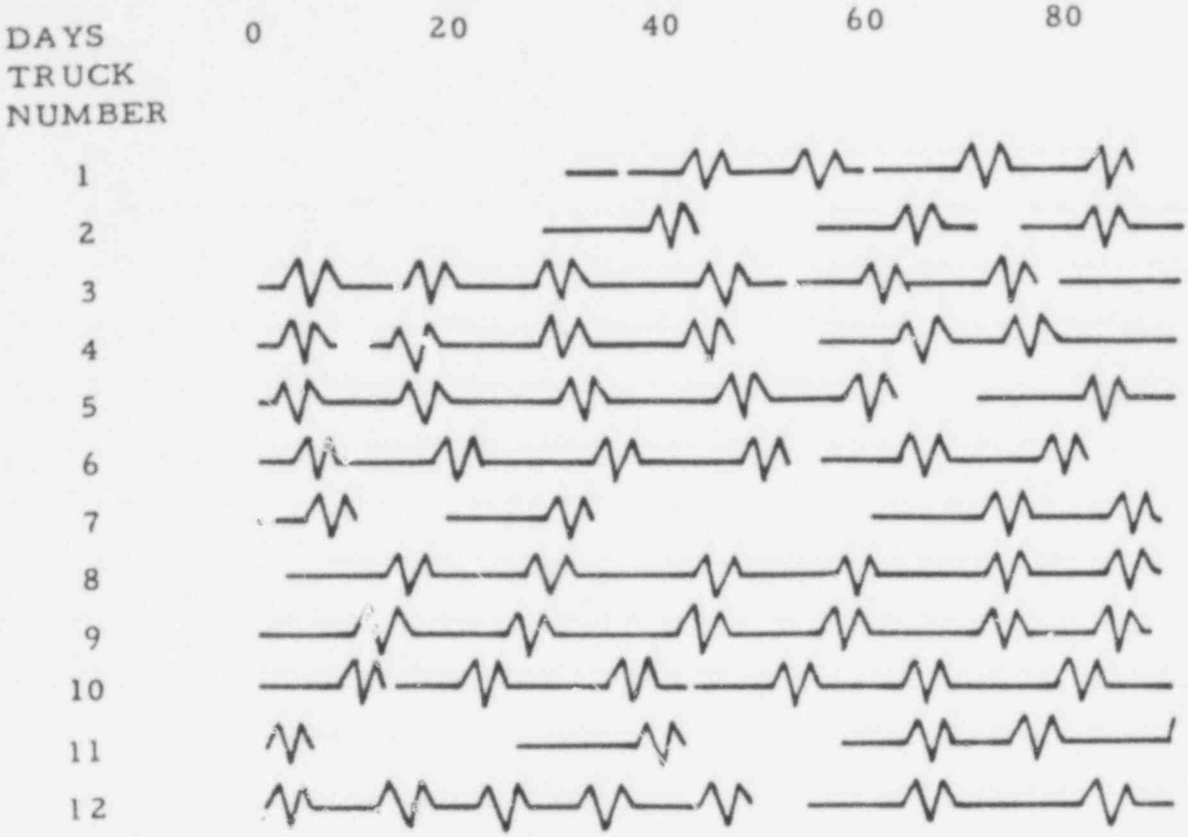
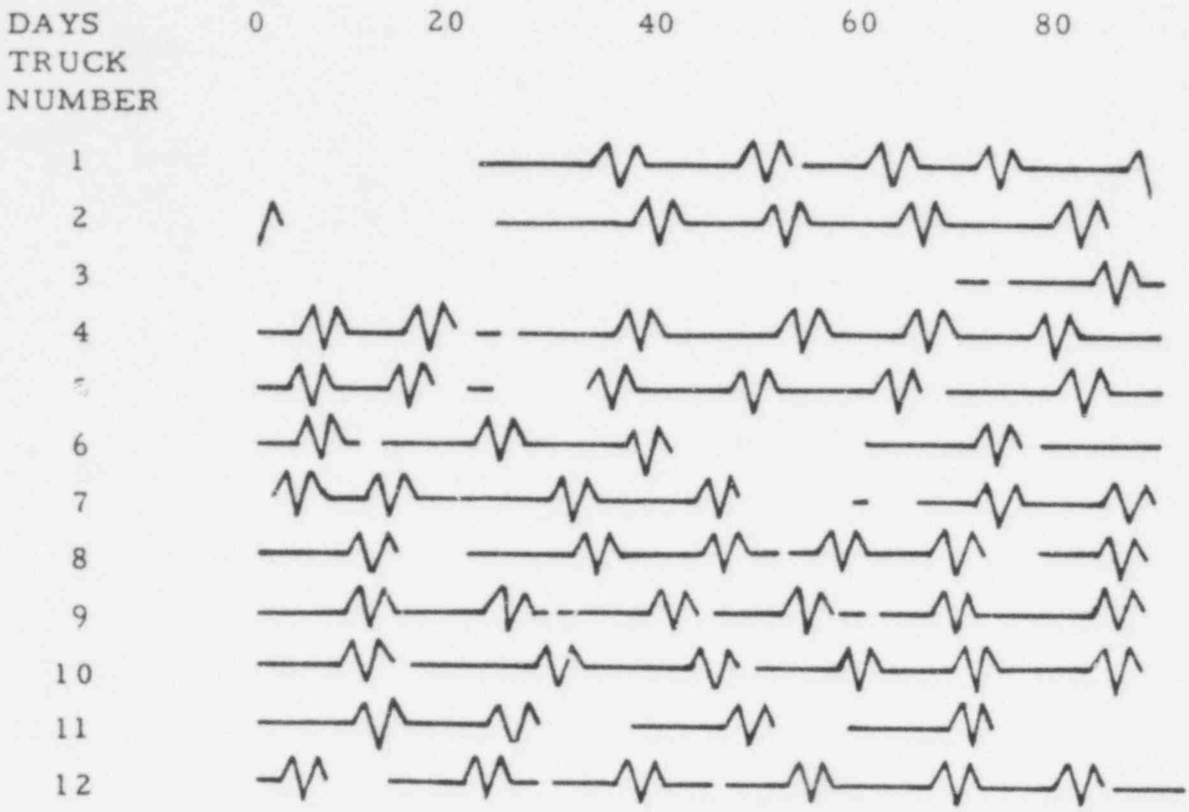


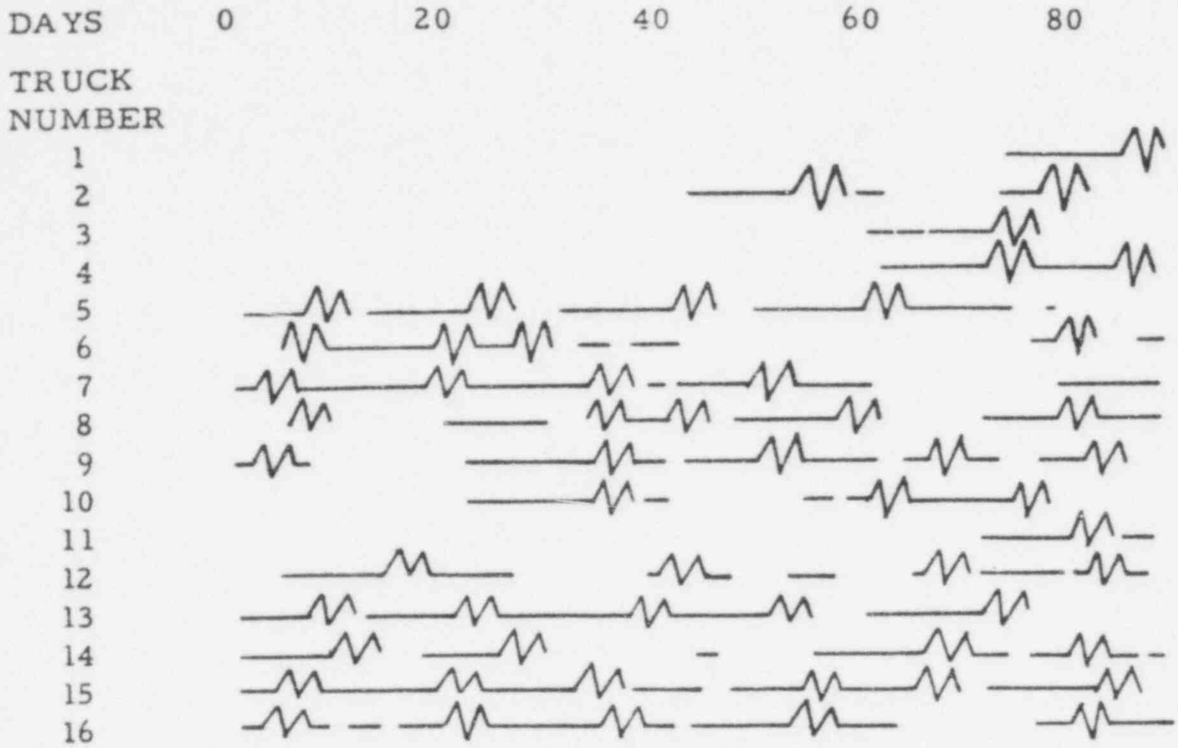
TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	44,341	23,459	20,882	[illegible]	38	52.9	42.2
2	40,325	25,859	14,466	12	47	64.1	52.2
3	72,316	45,482	26,834	24	3	62.9	3.3
4	68,687	46,355	22,332	24	9	67.5	10.0
5	71,292	43,684	27,608	24	9	61.3	10.0
6	62,716	44,874	17,842	24	11	71.6	12.2
7	46,234	27,502	18,732	16	37	59.5	41.1
8	73,523	47,692	25,831	24	4	64.9	4.4
9	75,755	47,581	2[illegible],174	24	1	62.8	1.1
10	78,223	43,640	34,583	24	2	55.8	2.2
11	43,493	26,149	17,344	20	38	60.1	42.2
12	66,056	38,489	27,567	24	8	58.3	8.9
TOTAL	742,962	460,767	282,195	256	209	-	-
AVE.	61,913	38,397	23,516	21	17	62.0	19.3

Figure 3.17. Schedule 2 trailer/tractor itineraries with linking value penalty coefficients idle 1, deadhead 1, flexibility loss 0.1, and total time 0.



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	55,128	34,815	20,313	20	26	63.2	28.9
2	46,859	31,070	15,789	16	31	66.3	34.4
3	16,444	10,940	5,504	4	74	66.5	82.2
4	71,604	49,218	22,386	24	6	68.7	6.7
5	70,413	44,905	25,508	24	9	63.8	10.0
6	52,184	37,697	14,487	16	28	72.2	31.1
7	60,049	38,517	21,532	24	19	64.1	21.1
8	65,297	39,496	[illegible]	24	12	60.5	13.3
9	70,664	46,935	3,729	24	7	66.4	7.8
10	71,461	[illegible]	10,576	24	7	71.2	7.8
11	49,531	[illegible]	15,676	16	31	68.4	34.4
12	68,762	[illegible]	[illegible]	24	9	61.7	10.0
TOTAL	698,399	460,767	237,632	[illegible]	258	-	-
AVE.	58,200	38,397	19,803	20	22	66.0	23.9

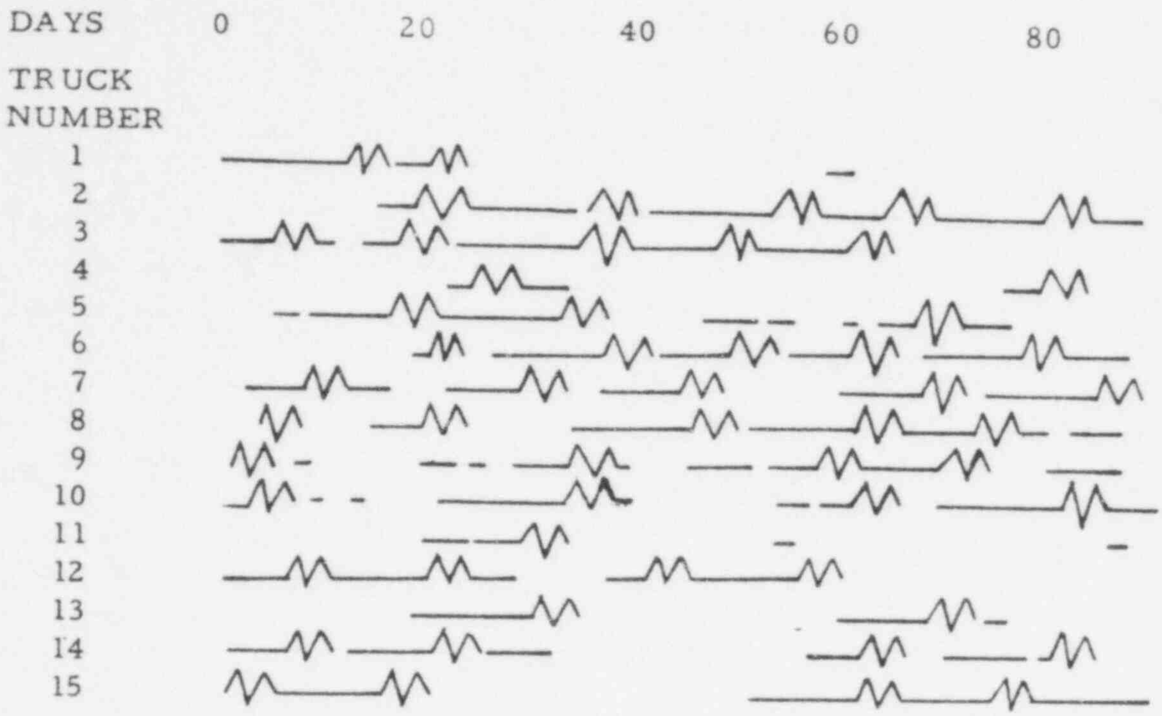
Figure 3.18. Schedule 2 trailer/tractor itineraries with linking value penalty coefficients idle 1, deadhead 2, flexibility loss 0.1, and total time 0.



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	11,875	8,668	3,208	4	76	73.0	84.4
2	20,221	11,604	8,617	8	66	57.4	73.3
3	12,616	9,037	3,579	4	75	71.6	83.3
4	25,527	17,125	7,402	8	62	67.1	68.9
5	58,893	40,421	18,472	16	25	68.6	27.8
6	38,753	23,878	14,875	16	43	61.6	47.8
7	52,323	37,353	14,970	16	29	71.4	32.2
8	51,911	37,569	14,342	20	28	72.4	31.1
9	53,634	34,563	19,071	20	24	64.4	26.7
10	35,035	28,472	6,563	12	50	81.3	55.6
11	13,325	10,591	2,734	4	75	79.5	83.3
12	52,282	38,173	14,109	16	32	23.0	35.6
13	59,584	39,077	20,507	20	20	65.6	22.2
14	53,683	37,756	15,927	16	30	70.3	33.3
15	66,404	43,162	23,242	24	9	65.0	10.0
16	62,274	43,317	18,957	20	17	69.6	18.9
TOTAL	667,342	460,767	206,575	224	658	--	--
AVG.	41,709	28,798	12,911	14	41	69.1	45.7

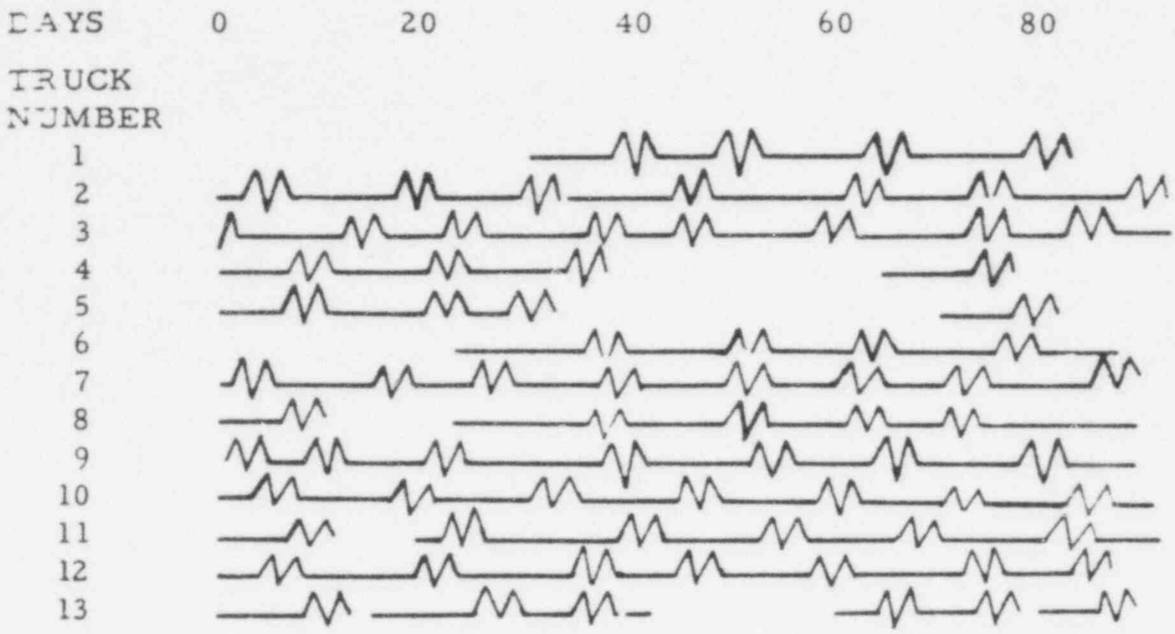
Figure 3.19. Schedule 2 trailer/tractor itineraries with linking value penalty coefficients idle 1, deadhead 5, flexibility loss 0.1 and total time 0.

779 170



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	23,672	15,447	8,225	8	61	65.3	67.8
2	62,909	48,222	14,687	20	17	76.7	18.9
3	57,299	43,447	13,852	20	23	75.8	25.6
4	13,240	9,430	3,810	8	71	71.2	70.9
5	46,058	34,174	11,884	12	39	74.2	43.3
6	50,902	35,924	14,978	20	29	70.6	30.2
7	52,944	35,045	17,899	20	26	66.2	28.9
8	64,627	41,125	23,503	20	15	63.6	16.7
9	47,829	33,379	14,450	16	35	69.8	38.9
10	45,465	36,334	9,131	16	35	79.9	38.9
11	15,054	9,203	5,851	4	73	61.1	81.1
12	47,200	29,162	18,038	16	35	61.8	38.9
13	28,280	19,120	9,159	8	57	67.6	63.3
14	46,338	35,906	10,432	16	36	77.5	40.0
15	50,135	34,846	15,289	16	32	69.6	35.6
TOTAL	651,954	460,767	191,187	220	584	--	--
AVG.	43,464	30,718	12,746	15	39	70.7	43.2

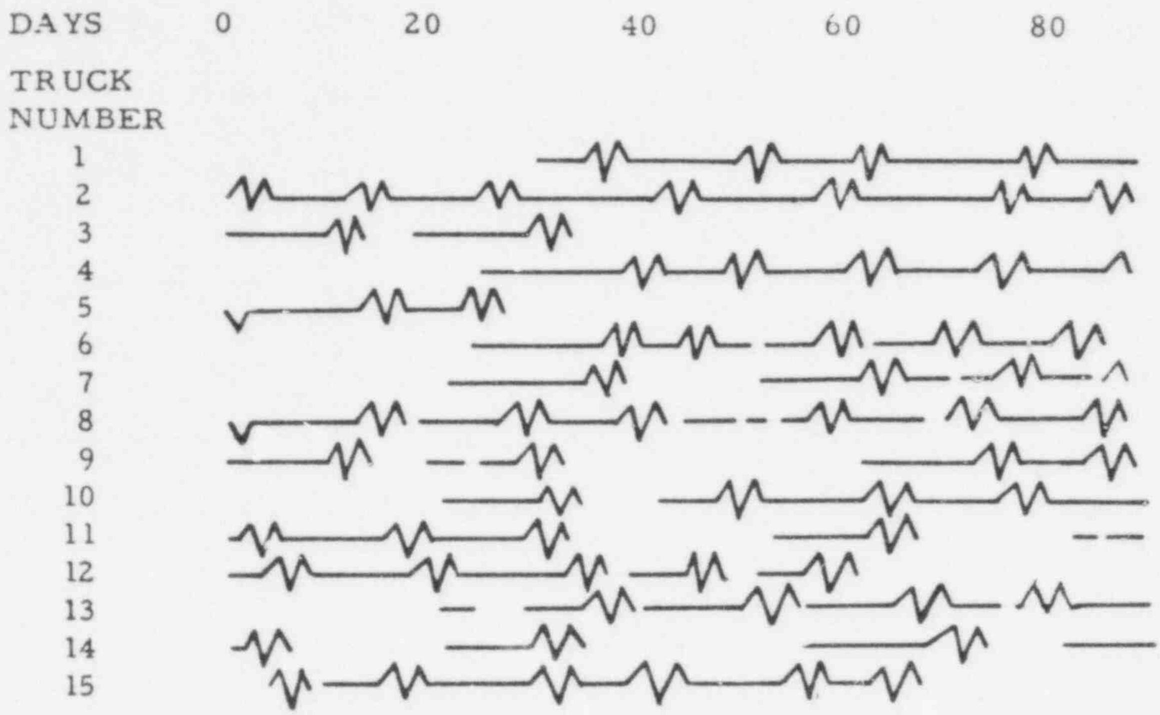
Figure 3.20. Schedule 2 trailer/tractor itineraries with linking value penalty coefficients idle 1, deadhead 10, flexibility loss 0.1, and total time 0.



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM / CTIVE	PERCENT DAYS IDLE
1	56,182	30,835	25,347	16	31	54.9	34.4
2	74,225	42,912	31,313	28	0	57.8	0
3	70,743	40,285	30,458	28	0	56.9	0
4	38,021	19,420	18,601	16	44	51.1	48.9
5	33,918	13,387	20,531	16	47	39.5	52.2
6	58,644	35,187	23,457	16	25	60.0	22.8
7	70,633	45,687	24,946	32	0	64.7	0
8	69,200	38,428	30,772	20	13	55.5	14.4
9	74,068	38,369	35,699	28	0	51.8	0
10	[illegible]	42,568	33,316	28	0	56.1	0
11	69,248	40,565	28,683	24	9	58.6	10.0
12	75,992	40,522	35,470	28	0	53.3	0
13	53,986	32,599	21,387	24	23	60.4	25.6
TOTAL	820,746	460,767	359,979	304	192	--	---
AVG.	63,134	35,443	27,691	23	15	56.1	16.4

Figure 3.21 Schedule 2 trailer/tractor itineraries with linking value penalty coefficients idle 10, deadhead 1, flexibility loss 1 and total time 0.

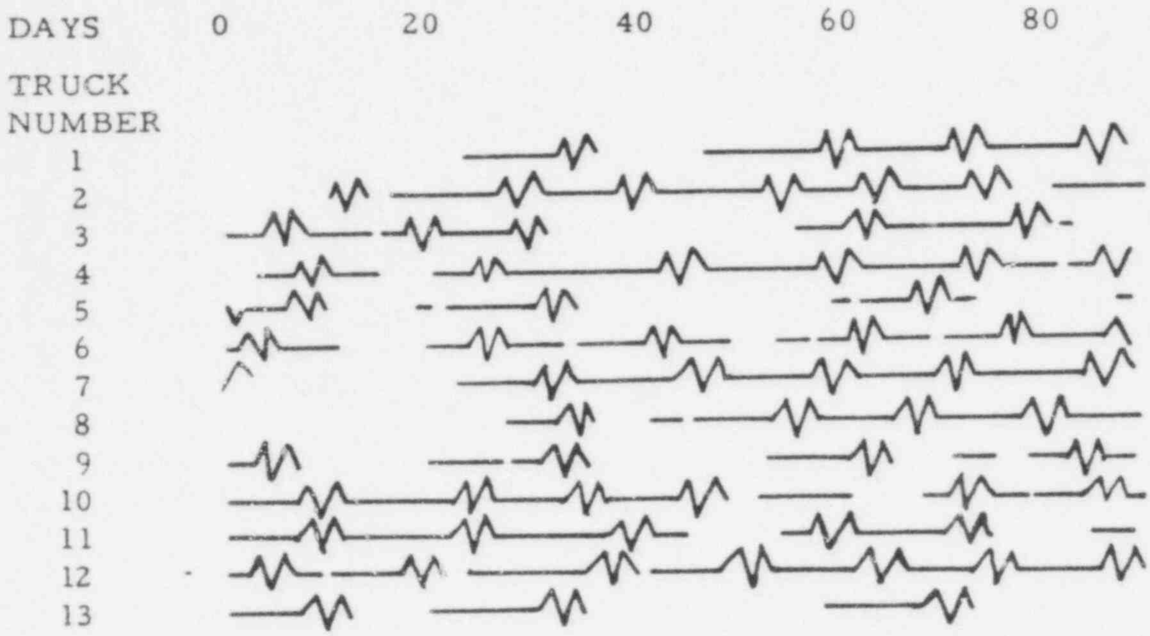
779 172



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	55,102	37,442	17,660	16	29	68.0	32.2
2	71,362	39,873	31,489	28	2	55.9	2.2
3	23,994	19,821	4,173	8	61	82.6	67.8
4	53,049	33,640	19,409	20	29	63.4	32.2
5	23,229	16,948	6,281	8	60	73.0	66.7
6	48,210	30,171	18,039	20	32	62.6	35.6
7	43,442	33,317	10,125	16	42	76.7	46.7
8	69,886	45,695	24,191	24	5	65.4	5.6
9	43,879	23,227	20,652	16	35	52.9	38.9
10	54,326	38,772	15,554	16	29	71.4	32.2
11	42,899	24,483	18,416	16	38	57.1	42.2
12	44,846	28,252	16,594	20	33	63.0	36.7
13	55,730	38,653	17,077	16	28	69.4	31.1
14	31,389	20,625	10,764	12	49	65.7	54.4
15	50,130	29,844	20,286	24	25	59.4	27.8
TOTAL	711,479	460,767	250,712	260	499	-	-
AVE.	47,432	30,718	16,714	17	33	64.8	36.9

Figure 3.22. Schedule 2 trailer/tractor itineraries with linking value penalty coefficients idle 2, deadhead 1, flexibility loss 0, and total time 0.

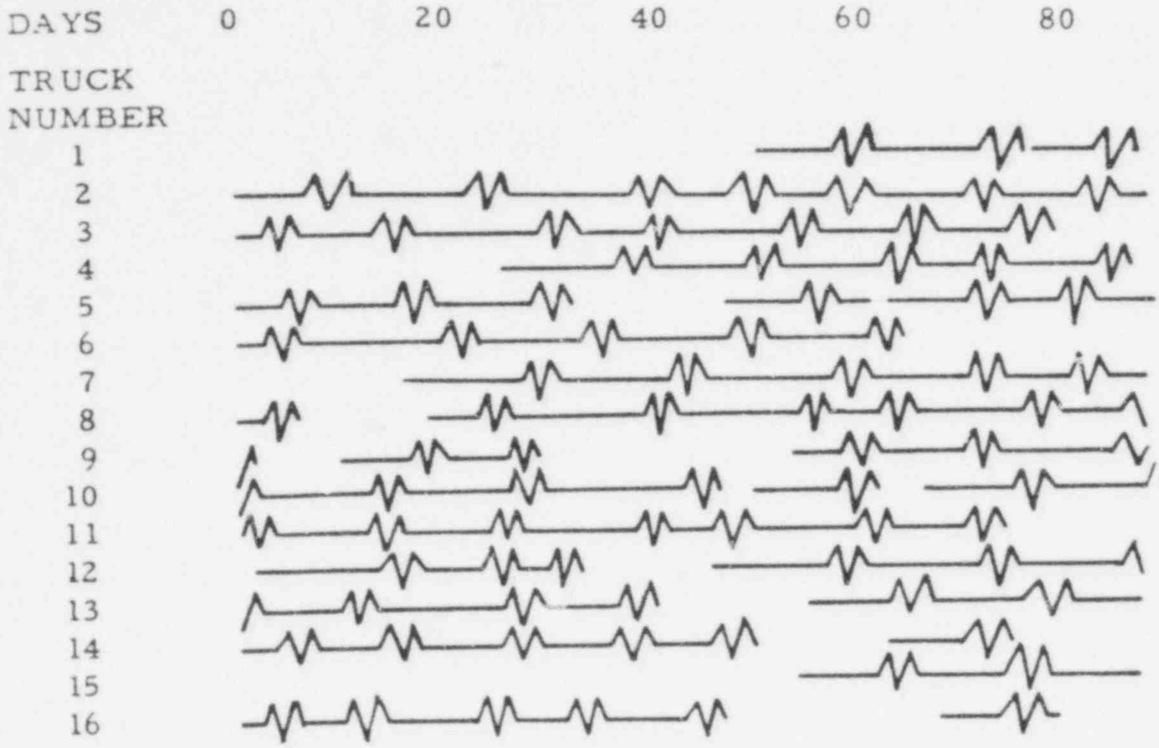
779 175



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	44,998	28,241	16,757	16	37	62.8	41.1
2	70,741	46,509	24,232	24	9	65.7	10.0
3	40,720	30,892	9,828	20	33	75.8	36.7
4	72,751	48,052	24,699	24	5	66.0	5.6
5	39,090	26,309	12,781	12	46	67.3	51.1
6	61,142	40,189	20,953	24	17	65.7	18.9
7	53,397	32,601	20,796	20	22	61.1	24.4
8	50,075	33,863	16,211	16	33	67.6	36.7
9	36,914	24,045	12,869	16	43	65.1	47.8
10	66,025	46,138	19,887	24	10	69.9	11.1
11	58,720	41,277	17,443	20	23	70.3	25.6
12	69,097	45,665	23,432	28	3	66.1	3.3
13	36,944	16,986	19,958	12	47	46.0	52.2
TOTAL	700,616	460,767	239,849	256	331	-	-
AVE.	53,894	35,444	18,450	20	25	65.8	28.3

Figure 3.23. Schedule 2 trailer/tractor itineraries with linking value penalty coefficients idle 1, deadhead 2, flexibility loss 0, and total time 0.

779 174



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	33,662	15,697	17,965	12	52	46.6	57.8
2	74,425	42,807	31,618	28	2	57.5	2.2
3	60,986	26,860	34,126	28	10	44.0	11.1
4	53,682	29,960	23,722	20	27	55.8	30.0
5	57,893	28,885	29,008	24	19	49.9	21.1
6	51,040	28,296	22,744	20	27	55.4	30.0
7	65,722	36,481	29,241	20	18	55.5	20.0
8	60,699	34,715	25,984	28	12	57.2	13.3
9	47,104	24,364	22,740	20	31	51.7	34.4
10	72,7[illegible]9	34,009	38,719	24	10	46.8	11.1
11	57,[illegible]0	33,857	23,633	24	15	58.9	16.7
12	59,113	32,740	26,373	24	17	55.4	18.9
13	67,955	29,080	38,875	20	14	42.8	15.6
14	45,928	25,261	20,667	24	29	55.0	32.2
15	33,718	17,980	15,738	8	54	53.3	60.0
16	41,621	19,774	21,897	24	33	47.5	36.7
TOTAL	883,816	460,767	423,049	348	370	--	--
AVG	55,239	28,798	26,441	22	23	52.1	25.7

Figure 3.24. Schedule 2 trailer/tractor itineraries with linking value penalty coefficients idle 10, deadhead 1, flexibility loss 0.1, and total time 10.

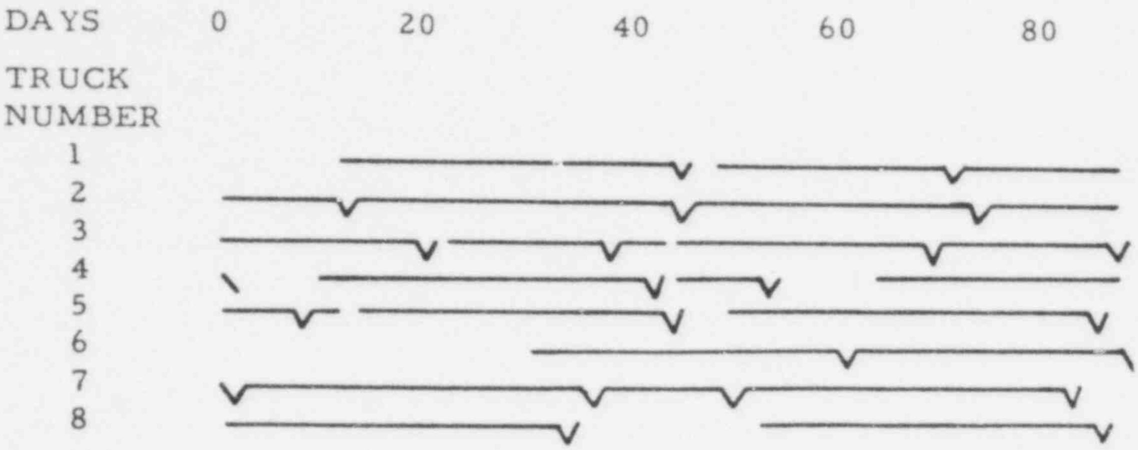
779 175

In order to investigate the sensitivity of the tractor itineraries to the linking value penalties, tractor itineraries for schedule 2 were generated to cover trailer service requirements for two choices of linking value penalties on the tractors. Figure 3.25 shows the trailer itineraries and their statistics. In generating these trailer itineraries, a two day maintenance stop was required before 40,232 km were traveled. The linking value penalties used for these trailer itineraries are idle 10, deadhead 1, flexibility loss 0.1, and time 0. Note that due to the less stringent maintenance requirements, the fleet size is reduced to 8 compared to 12 for the trailer/tractor itineraries discussed in Section 3.1.1.

For the tractors, a two day maintenance stop is required before 12,874 km is traveled since the previous maintenace stop. The flexibility loss and total time penalties were set to zero. The following two combinations of idle and deadhead penalties were investigated: 1) idle 2 and deadhead 1, and 2) idle 1 and deadhead 2. These tractor itineraries are shown in Figures 3.26 and 3.27 for these two sets of linking value penalties while Table 3.4 summarizes the resulting statistics. In Figure 3.26, the specific trailer (from Figure 3.25) being pulled on each tractor leg is indicated. Note that, in general, during the course of the 90 day scheduling period, each tractor pulls many different trailers. These variations in linking value penalties have little effect on the tractor fleet size.

3.2 Effects of Length of Planning Horizon

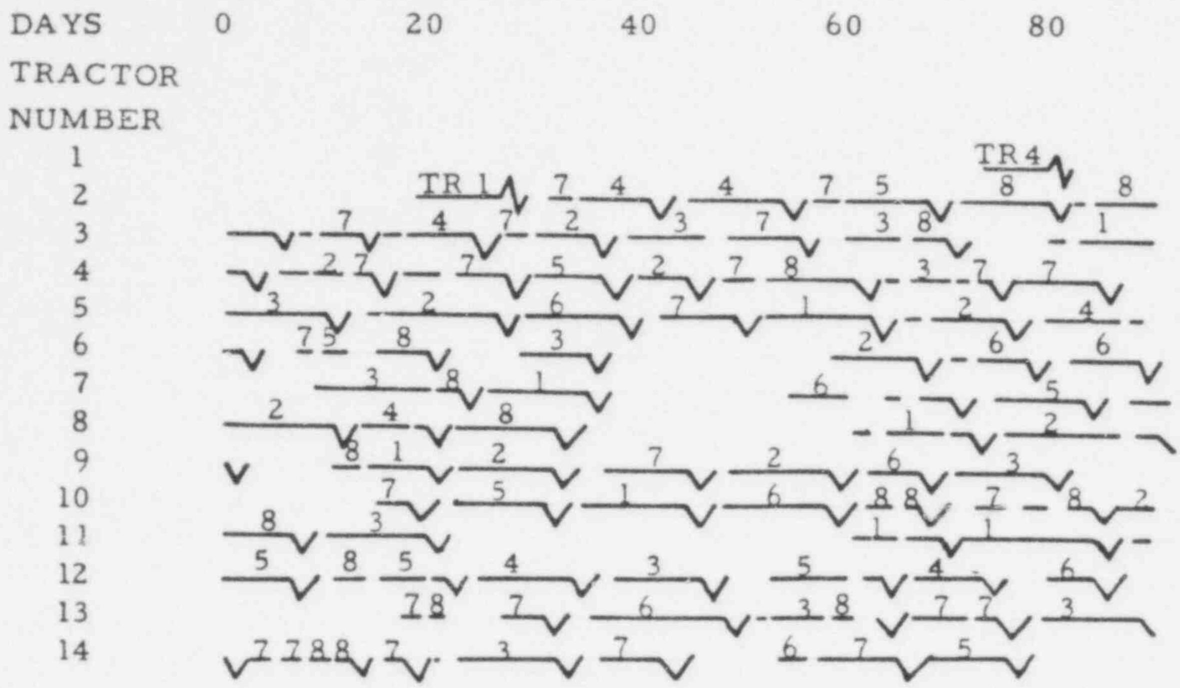
Schedule number 2 was used to generate trailer/tractor itineraries for planning horizons of 80, 90, 130 and 180 days. The



TRAILER NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	84,929	64.313	20,616	4	17	75.7	18.9
2	99,174	64,819	34,355	6	0	65.4	[illegible]
3	99,536	59,701	39,835	8	1	60.0	1.1
4	79,163	53,618	25,545	4	21	67.7	23.3
5	84,391	54,421	29,970	6	12	64.5	13.3
6	70,759	39,817	30,942	4	28	56.3	31.3
7	94,717	67,893	26,717	6	3	71.7	3.3
8	79,234	56,184	23,050	4	19	71.0	21.1
TOTAL	691,905	460,767	231,138	42	101	--	--
AVG.	86,488	57,596	28,892	5	13	66.6	14.1

Figure 3.25. Schedule 2 trailer itineraries with linking value penalty coefficients idle 10, deadhead 1, flexibility loss 0.1, and total time 0.

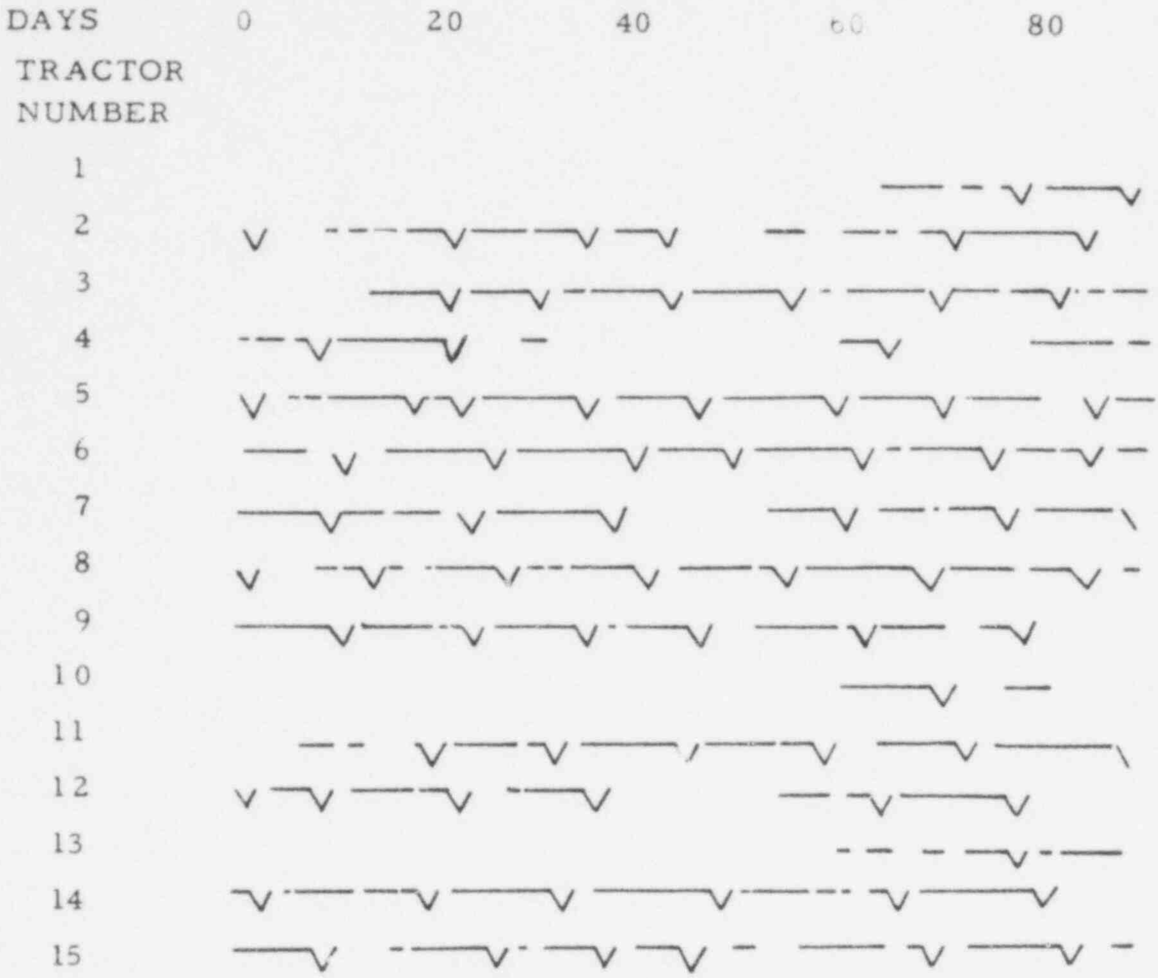
779 177



TRACTOR NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	12,794	8,294	4,500	2	77	64.8	85.6
2	65,980	58,089	7,891	10	28	88.0	31.1
3	74,935	59,017	15,918	12	15	78.8	16.7
4	72,289	57,851	14,438	16	14	80.0	15.6
5	82,930	77,551	5,379	12	8	93.5	8.9
6	58,004	44,255	13,749	12	34	76.3	37.8
7	50,112	35,438	14,674	8	40	70.7	44.4
8	59,284	49,412	9,872	10	32	83.3	35.6
9	67,385	60,944	6,440	12	21	90.4	23.3
10	58,252	49,894	11,358	12	28	85.7	31.1
11	51,616	36,008	15,608	8	42	69.8	46.7
12	73,613	61,963	11,650	14	15	84.2	16.7
13	56,920	47,482	9,438	10	35	83.4	38.9
14	60,065	48,706	11,359	12	27	81.0	30.0
TOTAL	844,182	691,905	152,277	150	418	-	-
AVE.	60,299	49,422	10,877	11	30	82.0	33.2

Figure 3.26. Schedule 2 tractor itineraries scheduled to cover trailer itineraries shown in Figure 3.25 with linking value penalty coefficients idle 2, deadhead 1, flexibility loss 0, and total time 0.

779 170



TRACTOR NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	24,359	18,241	6,118	4	68	74.9	75.6
2	58,560	49,508	9,052	10	32	84.5	35.6
3	69,757	57,183	12,574	12	23	82.0	25.6
4	38,014	25,890	12,124	6	51	68.1	56.7
5	73,743	62,582	11,161	16	14	84.9	15.6
6	84,068	71,342	12,726	14	8	84.9	8.9
7	67,531	57,112	10,419	12	23	84.6	25.6
8	68,458	50,210	18,248	12	21	73.3	23.3
9	71,827	64,992	6,835	12	18	90.5	20.0
10	16,409	11,484	4,925	2	75	70.0	83.3
11	67,421	56,180	11,241	12	23	83.3	25.6
12	52,277	41,801	10,476	10	36	80.0	40.0
13	20,553	16,958	3,595	2	71	82.6	78.9
14	65,429	51,766	13,663	12	22	79.1	24.4
15	69,048	56,655	12,393	12	22	82.1	24.4
TOTAL	847,456	691,905	155,551	148	507	-	-
AVE.	56,497	46,127	10,370	10	22	81.6	37.6

Figure 3.27. Schedule 2 tractor itineraries scheduled to cover trailer itineraries shown in Figure 3.25 with linking value penalty coefficients idle 1, deadhead 2, flexibility loss 0, and total time 0.

779 179

Table 3.4. **Summary of** tractor itinerary statistics when tractors are assigned to cover service requirements generated by trailer itineraries

Idle Penalty	2	1
Deadhead Penalty	1	2
Fleet Size	14	15
Total KM	844,182	847,456
KM Active*	691,905	691,905
KM Deadhead	152,277	155,551
Tractor Days Active*	577	577
Tractor Days Deadhead	115	118
Tractor Days Idle	418	507
Tractor Days in Maintenance	150	148
Percent KM Active*	82.0	81.6
Percent Tractor Days Idle	33.2	37.6

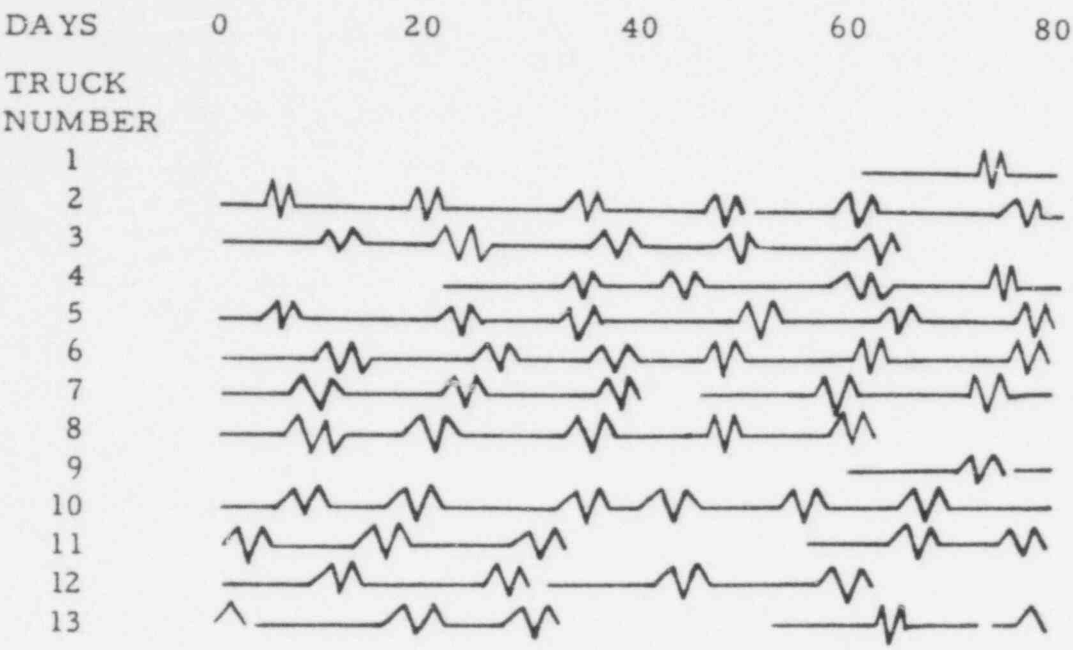
*Active service for a tractor is defined to be when the tractor is pulling a trailer regardless of whether or not the trailer is loaded.

individual itineraries and their statistics are depicted in Figures 3.2 and 3.28 through 3.30. Table 3.5 compares the significant statistics obtained for these itineraries. Note that the total distance and time variables increase with an increase in the planning horizon, as expected. The most interesting statistic in this table is the variation in the fleet size with changes in the planning horizon. For the 80 days planning horizon, the fleet size is 13 vehicles, for the 90 and 130 day horizons it is 12, and for the full schedule it is 18 vehicles. The main reason for this variance is that the average density of scheduled shipments (in shipments per day) is not uniform over the entire 180 day schedule. For the first 80 days this density is 3.63 shipments per day. From day 80 through day 90, there are only 25 shipments for a density of 2.5 reducing the shipment density to 3.50 for the first 90 days. There are 128 shipments between day 90 and day 130 for a shipment density 3.20 resulting in a density for the first 130 days of 3.40. However, from day 130 through day 180, there are 239 shipments for a density of 4.78 and an average density over the entire 180 days of 3.79. This increased shipping density over the last 50 days caused the increase in fleet size to 18 for the 180 day planning horizon from the lower values of 12 and 13 obtained with the smaller planning horizons.

This investigation shows that the fleet size is bascially controlled by the portion of the shipping schedule which has the highest shipping density. The length of the planning horizon has little effect on the resulting fleet size.

3.3 Effects of Maintenance Parameters

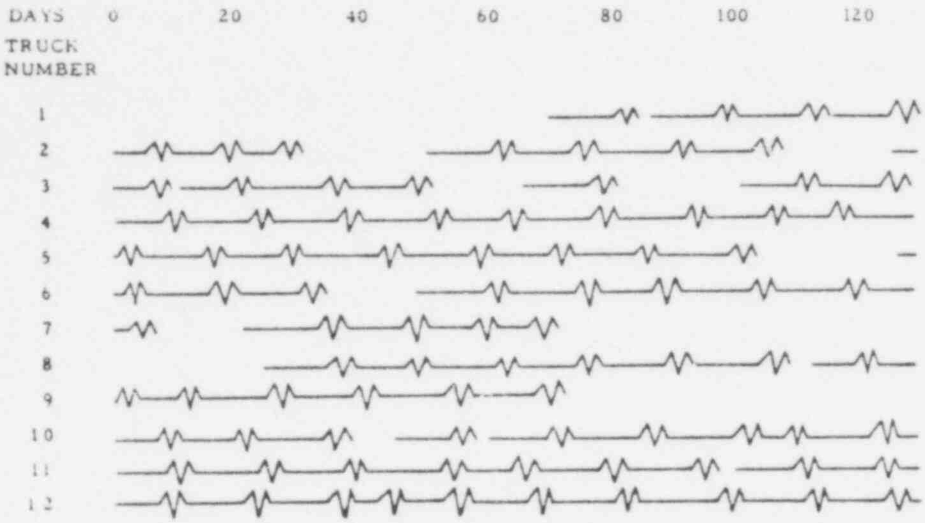
The parameters which define the maintenance rules for the vehicles affect the fleet size and the characteristics of the itineraries. The specific parameters which are investigated in this section



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	19,959	11,282	8,677	4	61	56.6	67.8
2	65,730	43,234	22,496	24	1	65.8	1.1
3	55,576	34,633	20,943	20	14	62.3	15.6
4	52,146	34,968	17,178	16	22	67.1	24.4
5	66,664	45,697	20,967	24	0	68.5	0
6	67,574	46,652	20,922	24	0	69.0	0
7	64,426	40,740	23,685	20	6	63.2	6.7
8	51,263	35,544	15,719	20	17	69.3	18.9
9	19,192	10,276	8,916	4	62	53.5	68.9
10	67,430	40,965	26,465	24	0	60.8	0
11	45,072	24,276	20,796	20	24	53.9	26.7
12	49,121	30,084	19,037	16	20	61.2	22.2
13	50,324	35,746	14,578	16	22	71.0	24.4
TOTAL	674,477	434,096	240,381	232	249	-	-
AVE.	51,883	33,392	18,491	22	24	64.4	23.9

Figure 3.28. Schedule 2 trailer/tractor itineraries for 80 day planning horizon with linking value penalty coefficients idle 10, deadhead 1, flexibility loss 0.1, and total time 0.

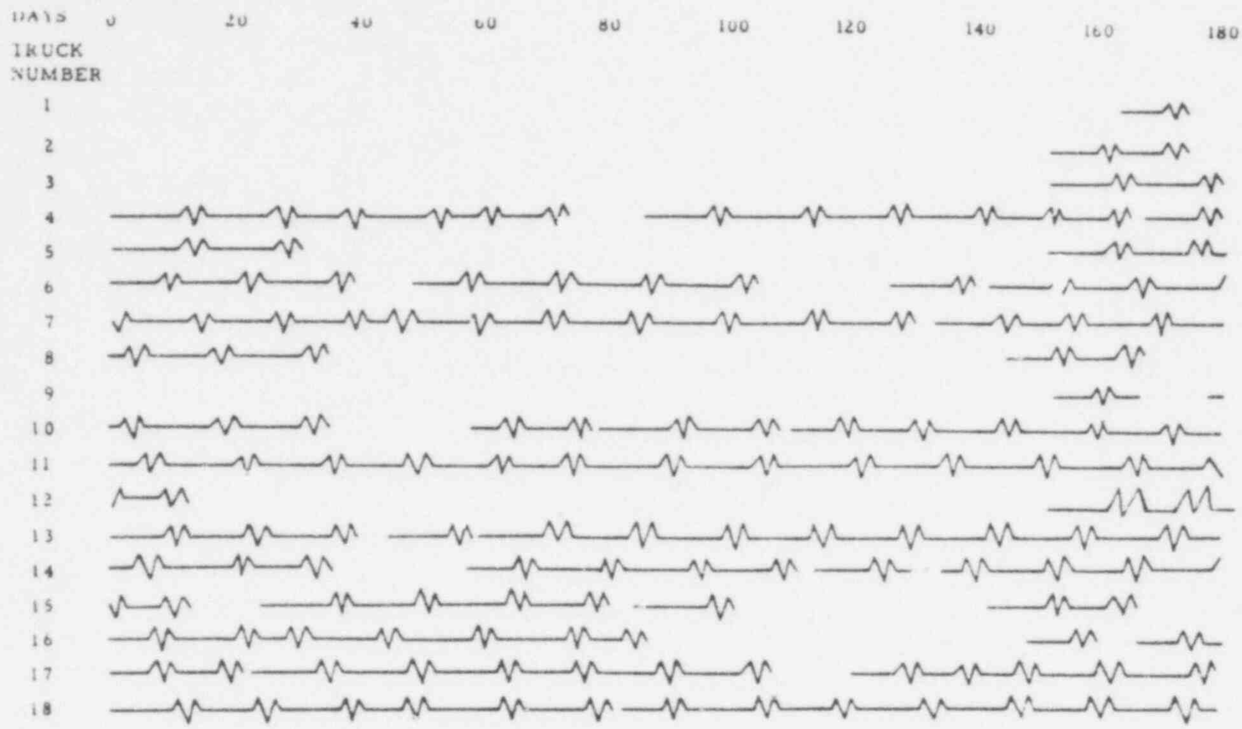
779 182



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	48,199	29,237	18,962	16	74	60.7	56.9
2	77,217	47,163	30,054	28	39	61.1	30.0
3	78,797	49,532	29,265	28	37	62.9	28.5
4	114,872	71,485	43,387	36	1	62.2	0
5	91,509	56,202	35,307	32	23	61.4	17.7
6	100,015	64,708	35,307	32	14	64.7	10.8
7	40,321	23,816	16,505	20	75	59.1	57.7
8	88,405	59,040	29,365	28	30	65.7	23.1
9	58,084	32,713	25,371	24	58	56.3	44.6
10	100,272	63,039	37,233	36	10	62.9	7.7
11	109,348	66,893	42,455	36	3	61.2	2.3
12	107,723	75,462	32,261	[illegible]	0	70.1	0
TOTAL	1,014,763	639,291	375,473	356	361	-	-
AVE.	84,563	53,274	31,289	30	30	63.0	23.2

Figure 3.29. Schedule 2 trailer/tractor itineraries for 130 day planning horizon with linking value penalty coefficients idle 10, deadhead 1, flexibility loss 0.1 and total time 0.

779 185



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	8,799	3,769	5,030	4	169	42.8	93.9
2	17,598	7,537	10,061	8	158	42.8	87.8
3	25,377	14,806	10,571	8	152	58.3	84.4
4	139,724	78,327	61,400	52	15	56.1	8.3
5	52,439	30,916	21,523	16	121	59.0	67.2
6	125,967	85,703	40,264	44	34	68.0	18.9
7	149,423	95,766	53,657	52	5	64.1	2.8
8	43,462	22,453	21,009	20	124	51.7	68.9
9	16,019	9,735	6,284	4	165	60.8	91.7
10	126,214	79,184	47,030	48	28	62.7	15.6
11	150,793	105,152	45,641	52	0	69.7	0
12	34,529	18,184	16,345	12	138	52.7	76.7
13	150,856	96,329	54,527	48	7	63.9	3.9
14	133,083	86,164	46,919	48	24	64.7	13.3
15	89,891	52,420	37,471	32	71	58.3	39.4
16	92,973	54,726	38,247	36	66	58.9	36.7
17	137,164	77,014	60,150	52	15	56.1	8.3
18	152,104	93,004	59,100	52	1	61.2	0.6
TOTAL	1,646,419	1,011,190	635,229	588	1,291	-	-
AVE.	91,467	56,177	35,290	33	72	61.4	39.[illegible]

Figure 3.30. Schedule 2 trailer/tractor itineraries for 180 day planning horizon with linking value penalty coefficients idle 10, deadhead 1, flexibility loss 0.1, and total time 0.

Table 3.5 Effects of planning horizon on trailer/tractor itineraries for Schedule 2. Linking value penalties: idle 10, deadhead 1, flexibility loss 0.1, and time 0.

Planning Horizon (Days)	80	90	130	180
No. of Shipments	290	315	443	682
Fleet Size	13	12	12	18
KM Total	674,477	702,198	1,014,763	1,646,419
KM Active	434,096	460,767	639,291	1,011,190
KM Deadhead	240,381	241,431	375,473	635,290
Truck Days in Maintenance	232	240	356	588
Truck Days Idle	249	256	361	1,291
% KM Active	64.4	65.6	63.0	61.4
% Days Idle	23.9	23.7	23.2	39.9
Average Number of Shipments per Day over Total Planning Interval	3.63	3.50	3.41	3.79

using sample schedule 2 are the maximum distance which can be travelled between maintenance stops, the length of each maintenance stop, and the number and location of maintenance bases.

3.3.1 Maximum Distance between Maintenance Stops

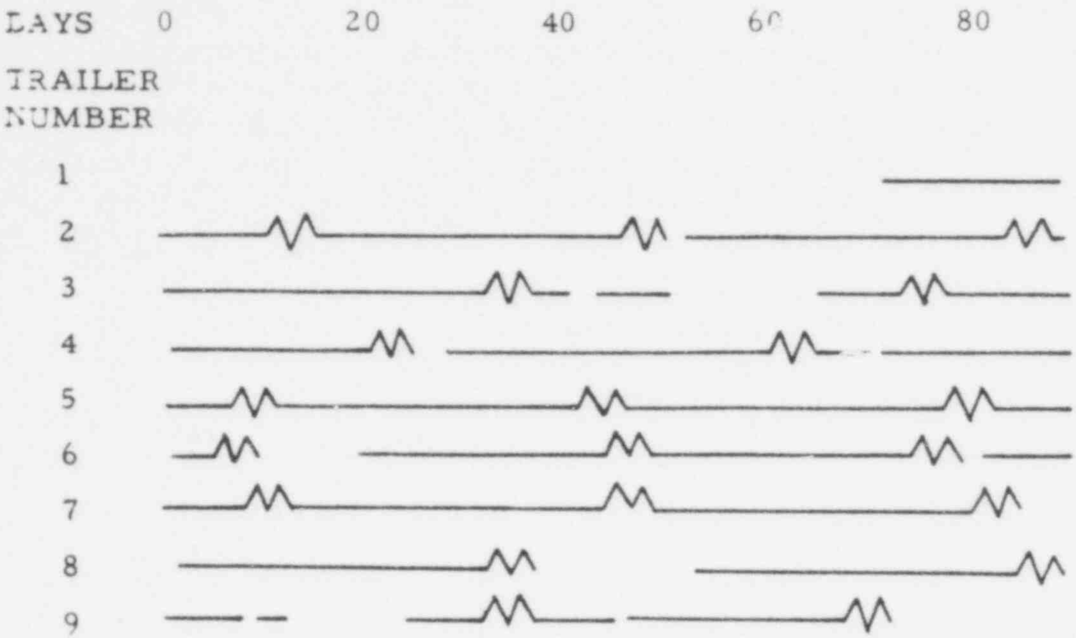
Table 3.6 presents a comparison of the statistics of trailer/tractor itineraries, where a four day maintenance stop is required before 12,874 km have been travelled since the previous maintenance stop, and trailer itineraries where a four day maintenance stop is required before 40,232 km have been travelled since the previous maintenance stop. The itineraries and their statistics for these two cases are given in Figures 3.2 and 3.31, respectively. The two most significant statistics in comparing these two cases are the fleet sizes and the deadhead distance travelled (from 241,431 km to 227,112 km, a 14 percent decrease). The larger deadhead distance obtained with the 12,874 km maintenance criterion is due to the more frequent requirement for deadhead travel to and from the maintenance base.

3.3.2 Length of Stay in Maintenance

Table 3.7 presents a comparison of trailer itinerary statistics for lengths of stay in maintenance of 2 and 4 days. The corresponding itineraries and the detailed statistics are presented in Figures 3.25 and 3.31, respectively. The difference between a 2 and a 4 day maintenance stop is not enough to make a significant difference in the itinerary statistics except for the number of truck days in maintenance. Although increasing this length of stay in maintenance from 2 to 4 days increases the fleet size from 8 to 9,

Table 3.6 Effect of maximum allowable distance which can be travelled between maintenance stops on trailer and trailer/tractor itineraries for Schedule 2 with a 4 day length of stay in maintenance. Linking value penalty coefficients are idle 10, deadhead 1, flexibility loss 0.1, and time 0.

	Trailer/Tractor	Trailer
Maximum Distance between Maintenance Stops	12,874 km	40,232 km
Length of Maintenance Stop (Days)	4	4
Fleet Size	12	9
Total KM	702,198	687,880
KM Active	460,767	460,767
KM Deadhead	241,431	227,112
Truck Days Active	402	402
Truck Days Deadhead	182	172
Truck Days Idle	256	156
Truck Days in Maint.	240	80
Percent KM Active	65.6	67.0
Percent Days Idle	23.7	19.3



TRAILER NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	21,610	13,763	7,847	0	72	63.7	80.0
2	93,037	59.394	33,643	12	2	63.8	2.2
3	75,079	51,076	24,003	8	18	68.0	20.0
4	92,625	61,095	31,530	8	3	66.0	3.3
5	96,285	62,984	33,301	12	0	65.4	0
6	75,930	49,049	26,881	12	13	64.6	14.4
7	90,531	68,697	21,834	12	3	75.9	3.3
8	78,347	53,489	24,858	8	17	68.3	18.9
9	64,436	41,220	23,216	8	28	64.0	31.1
TOTAL	687,880	460,767	227,112	80	156	-	-
AVE.	76,431	51,196	25,235	9	17	67.0	19.3

Figure 3.31. Schedule 2 trailer itineraries with 4 day maintenance stop required before 40,232 km have been exceeded. Linking value penalty coefficients are idle 10, deadhead 1, flexibility loss 0.1, and total time 0.

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Table 3.7 Effect of length of stay in maintenance on trailer itineraries for Schedule 2. Maximum allowable distance between maintenance stops is 40,232 km and linking value penalty coefficients are idle 10, deadhead 1, flexibility loss 0.1, and total time 0.

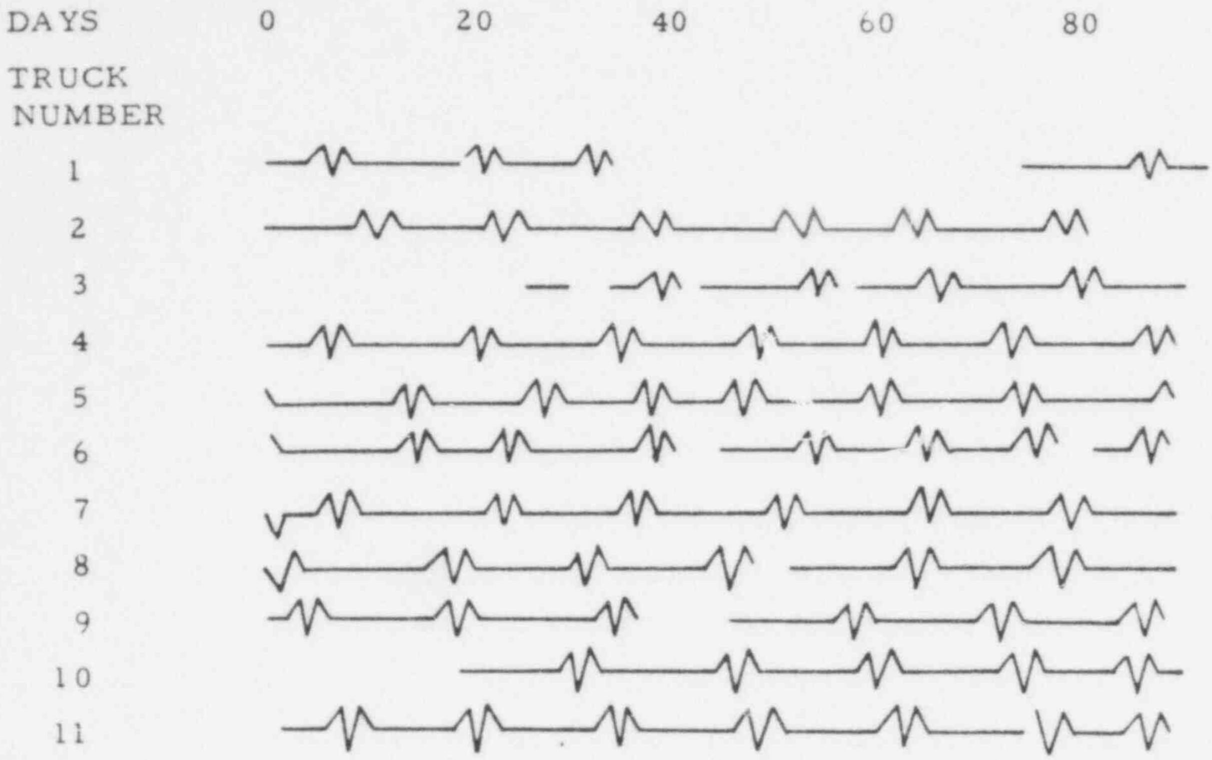
Length of Maintenance Stay (Days)	2	4
Fleet Size	8	9
Total KM	691,905	687,880
KM Active	460,767	460,767
KM Deadhead	231,138	227,112
Truck Days Active	402	402
Truck Days Deadhead	175	172
Truck Days Idle	101	156
Truck Days in Maint.	42	80
Percent KM Active	66.6	67.0
Percent Days Idle	14.1	19.3

this increase is not significant. As can be seen from Figure 3.31 (for the 4 day maintenance stop) it is almost possible to combine itineraries 1 and 9 into a single itinerary to reduce the fleet size to 8. It is possible that variations in other itinerary parameters, such as the linking value penalty coefficients, would reduce this fleet size to 8 trailers, which is probably the minimum value.

3.3.3 Location and Number of Maintenance Bases

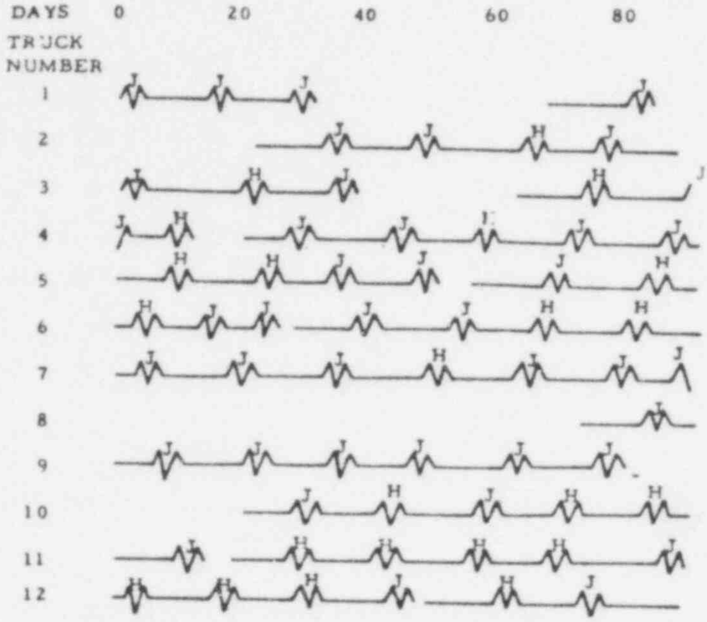
The effects on trailer/tractor itineraries of the location and number of maintenance bases are summarized in Table 3.8. The specific cases considered are a single maintenance base at Youngsville, NC, (HNC), a single maintenance base at Joplin, MO (JOP), and two maintenance bases at Youngsville and Joplin with a nearest base maintenance policy. The corresponding itineraries and their statistics are given in Figures 3.2, 3.32, and 3.33, respectively.

As can be seen from Table 3.8, these variations in the location and number of maintenance bases have negligible effect on the fleet size and the itinerary statistics. The difference in the fleet size of 11 obtained with the single maintenance base at Joplin, and 12 obtained for the other two cases is not significant since it is likely that the minimum fleet size is 11 in all cases. Examination of the individual itineraries in Figures 3.2 and 3.33 shows that, with some rearrangement of itinerary segments, it is probably possible to reduce the fleet size from 12 to 11 for these two cases.



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	44,070	28,602	15,468	16	39	64.9	43.3
2	67,578	45,040	22,538	24	7	66.6	7.8
3	52,531	33,170	19,362	16	31	63.1	3.4
4	75,238	47,711	27,527	28	0	63.3	0
5	76,286	46,035	30,251	28	0	60.3	0
6	67,619	36,719	30,900	28	7	54.3	7.8
7	78,302	50,812	27,490	24	0	64.9	0
8	71,246	44,160	27,086	24	5	62.0	5.6
9	65,498	43,180	22,318	24	10	65.9	11.1
10	61,542	37,596	23,946	20	19	61.1	21.1
11	75,383	47,741	27,642	28	1	63.3	1.1
TOTAL	735,294	460,767	274,527	260	120	-	-
AVE.	66,845	41,888	24,957	24	11	62.7	12.2

Figure 3.32. Schedule 2 trailer/tractor itineraries with a single maintenance base at Joplin, MO (JOP). Linking value penalty coefficients are idle 10, deadhead 1, flexibility loss 0.1, and total time 0.



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	36,856	23,659	13,197	12	43	64.2	47.8
2	64,212	43,088	21,124	16	22	67.1	24.4
3	49,019	26,929	22,090	20	32	54.9	35.6
4	65,547	38,419	27,128	24	10	58.6	11.1
5	73,585	45,935	27,650	24	4	62.4	4.4
6	73,370	46,273	27,097	28	3	63.1	3.3
7	75,896	45,299	30,597	28	0	59.7	0
8	16,883	11,585	5,298	4	74	68.6	82.2
9	66,994	44,491	22,503	24	9	66.4	10.0
10	54,555	34,061	20,494	20	26	62.4	28.9
11	72,133	47,560	24,573	24	6	68.9	6.7
12	74,734	53,467	21,267	24	1	71.5	1.1
TOTAL	723,785	460,767	263,018	248	231	----	----
AVG.	60,315	38,397	21,918	21	19	63.7	21.4

Figure 3.33. Schedule 2 trailer/tractor itineraries with a nearest base maintenance policy, and maintenance bases at Youngsville, NC, (HNC) and Joplin, MO, (JOP). Linking value penalty coefficients are idle 10, deadhead 1, flexibility loss 0.1, and total time 0.

Table 3.8. Effects of number and location of maintenance bases on tractor/trailer itineraries for Schedule 2. Linking value penalties are idle 10, deadhead 1, flexibility loss 0.1, and total time 0.

Maintenance Bases	HNC	JOP	HNC and JOP
Fleet Size	12	11	12
Total KM	702,198	735,294	723,785
KM Active	460,767	460,767	460,767
KM Deadhead	241,431	274,527	263,018
Truck Days Active	402	402	402
Truck Days Deadhead	183	208	199
Truck Days Idle	256	120	231
Truck Days in Maint.	240	260	248
Percent KM Active	65.6	62.7	63.7
Percent Days Idle	23.7	12.2	21.4
No. HNC Maint. Stops	60	0	23
No. JOP Maint. Stops	0	65	39

3.4 Effects of Work Rules

The work rules which were investigated with the TRNSM 2 model were the length of the work day and the length of the work week at the bases.

3.4.1 Length of Work Day at Bases

Table 3.9 shows the effects of reducing the length of the work day at bases from 24 hours to 16 hours. The corresponding itineraries and their statistics are given in Figures 3.2 and 3.34, respectively. As can be seen from this table, this decrease in the length of the work day has negligible effect on the itineraries. As was discussed in Section 3.3.3, the difference in fleet size of 12 with a 24 hour work day and 11 with a 16 hour work day is not significant with the TRNSM 2 model.

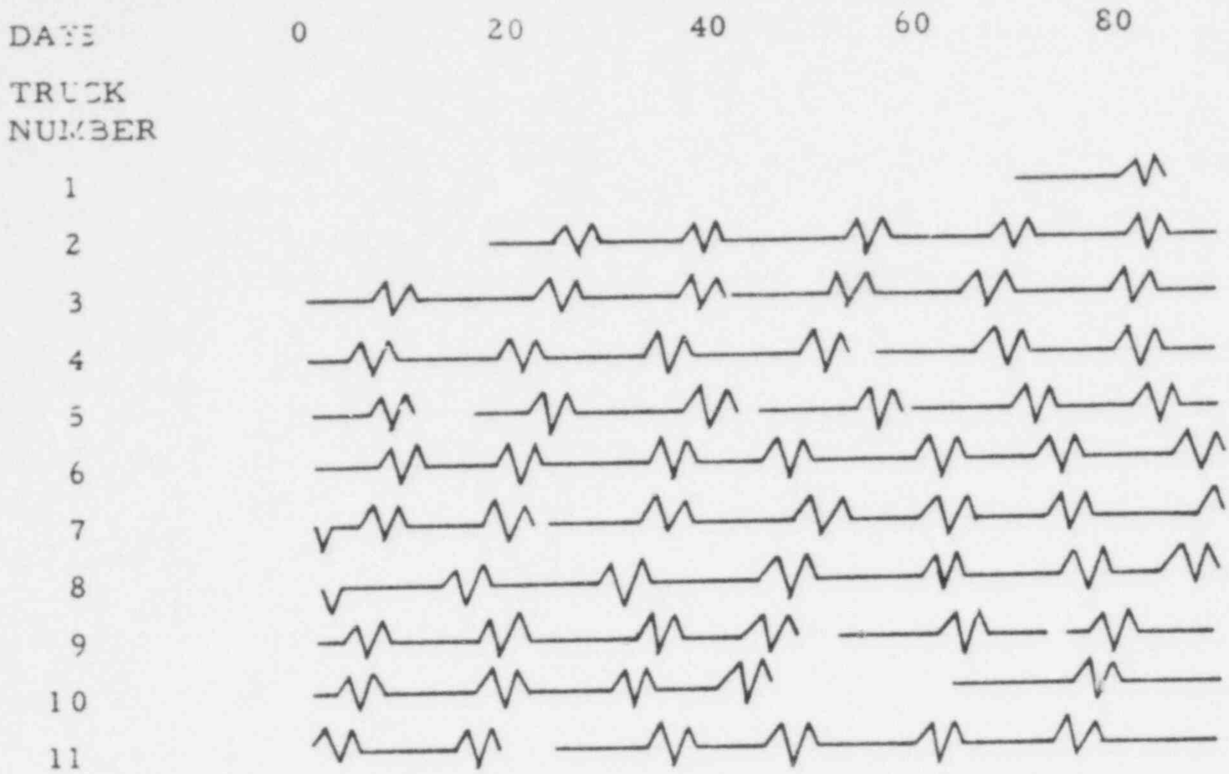
The reason that this decrease in the length of the work day has so little effect is that most of the time the vehicles are traveling on the road, with relatively little active time at the bases. This, therefore, results in the itinerary statistics being insensitive to a decrease in the length of the work day from 24 to 16 hours.

3.4.2 Length of Work Week at Bases

The effects of reducing the length of the work week at bases from 7 to 6 days on trailer/tractor itineraries is shown in Table 3.10. The corresponding itineraries and their statistics are given in Figures 3.2 and 3.35, respectively. Note that a 91 day planning horizon is used for the 6 day work week case since the non-fixed fleet algorithm requires that the planning horizon be a multiple of 7 when weekend loading or travel restrictions are imposed. This

Table 3.9 Effect of length of duty day at bases on trailer/tractor itineraries for Schedule 2. Length of duty day on the road is 24 hours. Linking value penalty coefficients are idle 10, deadhead 1, flexibility loss 0.1, and total time 0.

Length of Duty Days at Bases (Hrs.)	16	24
Fleet Size	11	12
Total KM	697,974	702,198
KM Active	460,767	460,767
KM Deadhead	237,207	241,431
Truck Days Active	428	402
Truck Days Deadhead	180	183
Truck Days Idle	138	256
Truck Days in Maint.	244	240
Percent KM Active	66.0	65.6
Percent Days Idle	14.0	23.6



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	12,867	10,132	2,735	4	75	78.7	83.3
2	59,468	45,015	14,453	20	19	75.7	21.1
3	76,004	49,361	26,643	24	0	64.9	0
4	70,696	45,531	25,165	24	3	64.4	3.3
5	66,742	37,272	29,469	24	11	55.8	12.2
6	72,890	47,630	25,260	28	0	65.3	0
7	75,085	48,729	26,355	28	1	64.9	1.1
8	69,539	47,279	22,260	24	0	68.0	0
9	68,233	45,917	22,316	24	5	67.3	5.6
10	56,376	37,082	19,294	20	19	65.8	2.1
11	70,076	46,819	23,257	24	5	66.8	5.6
TOTAL	697,974	460,767	237,207	244	138	--	--
AVG.	63,452	41,888	21,564	22	13	66.0	14.0

Figure 3.34. Schedule 2 trailer/tractor itineraries with 16 hour working day at bases and linking value penalty coefficients idle 10, deadhead 1, flexibility loss 0.1, and total time 0.

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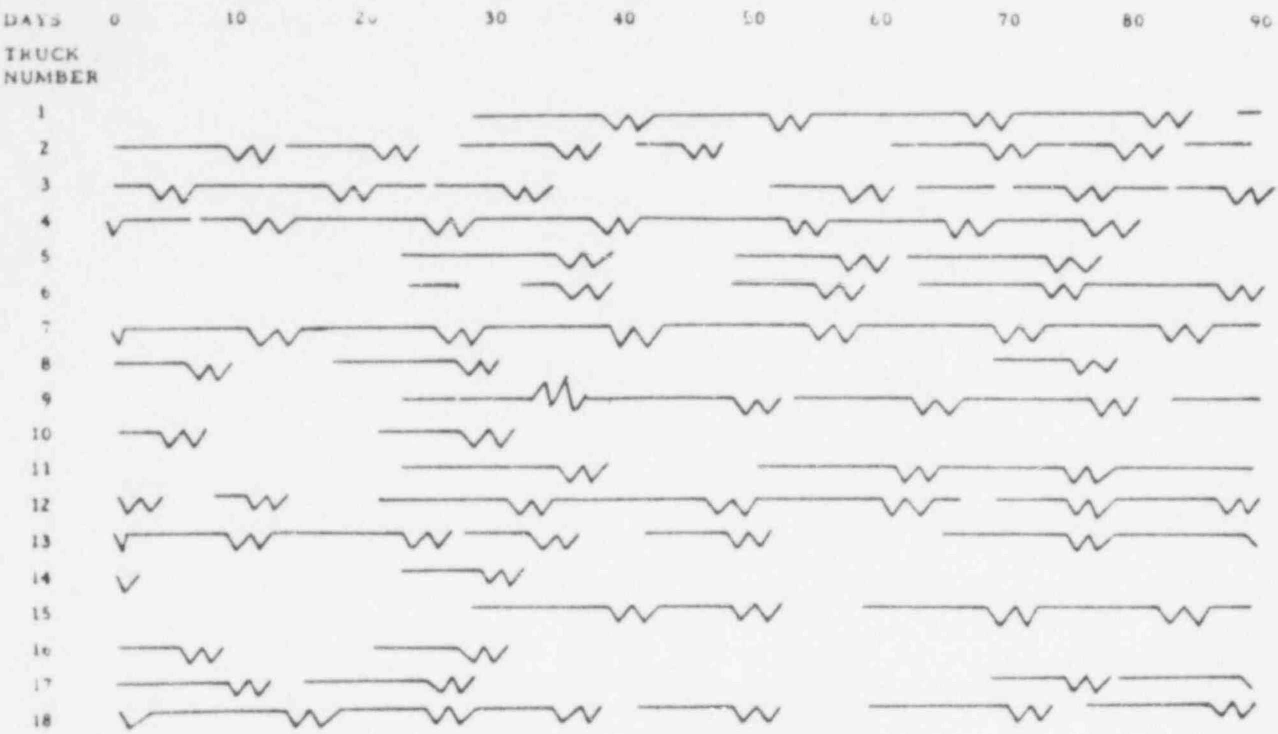
Table 3.10 Effect of length of work week at bases on trailer/tractor itineraries for Schedule 2. Length of work week on the road is 7 days. Linking value penalty coefficients are idle 10, deadhead 1, flexibility loss 0.1, and total time 0.

Length of Work Week at Bases (Days)	6	7
Planning Horizon (Days)	91	90
Fleet Size	18	12
Total KM	852,543	702,198
KM Active	474,358	460,767
KM Deadhead	378,185	241,431
Truck Days Active	413	402
Truck Days Deadhead	287	183
Truck Days Idle	630	256
Truck Days in Maint.	308	240
Percent KM Active	55.6	65.6
Percent Days Idle	38.5	23.7



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	55,985	31,038	24,947	16	31	55.4	34.4
2	60,036	28,154	31,882	24	17	46.9	18.9
3	56,698	34,005	22,693	24	19	60.6	21.1
4	67,052	35,051	32,001	24	11	52.3	12.2
5	36,098	19,632	16,466	12	48	54.4	53.3
6	42,977	25,443	17,534	16	40	59.2	44.4
7	79,736	48,232	31,504	24	0	60.5	0
8	27,738	16,951	10,787	12	56	61.4	62.2
9	59,541	29,522	30,019	16	26	49.6	28.9
10	11,003	5,178	5,825	8	73	47.1	81.1
11	50,691	31,182	19,509	12	36	61.5	40.0
12	61,243	36,593	24,650	28	14	59.6	15.6
13	61,735	35,721	26,014	24	19	57.9	21.1
14	8,154	3,854	4,300	4	78	47.3	86.7
15	50,760	29,225	21,535	16	34	57.6	37.8
16	14,842	5,646	9,196	8	70	38.0	77.8
17	45,178	26,960	18,218	16	41	59.7	45.6
18	63,070	31,969	31,101	24	13	50.7	14.4
TOTAL	852,543	474,358	378,185	308	630	-	-
AVE.	47,363	26,353	21,010	17	35	55.6	38.5

Figure 3.35. Schedule 2 trailer/tractor itineraries with 6 day work week at bases and linking value penalty coefficients idle 10, deadhead 1, flexibility loss 0.1 and total time 0.

addition of one day to the planning horizon results in the addition of 8 more shipments to the shipping schedule.

The main effect of this decrease in the length of the work week at the bases is a significant increase in fleet size from 12 to 18. With the work week on the road maintained at 7 days, the heavy idle penalty of 10 compared to the deadhead penalty of 1 tends to force the trucks to deadhead between two active services on the non-working day at the base, rather than spending this day idling at a base awaiting a shipment.

3.5 Effects of Truck Related Parameters

The truck related parameters investigated were average truck speed, loading/unloading time, and truck capacity.

3.5.1 Truck Speed

Table 3.11 shows the effects on trailer/tractor itineraries of a reduction in average truck speed from 55 kph to 45 kph. The corresponding itineraries and their statistics are given in Figures 3.2 and 3.36.

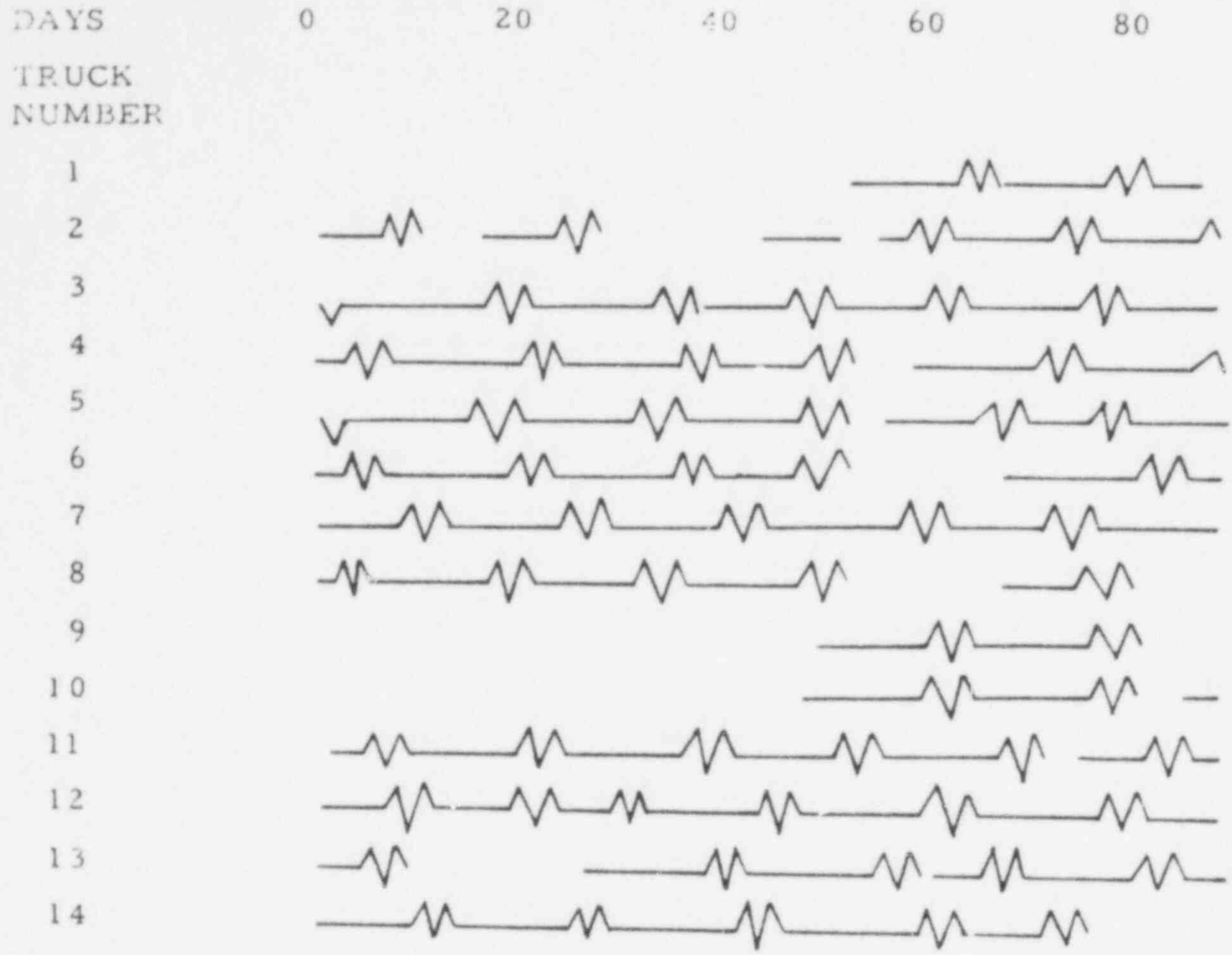
This reduction in truck speed increases the total truck days required to be spent on active service from 402 to 475. This, in turn, increases the required fleet size from 12 to 14.

3.5.2 Loading/Unloading Time

The effects of increasing the times for loading and unloading the trailers from 2 hours to 4 hours is shown in Table 3.12. The itineraries and itinerary statistics for these two cases are presented in Figures 3.2 and 3.37, respectively.

Table 3.11 Comparison of results of 45 kph and 55 kph average speeds on trailer/tractor itineraries with penalty coefficients idle 10, deadhead 1, flexibility loss 0.1, and time 0.

	55 kph	45 kph
Fleet Size	12	14
Total KM	702,198	718,189
KM Active	460,767	460,767
KM Deadhead	241,431	257,422
Truck Days Active	402	479
Truck Days Deadhead	183	238
Truck Days Idle	256	287
Truck Days in Maint.	240	256
Percent KM Active	65.6	64.2
Percent Days Idle	23.7	22.7



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	30,428	19,013	11,415	8	52	62.5	57.2
2	49,152	30,073	19,079	20	25	61.2	27.8
3	65,262	46,755	18,507	20	1	71.6	1.1
4	61,768	42,315	19,453	24	6	68.5	6.7
5	64,567	39,986	24,581	20	3	61.9	3.3
6	51,085	35,157	15,932	20	18	68.3	20.0
7	70,020	47,860	22,168	20	1	68.3	1.1
8	44,137	25,790	18,347	20	25	58.4	27.8
9	21,188	13,366	7,822	8	60	63.1	66.7
10	27,647	18,639	9,008	8	56	67.4	62.2
11	63,079	31,704	31,375	24	3	50.3	3.3
12	65,341	46,518	18,823	24	0	71.2	0
13	48,280	29,764	12,516	20	21	61.6	23.3
14	56,218	33,825	22,393	20	13	60.2	14.4
TOTAL	718,189	460,767	257,422	256	287	--	---
AVG.	51,299	32,912	18,387	18	21	64.2	22.7

Figure 3.36. Schedule 2 trailer/tractor itineraries with truck speed of 45 kph and linking value penalty coefficients idle 10, deadhead 1, flexibility loss 0.1, and total time 0.

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Table 3.12 Comparison of results of 4 hour and 2 hour loading/unloading time for trailer/tractor itineraries with penalty coefficients idle 10, deadhead 1, flexibility loss 0.1, and time 0.

	2 hour loading/ unloading time	4 hour loading/ unloading time
Fleet Size	12	11
Total KM	702,198	710,349
KM Active	460,767	460,767
KM Deadhead	241,431	249,582
Truck Days Active	402	454
Truck Days Deadhead	183	189
Truck Days Idle	256	103
Truck Days in Maint.	240	244
Percent KM Active	65.6	64.9
Percent Days Idle	23.7	10.4

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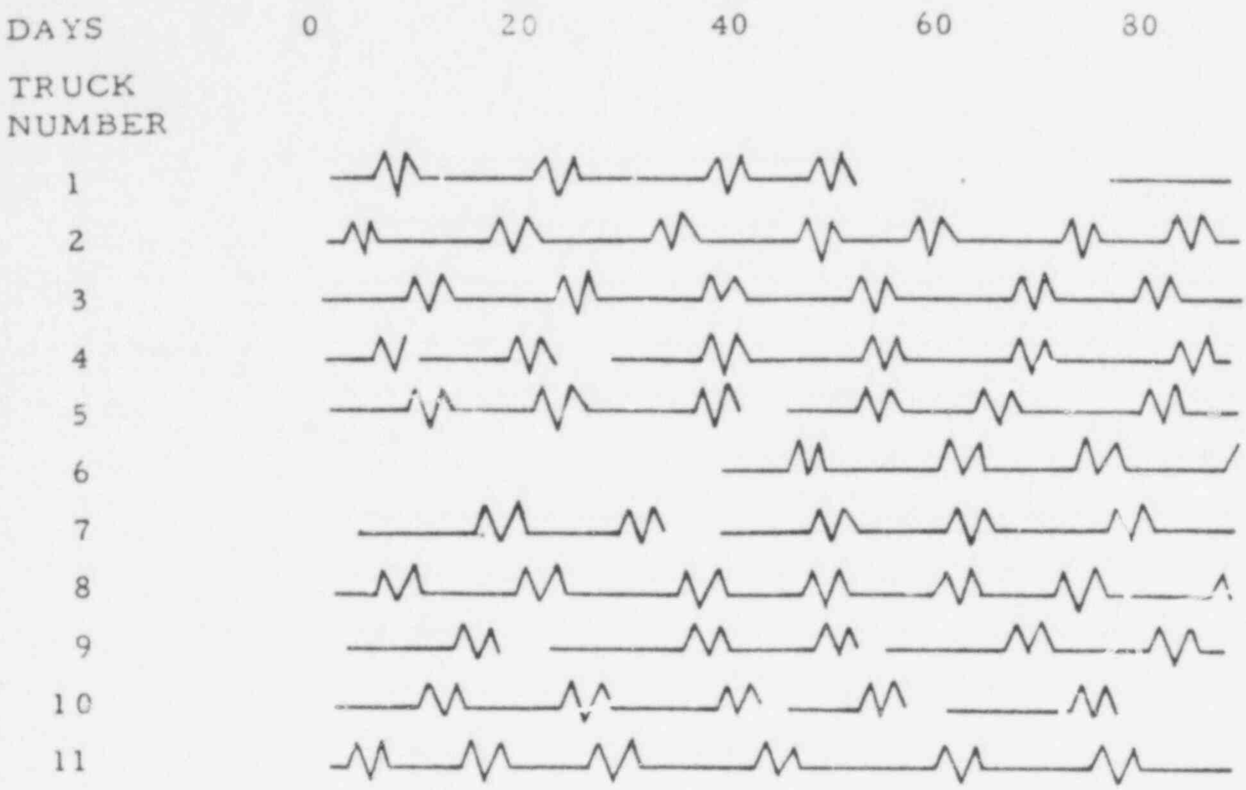


TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	49,749	30,809	18,940	16	26	61.9	28.9
2	70,741	44,957	25,784	28	0	63.6	0
3	70,453	48,813	21,640	24	0	69.3	0
4	69,010	38,971	30,039	24	5	56.5	5.6
5	72,444	46,801	25,643	24	5	64.6	5.6
6	44,028	28,845	15,183	16	39	65.5	43.3
7	68,848	48,436	20,412	20	4	70.4	4.4
8	72,525	52,335	20,190	28	0	72.2	0
9	64,866	38,936	25,930	20	8	60.0	8.9
10	57,899	39,414	18,485	20	16	68.1	17.8
11	69,785	42,450	27,335	24	0	60.8	0
TOTAL	710,349	460,767	249,582	244	103		--
AVG.	64,577	41,888	22,689	22	9	64.9	10.4

Figure 3.37. Schedule 2 trailer/tractor itineraries with 4 hour loading/unloading times and linking value penalty coefficients idle 10, deadhead 1, flexibility loss 0.1, and total time 0.

The main effect of increasing these times is an increase in total active truck days since the loading and unloading functions are considered active service. The fleet size decrease from 12 to 11 is not significant.

3.5.3 Reduced Truck Capacity

In the process of operating on the shipment schedule to derive the service requirements for truck trailers, trailer/tractor combinations, or aircraft, the size of each shipment is compared to the capacity of the transport unit element to determine the number of elements required to handle that shipment. This required number of vehicles is then associated with the shipment and used in the linking process.

The process of linking of services which require different numbers of vehicles is best illustrated by a simple example. Assume services numbers 1 and 2 **each** require one truck, whereas service 3 requires two trucks. Further assume that the linking of services 1 and 3 is feasible and has the best linking value. This linking is then selected. Let the resulting combined service be labeled number 4. The number of trucks required for this combined service is one, the lowest value of the two original services. Since not all of service 3 is included in combined service 4, the original service 3 is retained in the list of required services, but with the required number of vehicles reduced to one. Next assume that the linking of service 2 and 3 is feasible and has the best linking value. This linking is now selected and the resulting composite service which requires one truck, is labeled number 5. Thus part of the original service 3 is included in combined service 4 and part in combined service 5.

Each of the two shipment schedules used to study the characteristics of the TRNSM 2 model consists of single truckload shipments. This can be seen by comparing the shipment sizes in the sample schedules given in Appendices B and C with the truck trailer capacities given in Table 3.1. Note that for each fuel type the capacity equals the shipment size.

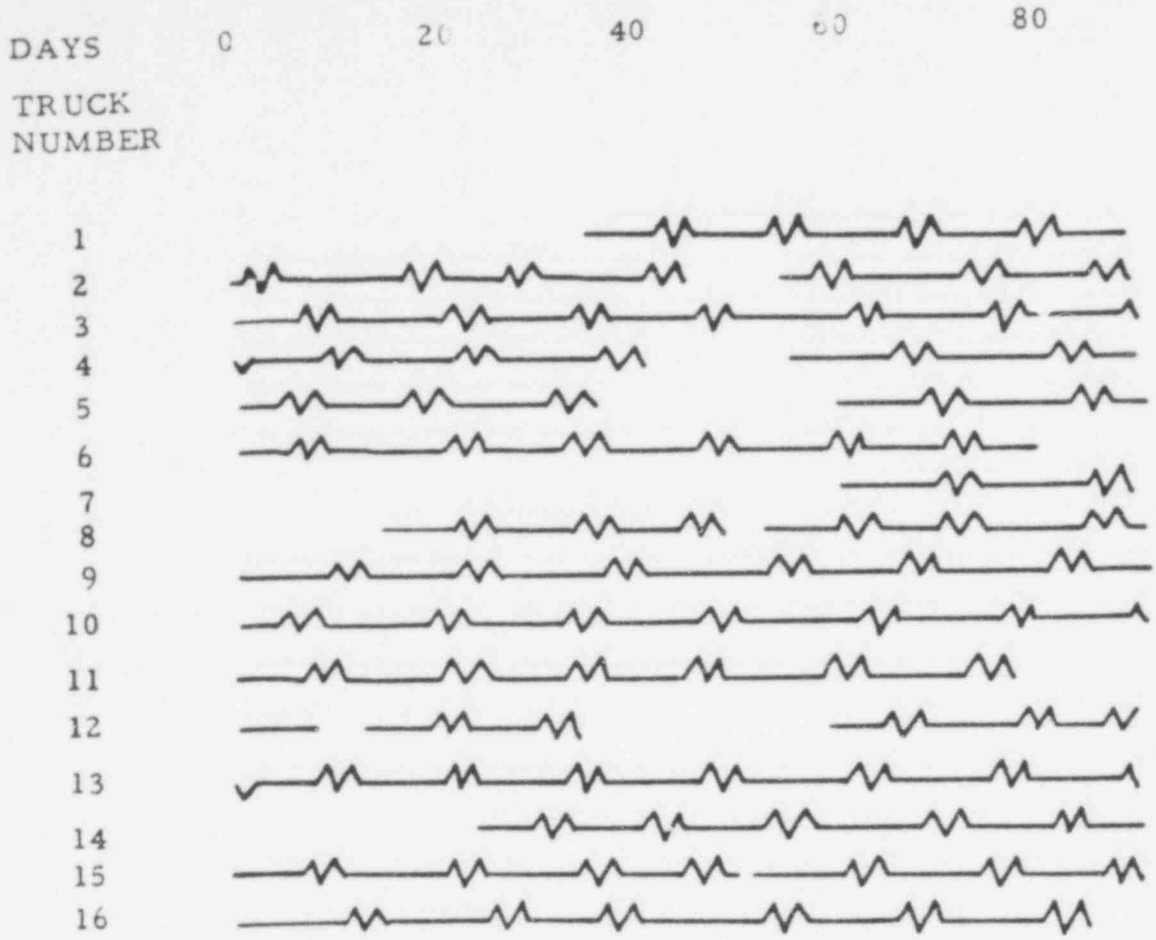
In order to investigate the effect of reduced truck capacity, the truck capacity for fuel type 3 was reduced from 16 containers to 8 containers, so that each shipment of fuel type 3 now requires two trucks. The capacities for fuel types 1 and 2 were kept the same. The resulting itineraries and itinerary statistics for this case are given in Figure 3.38 while Table 3.13 compares these itinerary statistics with the statistics for the baseline case with the truck capacity of 16 containers for fuel type 3. This reduction in capacity increases the required distance to be travelled on active service by 35 percent, and increases the fleet size from 12 to 16 trucks.

3.6 Effects of Rules for Assignment of Transport Unit Elements

The fleet sizes for the various types of transport unit elements are dependent on the rules used to assign them to cover required services. In this section, the results of varying the rules for assignment of escort vehicles to cover services imposed by truck itineraries are first examined. Then the effects on aircraft and truck itineraries produced by varying the rules for assignment of aircraft to handle shipments are investigated.

3.6.1 Escort Assignment Rules

To study the effect of escort assignment rules, two cases were considered. First escort vehicles were assigned according to



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	44,615	28,833	15,782	16	35	64.6	38.9
2	60,523	34,602	25,921	28	10	57.2	11.1
3	77,703	53,335	24,368	28	0	68.6	0
4	59,342	38,821	20,521	20	16	65.4	17.8
5	53,935	33,300	20,635	20	25	61.7	27.8
6	66,194	39,227	26,967	24	12	59.3	13.3
7	25,081	15,568	9,513	8	61	62.1	67.8
8	57,630	28,019	29,611	24	20	48.6	22.2
9	77,337	53,474	23,863	24	0	69.1	0
10	78,543	46,727	31,816	28	0	59.5	0
11	59,846	37,250	22,596	24	14	62.2	15.6
12	50,550	27,247	23,303	20	28	53.9	31.1
13	76,621	43,124	33,497	28	0	56.3	0
14	54,688	26,704	27,984	20	25	48.0	27.8
15	71,947	46,105	25,842	28	2	64.1	2.2
16	67,165	43,288	23,877	24	5	64.4	5.6
TOTAL	981,718	595,624	386,094	364	252	---	---
AVG.	61,357	37,226	24,131	23	16	60.7	17.5

Figure 3.38. Schedule 2 trailer/tractor itineraries with truck capacity for fuel type 3 reduced from 16 containers to 8 containers so that two trucks are required to handle each shipment of fuel type 3. Linking value penalty coefficients are idle 10, deadhead 1, flexibility loss 0.1 and total time 0.

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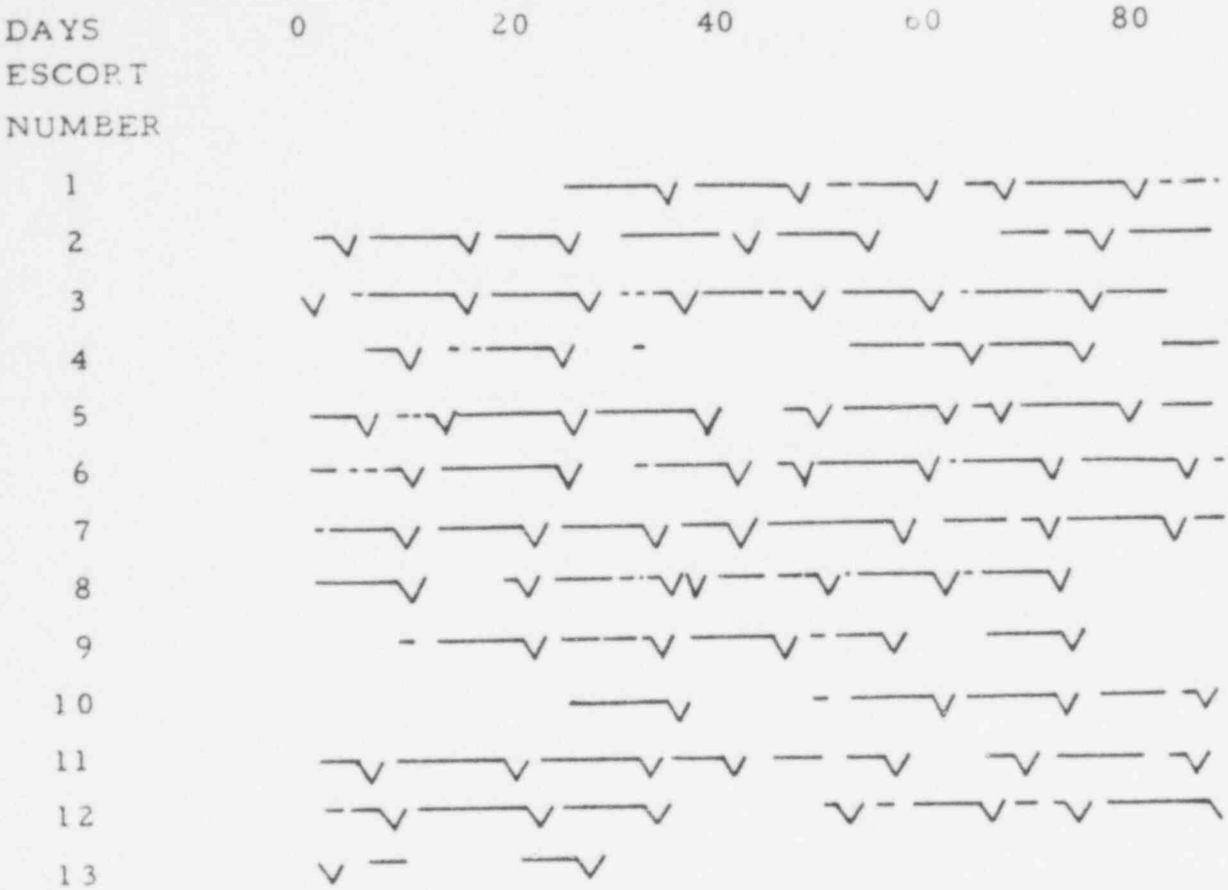
Table 3.13. Comparison of effects of reduced truck capacity for fuel type 3 on trailer/tractor itineraries with penalty coefficients idle 10, deadhead 1, flexibility loss 0.1, and total time 0. The truck capacities for fuel types 1 and 2 are retained at 12 and 7 containers, respectively, so that one truck is required for a shipment of fuel type 1 or 2.

Truck Capacity for Fuel Type 3	16	8
No. of Trucks Required for One Shipment of Fuel Type 3	1	2
Fleet Size	12	16
Total KM	702,198	981,718
KM Active	460,767	595,624
KM Deadhead	241,431	386,094
Truck Days Active	402	531
Truck Days Deadhead	183	293
Truck Days Idle	256	252
Truck Days in Maint.	240	364
Percent KM Active	65.6	60.7
Percent Days Idle	23.7	17.5

the rule that escorts are always required to accompany trucks when they are travelling. Then escort vehicles were assigned using the rule that such a vehicle must accompany each truck only while the truck is travelling with a load of nuclear materials. The maintenance parameters used for the escort vehicles were a two day maintenance stop being required before 12,874 km had been travelled since the previous maintenance.

The truck itineraries used to determine the service requirements for the escort vehicles are shown in Figure 3.2, while the resulting escort vehicle itineraries and statistics for the two cases are given in Figures 3.39 and 3.40, respectively. The statistics for the escort vehicle itineraries are summarized in Table 3.14. The fleet size is comparable in both cases while the total distance that must be travelled by the escort vehicles is greater when both active and deadhead truck itinerary legs must be covered than when only active must be covered.

An important consideration in analyzing these escort vehicle itineraries is the linking value penalty coefficients that were used. In both cases, penalty coefficients of 1 were used for idle and deadhead time, while values of 0 were used for flexibility loss and total time. In contrast, the truck itineraries used penalty coefficients of idle 10, deadhead 1, flexibility loss 0.1, and total time 0. If the same penalty coefficients were used for the escort vehicle itineraries as were used for the trucks, it can be expected that the resulting escort itineraries would closely follow the truck itineraries, thereby producing an escort vehicle fleet size which is comparable to the truck fleet size.



ESCORT NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	59,982	51,014	8,968	10	32	85.0	35.6
2	71,388	66,165	5,223	12	18	92.7	20.0
3	76,451	70,154	6 297	14	12	91.8	13.3
4	48,999	41,392	7,607	8	45	84.5	50.0
5	72,922	68,847	4,075	16	15	94.4	16.7
6	66,927	63,843	3,084	14	19	95.4	21.1
7	80,649	78,923	1,[illegible]26	14	7	97.9	7.8
8	61,752	55,469	6 283	14	26	89.8	28.9
9	55,990	51,343	[illegible],647	10	35	91.7	38.9
10	50,307	46,063	[illegible],244	8	41	91.6	45.6
11	69,368	65,494	3,874	14	13	94.4	20.0
12	63,509	59,325	4,184	14	25	93.4	27.8
13	12,149	7,665	4,434	2	77	63.1	85.6
TOTAL	790,395	725,698	64,697	150	369	--	--
AVG.	50,800	55,823	4,977	12	28	91.8	31.5

Figure 3.39. Schedule 2 escort vehicle itineraries required to cover trailer/tractor itineraries shown in Figure 3.2 with assignment rule that escorts are required for both active and deadhead truck itinerary legs. Escort linking value penalties are idle 1, deadhead 1, flexibility loss 0, and total time 0.

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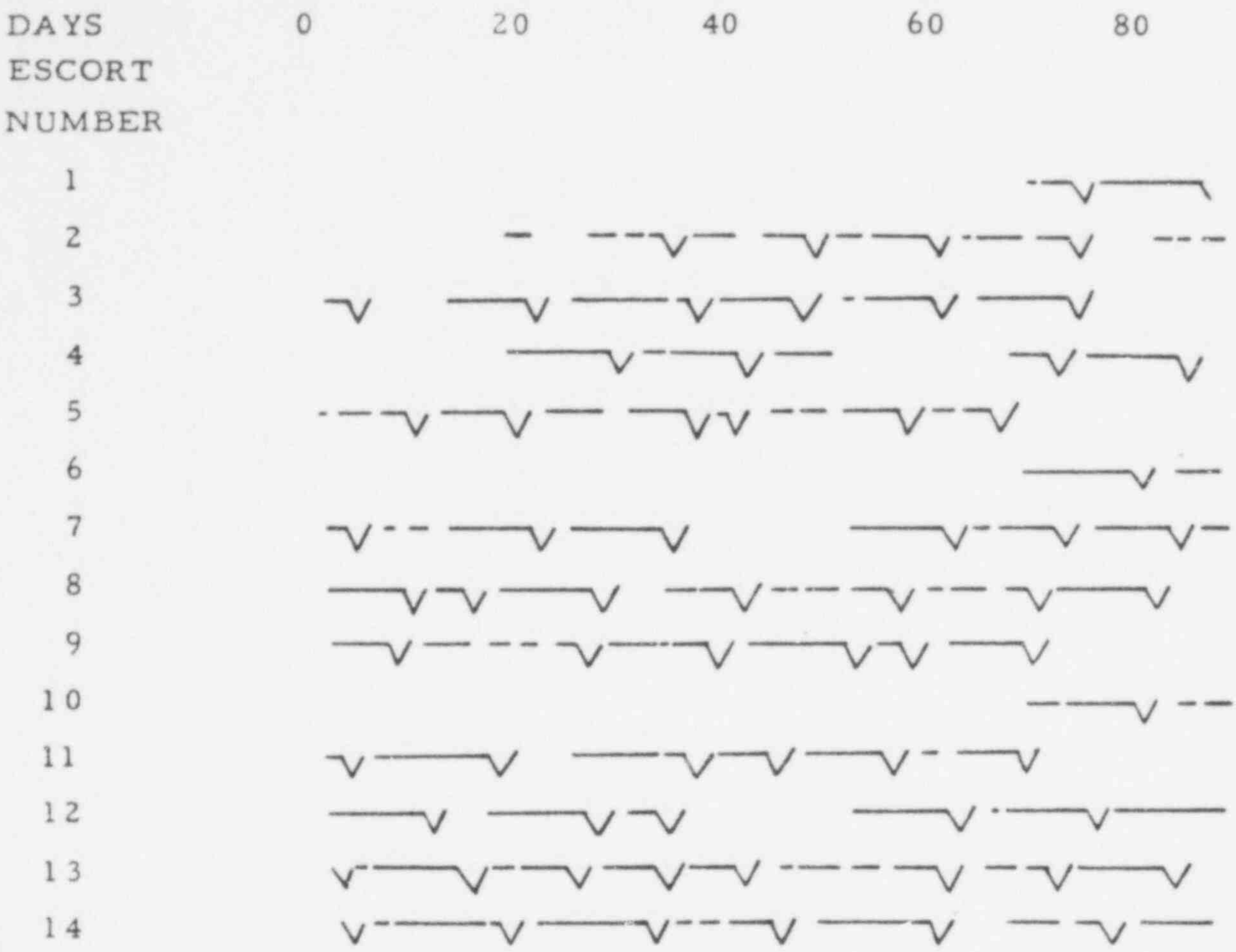

ESCORT NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	18,671	10,304	8,367	4	72	55.2	80.0
2	53,683	34,304	19,379	8	38	63.9	42.2
3	58,229	35,881	22,343	12	29	61.6	32.2
4	50,395	38,442	11,953	8	42	76.3	46.7
5	58,949	40,266	18,683	12	28	68.3	31.1
6	21,358	15,525	5.333	2	73	72.7	81.1
7	61,710	39,448	22,262	12	24	63.9	26.7
8	70,733	41,258	29,475	14	18	58.3	20.0
9	60,516	33,631	26,855	12	28	55.6	31.1
10	16,970	9,319	7,651	2	75	54.9	83.3
11	61,475	32,695	28,780	12	27	53.2	30.0
12	66,027	44,209	21,818	10	25	67.0	27.8
13	66,567	35,715	30,852	16	18	53.7	20.0
14	74,152	49,768	24,384	12	14	67.1	15.6
TOTAL	739,439	460,767	278,672	136	511	---	---
AVG.	52,817	32,912	19,905	10	37	62.3	40.6

Figure 3.40. Schedule 2 escort vehicle itineraries required to cover trailer/tractor itineraries shown in Figure 3.2 with assignment rule that escorts are required only for active truck itinerary legs. Escort linking value penalties are idle 1, deadhead 1, flexibility loss 0, and total time 0.

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Table 3.14 Comparison of escort vehicle itineraries for rules when 1) escort vehicle required only for active trailer/tractor itinerary leg and 2) escort vehicle required for both active and deadhead trailer/tractor itinerary leg.

	Active Legs Only	Active and Deadhead Legs
Escort Fleet Size	14	13
Total KM	739,439	790,395
KM Active	460,767	725,698
KM Deadhead	278,672	64,697
Escort Days Active	402	602
Escort Days Deadhead	211	49
Escort Days Idle	511	369
Escort Days in Maint.	136	150
Percent KM Active	62.3	91.8
Percent KM Deadhead	40.6	31.5

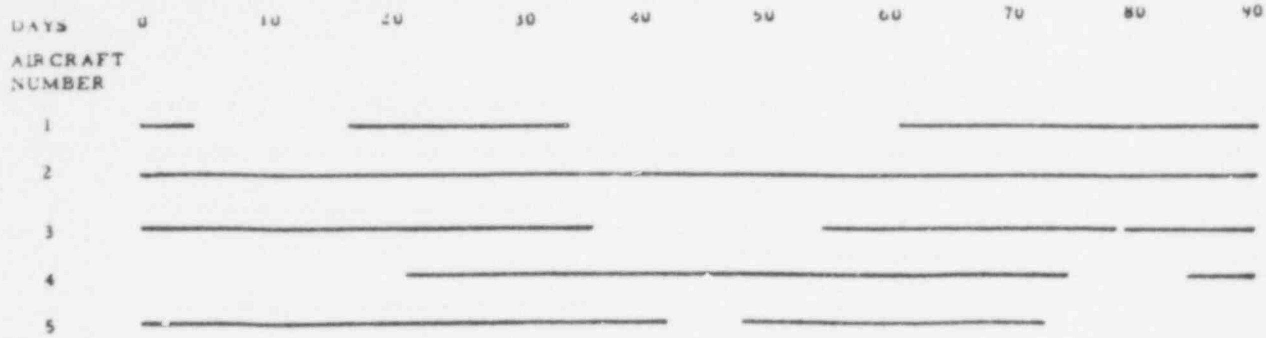
3.6.2 Aircraft Assignment Rules

Aircraft and trailer/tractors were sequentially scheduled under two sets of rules for the assignment of shipments to the aircraft mode. In one case, a shipment was assigned to the aircraft mode whenever the truck travel time for that shipment exceeded 8 hours. In the other case, this travel time parameter was increased to 16 hours. Table 3.15 summarizes the overall statistics for these two cases, while the detailed aircraft itineraries and the itinerary statistics for both the aircraft and trailer/tractors are given in Figures 3.41 and 3.42. The resulting trailer/tractor itineraries are not pictorially presented, as was done in other sensitivity studies, because these itineraries generally consist of short periods of active and deadhead service, usually with just one active service, separated by idle periods. This type of itinerary is very difficult to depict in the same manner as was done previously.

With the 8 hour truck travel time criterion, 275 shipments are handled by the aircraft mode while 40 are handled solely by the truck mode. However, each shipment handled by the aircraft mode imposes two service requirements for trucks to transport the material to and from the airfields. Thus there are a total of 590 truck service requirements. An additional factor is that each truck service requirement imposed by an aircraft itinerary has no flexibility in departure date which results in relatively inefficient truck itineraries obtained from the process of linking services. For this 8 hour truck travel time case, the aircraft fleet size is 5 and the truck fleet size is 17. Note that only 1.5 percent of the total truck distance travelled is on active service. This low figure results from the fact that, for a truck service from a base to a nearby airfield, zero distance between the base and airfield was assumed for simplicity.

Table 3.15 Effects of rules for assignment of aircraft to a shipment on aircraft and trailer/tractor itineraries for Schedule 2.

Maximum Allowable Travel Time via Truck (Hours)	8	16
Shipments by Aircraft	275	190
Aircraft Fleet Size	5	4
Total A/C KM	804,874	700,233
A/C Active KM	449,118	392,795
A/C Deadhead KM	335,756	307,438
A/C Days Active	309	220
A/C Days Deadhead	27	23
A/C Days Idle	114	117
Percent A/C KM Active	55.8	56.1
Percent A/C Days Idle	25.3	32.5
Shipments by Truck Only	40	125
Total Required Truck Services	590	505
Truck Fleet Size	17	16
Total Truck KM	792,423	727,421
Truck Active KM	11,648	67,972
Truck Deadhead KM	780,775	659,449
Truck Days Active	35	87
Truck Days Deadhead	592	500
Truck Days Idle	588	561
Truck Days in Maint.	316	292
Percent Truck KM Active	1.5	9.3
Percent Truck Days Idle	38.4	39.0



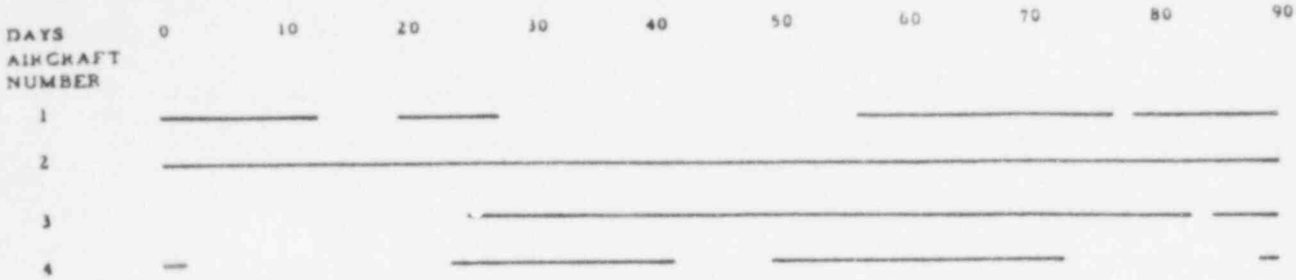
AIRCRAFT NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	116,317	61,468	54,849	40	52.8	44.4
2	183,627	103,641	79,986	0	56.4	0
3	193,998	109,488	84,510	19	56.4	21.1
4	164,521	91,825	72,696	32	55.8	35.6
5	146,411	82,697	63,714	23	55.8	25.3
					---	----
TOTAL	804,874	449,118	355,756	114		
AVG.	160,975	89,824	71,151	23	55.8	25.3

a) Aircraft itinerary and itinerary statistics.

TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	32,619	435	32,184	8	58	1.3	64.4
2	54,915	354	54,561	28	19	0.1	21.1
3	50,414	729	49,685	20	28	1.3	31.1
4	56,942	3,083	53,859	24	20	5.4	22.2
5	47,155	1,434	45,722	20	32	3.0	35.6
6	50,307	638	49,669	20	31	1.3	34.4
7	55,209	1,083	54,127	20	26	2.0	28.9
8	47,361	0	47,361	20	33	0	36.7
9	62,317	1,619	60,698	28	12	2.6	13.3
10	68,797	354	68,443	24	12	0.1	13.3
11	63,538	772	62,765	28	12	1.2	13.3
12	28,007	0	28,007	12	56	0	62.2
13	43,075	0	43,075	12	45	0	50.0
14	12,065	0	12,465	8	72	0	80.0
15	69,023	0	69,023	20	16	0	17.8
16	50,278	1,148	49,130	24	26	2.3	28.9
17	0	0	0	0	90	0	100.0
TOTAL	792,423	11,648	780,775	316	588	---	-------
AVG.	46,613	685	45,928	19	36	1.5	38.4

b) Truck itinerary statistics

Figure 3.41. Schedule 2 aircraft itineraries and statistics, with associated truck itinerary statistics, for assignment of aircraft and trucks using the rule that a shipment is assigned to the aircraft mode if truck driving time exceeds 8 hours. Linking value penalties for both transport unit elements are idle 10, deadhead 1, flexibility loss 0.1, and total time 0.



AIRCRAFT NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	150,417	83,978	66,439	44	55.8	48.9
2	236,838	126,485	110,353	1	53.4	1.1
3	191,363	107,762	83,602	28	59.4	31.1
4	121,614	74,569	47,045	44	61.3	48.9
TOTAL	700,233	392,795	307,438	117	----	------
AVG.	175,058	98,199	76,859	29	56.1	32.5

a) Aircraft itinerary and itinerary statistics.

TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	19,927	0	19,927	8	68	0	75.6
2	58,941	7,437	51,503	28	12	12.6	13.3
3	59,042	9,814	49,228	24	21	16.6	23.3
4	55,223	6,785	48,438	20	22	12.3	24.4
5	45,382	6,262	39,120	20	33	13.8	36.7
6	42,462	1,578	40,884	16	41	3.7	45.6
7	21,028	0	21,028	8	66	0	73.3
8	36,258	863	35,395	16	45	2.4	50.0
9	45,897	750	45,147	20	36	1.6	40.0
10	61,731	17,818	43,913	24	11	28.9	12.2
11	53,451	2,847	50,604	24	25	5.3	27.8
12	55,456	6,188	49,268	20	26	11.2	37.8
13	43,943	920	43,022	20	34	2.1	17.8
14	65,404	1,869	63,535	20	16	2.9	16.7
15	63,277	4,840	58,436	24	[illegible]	7.6	100.0
16	0	0	0	0	90	0	
TOTAL	727,421	67,972	659,449	292	561	---	----
AVG.	45,464	4,248	41,216	18	35.1	9.3	39.0

b) Truck itinerary statistics.

Figure 3.42. Schedule 2 aircraft itineraries and statistics, with associated truck itinerary statistics, for assignment of aircraft and trucks using the rule that a shipment is assigned to the aircraft mode if truck driving time exceeds 16 hours. Linking value penalties for both transport unit elements are idle 10, deadhead 1, flexibility loss 0.1, and total time 0.

For such a service only loading and unloading time comprised active service.

With the 16 hour truck travel time criterion for selection of the aircraft mode, the aircraft fleet size is 4, the truck fleet size is 16, and the percentage of total distance travelled on active service increased to 9.3 percent. This increased percentage for active service resulted from the larger number of shipments serviced only by truck, which all require non-zero active travel distance, and the fewer number of truck service requirements imposed by aircraft itineraries. The reduced aircraft fleet size results from the smaller number of shipments handled by aircraft, while the reduced truck fleet size is caused by the reduced total truck service requirements of 505 services compared with 590 for the 8 hour case.

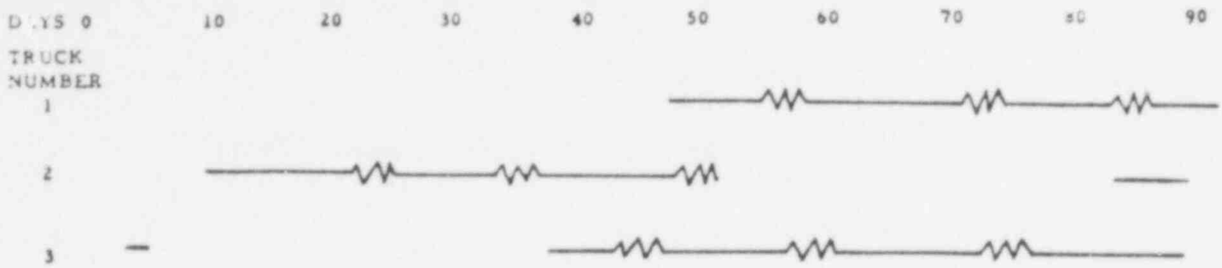
An interesting feature of the truck itineraries in each case is that there is one itinerary that consists of exactly one service between a base and its local airfield. The lack of flexibility in this service, which was imposed by an aircraft itinerary, probably prevented its being included in another itinerary. If these shipments could have been advanced or delayed by a short period, it is likely that these services could have been accommodated in another itinerary, thereby reducing each of the truck fleet sizes by one.

3.7 Effects of Warm-up Period in Fixed-Fleet Sizing Mode

The TRNSM 2 model was exercized using the fixed-fleet sizing mode with Schedule 1 to generate trailer/tractor itineraries using warm-up periods of 15 and 30 days to generate representative initial conditions for the scheduling period. Table 3.16 summarizes the overall statistics for these two cases, while the detailed itineraries and their statistics are presented in Figures 3.43 and 3.44.

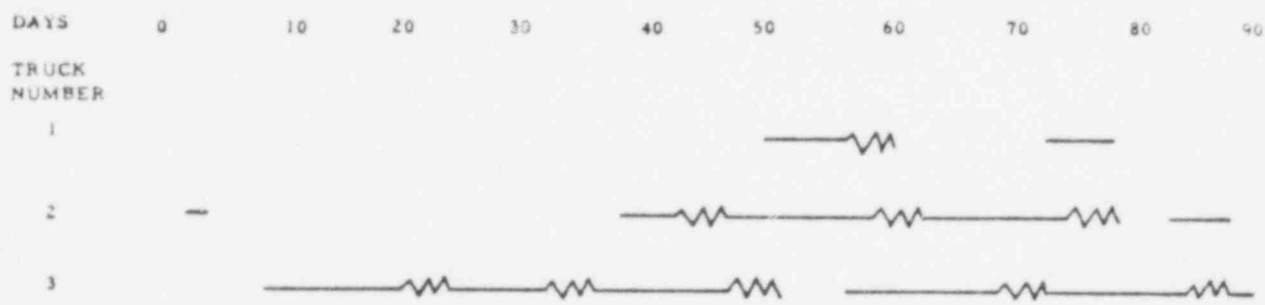
Table 3.16 Effect of warm-up period on Schedule 1 trailer/tractor itineraries generated by using the fixed-fleet sizing mode with linking value penalty coefficients idle 10, deadhead 1, flexibility loss 0.1, and total time 0.

Warm-up Period (Days)	15	30
Fleet Size	3	3
Total KM	111,005	107,705
KM Active	44,249	44,249
KM Deadhead	66,756	63,456
Truck Days Active	59	59
Truck Days Deadhead	51	48
Truck Days Idle	127	132
Truck Days in Maint.	36	36
Percent KM Active	39.9	41.1
Percent Days Idle	46.7	48.9



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	34,256	13,805	20,451	12	47	40.3	52.2
2	35,690	13,317	22,373	12	42	37.3	46.7
3	41,059	17,127	23,932	12	38	41.7	42.2
TOTAL	111,005	44,249	66,756	36	127	----	----
AVG.	37,002	14,750	22,252	12	42	39.9	46.7

Figure 3.43. Schedule 1 trailer/tractor itineraries using fixed fleet sizing mode with a 15 day warm-up period and linking value penalty coefficients idle 10, deadhead 1, flexibility loss 0.1, and total time 0.



TRUCK NUMBER	KM TOTAL	KM ACTIVE	KM DEADHEAD	DAYS IN MAINT.	DAYS IDLE	PERCENT KM ACTIVE	PERCENT DAYS IDLE
1	12,496	5,539	6,956	4	74	44.3	82.2
2	33,538	12,588	20,950	12	43	37.5	47.8
3	61,671	26,121	35,550	20	15	42.4	16.7
TOTAL	107,705	44,249	63,456	36	132	----	----
AVG.	35,902	14,750	21,152	12	44	41.1	48.9

Figure 3.44. Schedule 1 trailer/tractor itineraries using fixed fleet sizing mode with a 30 day warm-up period and linking value penalty coefficients idle 10, deadhead 1, flexibility loss 0.1 and total time 0.

While the warm-up period does affect the specific itineraries which are produced, it does not appear to have any significant effect on fleet size or the overall itinerary statistics.

3.8 Example of Sequential Scheduling of All Transport Unit Elements

To demonstrate the capability of the TRNSM 2 model to sequentially generate itineraries for a large number of transport unit element types, Schedule 1 was used to sequentially generate itineraries for aircraft, truck trailers, truck tractors, escort vehicles, truck tractor/escort crews, and aircraft crews. The resulting detailed itinerary statistics are given in Table 3.17.

The aircraft mode was selected if truck driving time exceeded 16 hours. This resulted in a total of 6 services being handled by aircraft for a fleet size of 1 with the aircraft being idle 97.1 percent of the time.

The truck trailers require a two day maintenance stop at least every 40,232 km. The total number of services required to be handled by truck trailers is 158, 12 of these imposed by the aircraft itinerary. The resulting fleet size is 5, with three of the itineraries being very short. Itinerary 1 handled four services, itinerary 3 handles three, and itinerary 5 handles only one service, all of which are imposed by the aircraft itinerary and, therefore, have zero flexibility. As discussed in Section 3.6.2, this lack of flexibility results in the construction of inefficient itineraries.

Truck tractors require a four day maintenance stop at least every 12, 874 km. A fleet size of 5 truck tractors is required to handle the service imposed by the five truck trailer itineraries. These tractor itineraries are more evenly balanced than the trailer itineraries, with only itinerary 1 with three active services being very short.

Table 3.17 Detailed itinerary statistics for the sequential scheduling of aircraft, truck trailers, truck tractors, escort vehicles, tractor/escort crews, and aircraft crews using Schedule 1 with the non-fixed fleet mode.

a) Aircraft

Linking value penalties: idle 10, deadhead 1, flexibility loss 0.1, and total time 0.

Fleet Size = 1 Aircraft

KM Total	KM Active	KM Deadhead	Days Active	Days Idle	Percent KM Active	Percent Days Idle
21,870	9,877	11,993	2	87	45.2	97.1

b) Truck Trailers

Linking value penalties: idle 10, deadhead 1, flexibility loss 0.1, and total time = 0.

Fleet Size = 5 Truck Trailers

Trailer No.	KM Total	KM Active	KM Deadhead	Days in Maint.	Days Idle	Percent KM Active	Percent Days Idle
1	9,131	0*	9,131	0*	83	0*	92.2
2	40,731	16,115	24,616	4	45	39.6	50.0
3	2,315	0	2,315	0*	88	0*	97.8
4	54,887	18,257	36,630	4	30	33.3	33.3
5	0*	0*	0*	0*	90	0*	100*
Total	107,064	34,372	72,692	8	336	----	----
Avg.	21,412	6,874	14,538	2	67	32.1	74.7

*These figures result from the fact that TRNSM 2 assumes zero distance to be travelled between bases and airfields. All the services in itineraries 1, 3 and 5 are of this type.

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Table 3.17 (cont'd)

c) Truck Tractors

Linking value penalties: idle 1, deadhead 1, flexibility loss 0, and total time 0.

Fleet size = 5 truck tractors

Tractor Number	KM Total	KM Active	KM Deadhead	Days in Maint.	Days Idle	Percent KM Active*	Percent Days Idle
1	9,728	3,007	6,721	0	84	30.9	93.3
2	33,207	25,298	7,909	20	38	76.2	42.2
3	21,561	18,107	3,454	8	62	84.0	68.9
4	36,582	29,508	7.074	16	39	80.7	43.3
5	34,988	31,144	3,844	12	44	89.0	48.9
Total	136,067	107,064	29,003	56	266	- -	- -
Ave.	27,214	21,413	5,801	11	53	78.7	59.2

*Active service for a tractor is defined to occur anytime the tractor is pulling a trailer, whether loaded or empty.

d) Escort Vehicles

Linking value penalties: idle 1, deadhead 1, flexibility loss 0, and total time 0.

Fleet size = 7 escort vehicles

Escort Number	KM Total	KM Active	KM Deadhead	Days in Maint.	Days Idle	Percent KM Active	Percent Days Idle
1	520	118	402	0	89	22.7	98.9
2	15,215	4,342	10,873	4	70	28.5	77.8
3	33,048	10,717	22,331	16	43	32.4	47.8
4	1,439	-0-	1,439	0	87	-0-	96.7
5	10,123	614	9,509	4	81	6.1	90.0
6	25,087	11,249	13,838	8	55	44.8	61.1
7	31,970	7,332	24,638	16	43	22.9	47.8
Total	117,403	34,372	83,031	48	468	---	---
Ave.	16,772	4,910	11,862	7	67	29.3	74.3

Table 3.17 (concluded)

e) Truck Tractor/Escort Crews

Linking value penalties: idle 1, deadhead 1, flexibility loss 0, and total time 0.

Crew size = 12 crews

Crew Number	KM Total	KM Active	KM Deadhead	Break Days	Days Idle	Percent KM Active	Percent Days Idle
1	8,252	6,841	1,411	0	85	82.9	94.4
2	41,690	36,895	4,795	14	36	88.5	40.0
3	45,320	41,157	4,163	28	26	90.8	28.9
4	23,317	18,947	4,370	7	59	81.3	65.6
5	48,508	45,339	31,169	28	18	93.5	20.0
6	10,940	3,745	7,195	14	68	34.2	75.6
7	9,674	6,264	3,410	0	76	64.8	84.4
8	32,320	30,320	2,000	28	37	93.8	41.1
9	16,228	15,440	788	7	61	95.1	67.8
10	3,682	1,841	1,841	7	80	50.0	88.9
11	1,044	213	832	7	82	20.4	91.1
12	49,302	46,468	2,833	21	22	94.3	24.4
Total	290,277	253,469	36,808	161	650	---	---
Ave.	24,189	21,122	3,067	13	54	87.3	60.2

f) Aircraft Crews

Linking value penalties: idle 1, deadhead 1, flexibility loss 0, and total time 0.

Crew size = 1 crew

KM Total	KM Active	KM Deadhead	Break Days	Days Idle	Percent KM Active	Percent Days Idle
32,122	21,870	10,252	14	73	68.1	68.4

The maintenance parameters used for the escort vehicles were the same as for the truck tractors, i.e., a four day maintenance stop is required before 12,874 km had been travelled since the previous maintenance. The rule used to assign escort vehicles is that an escort must accompany a loaded trailer, but not an empty one. An escort fleet size of 7 resulted with three short itineraries, itineraries 1, 4 and 5, which respectively contained one, one, and four active services.

In assigning crews to truck tractors and escort vehicles, a 7 day rest break was required before 30 days had been exceeded since the previous break. A total of 12 crews was required. Crew numbers 1, 6, 7, 10, and 11 were used for only a relatively short period, roughly between day 80 and day 90 in the schedule. The percentage of total distance travelled by the crews on active duty with tractors (full and empty) and escort vehicles is 87.3 percent.

Finally aircraft crews were assigned to cover the single aircraft itinerary using the same rest break rules as for tractor/escort crews. Only one aircraft crew was required to man the single aircraft. It turned out that the aircraft itinerary had a convenient idle period between day 53 and day 81 which is when the aircraft crew required a rest break.

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3. Woo, C. W. and Anderson, G. M., "Programmer's Manual for TRNSM2," ORINCON Tehcnical Report OC-R-77-87-9964-6, January 15, 1979.

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APPENDIX A

Definition of Symbols Specifying Base Locations in Sample Shipment Schedules.

Symbol	Base Location
JOH	Erwin, TN
HNT	Nashville, TN
DJI	Morris, IL
TMI	Harrisburg, PA
SWV	Williamsburg, VA
BFD	Decatur, AL
OAS	Anderson, SC
CNC	Charlotte, NC
FDA	Dothan, AL
CSJ	St. Joseph, MI
LPP	Pottstown, PA
BSC	Barnwell, SC
DBO	Fremont, OH
TPF	Miami, FL
PAO	Ashtabula, OH
SHP	Hazleton, PA
GPH	Port Huron, MI
NMP	Oswego, NY
JNY	Riverhead, NY
SCT	Chattanooga, TN
FCN	Blair NB
CRF	Ocala, FL
BRI	Rockford, IL
BRL	Baton Rouge, LA
PPM	Bourne, MA
QCI	Clinton, IA
SOC	Oceanside, CA
GCC	Catskill, NY
SSS	Sumter, SC
JOP	Joplin, MO
HNC	Youngsville, NC
LBP	Leechburg, PA

APPENDIX A (contd)

Symbol	Base Location
OCO	Cimarron, OK
FLP	Lancaster, PA
WPW	Pasco, WA
BNC	Wilmington, NC
BVP	Rochester, PA
WVN	West Valley, NY
HTF	Hartford, CT
NCV	Charlottesville, VA
WAW	Aberdeen, WA
ZWI	Waukegan, IL
TPO	Kelso, WA
BHA	Huntville, AL
PSN	Statesville, NC
AUG	Augusta, GA
DSM	Des Moines, IA
IPP	Peekskill, NY
STX	Victoria, TX
PVA	Phoenix, AR
SLF	Okeechobee, FL
LSI	La Salle, IL
MDM	Midland, MI
SNJ	Deepwater, NJ
CMO	Columbia, MO
MHI	Madison, IN
KKW	Jonesville, WI
HMG	McRae, GA
SNY	Patchoque, NY
WNO	New Orleans, LA
TRN	Toms River, NJ
GGM	Vicksburg, MI
CRI	Newport, RI
PIM	Red Wing, MN
KGB	Green Bay, WI
DCC	San Luis Obispo, CA
ZCO	Cincinnati, OH
BFO	Tulsa, OK
WCK	Emporia, KS

APPENDIX A (contd)

Symbol	Base Location
CHE	Spartanburg, SC
CAM	Annapolis, MD
CPT	Hillsboro, TX
SNH	Portsmouth, NH
HBC	Eureka, CA
WBT	Crossville, TN
HCO	Middletown, CN
SBW	Bellingham, WA
ACR	Cedar Rapids, IA
ARA	Russellville, AK
ARZ	Blythe, CA
LCW	La Cross, WI
MNL	New London, CN
FWR	Willow Run, MI
MSM	St. Cloud, MI
TNW	Nelson, WI
PBW	Manitowoc, WI
CNB	Nebraska City, NB
ANJ	Atlantic City, NJ

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APPENDIX B

Sample Shipment Schedule 1

This appendix lists the short sample shipment schedule that was employed in the sensitivity studies. The definitions of the three letter symbols used to denote the base locations are given in Appendix A.

SAMPLE SHIPMENT SCHEDULE 1

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
JOH	HNT	1	22	3	16	0	30
DJI	DJI	1	8	1	12	0	43
DJI	DJI	2	9	1	12	0	42
TMI	SWV	3	24	2	7	0	1
JOH	JOH	3	10	1	12	0	39
JOH	HNT	4	25	3	16	0	17
TMI	TMI	4	11	1	12	0	45
DJI	DJI	5	12	1	12	0	41
JOH	BFD	6	27	3	16	0	4
JOH	HNT	8	29	3	16	0	21
OAS	CNC	8	29	2	7	0	24
OAS	CNC	8	29	2	7	0	25
OAS	FDA	9	30	2	7	0	15
JOH	HNT	9	30	3	16	0	16
DJI	CSJ	10	31	2	7	0	13
TMI	LPP	11	32	3	16	0	31
TMI	TMI	11	18	1	12	0	46
TMI	SWV	12	33	2	7	0	2
BSC	BSC	12	19	1	12	0	35
OAS	OAS	12	19	1	12	0	37
OAS	OAS	12	19	1	12	0	38
TMI	LPP	13	34	3	16	0	29
JOH	BFD	14	35	3	16	0	8
TMI	TMI	14	35	1	12	0	11
TMI	LPP	14	35	3	16	0	28
DJI	DJI	15	22	1	12	0	44
TMI	TMI	16	37	1	12	0	10
JOH	HNT	16	37	1	12	0	23
TMI	LPP	18	39	3	16	0	30
JOH	BFD	21	42	3	16	0	7

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SAMPLE SHIPMENT SCHEDULE 1 (CONT'D)

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
OAS	FDA	23	44	2	7	0	14
DJI	DBO	23	44	2	77	0	33
DJI	CSJ	24	45	2	7	0	12
JOH	HNT	24	45	3	16	0	19
JOH	JOH	24	31	1	12	0	40
JOH	BFD	25	46	3	16	0	5
JOH	HNT	25	46	3	16	0	22
BSC	BSC	26	33	1	12	0	34
JOH	BFD	27	48	3	16	0	6
JOH	HNT	27	48	3	16	0	18
DJI	DBO	27	48	2	7	0	32
BSC	BSC	27	34	1	12	0	36
JOH	BFD	28	49	3	16	0	3
TMI	LPP	28	49	3	16	0	26
TMI	LPP	29	50	3	16	0	27
JOH	BFD	30	51	3	16	0	9
BSC	TPF	32	53	2	7	0	48
DJI	DJI	31	52	1	12	0	61
JOH	JOH	31	38	1	12	0	92
TMI	PAO	32	53	3	16	0	67
TMI	SHP	32	53	3	16	0	79
TMI	TMI	35	42	1	12	0	96
OAS	OAS	36	43	1	12	0	88
TMI	TMI	36	43	1	12	0	93
DJI	GPH	37	58	2	7	0	69
TMI	PAO	38	59	3	16	0	66
OAS	CNC	38	59	2	7	0	71

SAMPLE SHIPMENT SCHEDULE 1 (CONT'D)

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
TMI	SHP	39	60	3	16	0	77
TMI	NMP	40	61	2	7	0	53
BSC	BSC	40	47	1	12	0	84
TMI	TMI	40	47	1	12	0	94
TMI	PAO	41	62	3	16	0	65
TMI	JNY	41	62	2	7	0	82
OAS	SCT	42	63	2	7	0	57
TMI	PAO	44	65	3	16	0	68
DJI	FCN	44	65	2	7	0	81
TMI	JNY	45	66	2	7	0	83
BSC	TPF	47	68	2	7	0	47
TMI	NMP	46	67	2	7	0	50
OAS	CNC	46	67	2	7	0	58
TMI	SHP	46	67	3	16	0	73
BSC	BSC	46	53	1	12	0	86
BSC	CRF	47	68	2	7	0	54
OAS	CNC	48	69	2	7	0	59
TMI	SHP	48	69	3	16	0	74
TMI	NMP	49	70	2	7	0	51
TMI	NMP	49	70	2	7	0	52
TMI	SHP	49	70	5	16	0	76
JOH	JOH	49	56	1	12	0	89
OAS	SCT	50	71	2	7	0	56
BSC	BSC	50	57	1	12	0	85
BSC	CRF	51	72	2	7	0	55
TMI	TMI	52	59	1	12	0	95
TMI	SHP	54	75	3	16	0	78
JOH	JOH	54	61	1	12	0	91
TMI	PAO	55	76	3	16	0	62

SAMPLE SHIPMENT SCHEDULE 1 (CONT'D)

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
OAS	CNC	55	76	2	7	0	72
OAS	OAS	55	62	1	12	0	87
DJI	DJI	56	77	1	12	0	60
TMI	PAO	56	77	3	16	0	63
JOH	JOH	56	63	1	12	0	90
TMI	PAO	57	78	3	16	0	64
DJI	GPH	57	78	2	7	0	70
TMI	SHP	57	78	3	16	0	75
TMI	NMP	58	79	2	7	0	49
DJI	FCN	58	79	2	7	0	80
TMI	PAO	59	80	3	16	0	124
TMI	PAO	59	80	3	16	0	129
DJI	BRI	60	81	2	7	0	106
OAS	BRL	61	82	2	7	0	134
OAS	FDA	61	82	2	7	0	99
DJI	BRI	61	82	2	7	0	105
BSC	BSC	61	68	1	12	0	137
BSC	BSC	61	68	1	12	0	140
OAS	OAS	61	68	1	12	0	142
OAS	OAS	61	68	1	12	0	144
TMI	PAO	62	83	3	16	0	130
DJI	GPH	62	83	2	7	0	132
BSC	BSC	62	69	1	12	0	139
JOH	JOH	62	69	1	12	0	145
TMI	PAO	64	85	3	16	0	125
OAS	OAS	64	71	1	12	0	143
TMI	PPM	65	86	3	16	0	111
DJI	QCI	65	86	3	16	0	117
DJI	DJI	66	73	1	12	0	150

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SAMPLE SHIPMENT SCHEDULE 1 (CONT'D)

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
TMI	PAO	67	88	3	16	0	128
DJI	SOC	70	91	2	7	0	120
TMI	GCC	68	89	2	7	0	123
DJI	QCI	70	91	3	16	0	119
DJI	GPH	70	91	2	7	0	131
JOH	JOH	70	77	1	12	0	146
JOH	JOH	70	77	1	12	0	147
BSC	BSC	71	78	1	12	0	138
DJI	DJI	71	78	1	12	0	148
OAS	OAS	72	93	1	12	0	98
TMI	PPM	72	93	3	16	0	112
TMI	PPM	73	94	3	16	0	107
TMI	GCC	73	94	2	7	0	122
TMI	PAO	74	95	3	16	0	126
BSC	BSC	74	81	1	12	0	135
DJI	DJI	74	81	1	12	0	152
TMI	PPM	76	97	3	16	0	109
TMI	PPM	76	97	3	16	0	110
TMI	PPM	78	99	3	16	0	108
TMI	PPM	78	99	3	16	0	113
DJI	QCI	78	99	3	16	0	116
DJI	SOC	80	101	2	7	0	121
BSC	BSC	78	85	1	12	0	136
BSC	SSS	80	101	2	7	0	103
TMI	PAO	80	101	3	16	0	127
OAS	FDA	81	102	2	7	0	100
DJI	QCI	81	102	3	16	0	114
OAS	OAS	83	104	1	12	0	97

SAMPLE SHIPMENT SCHEDULE 1 (CONCLUDED)

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
OAS	SCT	84	105	2	7	0	101
DJI	QCI	84	105	3	16	0	115
OAS	OAS	84	91	1	12	0	141
BSC	SSS	85	106	2	7	0	104
DJI	DJI	85	91	1	12	0	149
OAS	SCT	87	108	2	7	0	102
DJI	QCI	87	108	3	16	0	118
OAS	BRL	88	109	2	7	0	133
DJI	DJI	88	95	1	12	0	151

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APPENDIX C

Sample Shipment Schedule 2

This appendix lists the long sample schedule that was employed in the sensitivity studies. The definitions of the three letter symbols used to denote the base locations are given in Appendix A.

SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
LBP	SWV	15	36	2	6	0	1
LBP	SWV	15	36	2	6	0	2
OCO	FLP	21	42	3	16	0	3
OCO	FLP	21	42	3	16	0	4
OCO	FLP	21	42	3	16	0	5
OCO	FLP	21	42	3	1[illegible]	0	6
OCO	FLP	21	42	3	16	0	7
OCO	FLP	21	42	3	16	0	8
WPW	BFD	16	37	3	16	0	9
WPW	BFD	16	37	3	16	0	10
WPW	BFD	16	37	3	16	0	11
WPW	BFD	16	37	3	16	0	12
WPW	BFD	16	37	3	16	0	13
WPW	BFD	16	37	3	16	0	14
BNC	CSJ	1	22	2	6	0	15
BNC	CSJ	1	22	2	6	0	16
WPW	BVP	21	42	2	6	0	17
WPW	BVP	21	42	2	6	0	18
WVN	CSJ	5	26	2	6	0	19
WVN	CSJ	5	26	2	6	0	20

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SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
HTF	CNC	20	41	2	6	0	21
HTF	CNC	20	41	2	6	0	22
JOH	BRL	25	46	3	16	0	23
JOH	BRL	25	46	3	16	0	24
JOH	BRL	25	46	3	16	0	25
JOH	BRL	25	46	3	16	0	26
JOH	BRL	25	46	3	16	0	27
HTF	NCV	24	45	2	6	0	28
HTF	NCV	24	45	2	6	0	29
BNC	CNC	8	29	2	6	0	30
BNC	CNC	8	29	2	6	0	31
HTF	PAO	4	25	3	16	0	32
HTF	PAO	4	25	3	16	0	33
HTF	PAO	4	25	3	16	0	34
HTF	PAO	4	25	3	16	0	35
HTF	PAO	4	25	3	16	0	36
HTF	PAO	4	25	3	16	0	37
HTF	PAO	4	25	3	16	0	38
WVN	FCN	6	27	2	6	0	39
WVN	FCN	6	27	2	6	0	40
BNC	WAW	10	31	2	6	0	41
BNC	WAW	10	31	2	6	0	42
HTF	TPF	25	46	2	6	0	43
HTF	TPF	25	46	2	6	0	44
WVN	OAS	24	31	1	7	0	45
WVN	LBP	14	21	1	7	0	46
WVN	JOH	23	30	1	7	0	47
BSC	OAS	3	10	1	7	0	48
BSC	OAS	3	10	1	7	0	49
BSC	JOH	28	35	1	7	0	50

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SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
BSC	JOH	28	35	1	7	0	51
BSC	WVN	3	10	1	7	0	52
JOH	WVN	24	31	1	7	0	53
DJI	BNC	9	16	1	7	0	54
DJI	LBP	9	16	1	7	0	55
DJI	LBP	9	16	1	7	0	56
TMI	LBP	22	29	1	7	0	57
TMI	LBP	22	29	1	7	0	58
TMI	OCO	11	18	1	7	0	59
TMI	WPW	25	32	1	7	0	60
OCO	ZWI	5	26	2	6	0	61
OCO	ZWI	5	26	2	6	0	62
JOH	MNL	8	29	2	6	0	63
JOH	MNL	8	29	2	6	0	64
WVN	TPO	8	29	2	6	0	65
WVN	TPO	8	29	2	6	0	66
HTF	SCT	14	35	2	6	0	67
HTF	SCT	14	35	2	6	0	68
BNC	BHA	18	39	2	6	0	69
BNC	BHA	18	39	2	6	0	70
LBP	WAW	30	51	2	6	0	71
LBP	WAW	30	51	2	6	0	72
LBP	NMP	9	30	3	16	0	73
LBP	NMP	9	30	3	16	0	74
LBP	NMP	9	30	3	16	0	75
LBP	NMP	9	30	3	16	0	76
LBP	NMP	9	30	3	16	0	77
LBP	NMP	9	30	3	16	0	78
HTF	PSN	19	40	2	6	0	79
HTF	PSN	19	40	2	6	0	80

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SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
LBP	AUG	20	41	2	6	0	81
LBP	AUG	20	41	2	6	0	82
OAS	DSM	20	41	2	6	0	83
OAS	DSM	20	41	2	6	0	84
WVN	OCO	24	31	1	7	0	85
WVN	OCO	24	31	1	7	0	86
WVN	WVN	10	17	1	7	0	87
BSC	BNC	21	28	1	7	0	88
BSC	OCO	19	26	1	7	0	89
BSC	WPW	23	30	1	7	0	90
BSC	WPW	23	30	1	7	0	91
JOH	BNC	16	23	1	7	0	92
JOH	BNC	16	23	1	7	0	93
JOH	LBP	9	16	1	7	0	94
JOH	WPW	17	24	1	7	0	95
JOH	WPW	17	24	1	7	0	96
JOH	HTF	6	13	1	7	0	97
DJI	LBP	26	33	1	7	0	98
DJI	LBP	26	33	1	7	0	99
DJI	WVN	30	37	1	7	0	100
TMI	OCO	25	32	1	7	0	101
TMI	JOH	29	36	1	7	0	102
JOH	OAS	47	68	2	6	0	103
JOH	OAS	47	68	2	6	0	104
OAS	NMP	42	63	3	16	0	105
OAS	NMP	42	63	3	16	0	106
OAS	NMP	42	63	3	16	0	107
OAS	NMP	42	63	3	16	0	108

SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
OAS	NMP	42	63	3	16	0	109
HTF	IPP	34	55	2	6	0	110
HTF	IPP	34	55	2	6	0	111
OAS	TMI	41	62	2	6	0	112
OAS	TMI	41	62	2	6	0	113
OCO	WPW	45	66	2	6	0	114
OCO	WPW	45	66	2	6	0	115
OCO	STX	60	81	2	6	0	116
OCO	STX	60	81	2	6	0	117
WPW	PPM	54	75	3	16	0	118
WPW	PPM	54	75	3	16	0	119
WPW	PPM	54	75	3	16	0	120
WPW	PPM	54	75	3	16	0	121
WPW	PPM	54	75	3	16	0	122
WPW	PPM	54	75	3	16	0	123
WPW	PPM	54	75	3	16	0	124
BNC	AUG	38	59	2	6	0	125
BNC	AUG	38	59	2	6	0	126
JOH	PVA	50	71	2	6	0	127
JOH	PVA	50	71	2	6	0	128
BNC	WPW	33	54	2	6	0	129
BNC	WPW	33	54	2	6	0	130
WVN	JOH	41	48	1	7	0	131
WVP	WPW	46	53	1	7	0	132
BSC	BNC	53	60	1	7	0	133
BSC	HTF	47	54	1	7	0	134
JOH	LBP	47	54	1	7	0	135
JOH	WPW	51	58	1	7	0	136

SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
JOH	WPW	51	58	1	7	0	137
JOH	WVN	42	49	1	7	0	138
DJT	OCO	38	45	1	7	0	139
DJI	WVN	46	53	1	7	0	140
DJI	WVN	46	53	1	7	0	141
TMI	BNC	39	46	1	7	0	142
TMI	LBP	43	50	1	7	0	143
TMI	OCO	55	62	1	7	0	144
TMI	OCO	55	62	1	7	0	145
WPW	TPF	55	76	2	6	0	146
LBP	BNC	42	63	3	16	0	147
LBP	BNC	42	63	3	16	0	148
LBP	BNC	42	63	3	16	0	149
LBP	BNC	42	63	3	16	0	150
LBP	BNC	42	63	3	16	0	151
OAS	SLF	59	80	2	6	0	152
OAS	SLF	59	80	2	6	0	153
WVN	BNC	55	76	3	16	0	154
WVN	BNC	55	76	3	16	0	155
WVN	BNC	55	76	3	16	0	156
WVN	BNC	55	76	3	16	0	157
WVN	BNC	55	76	3	16	0	158
BNC	LSI	60	81	3	16	0	159
BNC	LSI	60	81	3	16	0	160
BNC	LSI	60	81	3	16	0	161
BNC	LSI	60	81	3	16	0	162
BNC	LSI	60	81	3	16	0	163
BNC	LSI	60	81	3	16	0	164
LBP	SCT	42	63	2	6	0	165

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SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
LBP	SCT	42	63	2	6	0	166
JOH	HMG	31	52	3	16	0	167
JOH	HMG	31	52	3	16	0	168
JOH	HMG	31	52	3	16	0	169
JOH	HMG	31	52	3	16	0	170
JOH	HMG	31	52	3	16	0	171
JOH	MDM	45	66	2	6	0	172
JOH	MDM	45	66	2	6	0	173
JOH	MNL	39	60	2	6	0	174
JOH	MNL	39	60	2	6	0	175
WVN	SNJ	33	54	3	16	0	176
WVN	SNJ	33	54	3	16	0	177
WVN	SNJ	33	54	3	16	0	178
WVN	SNJ	33	54	3	16	0	179
WVN	SNJ	33	54	3	16	0	180
WVN	SNJ	33	54	3	16	0	181
LBP	CMO	52	73	2	6	0	182
LBP	CMO	52	73	2	6	0	183
OAS	MHI	45	66	2	6	0	184
OAS	MHI	45	66	2	6	0	185
OCO	KKW	46	67	2	6	0	186
OCO	KKW	46	67	2	6	0	187
WVN	OAS	36	43	1	7	0	188
WVN	OAS	36	43	1	7	0	189
WVN	LBP	46	53	1	7	0	190
WVN	OCO	54	61	1	7	0	191
WVN	OCO	54	61	1	7	0	192
BSC	WPW	39	46	1	7	0	193
BSC	WPW	39	46	1	7	0	194

SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
BSC	WVN	52	59	1	7	0	195
JOH	OAS	59	66	1	7	0	196
JOH	OAS	59	66	1	7	0	197
JOH	LBP	35	42	1	7	0	198
DJT	OCO	53	60	1	7	0	199
DJI	HTF	55	62	1	7	0	200
TMI	OAS	45	52	1	7	0	201
TMI	HTF	46	53	1	7	0	202
TMI	HTF	46	53	1	7	0	203
WVN	FCN	80	101	2	6	0	204
OCO	HMG	79	100	3	16	0	205
OCO	HMG	79	100	3	16	0	206
OCO	HMG	79	100	3	16	0	207
OCO	HMG	79	100	3	16	0	208
OCO	HMG	79	100	3	16	0	209
BNC	BFD	78	99	3	16	0	210
BNC	BFD	78	99	3	16	0	211
BNC	BFD	78	99	3	16	0	212
BNC	BFD	78	99	3	16	0	213
BNC	BFD	78	99	3	16	0	214
BNC	BFD	78	99	3	16	0	215
LBP	CRF	65	86	2	6	0	216
LBP	CRF	65	86	2	6	0	217
OCO	CNC	81	102	2	6	0	218
OCO	CNC	81	102	2	6	0	219
WVN	SNY	78	99	3	16	0	220
WVN	SNY	78	99	3	16	0	221
WVN	SNY	78	99	3	16	0	222

SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
WVN	SNY	78	99	3	16	0	223
WVN	SNY	78	99	3	16	0	224
WPW	WNO	77	98	2	6	0	225
WPW	WNO	77	98	2	6	0	226
WPW	TRN	77	98	2	6	0	227
WPW	TRN	77	98	2	6	0	228
HTF	SHP	75	96	3	16	0	229
HTF	SHP	75	96	3	16	0	230
HTF	SHP	75	96	3	16	0	231
HTF	SHP	75	96	3	16	0	232
HTF	SHP	75	96	3	16	0	233
HTF	SHP	75	96	3	16	0	234
HTF	SHP	75	96	3	16	0	235
OCO	KKW	79	100	2	6	0	236
OCO	KKW	79	100	2	6	0	237
BNC	GGM	70	91	3	16	0	238
BNC	GGM	70	91	3	16	0	239
BNC	GGM	70	91	3	16	0	240
BNC	GGM	70	91	3	16	0	241
BNC	GGM	70	91	3	16	0	242
BNC	GGM	70	91	3	16	0	243
BNC	GGM	70	91	3	16	0	244
LBP	CRI	77	98	2	6	0	245
LBP	CRI	77	98	2	6	0	246
JOH	PSN	85	106	2	6	0	247
JOH	PSN	85	106	2	6	0	248
WPW	MDM	75	96	2	6	0	249
WPW	MDM	75	96	2	6	0	250
WVN	OAS	85	92	1	7	0	251

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SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
WVN	OAS	85	92	1	7	0	252
WVN	WPW	69	76	1	7	0	253
WVN	WPW	69	76	1	7	0	254
WVN	WPW	69	76	1	7	0	255
BSC	OAS	64	71	1	7	0	256
BSC	BNC	71	78	1	7	0	257
BSC	BNC	71	78	1	7	0	258
BSC	LBP	67	74	1	7	0	259
BSC	LBP	67	74	1	7	0	260
BSC	WPW	64	71	1	7	0	261
BSC	WPW	64	71	1	7	0	262
JOH	OCO	63	70	1	7	0	263
JOH	WVN	71	78	1	7	0	264
JOH	HTF	63	70	1	7	0	265
TMI	OAS	68	75	1	7	0	266
TMI	OAS	68	75	1	7	0	267
TMI	JOH	82	89	1	7	0	268
TMI	HTF	83	90	1	7	0	269
TMI	HTF	83	90	1	7	0	270
WPW	SOC	89	110	2	6	0	271
HTF	PIM	66	87	2	[illegible]	0	272
LNP	KGB	67	88	2	[illegible]	0	273
OCO	DCC	85	106	2	6	0	274
OCO	DCC	85	106	2	6	0	275
WPW	FDA	67	88	2	6	0	276
WPW	FDA	67	88	2	6	0	277
LBP	ZCO	67	88	3	16	0	278
LBP	ZCO	67	88	3	16	0	279
LBP	ZCO	67	88	3	16	0	280

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SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
LBP	ZCO	67	88	3	16	0	281
LBP	ZCO	67	88	3	16	0	282
WVN	NCV	90	111	2	6	0	283
WVN	NCV	90	111	2	6	0	284
WVN	WCK	82	103	2	6	0	285
WVN	WCK	82	103	2	6	0	286
BNC	LPP	85	106	3	16	0	287
BNC	LPP	85	106	3	16	0	288
BNC	LPP	85	106	3	16	0	289
BNC	LPP	85	106	3	16	0	290
JOH	DBO	61	82	2	6	0	291
JOH	DBO	61	82	2	6	0	292
OCO	GCC	78	99	2	6	0	293
OCO	GCC	78	99	2	6	0	294
BNC	PVA	62	83	2	6	0	295
BNC	PVA	62	83	2	6	0	295
WVN	OAS	62	69	1	7	0	297
WVN	OAS	62	69	1	7	0	298
WVN	JOH	79	86	1	7	0	299
WVN	JOH	79	86	1	7	0	300
BSC	BNC	87	94	1	7	0	301
BSC	BNC	87	94	1	7	0	302
BSC	LBP	83	90	1	7	0	303
BSC	WVN	62	69	1	7	0	304
BSC	WVN	62	69	1	7	0	305
BSC	WVN	62	69	1	7	0	306
BSC	HTF	61	68	1	7	0	307
JOH	OCO	90	97	1	7	0	308

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SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
JOH	OCO	90	97	1	7	0	309
JOH	WVN	75	82	1	7	0	310
DJI	OCO	77	84	1	7	0	311
DJI	OCO	77	84	1	7	0	312
DJI	HTF	80	87	1	7	0	313
DJI	HTF	80	87	1	7	0	314
TMI	JOH	69	76	1	7	0	315
WVN	HCO	101	122	2	6	0	316
CAS	ZWI	91	112	2	6	0	317
OAS	ZWI	91	112	2	6	0	318
OCO	IPP	120	141	2	6	0	319
OCO	IPP	122	141	2	6	0	320
HTF	SSS	105	126	2	6	0	321
HTF	SSS	105	126	2	6	0	322
OCO	LSI	98	119	3	16	0	323
OCO	LSI	98	119	3	16	0	324
OCO	LSI	98	119	3	16	0	325
OCO	LSI	98	119	3	16	0	326
OCO	LSI	98	119	3	16	0	327
OCO	LSI	98	119	3	16	0	328
HTF	BVP	93	114	2	6	0	329
HTF	BVP	93	114	2	6	0	330
OAS	PVA	114	135	2	6	0	331
OAS	PVA	114	135	2	6	0	332
LBP	QCI	98	119	3	16	0	333
LBP	QCI	98	119	3	16	0	334
LBP	QCI	98	119	3	16	0	335
LBP	QCI	98	119	3	16	0	336
WPW	JNY	98	119	2	6	0	337
WPW	JNY	98	119	2	6	0	338

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SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
OAS	CHE	115	136	2	6	0	339
OAS	CHE	115	136	2	6	0	340
LBP	CRI	116	137	2	6	0	341
LBP	CRI	116	137	2	6	0	342
BSC	BNC	103	110	1	7	0	343
BSC	BNC	103	110	1	7	0	344
BSC	OCO	93	100	1	7	0	345
JOH	OAS	111	118	1	7	0	346
JOH	LBP	119	126	7	7	0	347
JOH	OCO	116	123	1	7	0	348
JOH	OCO	116	123	1	7	0	349
DJI	OAS	99	106	1	7	0	350
DJI	OAS	99	106	1	7	0	351
DJI	BNC	97	104	1	7	0	352
DJI	JOH	92	99	1	7	0	353
DJI	JOH	92	99	1	7	0	354
DJI	HTF	114	121	1	7	0	355
TMI	OAS	113	120	1	7	0	356
TMI	OAS	113	120	1	7	0	357
TMI	BNC	92	99	1	7	0	358
TMI	BNC	92	99	1	7	0	359
TMI	JOH	115	122	1	7	0	360
TMI	JOH	115	122	1	7	0	361
HTF	OAS	101	122	2	6	0	362
HTF	OAS	101	122	2	6	0	363
WPW	CAM	114	135	2	6	0	364
WPW	CAM	114	135	2	6	0	365
OAS	SNJ	112	133	2	6	0	366
OAS	SNJ	112	133	2	6	0	367

SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
JOH	WPW	117	138	3	16	0	368
JOH	WPW	117	138	3	16	0	369
JOH	WPW	117	138	3	16	0	370
JOH	WPW	117	138	3	16	0	371
JOH	WPW	117	138	3	16	0	372
JOH	WPW	117	138	3	16	0	373
WPW	CPT	106	127	2	6	0	374
WPW	CPT	106	127	2	6	0	375
HTF	PAO	106	127	3	16	0	376
HTF	PAO	106	127	3	16	0	377
HTF	PAO	106	127	3	16	0	378
HTF	PAO	106	127	3	16	0	379
HTF	PAO	106	127	3	16	0	380
HTF	PAO	106	127	3	16	0	381
HTF	PAO	106	127	3	16	0	382
OAS	SNH	101	122	2	6	0	383
OAS	SNH	101	122	2	6	0	384
BNC	MHI	91	112	2	6	0	385
BNC	MHI	91	112	2	6	0	386
OAS	HNT	115	136	3	16	0	387
OAS	HNT	115	136	3	16	0	388
OAS	HNT	115	136	3	16	0	389
OAS	HNT	115	136	3	16	0	390
OAS	HNT	115	136	3	16	0	391
OAS	HNT	115	136	3	16	0	392
OAS	HNT	115	136	3	16	0	393
LBP	SNH	117	138	2	6	0	394
LBP	SNH	117	138	2	6	0	395
WPW	DBO	109	130	2	6	0	396

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SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
WPW	DBO	109	130	2	6	0	397
WVN	ACR	95	116	2	6	0	398
WVN	ACR	95	116	2	6	0	399
OCO	SOC	118	139	2	6	0	400
OCO	SOC	118	139	2	6	0	401
WVN	BNC	91	98	1	7	0	402
WVN	BNC	91	98	1	7	0	403
WVN	LBP	102	109	1	7	0	404
WVN	WVN	101	108	1	7	0	405
WVN	WVN	101	108	1	7	0	406
BSC	OCO	101	108	1	7	0	407
BSC	OCO	101	108	1	7	0	408
BSC	OCO	101	108	1	7	0	409
BSC	JOH	93	100	1	7	0	410
BSC	JOH	93	100	1	7	0	411
JOH	HTF	104	111	1	7	0	412
DJI	OAS	106	113	1	7	0	413
DJI	BNC	112	119	1	7	0	414
DJI	LBP	97	104	1	7	0	415
DJI	WPW	113	120	1	7	0	416
TMI	OAS	120	127	1	7	0	417
TMI	WPW	91	98	1	7	0	418
TMI	WPW	91	98	1	7	0	419
JOH	HBC	135	156	3	16	0	420
OAS	TMI	124	145	2	6	0	421
OAS	TMI	124	145	2	6	0	422
JOH	SNJ	139	160	2	6	0	423
JOH	SNJ	139	160	2	6	0	424
HTF	DBO	132	153	2	6	0	425

SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
HTF	DBO	132	153	2	6	0	426
BNC	WBT	124	145	2	6	0	427
BNC	WBT	124	145	2	6	0	428
WVN	WBT	141	162	2	6	0	429
WVN	WBT	141	162	2	6	0	430
LBP	SLF	122	143	2	6	0	431
LBP	SLF	122	143	2	6	0	432
OCO	BRI	132	153	2	6	0	433
OCO	BRI	132	153	2	6	0	434
WVN	SBW	146	167	3	16	0	435
WVN	SBW	146	167	3	16	0	436
WVN	SBW	146	167	3	16	0	437
WVN	SBW	146	167	3	16	0	438
WVN	SBW	146	167	3	16	0	439
WVN	SBW	146	167	3	16	0	440
WVN	SBW	146	167	3	16	0	441
WVN	SBW	146	167	3	16	0	442
OCO	CHE	134	155	2	6	0	443
OCO	CHE	134	155	2	6	0	444
WVN	TPF	136	157	2	6	0	445
WVN	TPF	136	157	2	6	0	446
HTF	BVP	150	171	2	6	0	447
HTF	BVP	150	171	2	6	0	448
WVN	BNC	123	130	1	7	0	449
WVN	JOH	123	130	1	7	0	450
WVN	WVN	139	146	1	7	0	451
WVN	WVN	139	146	1	7	0	452
WVN	HTF	135	142	1	7	0	453
WVN	HTF	135	142	1	7	0	454

SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
BSC	LBP	135	142	1	7	0	455
BSC	LBP	135	142	1	7	0	456
BSC	OCO	145	152	1	7	0	457
BSC	OCO	145	152	1	7	0	458
BSC	HTF	145	152	1	7	0	459
JOH	JOH	122	129	1	7	0	460
JOH	JOH	122	129	1	7	0	461
JOH	JOH	122	129	1	7	0	462
JOH	WPW	146	153	1	7	0	463
DJI	OAS	134	141	1	7	0	464
DJI	WPW	146	153	1	7	0	465
TMI	LBP	142	149	1	7	0	466
TMI	OCO	137	144	1	7	0	467
TMI	WPW	[illegible]	156	1	7	0	468
TMI	WVN	122	129	1	7	0	469
TMI	WVN	122	129	1	7	0	470
LBP	IPP	134	155	2	6	0	471
OCO	DJI	150	171	3	16	0	472
OCO	DJI	150	171	3	16	0	473
OCO	DJI	150	171	3	16	0	474
OCO	DJI	150	171	3	16	0	475
OCO	DJI	150	171	3	16	0	476
BNC	ACR	148	169	3	16	0	477
BNC	ACR	148	169	3	16	0	478
BNC	ACR	148	169	3	16	0	479
BNC	ARA	127	148	2	6	0	480
BNC	[illegible]RA	127	148	2	6	0	481
OAS	NCV	142	163	2	6	0	482
OAS	NCV	142	163	2	6	0	483

SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
OAS	BHA	127	148	2	6	0	484
OAS	BHA	127	148	2	6	0	485
BNC	GGM	149	170	3	16	0	486
BNC	GGM	149	170	3	16	0	487
BNC	GGM	149	170	3	16	0	488
BNC	GGM	149	170	3	16	0	489
BNC	GGM	149	170	3	16	0	490
BNC	GGM	149	170	3	16	0	491
BNC	GGM	149	170	3	16	0	492
OCO	DJI	150	171	2	6	0	493
OCO	DJI	150	171	2	6	0	494
JOH	DJI	140	161	2	6	0	495
JOH	DJI	140	161	2	6	0	496
HTF	BFO	149	170	3	16	0	497
HTF	BFO	149	170	3	16	0	498
HTF	BFO	149	170	3	16	0	499
HTF	BFO	149	170	3	16	0	500
HTF	BFO	149	170	3	16	0	501
HTF	BFO	149	170	3	16	0	502
HTF	BFO	149	170	3	16	0	503
JOH	KKW	146	167	2	6	0	504
JOH	KKW	146	147	2	6	0	505
BNC	ARZ	128	149	2	6	0	506
BNC	ARZ	128	149	2	6	0	507
OAS	SNH	145	166	2	6	0	508
OAS	SNH	145	166	2	6	0	509
WVN	OCO	128	135	1	7	0	510

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SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
BSC	OAS	136	143	1	7	0	511
BSC	WPW	127	134	1	7	0	512
BSC	WVN	136	143	1	7	0	513
BSC	WVN	136	143	1	7	0	514
JOH	OAS	133	140	1	7	0	515
JOH	OAS	133	140	1	7	0	516
JOH	LBP	147	154	1	7	0	517
JOH	LBP	147	154	1	7	0	518
JOH	OCO	143	150	1	7	0	519
JOH	OCO	143	150	1	7	0	520
JOH	JOH	140	147	1	7	0	521
JOH	WVN	142	149	1	7	0	522
DJI	WVN	142	149	1	7	0	523
DJI	LBP	150	157	1	7	0	524
DJI	JOH	138	145	1	7	0	525
DJI	JOH	138	145	1	7	0	526
DJI	WPW	134	141	1	7	0	527
DJI	WVN	126	133	1	7	0	528
DJI	WVN	126	133	1	7	0	52[illegible]
TMI	BNC	138	145	1	7	0	5[illegible]
TMI	WVN	138	145	1	7	0	531
HTF	LCW	179	200	3	16	0	532
WPW	MNL	179	200	3	16	0	533
WPW	MNL	179	200	3	16	0	534
WPW	MNL	179	200	3	16	0	535
WPW	MNL	179	200	3	16	0	536
LBP	QCI	160	181	3	16	0	537
LBP	QCI	160	181	3	16	0	538
LBP	QCI	160	181	3	16	0	539
LBP	QCI	160	181	3	16	0	540

SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
LBP	QCI	160	181	3	16	0	541
JOH	FLP	170	191	3	16	0	542
JOH	FLP	170	191	3	16	0	543
JOH	FLP	170	191	3	16	0	544
JOH	FLP	170	191	3	16	0	545
JOH	FLP	170	191	3	16	0	546
JOH	FLP	170	191	3	16	0	547
BNC	FDA	175	196	2	6	0	548
BNC	FDA	175	196	2	6	0	549
LBP	FWR	168	189	3	16	0	550
LBP	FWR	168	189	3	16	0	551
LBP	FWR	168	189	3	16	0	552
LBP	FWR	168	189	3	16	0	553
LBP	FWR	168	189	3	16	0	554
LBP	FWR	168	189	3	16	0	555
OCO	BRI	170	191	2	6	0	556
OCO	BRI	170	191	2	6	0	557
WPW	CMO	172	193	2	6	0	558
WPW	CMO	172	193	2	6	0	559
OAS	MSM	159	180	2	6	0	560
OAS	MSM	159	180	2	6	0	561
OAS	HNT	177	198	3	16	0	562
OAS	HNT	177	198	3	16	0	563
OAS	HNT	177	198	3	16	0	564
OAS	HNT	177	198	3	16	0	565
OAS	HNT	177	198	3	16	0	566
OAS	HNT	177	198	3	16	0	567
OAS	HNT	177	198	3	16	0	568
WVN	GPH	155	176	2	6	0	569
WVN	GPH	155	176	[illegible]	6	0	570

SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
OCO	TNW	169	190	2	6	0	571
OCO	TNW	169	190	2	6	0	572
BNC	SLF	167	188	2	6	0	573
BNC	SLF	167	188	2	6	0	574
WVN	OAS	172	179	1	7	0	575
WVN	BNC	152	159	1	7	0	576
WVN	WPW	179	186	1	7	0	577
WVN	WPW	179	186	1	7	0	578
WVN	HTF	155	162	1	7	0	579
WVN	HTF	155	162	1	7	0	580
BSC	JOH	174	181	1	7	0	581
BSC	HTF	164	171	1	7	0	582
BSC	HTF	164	171	1	7	0	583
JOH	OAS	180	187	1	7	0	584
JOH	OAS	180	187	1	7	0	585
JOH	OAS	180	187	1	7	0	586
JOH	WPW	176	183	1	7	0	587
JOH	HTF	176	183	1	7	0	588
JOH	HTF	176	183	1	7	0	589
DJI	BNC	167	174	1	7	0	590
DJI	BNC	167	174	1	7	0	591
DJI	OCO	157	164	1	7	0	592
DJI	OCO	157	164	1	7	0	593
DJI	WPW	151	158	1	7	0	594
DJI	WPW	151	158	1	7	0	595
DJI	HTF	168	175	1	7	0	596
TMI	OAS	180	187	1	7	0	597
TMI	OAS	180	187	1	7	0	598
TMI	JOH	156	163	1	7	0	599
TMI	WPW	153	160	1	7	0	600

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SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
TMI	WPW	153	160	1	7	0	601
TMI	WVN	176	183	1	7	0	602
TMI	HTF	157	164	1	7	0	603
OAS	NMP	151	172	3	16	0	604
OAS	NMP	151	172	3	16	0	605
OAS	NMP	151	172	3	16	0	606
OAS	NMP	151	172	3	16	0	607
HTF	MSM	154	175	3	16	0	608
HTF	MSM	154	175	3	16	0	609
HTF	MSM	154	175	3	16	0	610
OCO	QCI	180	201	3	16	0	611
OCO	QCI	180	201	3	16	0	612
OCO	QCI	180	201	3	16	0	613
OCO	QCI	180	201	3	16	0	614
OCO	QCI	180	201	3	16	0	615
JOH	PBW	166	187	2	6	0	616
WPW	CNB	167	188	3	16	0	617
WPW	CNB	167	188	3	16	0	618
WPW	CNB	167	188	3	16	0	619
WPW	CNB	167	188	3	16	0	620
WPW	CNB	167	188	3	16	0	621
LBP	DCC	188	201	2	6	0	622
LBP	DCC	180	201	2	6	0	623
JOH	STX	168	189	2	6	0	624
JOH	STX	168	189	2	6	0	625
WPW	SHP	177	198	3	16	0	626
WPW	SHP	177	198	3	16	0	627
WPW	SHP	177	198	3	16	0	628
WPW	SHP	177	198	3	16	0	629
WPW	SHP	177	198	3	16	0	630

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SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
WPW	SHP	177	198	3	16	0	631
WVN	NMP	158	179	2	6	0	632
WVN	NMP	158	179	2	6	0	633
OAS	LPP	170	191	3	16	0	634
OAS	LPP	170	191	3	16	0	635
OAS	LPP	170	191	3	16	0	636
OAS	LPP	170	191	3	16	0	637
OAS	LPP	170	191	3	16	0	638
OAS	LPP	170	191	3	16	0	639
WVN	SOC	179	200	2	6	0	640
WVN	SOC	179	200	2	6	0	641
OCO	WPW	174	195	2	6	0	642
OCO	WPW	174	195	2	6	0	643
BNC	BRL	159	180	3	16	0	644
BNC	BRL	159	180	3	16	0	645
BNC	BRL	159	180	3	16	0	646
BNC	BRL	159	180	3	16	0	647
BNC	BRL	159	180	3	16	0	648
BNC	BRL	159	180	3	16	0	649
WPW	HNT	168	189	3	16	0	650
WPW	HNT	168	189	3	16	0	651
WPW	HNT	168	189	3	16	0	652
WPW	HNT	168	189	3	16	0	653
WPW	HNT	168	189	3	16	0	654
WPW	HNT	168	189	3	16	0	655
WPW	HNT	168	189	3	16	0	656
HTF	HNC	152	173	2	6	0	657
HTF	HNC	152	173	2	6	0	658
JOH	ANJ	165	186	2	6	0	659
JOH	ANJ	165	186	2	6	0	660

SAMPLE SHIPMENT SCHEDULE 2

Origin Base	Destination Base	Earliest Shipping Day	Latest Arrival Day	Material Type	Material Quantity	Mode/Container Designation	Shipment Number
LBP	DJI	154	175	2	6	0	661
LBP	DJI	154	175	2	6	0	662
WVN	BNC	158	165	1	7	0	663
WVN	LBP	167	174	1	7	0	664
WVN	WVN	152	159	1	7	0	665
WVN	WVN	152	159	1	7	0	666
WVN	HTF	171	178	1	7	0	667
JOH	BNC	173	180	1	7	0	668
JOH	BNC	173	180	1	7	0	669
JOH	LBP	154	161	1	7	0	670
JOH	WPW	175	182	1	7	0	671
DJI	BNC	157	164	1	7	0	672
DJI	BNC	157	164	1	7	0	673
DJI	JOH	177	184	1	7	0	674
DJI	WPW	156	163	1	7	0	675
DJI	WPW	156	163	1	7	0	676
DJI	WVN	174	181	1	7	0	677
TMI	BNC	170	177	1	7	0	678
TMI	BNC	170	177	1	7	0	679
TMI	LBP	178	185	1	7	0	680
TMI	WVN	180	187	1	7	0	681
TMI	WVN	180	187	1	7	0	682

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A computerized model of the transportation system for shipment of nuclear fuel cycle materials is required to investigate the effects on fleet size, fleet composition and efficiency of fleet utilization resulting from changes in a variety of physical and regulatory factors, including shipping requirements, security regulations, work rules, maintenance requirements, and vehicle capacities. Such a model has been developed which provides a capability for complete sizing requirements studies of a combined aircraft and truck fleet. This report presents the results of a series of sensitivity studies performed using this model. These studies include the effects of the intinerary optimization criteria, work rules, and maintenance policies. These results demonstrate the effectiveness and versatility of the model for investigating the effects of a wide variety of physical and regulatory factors on the transportation fleet.

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