Arthur D Little

23 - Passenger Operations

Arthur D Little

# Appendix E

## Explanation of Cost Models in Appendix C and Appendix D

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# Appendix E

## Description of Cost Models

### E.1 Introduction

This appendix explains the two cost models which appear as Appendices C and D. It begins with a description of the parameter tables from which the costs were derived.

The models were written in Lotus 123 spreadsheet format and are parameter driven. That is they do not contain input values but rather look up each value, or parameter, in one of a number of look-up tables. The tables that are described are:

- The Equipment Table (Table E.1)
- The General Parameter Table (Table E.2)
- The Route Table (Table E.3)
- The Amtrak Car Table (Table E.4)

The determination of which value to retrieve from a given look-up table is based upon several factors. For the model which calculates costs by route (Appendix C), these factors are:

- Route
- Toilet System Type
- Scenario (Expected, Favorable, Unfavorable)

For the cost model which calculates costs by car type (Appendix D), the factors are:

- Car Type
- Toilet System Type

This latter model calculates the costs under all three scenarios essentially at the same time.

### E.2 The Equipment Table

The Equipment Table lists each of the toilet systems which are used in the model run.

**Manufacturer** The name of the company which manufactures the toilet system. The manufacturers used in this analysis are Monogram, Microphor, Evac and Railtech.

**Model** The particular retention toilet model used in this analysis. The models evaluated were the Monogram "Modified" Vacuum System, the Monogram Self-Contained Recirculating System, the Microphor Gravity System, the Evac Ultimate System, and the Railtech WTS 8300.

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## The Equipment Table

| | Mft'r | Model | Flush Effic'y | Fluid Gallons/ Flush |
|---|---|---|---|---|
| 1 | Monogram | Modified Vacuum | 1.1 | 0.063 |
| 2 | Monogram | Self-Cont'd Recirc | 1 | 0 |
| 3 | Microphor | Gravity | 1.1 | 0.172 |
| 4 | Evac | Ultimate | 1.1 | 0.047 |
| 5 | Railtech | WTS 8300 | 1.1 | 0.263 |

**Table E.1**

| Usable Tank Capacity | Capital Cost | | Installation Hours | | Servicing Hours/ Toilet | Cleaning Minutes/ Toilet |
|---|---|---|---|---|---|---|
| | Collect. System | Per Toilet | Collect. System | Per Toilet | | |
| 235 | $21,000 | $2,500 | 40 | 8 | 2 | 10 |
| 13.5 | $0 | $3,250 | 0 | 8 | 8 | 10 |
| 300 | $10,000 | $5,000 | 16 | 8 | 2 | 10 |
| 200 | $12,000 | $2,900 | 40 | 8 | 2 | 10 |
| 50 | $4,000 | $3,000 | 8 | 8 | 2 | 10 |

## Table E.2

### The General Parameter Table

| | Favorable | Expected | Unfavorable | |
|---|---|---|---|---|
| 1 | 0.449 | 0.449 | 0.449 | Gallons of Human Waste/Day |
| 2 | 6 | 7 | 8 | Uses/Person/Day |
| 3 | 25% | 25% | 25% | Tank Capacity Buffer Factor |
| 4 | $36 | $36 | $36 | Installation Cost/Hour |
| 5 | $36 | $36 | $36 | Cleaning Cost/Hour |
| 6 | $36 | $36 | $36 | Servicing Cost/Hour |
| 7 | $36 | $36 | $36 | Crew Cost/Hour |
| 8 | $0.017 | $0.017 | $0.017 | Disposal Cost/Gallon |
| 9 | 1.00% | 3.00% | 5.00% | Spare Parts Pct. of Capital Cost |
| 10 | 2 | 3 | 4 | Major Servicings per Year |
| 11 | 1 | 1 | 1 | Pumpout Seconds per Gallon |
| 12 | 3.5 | 3.5 | 3.5 | Connect/Disconnect Minutes per Tank |
| 13 | 365 | 365 | 365 | Days per Year |
| 14 | 60% | 70% | 80% | Car Availability Factor |
| 15 | 1 | 1.1 | 1.25 | Flush Efficiency |

## The Route Table

| Route Number | Name | Origin - Destination | Miles | Hours |
|---|---|---|---|---|
| 1 #1-2 | Sunset Limited | New Orleans-Los Angeles | 2033 | 43 |
| 5 #5-6 | California Zephyr | Chicago-Oakland | 2422 | 51.17 |
| 58 #58 | City of New Orleans | New Orleans-Chicago | 924 | 18.33 |
| 87 #87-88 | Silver Meteor | New York-Tampa | 1270 | 23.28 |
| 193 #193 | Benjamin Franklin | Boston-Philadelphia | 322 | 6.55 |
| 200 #200 | Metroliner | Washington DC-New York | 225 | 2.78 |
| 242 #242 | Hudson Highlander | Albany-New York City | 142 | 2.62 |
| 250 #250 | Electric City Express | Schenectady-New York City | 160 | 3.03 |

## Table E.3

| Car Type One | Qty | Car Type Two | Qty | Car Type Three | Qty | Car Type Four | Qty | Car Type Five | Qty | Car Type Six | Qty | Routes per Day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 4 | 1 | 1 | 4 | 3 | 2 | 1 | NA | NA | NA | NA | 1 |
| 3 | 1 | 4 | 3 | 5 | 3 | 6 | 5 | NA | NA | NA | NA | 1 |
| 7 | 1 | 8 | 4 | 9 | 1 | 10 | 1 | 11 | 1 | 12 | 1 | 1 |
| 13 | 7 | 11 | 1 | 12 | 2 | 14 | 1 | 15 | 1 | NA | NA | 1 |
| 16 | 1 | 17 | 1 | 18 | 3 | NA | NA | NA | NA | NA | NA | 2 |
| 19 | 1 | 20 | 4 | 21 | 1 | NA | NA | NA | NA | NA | NA | 6 |
| 17 | 3 | 22 | 1 | 23 | 1 | NA | NA | NA | NA | NA | NA | 6 |
| 24 | 1 | 25 | 3 | 26 | 1 | 27 | 1 | NA | NA | NA | NA | 4 |

## The Amtrak Car Table

**Table E.4**

| | Type | Number | Toilets per Car | Seated Capacity per Car | Note | Cars in Fleet | Railtech Tanks per Car |
|---|---|---|---|---|---|---|---|
| 1 | Coach-HEP-HLV | 39940 | 4 | 72 | | 21 | 2 |
| 2 | Lounge-HEP-HLV | 39970 | 2 | 86 | * | 6 | 2 |
| 3 | Trans Dorm Coach | 39900 | 4 | 40 | | 36 | 2 |
| 4 | Sleeper Super | 32000 | 12 | 44 | * | 68 | 6 |
| 5 | Bag Coach Super | 31000 | 5 | 78 | 78/62 | 48 | 3 |
| 6 | Coach Super | 34000 | 6 | 75 | | 91 | 3 |
| 7 | Horizon | 54000 | 2 | 82 | | 103 | 2 |
| 8 | Coach | 4600 | 2 | 48 | 44/48 | 78 | 2 |
| 9 | Coach (HDCP) | 4000 | 3 | 44 | | 21 | 2 |
| 10 | Dome Coach | 9400 | 2 | 46 | | 12 | 2 |
| 11 | Amlounge II | 28000 | 2 | 49 | | 25 | 2 |
| 12 | Sleeper 10-6 | 2400(30) | 17 | 22 | | 82 | 9 |
| 13 | Amcoach II | 25000 | 2 | 59 | | 119 | 2 |
| 14 | Slumbercoach 24-8 | 2080 | 32 | 40 | | 16 | 16 |
| 15 | Viewliner-Sleeper | 2300 | 17 | 34 | | 2 | 9 |
| 16 | Amcafe | 20000 | 2 | 53 | | 45 | 2 |
| 17 | Amcoach | 21000 | 2 | 84 | | 266 | 2 |
| 18 | Amclub | 20100 | 2 | 41 | 18+23 | 24 | 2 |
| 19 | Met-Srvc Dinette | 20900 | 2 | 23 | | 13 | 2 |
| 20 | Met-Srvc Coach | 21900 | 2 | 60 | | 50 | 2 |
| 21 | Met-Srvc Club | 20970 | 2 | 33 | | 13 | 2 |
| 22 | Amdinette | 20200 | 2 | 23 | | 25 | 2 |
| 23 | Amcoach | 21800 | 2 | 60 | | 31 | 2 |
| 24 | Turbo Power Club | 151-Odd | 1 | 27 | | 6 | 1 |
| 25 | Turbo Coach | 170 | 2 | 72 | | 21 | 2 |
| 26 | Turbo Cafe | 170 | 1 | 52 | | 3 | 1 |
| 27 | Turbo Power Coach | 150-Even | 1 | 40 | | 14 | 1 |

| Route Length One | Trips per Day | Route Length Two | Trips per Day | Route Length Three | Trips per Day |
|---|---|---|---|---|---|
| 24 | 1 | 48 | 1 | 72 | 1 |
| 24 | 1 | 48 | 1 | 72 | 1 |
| 24 | 1 | 48 | 1 | 72 | 1 |
| 24 | 1 | 48 | 1 | 72 | 1 |
| 24 | 1 | 48 | 1 | 72 | 1 |
| 24 | 1 | 48 | 1 | 72 | 1 |
| 12 | 1 | 24 | 1 | 48 | 1 |
| 12 | 1 | 24 | 1 | 48 | 1 |
| 12 | 1 | 24 | 1 | 48 | 1 |
| 12 | 1 | 24 | 1 | 48 | 1 |
| 12 | 1 | 24 | 1 | 48 | 1 |
| 12 | 1 | 24 | 1 | 48 | 1 |
| 24 | 1 | 48 | 1 | 72 | 1 |
| 24 | 1 | 48 | 1 | 72 | 1 |
| 24 | 1 | 48 | 1 | 72 | 1 |
| 8 | 2 | 16 | 1 | 24 | 1 |
| 8 | 2 | 16 | 1 | 24 | 1 |
| 8 | 2 | 16 | 1 | 24 | 1 |
| 2 | 5 | 12 | 1 | 7 | 2 |
| 2 | 5 | 12 | 1 | 7 | 2 |
| 2 | 5 | 12 | 1 | 7 | 2 |
| 2 | 5 | 12 | 1 | 7 | 2 |
| 2 | 5 | 12 | 1 | 7 | 2 |
| 2 | 5 | 12 | 1 | 7 | 2 |
| 2 | 5 | 12 | 1 | 7 | 2 |
| 2 | 5 | 12 | 1 | 7 | 2 |
| 2 | 5 | 12 | 1 | 7 | 2 |

**Flush Efficiency** This value represents the estimated average number of flushes per use of the toilet. The same value is assigned to each system (see paragraph below for recirculating systems) and is taken from the General Parameter Table depending on the scenario being analyzed. While not necessarily a function of the efficiency of the flush -- some number of people flush prior to use even when the bowl appears clean -- it is used to determine how much flush fluid is required per use. This effects the amount of holding tank capacity required.

For the Monogram Self-Contained Recirculating System the Flush Efficiency is fixed at 1.0 because no new flush fluid is added to the system with each flush.

**Fluid: Gallons per Flush** These numbers were supplied to us by the manufacturers and represent the gallons of flush fluid used per flush. They are used to calculate the required tank capacity for a trip of a given length and given passenger density.

Note that for the recirculating system the value is zero since no new fluid is added to the system with each flush.

**Usable Tank Capacity** These values were supplied to us by the manufacturer. It is based on manufacturers' recommended tank sizes in the case of both Monogram Systems, the Microphor Gravity System, and the Evac Ultimate System.

In the case of the Monogram Self-Contained Recirculating System the capacity is on a per toilet basis. This is taken into account in the model.

In the case of the Railtech case, the capacity is based on the current dump enroute configuration. Each tank is used for up to two toilets. The number of tanks per car is found on the Amtrak Car Table and is an Arthur D. Little estimate.

**Cost: Collection System** These values were supplied to us by the manufacturers. They are rough estimates and not intended to be viewed as a quoted prices.

The collection system comprises those items which are not dependent on the number of toilets installed. There is usually only one collection system per car with the exception of the Railtech system where there may be multiple holding tanks per car. Components of the collection system include the holding tank, the piping, the discharge valve, and vacuum generators, odor filters, and inter-holding tank pumps where required.

Since the Monogram Self-Contained Recirculating System collects the waste at the toilet there is no additional cost for a collection system.

**Cost: Per Toilet** These values were supplied by the manufacturers and are rough estimates not to be interpreted as price quotes. They include the cost of all equipment located in the vicinity of the toilet, or which is purchased in direct proportion to the number of toilets purchased.

**Installation Hours: Collection System** These numbers are Arthur D. Little estimates based on the complexity of the collection system. In each case they are estimates of the time required to install a new system on a new car. It is assumed that retro-fitting the current fleet with new collection systems would require more installation time.

Vacuum systems require more time to install due to the added complexity of the pipe profiling and the serious consequences on operating efficiency of vacuum leaks.

The Railtech system is assumed to take less time to install on a per tank basis due to the absence of piping.

The Monogram Self-Contained Recirculating System does not have a remote collection system or piping configuration so there is no installation time required.

**Installation Hours: Per Toilet** These values are Arthur D. Little estimates for the number of hours to install a new toilet on a new car. The values are the same for each toilet system as we were unable to identify reasons why one toilet would take longer to install than another.

**Servicing Hours per Toilet** These values are Arthur D. Little estimates for the number of servicing hours per toilet required at each major servicing interval. They are based on current Amtrak experience with similar system.

The Monogram Self-Contained Recirculating System is assigned more hours per toilet than the other systems because it is Amtrak's experience that they need to be removed from the car for servicing whereas the other non-recirculating systems do not.

The other systems were given equal service time requirements because we could not identify any characteristics which would cause one system to take more time than another.

**Cleaning Minutes per Toilet** These values are Arthur D. Little estimates of the time required to clean the toilet at the end of a trip or service day. It is used to compute annual operating costs. All systems were assigned the same value because we were unable to discern any difference in cleaning requirements between systems.

### E.3 The General Parameter Table

Whereas many of the input parameters in the model are not expected to vary or whose value we know with some certainty, this table contains those input parameters which are likely to vary or whose value we shall vary in order to estimate their impact on cost and operations (i.e. intermediate stops for pump-out. The table contains three columns, one for each scenario: Expected, Favorable, and Unfavorable.

The Expected Scenario column contains those values we believe to be correct. These values are used to determine the base case. The Favorable Scenario column contains values which would produce lower operating costs and lower tank capacity requirements. These values are used to determine a best case scenario. Conversely, the Unfavorable Scenario column contains values which result in higher operating costs and tank capacity requirements to calculate a worst case scenario.

**Gallons of Human Waste per Day** This value, .449 gallons per person per day, was supplied to us by Amtrak. It was corroborated by the manufacturers we visited. This value is held constant in all three scenarios because it is a well established quantity. In addition, small variations are not expected to have great impact on either costs or capacity requirements.

**Uses per Person per Day** This number represents the number of times the average person flushes a toilet per day. The number is based upon normal household usage and therefore is not the actual number of uses per day that the model uses to calculate waste volume generation. The actual number of flushes per day is expected to be greater because of one of two reasons:

- More than one flush is required to clear the waste from the bowl
- The passenger flushes the toilet both prior to and after using the toilet

Based on discussions with Amtrak officials and the manufacturers, we determined that the expected number of uses per person per day is seven. This number is varied across the scenarios. In the favorable scenario it is six; in the unfavorable it is eight.

**Tank Capacity Buffer Factor** This parameter is used to artificially reduce the amount of tank capacity available. The reasoning behind this is that in cars with multiple tanks a pump-out penalty would not be applied until each and every tank is full. Since the tanks will not fill at an equal rate, it is assumed that when they are all 75% full some will be completely full and others only half full. Once some are

completely full the pump-out penalty cost is applied. This parameter is not varied across scenarios.

**Installation Cost per Hour** This value, $36 per hour, was given to us by Amtrak as their standard labor rate. This rate is not varied across scenarios.

**Cleaning Cost per Hour** This value, $36 per hour, was given to us by Amtrak as their standard labor rate. This rate is not varied across scenarios.

**Servicing Cost per Hour** This value, $36 per hour, was given to us by Amtrak as their standard labor rate. This rate is not varied across scenarios.

**Crew Cost per Hour** This value, $36 per hour, was given to us by Amtrak as their standard labor rate. This rate is not varied across scenarios.

**Disposal Cost per Gallon** In order to dump waste into local sewer systems, Amtrak will have to pay a per gallon fee to the local authorities. This fee is based upon the type of sewage being dumped into the system. For systems which add chemicals (Monogram Self-Contained Recirculating) this fee is $0.022 per gallon. For the other systems which dump only human waste and water, the fee is $0.017 per gallon. This fee is not varied across scenarios.

**Spare Parts Percentage of Capital Cost** The annual cost for spare parts is not known for these systems. Many of them have not ever been used as a total retention system before and therefore no historical data exists. In the model we use a fixed percent of original capital cost as a surrogate. In the Expected Scenario this value is 3.0%. It varies from 1.0% to 5%.

**Major Servicings per Year** Currently Amtrak performs major servicing on the toilets three times per year. This frequency is assumed in the Expected Scenario. For the Favorable Scenario this frequency is reduced to semi-annually; in the Unfavorable Scenario it is increased to quarterly service intervals.

**Pumpout Seconds per Gallon** This parameter is used to calculate the labor cost for pumping the waste out of the holding tanks at the end of the trip or of the service day. Since certain systems generate more volume on account of their higher flush fluid volumes this is a discriminating factor. A value of one gallon per second is used in all three scenarios.

**Connect/Disconnect Minutes per Tank** This parameter is used to calculate the labor cost for connecting and disconnecting the hoses to the holding tanks, for pump-out, at the end of the trip or of the service day. Since some systems have multiple holding tanks per car, this parameter is used to calculate the labor cost differential between systems based on the number of tanks per car.

**Days per Year** This parameter is fixed at 365 days per year.

**Car Availability Factor** This parameter is used to determine the available car days per year in order to calculate annual operating costs. The more days a car is in service, the higher the annual operating costs. Since a given car is not in revenue service each and every day of the year this factor is used to reduce the number of days per year from 365 to some lower number. As the exact availability is not known this value is varied across the scenarios.

**Flush Efficiency** This parameter is used to vary the number of flushes per use. The more flushes per use, the more flush fluid added to the holding tank and the higher the disposal cost. The actual number of flushes per use will depend on the efficiency of the flush in clearing the bowl and the frequency with which passengers flush prior to using the toilet. Since neither of these are known, this parameter is varied across the scenarios.

### E.4 The Route Table

This table contains all of the pertinent information about the eight routes modelled in Appendix C. All of the information was supplied by Amtrak.

**Route Number** This is the number which has been assigned by Amtrak for the particular route.

**Name** This is the name which has been assigned to the route by Amtrak.

**Origin - Destination** This is origin and destination of the particular route.

**Miles** This is the one-way length of the route in miles.

**Hours** This is the scheduled duration of the route. It is used for calculating the number of toilet uses.

**Car Type One - Six** These are six fields which contain key values to the Amtrak Car Table. From the consist data supplied by Amtrak, each car type was assigned a look-up key from 1 to 27. Car Type One contains the look-up key for one of the car types in the consist for that particular route. Similarly, Car Type Two through Car Type Six contain the look-up keys for the other car types in the consist. In the event that there are fewer than six different car types in the consist, the field is formatted "NA": Not Applicable.

NOTE: Only car types which have toilets, excluding locomotives, are included in the model.

**Quantity** These six fields follow each of the Car Type fields and indicate the number of cars of that type in the consist.

**Routes per Day** This is an Arthur D. Little estimation of the number of routes which a set of cars may be involved in on a given day. It is assumed that routes which have a relatively short duration will be run more than once per day (or a different route of a similar duration). When the route has a duration of 12 hours or greater, the Routes per Day equals one.

### E.5 The Amtrak Car Table

This table contains all of the relevant information about each car type. This data was supplied to us primarily by Amtrak. Some of the information is based on Arthur D. Little estimates. These entries are noted in the descriptions below.

**Type** This is a typical name for the car type.

**Number** This is a typical car number to indicate which series is being described.

**Toilets per Car** This is the number of toilets usually installed on the particular car.

**Seated Capacity per Car** This is the maximum number of revenue passengers which can be seated in the car. It is used in determining the amount of human waste generated for a particular car type.

There are certain car types for which no tickets are typically sold, but which have toilets on them (i.e. Diner cars). We have calculated waste generation data as if there were revenue passengers on these cars. This will cause the output of the model to slightly overstate costs.

**Notes** This field is for display only and contains information about the number of seats on cars of the same type which are configured differently. In each case, the higher number of seats was used in the model.

**Cars in Fleet** This value was supplied to us by Amtrak and represents the number of cars in the Amtrak fleet of that particular car type. It is used to determine fleet-wide costs.

**Railtech Tanks per Car** This is an Arthur D. Little estimate of the number of Railtech retention tanks per car. Since the current Railtech WTS 8300 configuration requires that the holding tank be located directly beneath the toilet, or that two adjacent toilets share a single tank located directly beneath them, this value is a minimum of one for every two toilets and a maximum of one tank per toilet.

**Route Length** These three columns are used in the second cost model (Appendix D) which calculates costs by car type. The three values are for different typical lengths of routes on which this particular car type might operate. For example, a Metroliner car could be used on a variety of routes but none would likely be long-haul. Conversely, a Super Sleeper will likely be used exclusively on long-haul routes, but these may vary in length from 24 to 50 or 60 hours or longer. Since the annual operating costs vary depending on length of route, three different route lengths are used.

**Routes per Day** These values correspond to the Route Length parameter above. This column represents the likely number of daily trips the car would be in service for a given route length.

### E.6 Route Cost Model Explanation (Appendix C)

This appendix contains the full Route Cost Model as well as a summary of costs by car type, route, scenario, and toilet type. The values in this model are taken directly from the pages that follow. The model is self-explanatory once the detailed Route Cost Model is understood with three exceptions:

- **Cars in Service** This is the number of cars of this car type in service on this particular route. This number is an Arthur D. Little estimate. It is different from the number of cars of the car type in the fleet in those instances where a car type is included in the consist of more than one route. In this case the total number of cars in the fleet of this type was divided amongst the routes using a simple weighted average of the number of cars in each route's consist.

- **Operating Cost/Car** This is the Annual operating cost of the toilet system on each car.

- **Entire Fleet Totals** Since only 1,239 of the cars were used in the model, these totals fields are extrapolations of the totals for 1,239 cars to the entire Amtrak fleet of 1,367 cars with toilets.

Following is the description of the detailed Route Cost Model (sections 1 through 3 in Appendix C).

**Amtrak Route** This field is formatted by performing a look-up to the Route Table and retrieving the Route Name according to the input route parameter.

**Route Number** This field is formatted by performing a look-up to the Route Table and retrieving the Route Number according to the input route parameter.

**Origin/Destination** This field is formatted by performing a look-up to the Route Table and retrieving the Origin and Destination for the route according to the input route parameter.

**Length in Miles** This field is formatted by performing a look-up to the Route Table and retrieving the Route Length in miles according to the input route parameter.

**Length in Hours** This field is formatted by performing a look-up to the Route Table and retrieving the Route Length in hours according to the input route parameter.

**Expected Trips per Day** This field is formatted by performing a look-up to the Route Table and retrieving the Route Trips per Day according to the input route parameter.

**Manufacturer** This field is formatted by performing a look-up to the Equipment Table and retrieving the name of the manufacturer according to the input equipment parameter.

**Equipment** This field is formatted by performing a look-up to the Equipment Table and retrieving the toilet system model name according to the input equipment parameter.

**Scenario** This field is formatted by decoding the input parameter (1 = Favorable, 2 = Expected, 3 = Unfavorable) for the Scenario to be analyzed.

**Car Number Column Heading** This field is an actual Amtrak car number for a car of the type used to derive the values in that column throughout the model. For the first column a look-up is performed on the Route Table for Car Type One. The Route Table has been formatted to include all of the car types currently in service on that particular route. The value from the Route Table is the key for retrieving the corresponding Car Number from the Equipment Table.

For each the second column the value in the Route Table for Car Type Two is retrieved. Each of the six columns is formatted with the appropriate Car Number of the car type for that route in a similar fashion. If there are less than six different types of cars used on a particular route, the field is formatted "NA".

**Car Name Column Heading** The car name is retrieved for each of the six columns in the same manner as the Car Number. A look-up is performed first on the Route Table according to the route chosen and the column to be formatted. The value retrieved is used to look-up the Car Name on the Equipment Table.

**Quantity of cars** This field indicates the number of cars of a given type which are in a typical consist for a particular route. The field is formatted by retrieving the appropriate Quantity value from the Route Table corresponding to the column of the model being formatted. For instance, the third column of the model is formatted from the Quantity value in the Route Table next to Car Type Three.

**Capacity (# people) - seated** This field indicates the number of passengers that can be seated on the car. It is taken from the Amtrak Car Table and is used in calculating the volume of waste generated on a car.

**Toilets per car** This value is taken from the Amtrak Car Table and is used in calculating the capital and installation costs for the different toilet systems.

**Average persons/toilet on train** This field is calculated by dividing the Capacity (# people) - seated by the Toilets per car.

**Car Waste Data (per car)** This section of the model is used to calculate the volume of waste generated (both flush fluid and human waste) and to compare this to the available holding tank capacity.

**Human Waste/day (gals)** This field is calculated by determining the number of hours per day that the car is in operation, based on the route length, and multiplying that times the human waste per day from the General Parameter Table and multiplying that by the Capacity (# people).

**# Flushes/Person-day** This value is retrieved from the General Parameter Table based on the appropriate scenario.

**Flush efficiency adjustment** This value is retrieved from the General Parameter Table based on the appropriate scenario.

**Adj. # Flushes/Person-day** This value is calculated by multiplying # Flushes/Person-day by the Flush efficiency adjustment.

**Flush Fluids/flush (gals)** This value is retrieved from the Equipment Table and indicates the amount of fluids introduced into the waste retention system with each flush.

**Flush Fluids/day (gals)** This value is calculated by multiplying the Adj. # Flushes/Person-day by the flush fluids/flush (gals).

**Capacity Req'd/day (gals)** This value is the sum of the Human Waste/day and the Flush Fluids/day. It represents the expected amount of black water generated per day.

**Adj. Capacity Req'd w/ Buffer** This is an important value because of the variability in toilet usage among all cars in a consist. Since all tanks will not fill at

the same rate, some cars will need more capacity per passenger while others will need less. Which cars will need more cannot be predicted at this time. Therefore, we incorporate a buffer factor on each tank.

This value is generated by multiplying the Capacity Req'd/day by 1 + Tank Capacity Buffer Factor from the General Parameter Table. This is the capacity required to ensure that there is a buffer of capacity on each car.

**Tank Capacity per Car (gals)** This is the total retention tank capacity for one car. It is derived by multiplying the tank capacity from the Equipment Table by the number of tanks per car. For the Monogram Recirculating System the number of tanks equals the number of toilets per car. For the Railtech WTS 8300, the number of tanks per car is taken from the Amtrak Car Table which contains an Arthur D. Little estimate. For all other systems, the number of tanks per car is equal to one.

**Continuous Service Hours Supported** This field represents the number of continuous hours in service until the volume of waste generated, including the buffer, equals the retention tank capacity for this particular car type.

**As a percentage of 72 hours** This field shows what portion of Amtrak's 72 hour retention goal is satisfied by this particular toilet system on this particular car type. It is calculated by dividing Continuous Service Hours Supported by 72.

**Probable Service Hours per Day** This field represents the expected number of hours per day for which the car will have passengers given the route on which it is operating. It is calculated by multiplying the route's Length in Hours by the route's Expected Trips per Day.

**Service Days Supported** This field represents the number of whole days the car could be operated before the tanks would reach capacity. It differs from Continuous Service Hours Supported when the Probable Service Hours per Day is less than 24. It is calculated by dividing the Continuous Service Hours Supported by the Expected Service Hours.

**As a percentage of 3 days** This represents the portion of a three-day-between-servicing requirement which the toilet system satisfies for a particular car type. It is calculated by dividing Service Days Supported by three.

**Consecutive Trips before pump-out** This field shows the number of trips which can be run before the tank(s) reaches capacity. It is calculated by dividing Adj. Tank Capacity Req'd by 24 (hours) and multiplying by the Length of the trip to arrive at a tank capacity required per trip. This number is divided into the Tank Capacity per Car. It is always rounded down to indicate whole trips.

**CAPITAL COSTS** This section calculates the capital costs for each car in terms of fixed costs and installation. The costs are calculated separately for the collection system and for the toilets themselves.

**Collection System per Car** This is the cost supplied to us by the manufacturer for the cost of the on-board collection system. It is retrieved from the Equipment Table.

For the Railtech system, the value in the Equipment Table is per tank and is then multiplied in this field by the number of tanks per car.

**Toilet Cost per Car** This field is the product of the number of toilets per car and the capital cost per toilet as supplied to us by the manufacturer and retrieved from the Equipment Table.

**- Total Equip Cost** This is the sum of the Collection System per Car and Toilet Cost per Car fields. It is the total fixed capital cost for one car.

**Equipment Installation** These fields represent the labor costs for installing new equipment on new rail cars of a similar design to this particular car type.

**Collection System per Car** This value is calculated by multiplying the number of hours required to install the collection system by the Amtrak labor cost per hour. The installation hours are retrieved from the Equipment Table; the labor cost is retrieved from the General Parameter Table. In the case of the Railtech system, this value is then multiplied by the number of Railtech tanks per car which is retrieved from the Amtrak Car Table.

**Toilet Cost per Car** This value is calculated by multiplying the number of toilets per car by the number of hours required for installation (from the Equipment Table) by the Amtrak labor cost per hour from the General Parameter Table.

**- Total Installation Cost** This is the sum of the Collection System per Car installation cost and the Toilet Cost per Car installation cost. It is the total labor cost for installing a given toilet system on a new car of this type.

**Total Capital Cost** This is the sum of the Total Equipment Cost and the Total Installation Cost. It represents the total cost for installing a given toilet system on a new car of this type.

## OPERATING COSTS

**Non-Trip Related Costs:** These are operating costs which are not dependent on the route, its length, or the number of hours that the car is in service.

**Labor cost/major servicing** This is the labor cost for one major servicing of the all of the toilets on a particular car. It is calculated by multiplying the cost per labor hour from the General Parameter Table, by the number of servicing hours per toilet from the Equipment Table.

**Frequency per Year** This indicates the number of times per year that the toilets on a car are serviced. It is retrieved from the General Parameter Table.

**Servicing Cost/Year** This is the product of the Labor cost/major servicing and the Frequency per Year of the major servicings. It represents the total annual labor cost for servicing all of the toilets on a particular car.

**Annual spare parts cost per yr** This is the estimated annual spare parts cost for all of the toilets on a particular car. It is calculated by multiplying the Total Equipment Cost from the Capital Cost section of the model by the Spare Parts pct. of Capital Cost retrieved from the General Parameters Table.

**Total- Oprtng Non-Trip Related** This is the sum of the Servicing Cost/Year and the Annual spare parts cost per year.

**Trip Related Costs** These are the operating costs associated with trip related factors such as waste disposal costs and labor costs for pumping out the retention tanks.

**End of Day/Trip Servicing** These are costs which are incurred as a result of operations. They are assessed on a daily basis for trips which are less than twenty four hours, and on a per trip basis for trips whose length exceeds twenty four hours.

- **Cleaning** This is the cost of cleaning the toilet bowl at the end of a service day or trip. It is calculated by multiplying the labor rate per hour, from the General Parameter Table, by the hours required to clean a toilet, from the Equipment Table (this value is in minutes and is converted to hours by dividing by 60), by the number of toilets per car.

- **Light Repair** This field is formatted as zero in all cases because there was no estimation of the light repair requirement available at the time of this study.

**Pump out and Disposal** These are costs associated with pumping out the waste from the retention tanks and disposing of it.

- **Pump out Cost** This is the labor cost of actually pumping the waste out of the tank and of connecting and disconnecting the pump-out hoses or other apparatus to the retention tanks. It is calculated by multiplying the Amtrak labor rate from the General Parameter Table by the total minutes required. This total minutes value is the sum of the Pump out minutes and the Connect/Disc. minutes described below.

- **Pump out minutes** This is the number of minutes required for pumping waste out of the retention tank(s) of one car. It is calculated by multiplying the number of gallons of waste generated by the pump-out rate of flow from the General Parameter Table. This value will vary by toilet system type because the amount of flush fluid in the retention tank varies by toilet system type.

- **Connect/Disc. minutes** This is the number of minutes required to connect and disconnect the pump-out hoses or other apparatus from the holding tanks. It is calculated by multiplying the Connect/Disconnect time from the General Parameter Table by the number of tanks per car. For Railtech, the number of tanks per car is retrieved from the Amtrak Car Table. For the Monogram Self-Contained Recirculating System, the number of tanks is equal to the number of toilets per car. For all other systems the number of tanks is equal to one.

- **Waste Disposal** This is the cost to be paid by Amtrak to the local waste treatment authority for dumping sewage into the local system. It is calculated by multiplying the amount of waste dumped by the disposal cost per gallon from the General Parameter Table.

The amount of waste dumped is calculated by dividing the Capacity Req'd/day (not the Adj. Capacity Req'd w/ buffer) by the number of hours operated during the day, and multiplying this by the length of the trip in hours and by the number of trips per day.

NOTE: If an intermediate pump out is required, see below, the amount pumped out at the intermediate point is subtracted from the total waste generated for the period to avoid double counting errors.

**Subtotal- End of Day/Trip Srvc** This is the sum of Cleaning, Light Repair, Pump out and Disposal Cost and Waste Disposal.

**Train Delay** These are costs incurred when the capacity required exceeds the available tank capacity during a trip. These costs are incurred at the point at which the Adj. Capacity Req'd w/ Buffer exceeds Tank Capacity per Car. In other words, an intermediate pump-out will be required prior to the point when the tanks are completely full on any one car.

**- Pump out volume req'd** This field indicates the volume of waste to be pumped out at the intermediate point. While the intermediate pump-out is occurring because the Adj. Capacity Req'd w/ Buffer has exceeded the Tank Capacity per Car, the amount of waste to be pumped out is the actual amount of waste generated without the buffer. This is calculated in the same way as the Capacity Req'd/day.

**- # of stops req'd** This field will indicate the number of times in a given trip in which the train must stop for pump-out. It is determined by dividing the Adj. Capacity Req'd w/ Buffer by the Tank Capacity per Car.

**- Pump out minutes** This field indicates how long it will take to pump the waste out of the tank and is calculated in the same way as Pump out minutes above.

**- Connect/Disc. minutes** This field indicates how long it will take to connect and disconnect the hoses or other apparatus to the waste retention tanks at the intermediate pump out point. It is calculated the same way as Connect/Disc. minutes above.

**- Total Time Delay(mins/car)** This is the sum of Pump out minutes and Connect/Disc. minutes and represents the total time of the train delay for pump out.

**Average Cost Per Delay** This field is the labor cost for the delay incurred by the delay. It is calculated by multiplying the standard Amtrak labor cost from the General Parameter Table by the Total Time Delay (mins/car).

**Subtotal- Oprtng Trip Related** This is the total trip-related operating cost for the particular car type with this particular toilet system. It is the sum of Subtotal-End of Day/Trip Srvc and Average Cost per Delay.

**Total # Cars in fleet** This is the total number of cars in Amtrak's fleet of this type. It is retrieved from the Amtrak Car Table.

**Total Annual Car-days** This is the maximum number of car days in a year for a particular type of car. It is calculated by multiplying the Total # of Cars in fleet by 365 (days in a year).

**Adjusted Total Car-days** This field indicates the number of car days which Amtrak can realistically expect to operate a particular type of car. It is calculated by multiplying Total Annual Car-days by the Car Availability Factor from the General Parameter Table.

**Days per Trip (min. of 1)** This field indicates how many calendar days are required for one trip. Its purpose in the model is to calculate the number of trips annually for routes which are longer than 24 hours.

**Annual Oprtng Trip Related per Car** This field is calculated by multiplying the number of trips a car has per year on this route by the Subtotal-Oprtng Trip Related cost. It represents the annual trip-related cost of operating this toilet system on this car type on this route.

**Annual Non-Trip Related per Car** This field is merely a display field which contains the value of the field Total-Oprtng Non-Trip Related above.

**Annual Oprtng Trip Related per Car Type** This field is the total annual fleet wide trip related operating cost for this car type on this route with this type of toilet. It is calculated by multiplying Annual Oprtng Trip Related per Car by the Total # Cars in fleet.

**Annual Non-Trip Related per Car Type** This field is the total annual fleet wide non-trip related operating cost for this car type on this route with this type of toilet. It is calculated by multiplying Annual Oprtng Non-Trip Related per Car by the Total # Cars in fleet.

**Total OPRTNG COST per Car** This field is the sum of Annual Oprtng Trip Related per Car and Annual Oprtng Non-Trip Related per Car.

**Total CAPITAL COST per Car** This field is merely a display field which contains the value of the field Total Capital Cost above.

**Total OPRTNG COST for all cars** This field is calculated by multiplying Total Oprtng Cost per Car by Total # of Cars in fleet.

**Total CAPITAL COST for all cars** This field is calculated by multiplying Total Capital Cost per Car by Total # of Cars in fleet.

### E.7 Car Type Cost Model Explanation (Appendix D)

This model describes the costs of installing and operating the various toilet systems on each type of car in typical types of service. The costs are generated on a per service hour and per year basis.

The input parameters are the same as for the Route Cost Model in Appendix C except for the route data itself. This model uses hypothetical route distances to allow analysis of the costs without regard to a particular route. It also enables analysis of costs for a given car on three different route lengths.

**Car Type** This is the type of car being analyzed. It is retrieved from the Amtrak Car Table.

**Toilet Type** This is the type of toilet installed on the car for the purposes of the model. It is retrieved from the Equipment Table.

**Manufacturer** This is the name of the company which manufactures the toilet being modelled. It is retrieved from the Equipment Table.

**Number of Passengers** This is the maximum number of seated passengers on this car type. When a particular type of car is configured in a variety of passenger densities, the highest number of passengers will be used.

Some car types do not have passengers assigned to them (i.e. diner cars). These cars are modelled as if they always carried the maximum number of passengers which could occupy them.

**Number of Toilets** This is the number of toilets usually installed on a car of this type. It is retrieved from the Amtrak Car Table.

**Total Tank Capacity (gals)** This is the total capacity available for waste retention on the car with this particular toilet system. When multiple tanks are used. (e.g. Railtech or Monogram's Self-Contained Recirculating systems) it is the sum of the capacities of each tank net of pre-charge.

**Scenario** Each page of the model shows the costs under all three scenarios. this field is used a title for each of the cost tabulations within the box directly below.

**Capital Cost** This is the total capital cost for purchasing and installing the particular system on the particular car. It is the sum of the following two fields: Equipment and Installation.

**Equipment** This is the cost of purchasing the toilet systems, including all of the toilets for the car and the collection system. The costs are supplied by the manufacturer and are retrieved from the Equipment Table and multiplied by the number of toilets per car.

**Installation** This is the labor cost of installing the toilets and collection systems on the car. It is calculated by multiplying the number of labor hours per toilet, from the Equipment Table, by the standard Amtrak labor rate, from the General Parameter Table, by the number of toilets per car. To this is added the cost for installing the collection system which is calculated by multiplying the number of labor hours required, from the Equipment Table, by the standard Amtrak labor rate, from the General Parameter Table.

**Maintenance Cost** This is the total annual maintenance cost for labor and spare parts for this toilet system on this car. It is the sum of the two fields which follow: Labor and Spare Parts.

**Labor** This is the annual labor cost for major servicing of the toilet system. It is calculated by multiplying the hours required per major servicing, from the Equipment Table, by the number of toilets per car, by the number of major servicings per year, from the General Parameter Table, by the standard Amtrak labor rate, from the General Parameter Table.

**Spare Parts** This is the cost of spare parts per year for the toilet system. It is calculated as a percent of capital cost. The percentage used is retrieved from the General Parameter Table and multiplied by the Equipment Capital Cost above.

**Hours per Trip** Three different values are used here. They represent three typical route lengths for this car type. Costs are then calculated across these three different route lengths. The route lengths are retrieved from the Amtrak Car Table and are Arthur D. Little estimates.

**Trips per Day** This is the number of trips operated per day of the length given above. It is retrieved from the Amtrak Car Table and is an Arthur D. Little estimate.

**Waste Generated** This is the volume of human waste generated per day by the number of passengers on this particular car given the number of hours the car is operated. It is calculated by determining the volume of waste generated per person per hour. This is done by dividing the Human Waste per Day, from the General Parameter Table, by 24 (hours per day). This value is multiplied by the Hours per Trip and the Trips per Day to arrive at the waste per person. This is multiplied by the Number of Passengers.

**Flush Fluid Generated** This volume represents the amount of flush fluid added to the retention tanks by the passengers as they use the toilets. It is calculated by determining the number of flushes per day and the amount of flush fluid per flush. The number of flushes per day is retrieved from the General Parameter Table, divided by 24 (hours per day), and multiplied by the Hours per Trip and the Trips per Day to arrive at the flushes per day per person. This quantity is multiplied by the Flush Fluids per Flush from the Equipment Table and by the Number of Passengers to arrive at a total.

**Capacity Adjustment** This is the buffer adjustment to ensure that while the tanks fill at an uneven rate, when some are at capacity, others have capacity

**Total Fleet Capital Cost** This field is calculated by multiplying the Capital Cost per car, from above, by the number of cars in the fleet of this particular car type which is retrieved from the Amtrak Car Table. There is only one value per scenario because the capital cost is not dependent on trip length.

Explanation
Appendix E: ~~Evaluation~~ of Cost Models in
Appendix C and Appendix D, Arthur D Little, 1990 -
23-Passenger Operations

Arthur D Little

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