Maglev Cost Estimation:

Annual Operating & Maintenance Cost Elements

Volpe National Transportation
Systems Center
Cambridge, MA 02140

J.A. Harrison
J.C. Shirey
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Parsons Brinckerhoff Quade & Douglas, Inc.
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Interim Report

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16. Abstract

This report describes a proposed cost estimating approach and presents annual operating & maintenance (O&M) cost factors for use in conjunction with VNTSC's Scenario Assessment Models for planning and evaluating super-speed (250-300 mph) magnetic levitation (maglev) transportation systems applications. (Refer to the VNTSC Staff Scenario Assessment Models will be used in-house by VNTSC to evaluate selected maglev system concept definitions proposed under the National Maglev Initiative (NMI), an interagency partnership led by the Federal Railroad Administration and the U.S. Army Corps of Engineers, with support from the Department of Energy, the Environmental Protection Agency, and other federal agencies. NMI was formed to work with the private sector and state government to assess the role of maglev in the nation's transportation future. Future modifications by others of the models will also permit their use in evaluating high-speed rail (HSR) systems proposals.

The cost model is composed of two separate but linked components: *(1) Capital Costs and (2) Annual Operating and Maintenance (O&M) Costs*. Technology and corridor variables can be input by the users, or, if specific information is not available, built-in default values can be called upon. This report contains estimates of these default values for the Annual Operating and Maintenance Cost portion of the model.

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METRIC / ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

$[(x - 32)(5/9)]$ °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

$[(9/5)\,y + 32]$ °C = x °F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0	1	2	3	4	5	6	7	8	9	10

CENTIMETERS 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 | 25.40

QUICK FAHRENHEIT-CELCIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and/or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10 286.

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ACKNOWLEDGEMENT

The approach and procedures described in this report were developed by the authors and others working in support of the John A. Volpe National Transportation Systems Center (VNTSC) in Cambridge, Massachusetts under a contract with Arthur D. Little, Inc. to develop a High Speed Guided Ground Transportation (HSGGT) cost estimating model to be used by VNTSC in evaluating maglev system concepts proposed under the National Maglev Initiative. The authors gratefully acknowledge significant contributions to the model development by project manager Ronald Mauri of VNTSC, Todd Green of EG&G Dynatrend, and George Anagnostopoulos of VNTSC. (Section 2 of this draft report, in particular, is based on a VNTSC staff study draft report but is not verbatum.) Dr. Ashok Boghani and Thomas Rasmussen of Arthur D. Little also contributed to the modeling concept. Arrigo Mongini of the Federal Railroad Administration is the overall maglev economic assessment program sponsor.

1.0 INTRODUCTION

1.1 Background

The Federal Railroad Administration is studying the economic feasibility of magnetic levitation (maglev) guided ground transportation in the United States as part of the National Maglev Initiative. As part of this effort, the capability to evaluate various technological and corridor-specific scenarios is being developed. This scenario analysis involves assessing the economic viability of various maglev and HSR options by estimating costs and revenues.

Demand and cost models are being developed by the Volpe National Transportation Systems Center (VNTSC) to calculate measures such as passenger volumes, capital costs, annual operating and maintenance costs, and fare revenues. These models will be used to examine financial results for various system concepts and route alignments. Passenger volumes will be estimated for a 40 year period. Capital costs will be calculated for a system design that meets the ridership estimates and route characteristics. Capital costs include the initial cost of building the system, and on-going costs for vehicles to meet increasing ridership. Annual operating and maintenance costs, and fare revenues will be calculated for the 40 year period. Annual revenues will be compared to the annual operating and maintenance costs plus an annualized portion of the capital costs. The financial concepts of Net Present Value and Internal Rate of Return will be used to determine whether the system design covers costs.

The models being developed are in-house analytical tools for scenario analyses that can operate on a personal computer spreadsheet or database management system and can be readily modified to accommodate alternative technologies and varying route characteristics. The models are constructed as hierarchical arrays of formulas composed of user inputs, technology variables, corridor variables, cost parameters and constants. The technology and corridor variables can be input by the users, or, if specific information is not available to the user, built-in default values can be called upon.

The cost model is composed of two separate but linked components:

- Capital Costs (CC)
- Annual Operating and Maintenance Cost (AOMC)

The Capital Cost component is documented separately. This report describes the annual operating and maintenance (O&M) cost model elements. The ultimate purpose of these models will be to evaluate selected maglev system concept definitions proposed under the National Maglev Initiative (NMI), an interagency partnership led by the Federal Railroad Administration and the U.S. Army Corps of Engineers, with support from the Department of Energy, the Environmental Protection Agency, and other federal agencies. NMI was formed to work with the private sector and state governments to assess the role of maglev in the nation's transportation future.

1.2 Report Organization

Following this introduction is a general description of the Maglev Costing Model, originally prepared by VNTSC and modified by the authors. Next is a discussion of the cost estimating approach and methodology used in developing annual O&M cost estimates. A prototypical maglev operating organization is described which is used as the basis for estimating annual O&M labor costs. Section 4 contains a discussion of additional assumptions and estimates made in computing O&M costs. Section 5 contains estimates of default values for the technology related variables based on the Transrapid 07 technology.

Section 6 includes estimates of default values for the corridor related variables based generally on the New York City - Albany - Buffalo - Niagara Falls corridor. Section 7 provides estimate of parameter variables which are generally unit costs, contingency values, and other cost factors needed to run the annual O&M cost model. Section 8 provides a summary of the cost model development effort to date. A bibliography is contained in Appendix A.

2.0 MAGLEV COSTING MODEL DESCRIPTION

2.1 Introduction

This section presents an initial specification of the maglev cost model to be used in scenario analysis. It provides a general description of the structure and components of the model. The specific variables and equations of the model continue to be refined. Refer to the VNTSC Staff Study "Maglev Cost Estimation: Model Description" for further details. It is expected that changes to this specification will be made as the model development effort continues, and, in particular, that as data are collected for the various cost variables, new insights as to relevant factors and relationships will be identified. When the model development effort is complete and baseline (default) values estimated for the variables, a revised version of this report will be prepared to document the final version of the model.

A basic objective in specifying the maglev cost model described in this report is to identify all of the cost related components needed for construction and operation of a maglev intercity transportation system. The model is a large, but computationally straightforward, accounting framework that breaks costs into many subcomponents. The level of detail in each area is based on factors such as likely data availability, anticipated importance in total cost and cost variation, and potential for use in studying alternatives (sensitivity analysis). The model specification is general enough to accommodate a range of maglev concepts and operating scenarios, although this flexibility adds to its size and scope. A variation of the model for high speed rail is planned.

The general costing model design is discussed in Section 2.2. The capital cost model, and the annual operating and maintenance cost model are discussed in Sections 2.3 and 2.4, respectively.

2.2 Costing Model Overview

The costing model is composed of two major components:

Capital costs (CC)
Annual operating and maintenance costs (AOMC)

Each component is further subdivided into one or more levels of cost subcomponents. Figure 2-1 shows the major cost subcomponents of the CC and AOMC components.

CAPITAL COSTS

Mainline Guideway Costs
Right-of-Way (R.O.W.) and Other Land Costs
Total Civil Reconstruction and Relocation Costs
Systemwide Electrical and Telecommunications Costs
Station Costs
Other Building and Equipment Costs
Vehicle Costs
Program Management Costs

ANNUAL OPERATING AND MAINTENANCE COSTS

Maintenance Costs
Energy Costs
On-Board Operating Costs
Other Fixed Facility Operating Costs
General Sales and Administrative Costs

FIGURE 2-1 - COSTING MODEL COMPONENTS

The various components and subcomponents contain formulas that estimate costs using in total about 377 basic model elements. The costing model contains approximately 208 formulas of this total, fifty (50) of these formulas perform summation functions, while 158 perform calculation functions. The summation formulas aggregate cost data within components and subcomponents. Table 2-1 summarizes these formulas by component and function.

TABLE 2-1 - MODEL FORMULAS

COST MODEL COMPONENT	SUMMATION	CALCULATION	TOTAL
CAPITAL COSTS	28	98	126
ANNUAL OPERATING AND MAINTENANCE COSTS	22	60	82
TOTAL	50	58	208

There are four types of model elements:

User Inputs (UI-V)
Technology Variables (TECH)
Corridor Variables (COR)
Parameter Variables (PARA)

They are defined in Section 2.3. The model analyzes a scenario defined with data for the User Input elements. Default values for the TECH, COR, and PARA model elements were estimated as part of the model development effort reported here. The user may use these defaults or enter alternative values. Technology (TECH) default values are based on Transrapid 07 technology. Corridor (COR) default and Parameter (PARA) default values are based on a New York City-to-Niagara Falls route alignment analysis. TECH elements change based on the maglev technology under study. COR elements change based on the corridor under study. PARA elements are not expected to change from one model application to the next, but the user does have the option of entering new values.

2.3 Model Element Description

The costing model uses about 377 elements to calculate capital costs, and operating and maintenance costs. Thirteen (13) of these elements are User Inputs which are used for estimating both the capital and the operating and maintenance costs. Table 2-2 summarizes the elements by category and by model component. (The numbers shown are subject to revision upon completion of the model.)

TABLE 2-2 - MODEL ELEMENT SUMMARY

	MODEL ELEMENT			
COST MODEL COMPONENT	TECH	COR	PARA	TOTAL
USER INPUTS				13
CAPITAL COST	97	58	104	259
ANNUAL OPERATING AND MAINTENANCE COSTS	13	14	78	105
TOTAL	110	72	182	377

2.3.1 User Inputs (UI-V) Elements

The User Inputs are the basic information required for any scenario analysis. There are seven basic element classifications for a given corridor:

Annual number of passengers by Origin-Destination (O-D) pair
Daily number of trainset trips by O-D pair
Station sequence
Station mileage posts
Station designation as either on-line or off-line
Station designation as a trip terminus
Number of attendants per vehicle

This basic information is used to calculate 13 UI-V data elements used through the costing model:

System Route Miles
Annual Number of Passengers for a Station
Annual Number of Passengers
Number of Major City Stations
Number of Off-Line Major City Stations
Number of Intermediate Stations
Number of Off-Line Intermediate Stations
Number of Small Stations
Number of Off-Line Small Stations
Number of Terminus Stations
Number of Stations
Daily Number of Trips
Number of Attendants per Vehicle

For example, the Annual Number of Passengers by O-D Pair is used to calculate the Annual Number of Passengers for a Station which is used in the calculation of Parking Facilities costs. This information is also used to determine the size of a station.

The Annual Number of Passengers by O-D pair and the Daily Number of Trips by O-D pair are User Inputs for the costing model but are calculated as part of the demand analysis process. The demand process calculates the number of passengers based on the travel time, fare and frequency of service (number of trips) for a given Origin-Destination pair within a corridor.

2.3.2 Technology Variables (TECH)

Technology variables are based on the characteristics of a given maglev technology and are expected to change as different maglev technologies are studied. Some examples of TECH variables are:

Cost per Mile for Elevated Guideway (construction cost)
Width of R.O.W.
Unit Cost per Vehicle
Seats per Vehicle
Maintenance Hours per Mile of Guideway
Power Required for Propulsion

There are currently about 110 TECH elements in the costing model.

2.3.3 Corridor Variables (COR)

Corridor variables are based on the characteristics of a given route alignment and may change as different corridors or different route alignments are studied. Some examples of COR variables are:

Percent of Miles of Double Elevated Guideway
Percent of Passengers in the Peak Period
Days per Week of Operation
Regional Cost Multiplier

Elements like the Regional Cost Multiplier are used to avoid extensive data collection when a different corridor is studied. Base material costs and labor rates are provided as default values. The Regional Cost Multiplier is used to adjust these base rates for the particular corridor under study.

There are currently about 72 COR elements in the costing model.

2.3.4 Parameters (PARA)

Parameters are model elements which are not affected by changes in maglev technology or corridor selection. In many cases, they are elements that the user is not likely to change, or change infrequently. Some examples of PARA variables are:

Contingency Factors
Cost for Land (by type)

Hours per Year for Labor
Cost per Year for Labor
Square Footage for Parking Spaces
Cost per Passenger for Ticket Sales

There are currently about 182 PARA elements in the costing model.

2.4 Capital Cost Estimation Process

The Capital Cost model calculates capital costs in eight major subcomponents:

Mainline Guideway Costs
Right-of-Way (R.O.W.) and Other Land Costs
Civil Reconstruction Costs
Systemwide Electrical and Communications Costs
Stations Costs
Other Building and Equipment Costs
Vehicle Costs
Program Management Costs

Each of these subcomponents is discussed in more detail below. Figure 2-2 outlines the model subcomponents and identifies major category subdivisions.

The Capital Cost model has been developed around a guideway classification system that is used in costing each of the following subcomponents:

Mainline Guideway Costs
R.O.W. and Other Land Costs
Civil Reconstruction Costs

Guideway is classified by type of guideway, single or double "track", location of guideway (demographics), and topography. Table 2-3 outlines the categories used for each of these classifications. An example of a possible guideway classification is: Double Elevated Guideway in an Urban Area with Flat Terrain.

TABLE 2-3. GUIDEWAY CLASSIFICATION SCHEME		
TYPE OF GUIDEWAY	DEMOGRAPHICS	TOPOGRAPHY
Elevated At-Grade Tunnel	Urban Suburban Rural Interstate R.O.W. Other R.O.W.	Flat Undulating Rugged Mountainous
Single Track Double Track Low Speed Switch/Crossover High Speed Switch/Crossover		

For Elevated and At-Grade guideway, this classification scheme results in 60 possible guideway costing classifications, 30 for each guideway type. However, it is highly probable that some classifications will not occur in real systems. For example, it is unlikely that elevated guideway in urban areas would be single guideway. After eliminating these improbable categories 33 categories remain; however, in addition, a "special elevated guideway" category was added for extraordinary high and/or long-span structures bringing the total mainline elevated and at-grade guideway categories, exclusive of switches, to 34.

Tunnel guideway is classified by demographics, single or double track, but is not classified by topography. Tunnels are also classified by construction technique: cut-and-cover, and mined/bored. Seven tunnel guideway categories were developed based on these criteria. In addition, two categories of tunnel in mountainous terrain were developed for a total of 9 tunnel guideway categories.

Mainline switches (turnouts) for sidings, spurs and crossovers for multiple-guideway territory are required to permit system operational flexibility. Two types of switches are considered (high-speed and low-speed) in three types of guideway configuration (elevated, at-grade and cut-and-cover tunnel). In double-guideway territory, crossovers are required periodically for flexibility, generally at each end of each intermediate station and at other intermediate locations so as to achieve a maximum crossover spacing of not more than about 40 miles. Crossovers are comprised of two switches and a short piece of connecting guideway in between to permit traversing from one guideway to an adjacent guideway. Two types of crossovers are considered (high-speed and low-speed) in three types of guideway configuration (elevated, at-grade and cut-and-cover tunnel). High-speed switches and crossovers in tunnel were eliminated as model categories, leaving a total of ten (10) switch/crossover categories. Switch and crossover lengths are computed separately from other mainline categories and are included in the guideway totals by type.

TOTAL ALL CAPITAL COSTS

MAINLINE GUIDEWAY COSTS

- 53 Guideway Subclassifications (see text)

R.O.W. AND OTHER LAND COSTS

- Total R.O.W. Land Costs
- Total Other Land Costs

TOTAL CIVIL RECONSTRUCTION AND RELOCATION COSTS

- Demolition Costs
- Highway/Roadway Reconstruction/Relocation Costs
- Bridge Reconstruction/Relocation Costs
- Surface Reconstruction Costs
- Utility Relocation Costs
- Environmental Mitigation Costs

SYSTEMWIDE ELECTRICAL AND COMMUNICATIONS COSTS

- Total Electrification Costs
- Total Telecommunications Costs

STATION COSTS

- Station Building Costs
- Station Parking Facilities Costs
- Station Guideway Cost

OTHER BUILDING AND EQUIPMENT COSTS

- Main Vehicle Maintenance Facility Cost
- Service & Inspection Facility Costs
- R.O.W. Maintenance Centers Cost
- Special Equipment Cost

VEHICLE COSTS

- Number of Vehicles in Fleet

PROGRAM MANAGEMENT COSTS

FIGURE 2-2 - CAPITAL COST MODEL: MAJOR COST CATEGORIES

The total number of guideway categories is 53, including switches and crossovers. The model is designed so that the user will input total route miles and number of miles in each demographic classification and the model will allocate the miles to the other subclassifications. The user does have the option of providing mileage distributions for all subclassifications, if desired.

In addition to mainline guideway construction costs, these classifications are also used in determining R.O.W. Land Costs and Total Civil Reconstruction Costs.

2.4.1 Mainline Guideway Costs

The Mainline Guideway Cost subcomponent is divided into the 53 subclassifications as explained in Section 2.4. For each of the 53 subclassifications a single technology-based guideway cost per mile variable is used in the model. These variables are based on the quantities and costs of the materials (including fabrication and site construction) needed for the particular technology under study. Thus, if steel beams are part of a technology concept, their costs are included in each of these cost variables. Likewise the spacing and size of columns, beams, footings, etc. are used in estimating the values of these cost variables. For the default technology, guideway costs include stator packs (long stator windings are part of System Electrical and Communications). As part of the model development effort, cost work sheets (one for each cost variable) are being prepared that list this information. A draft of these work sheets for the default technology are included in Section 6.2. This same approach will also be used in estimating cost variations for alternative maglev system concepts to be studied in the future.

Special Structures (bridges) are calculated as part of Elevated Guideway Costs. Switches are calculated for elevated, at-grade and tunnel classifications.

2.4.2 R.O.W. Land and Other Land Costs

The R.O.W. and Other Land Costs subcomponent is divided into the following categories:

R.O.W. Land Costs
Other Land Costs

The model classifies R.O.W. land as either purchased or leased. Purchased land is considered a capital cost and its cost is calculated in this component of the model, while leased land is considered a yearly operating expense which is calculated in the model's annual operating and maintenance cost component. The model has corridor variables for the percent of land purchased in each of the five demographic categories.

2.4.2.1 R.O.W. Land Costs

TECH elements represent the required R.O.W. width for elevated and at-grade guideway. It is assumed that mined/bored tunnel guideway has no associated R.O.W. land capital cost requirements. The R.O.W. width elements were determined as part of the cost estimation process for Mainline Guideway Costs. The number of acres of R.O.W. is calculated for each of the five demographic classifications based on the number of miles of guideway in that classification, guideway configuration and its related R.O.W. width. A cost per acre is then applied to each demographic classification (urban, suburban, rural interstate R.O.W. and other R.O.W.)

2.4.2.2 Other Land Costs

The Other Land costs category includes costs for:

Stations
Main vehicle maintenance facility
Traffic control center
Power substations and switching stations
Service and inspection facilities

For each of these facilities square footage is the basis for determining acres of land required, and depending on demographic location, an appropriate cost per acre is assigned. Square footage for Stations is derived from User Inputs (passengers per station from the demand analysis), number of train platforms, etc. Square footage for power substations and switching stations is derived from technology based spacing requirements and the size of each station.

2.4.3 Civil Reconstruction and Relocation Costs

The Civil Reconstruction Costs subcomponent is subdivided into the following categories:

Demolition
Highway relocation/reconstruction
Bridge relocation/reconstruction
Surface restoration
Utility relocation
Environmental mitigation

These categories are subdivided into demographic classifications so that costs can be differentiated by location. In addition, each category is further divided by guideway classification.

The reconstruction cost for each of these categories is estimated as the product of the number of miles of a particular guideway classification times a reconstruction cost per mile. Only appropriate guideway classifications are included.

2.4.4 Systemwide Electrical and Communications Costs

The Systemwide Electrical and Communications Costs subcomponent is divided into the following categories:

Guideway Electrification Costs and
Communications and control systems costs

While these costs are based for the most part on miles of guideway, they were kept as a separate category because the cost could change depending on the maglev technology under study.

2.4.4.1 Guideway Electrification Costs

Guideway electrification includes the costs of:

Power substations and switching stations
Utility transmission lines including connections
Feeder lines
Motor switches
Long stator windings

The number of power substations and switching stations is determined based on corridor route miles and technology power requirements of a given technology. Utility transmission lines and connection costs is a parameter derived based on miles of line per power substation. Motor switches are technology-derived based on the number required per mile of guideway. Long stator windings are based on the number of guideway miles and technology-specific cost variables.

2.4.4.2 Communications and Control Systems Costs

The Communications and Control Systems subcomponent includes costs of:

Central control facility
Communications, command and control systems

The central control facility is a lump sum cost per facility. It is assumed that there is only one facility per system, but the model also provides an option for multiple facilities. The size of the central control facility is a parameter (PARA). Control units and communications systems costs are derived from TECH variables and are scaled to system size based on guideway miles.

2.4.5 Station Costs

Station cost estimates cover the station buildings including site development costs, parking facilities, and station guideway, i.e., all of the incremental capital costs associated with an additional station.

Station sizing takes into consideration user input variables that define:

Maximum passenger loading volumes
Trip terminus/origination station requirements
On-line or off-line station options

Station costs also include baggage handling facilities. Costs are based on PARA variables for cost per square foot and costs are adjusted depending on demographic and geographic location.

Three types of stations are postulated in the model to be selected by the user -- Major City, Intermediate and Small -- based on location and patronage. The user also has the option of selecting an on-line of off-line configuration for intermediate and small stations. Intermediate stations have three sizing options (1 platform/2 guideways, 2 platforms/3 guideways, and 3 platforms/4 guideways) that can accommodate increasing numbers of patrons and trains. The user will initially select the station size based on patronage (refer to Section 6.2 for details). If a station serves as a terminus, the size determined on the basis of patronage alone should be increased to the next higher category to accommodate train turns and longer platform dwell times.

Parking facilities (structures and lots) costs are based on anticipated passenger volumes and COR variables representing the number of passengers requiring parking. Facility cost is calculated on a square foot basis using PARA variables and costs based on demographic location. Parking requirements will vary significantly between major city and small size stations, as a result of passenger use of other modes. Experience at airports and rail terminals providing inter-city service is indicative of potential maglev station arrivals.

Private auto use increases while taxi, limo and transit service decreases as stations become smaller and "less" urban. Whereas a Major City Station might have only about one-third of its arrivals by private automobile, intermediate and small station auto arrivals might be up to 70%, depending on alternative mode availability.

Station guideway quantities and their costs are based on TECH cost variables and additional guideway and switch requirements for:

Access/egress to the mainline track
Platform requirements

Access/egress guideway and switch requirements are based on the type of station (on-line or off-line). On-line stations require no additional guideway for station access because the station is located on the mainline track. Two low-speed crossovers are assumed to be required at each intermediate station. Off-line stations require additional switches and guideway. Off-line stations can be located immediately adjacent to or some distance from to the mainline track. Guideway and switch requirements for platforms are based on the size and design of the stations. These quantities determined as part of the formulas for station size.

Stations (both on-line and off-line) classified as a trip terminus or origination point include a service and inspection facility. The cost for this facility is based on the number of trainsets that must be stored and serviced at a station to maintain schedules, and the time required to service and inspect trainsets between trips. Cost is based on the square footage required for trainsets, offices, stores and building services; and additional guideway and switch requirements.

2.4.6 Other Buildings and Equipment Costs

The Other Buildings and Equipment Costs category includes capital costs for:

Main vehicle maintenance facility building and equipment
R.O.W. maintenance facilities
Special maintenance equipment

2.4.6.1 *Main Vehicle Maintenance Facility Building and Equipment*

Main Maintenance facility building and equipment costs are calculated for:

Maintenance buildings, and
Yard and vehicle storage

The cost for maintenance buildings is based on the number of vehicles in the fleet and maintenance activity requirements. It includes shop equipment, is based on the size of the maintenance building and on the number of vehicles in the fleet. Yard and vehicle storage required are based on the size of the fleet.

2.4.6.2 R.O.W. Maintenance Facilities

R.O.W. maintenance facilities capital costs are included using a lump sum cost per facility, with the number of facilities based on technology requirements for maintenance of the R.O.W. Thus the model can accommodate either a single large R.O.W. maintenance facility or a series of smaller facilities at regular intervals along the corridor R.O.W.

2.4.6.3 Special Maintenance Equipment

Special maintenance equipment is included in the model as a lump sum dollar amount to cover the acquisition of specific items or vehicles needed for construction, maintenance and emergency situations. The baseline cost work sheets provide a list of these items and their costs.

2.4.7 Vehicle Costs

Capital costs for the maglev operating vehicle fleet is calculated from a TECH-based estimated cost per vehicle and the required fleet size. The cost per vehicle is a single value in the model, but can be based on a more detailed engineering analysis of the vehicle and its various subsystems, including the magnetic levitation, guidance, and propulsion components. Work sheets that describe vehicle costing assumptions are being developed as part of the effort to specify a set of baseline or default cost inputs, but the proprietary status of detailed information on Transrapid vehicles precluded the development of vehicle subsystem default costs. However, these work sheets would be the basis for developing vehicle cost estimates for alternative maglev technological concepts.

The required operating fleet size is developed from information on passenger loads, trip times, service frequencies (during peak periods), and the number of spare trainsets needed for schedule protection and maintenance. The calculation of fleet size involves many steps and data elements. For example, to estimate trip time for an O-D pair, distance, average cruising speed, acceleration and deceleration times, and number of stops (if any) and their dwell time are involved.

Additional vehicles for freight or baggage are not envisioned at this time and thus have been omitted from the model structure.

2.4.8 Program Management Costs

Program Management Costs are the cost of managing the design, construction and start-up of the system. These costs are based on a percentage of the other capital cost subcomponents, except Vehicle Costs. The procurement cost of vehicles is included in vehicle costs.

2.5 Annual Operating And Maintenance Cost Estimation Process

Annual operating and maintenance costs are calculated for 40 years for the following five major subcomponents:

Maintenance Costs
Energy Costs
On-Board Operating Costs
Other Fixed Facility Operating Costs
General Sales and Administrative Costs

Each of these subcomponents is discussed in more detailed below. Figure 2-3 outlines the model subcomponents and identifies major subdivisions.

2.5.1 Maintenance Costs

Maintenance Costs are calculated for Guideway, Vehicles and Other Fixed Facilities.

2.5.1.1 *Guideway Maintenance*

Guideway maintenance is subdivided into:

Guideway
Switches, and
Systemwide electrical and communication costs.

For guideway, and system electrical and communication costs, maintenance cost is estimated from annual maintenance hours per mile, labor costs per hour, and material costs. Switch maintenance costs is estimated from annual maintenance hours per switch, labor costs per hour, and material costs.

2.5.1.2 *Vehicle Maintenance*

Vehicle maintenance is estimated from annual hours per vehicle, labor costs and material costs.

ANNUAL OPERATING AND MAINTENANCE COSTS

MAINTENANCE COSTS

- Guideway Maintenance Costs
- Vehicle Maintenance Costs
- Other Fixed Facility Maintenance Costs

ENERGY COSTS

- Cost for Trainset Energy
- Cost for Fixed Facility Energy

ON-BOARD OPERATING COSTS

- On-Board Personnel Cost
- On-Board Services Cost

OTHER FIXED FACILITY OPERATING COSTS

- Traffic Control Costs
- Station Operations Costs
- Annual R.O.W. and Use Fees
- Mobile Equipment Costs

GENERAL SALES AND ADMINISTRATIVE COSTS

- Sales/Marketing Costs
- Insurance Costs
- Administration Costs

FIGURE 2-3 - OPERATING AND MAINTENANCE COST MODEL: MAJOR COST CATEGORIES

2.5.1.3 *Other Fixed Facilities Maintenance*

Other fixed facilities include:

- Stations
- Main vehicle maintenance center
- Service and inspection facilities
- R.O.W. maintenance centers
- Power substations and switching stations
- Traffic control center
- Administrative offices

Maintenance costs are based on a cost per square foot and building size. The number of square feet is taken from the capital cost portion of the model.

2.5.2 Energy Costs

Energy cost is based on energy requirements for trainsets and fixed facilities.

2.5.2.1 *Trainset Energy*

Trainset energy includes energy for:

- Propulsion
- Levitation
- Guidance
- Braking
- On-vehicle services

Trainset energy is estimated from information on trip length and number of vehicles per trainset, i.e. annual vehicle-miles.

2.5.2.2 *Fixed Facilities Energy*

Fixed facilities include:

- Stations
- Vehicle main maintenance center
- Service and inspection facilities
- R.O.W. maintenance centers
- Power substations and switching stations
- Traffic control center
- Administrative offices

Cost is based on square footage which is available from the capital cost portion of the model.

2.5.3 On-Board Operating Costs

On-Board Operating Costs are made up of Personnel Costs and Services Costs.

2.5.3.1 *Personnel Costs*

Personnel costs are estimated based on the required number and hourly wage rate for two classes of labor, operators and attendants. The number of operators is based on the number and length of trainset trips, and the number of attendants is based on the number of vehicle hours.

2.5.3.2 *Services Costs*

On-board services include passenger services like food and beverage, and train supplies. Passenger services are calculated on a per passenger cost, while train supplies are calculated based on the number of trips.

2.5.4 Other Fixed Facility Operating Costs

Other fixed facility operating costs include annual costs for the following facilities:

Traffic control center
Passenger stations
Mobile equipment (including its maintenance)
Annual lease for R.O.W.

Maintenance costs for the traffic control center building and station buildings are omitted from this cost category, but are included in Maintenance Costs, Other Fixed Facilities. Similarly, cost for energy to operate the traffic control center and the stations are included in Energy Cost. All other facility operating costs (labor, supplies, etc) are included in this cost category.

2.5.4.1 *Traffic Control Center Operation*

Personnel costs are calculated for the Traffic control center. Traffic Control Center costs are based on manpower requirements to operate the system.

2.5.4.2 *Station Operation*

Station operation costs are partly based on the size of the station, which is established in the formulas for capital costs for stations. Labor requirements are based on the number of days per week and the number of hours per day the station is in operation. Station costs also cover baggage handling costs.

2.5.4.3 *Mobile Equipment*

Mobile equipment is maintenance and other equipment which is not technology specific (trucks, etc.) and can be leased rather than purchased. Costs are based on factors accounting for annual lease costs, operating, and maintenance costs.

2.5.4.4 Annual Lease for R.O.W.

Annual lease for R.O.W. costs are based on a annual per acre lease fee. A different fee rate is used for each of the demographic categories, and a regional adjustment factor is part of the formula. The percent of R.O.W. leased is specified by the user for each corridor.

2.5.5 General Sales and Administrative Costs

General Sales and Administrative Costs include:

Sales/Marketing Costs
Insurance Costs, and
Administration Costs.

2.5.5.1 Sales/Marketing Costs

Sales/Marketing Costs included reservation and advertising costs. Reservation costs are based on the number of passengers and a cost per passenger plus a fixed cost for computer operations. Advertising costs are based on an advertising cost for the size of the market plus staffing costs.

2.5.5.2 Insurance Costs

Insurance costs include liability and other insurance costs and are based on a fixed amount of coverage.

2.5.5.3 Administration Costs

Administration costs are based on appropriate staffing requirements for the system size. The following administrative functions are separately accounted for: General Management, Legal, Financial, Public Affairs, Human Resources, Planning, Engineering, and Safety and Security. In addition to personnel costs, administration costs also include the rental of office space.

3.0 COST ESTIMATING APPROACH AND METHODOLOGY

3.1 Approach

The general approach used in preparing cost estimates for the annual O&M cost component of the model has been to define a prototypical maglev operating organization for the operation and maintenance of a Transrapid 07 maglev system in the New York State corridor, as defined in the companion capital cost report, and to postulate what the O&M costs for such a system would be. Estimates of how costs would most likely vary in other corridor applications are also provided.

3.2 Methodology

As many relevant sources of cost information as could be found were used in preparing the cost estimates. Refer to the Appendix A for a listing. Previous feasibility studies and recent franchise proposals in the U.S. were used, as appropriate. Since there is no comparable maglev system operation and maintenance experience to rely on, engineering judgment had to be used instead.

Each element of the model was considered separately as addressed in the sections which follow. The resulting estimates are based on technology- and corridor-specific assumptions as discussed. The estimates can be modified as appropriate to reflect varying assumptions. The basic framework and approach need not be changed, just the values of specific affected parameters.

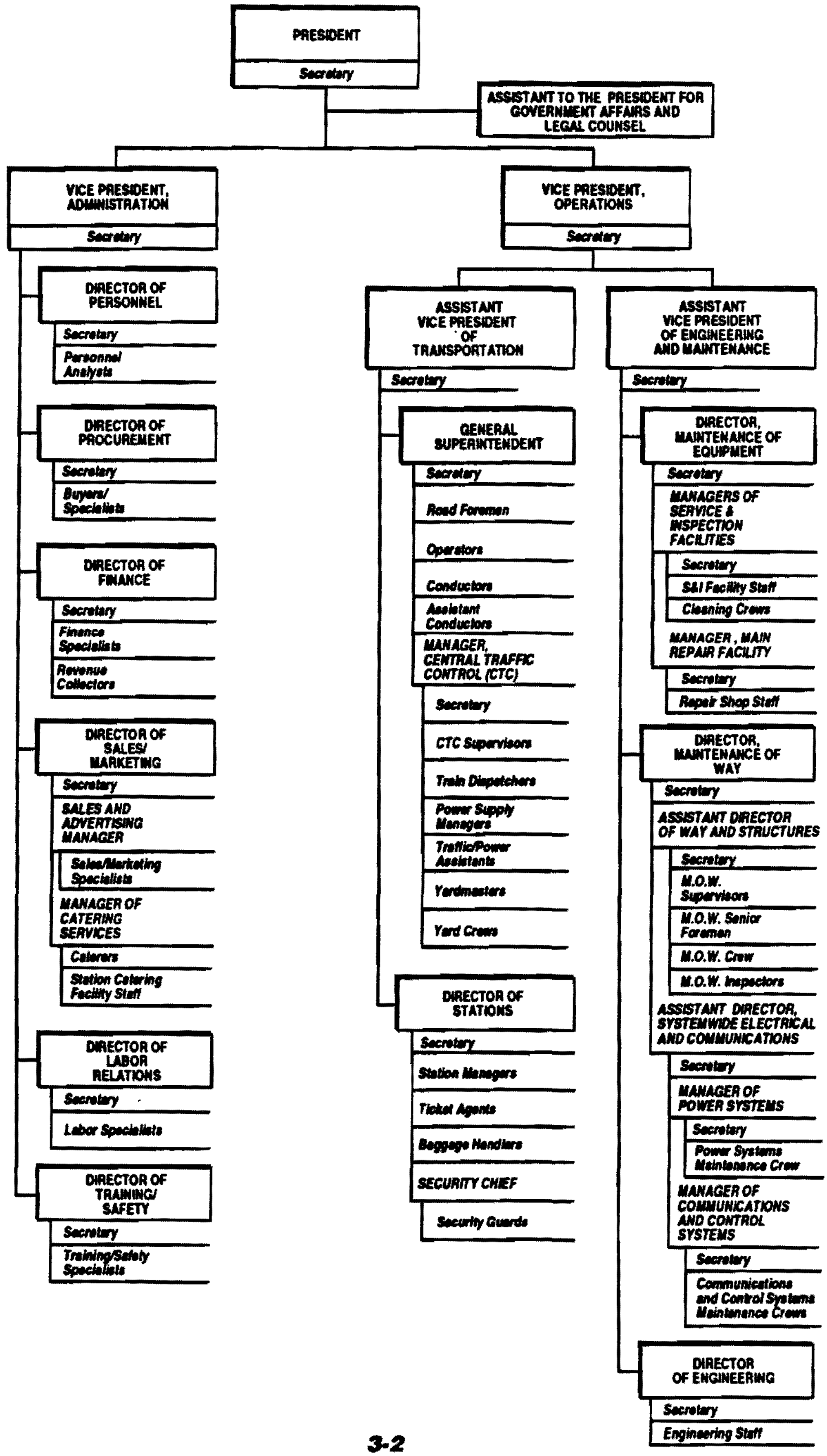
3.3 Prototypical Maglev Operating Organization

As mentioned above, the basic approach used in estimating annual O&M costs was to postulate a prototypical operating organization with defined staff functions and responsibilities. The operations and maintenance staff positions and the responsibilities of such a prototypical maglev operating organization, shown in Figure 3-1, are described in this section. The number of staff positions in most departments will vary in proportion to the size of the system (length of route, number of stations, number of trains, etc.) The New York State corridor is used as the base case. Variations from the base case are identified parenthetically. Where no variation is described, department staffing is not expected to vary from one corridor application to another.

3.3.1 Office of the President

The president directs all aspects of system operations and administration. An executive secretary is assigned to the president's office. An assistant to the president directs government affairs and serves as legal counsel.

FIGURE 3-1
PROTOTYPICAL OPERATIONS & MAINTENANCE ORGANIZATION



3.3.2 Vice President for Administration

The vice president for administration supervises the personnel, procurement, finance, sales and marketing, labor relations, training and safety departments. A secretary is assigned to this office.

3.3.2.1 *Director of Personnel*

The director of personnel is responsible for supervising benefits and the hiring of staff. He is assisted by two personnel analysts and a secretary.

3.3.2.2 *Director of Procurement*

The director of procurement is responsible for contracting services such as elevator and escalator maintenance, specialized personnel training, and safety training and inspections. He also manages contracts for station cleaning services, automotive vehicle maintenance, the purchase of consumables and material for the operations and maintenance organizations. He has a staff of four procurement specialists and a secretary. (The number or procurement specialists would vary with the overall size of the enterprise, say one procurement specialist per 100 miles of system route length.)

3.3.2.3 *Director of Finance*

The director of finance is responsible for the payroll and revenue collection. He disburses funds for contract services and material purchases and audits financial operations. His staff consists of financial specialists (nominally ten employees, including accountants, payroll clerk, MIS manager and staff), revenue collectors and a secretary. (The number of revenue collectors will vary depending on the number of stations and length of system, say two per 100 miles of system, assuming no more than 2 stations per collector.)

3.3.2.4 *Director of Sales/Marketing*

The director of sales/marketing supervises advertising, the sale of advertising space in the stations, and coordination of ticket sales by travel agents. He also supervises the catering operations. He is assisted by a sales and advertising manager, two sales and marketing specialists, a manager for catering services, and a secretary.

The manager for catering services supervises the catering staff on the trains and the operation of the support/provision facilities at the terminal stations. On-board catering staff will vary with train length. (For snack-bar service, one per train of 2-6 cars; two per train of 7-10 cars.) It is projected that the caterers and support staff will be paid largely from the profits of the food service operation. The extent of cost recovery will depend on the type of food service provided--in-seat or snack-bar. It is estimated that in-seat service will double the number of on-board attendants required.

3.3.2.5 *Director of Labor Relations*

The director of labor relations works with all elements of the organization. He is assisted by four labor relations specialists and a secretary.

3.3.2.6 *Director of Training and Safety*

The director of training and safety directs the development and conduct a safety training and inspections. His staff consists of four training/safety specialists and a secretary.

3.3.3 Vice President for Operations

The vice president for operations will supervise the assistant vice president for transportation and the assistant vice president for engineering and maintenance. He will be supported by a secretary.

3.3.3.1 *Assistant Vice President for Transportation*

The assistant vice president for transportation supervises the general superintendent, and the director of stations. He will be supported by a secretary.

A. The general superintendent will assign and supervise road foremen, train operators, conductors, assistant conductors, the manager of central traffic control, CTC supervisors, dispatchers, power supply personnel, yardmasters, and yardmen. He will be supported by a secretary.

- Road foremen: will be used on a roving systemwide basis, depending on the extent of the operation. Road foreman perform a supervisory and safety assurance function.

- A train operator: will be assigned to each train with a duty ratio that will vary with trip times and frequency of service. Ideally each operator will make at least one roundtrip of six hours or more per day starting and ending at home stations to avoid overnight accommodations, per diem, or deadheading. It is necessary to establish a train schedule before computing the number of train operators required. (For the purpose of this report, 19 train crews were assumed to be required to operate 38 trains/day in the NY State corridor service. Factored for 365-day operations, this amounts to 32 crews overall. Refer to Figure 4-1 for details.)

- A conductor: will be assigned per train with the same work duty ratio as the train operators.

- Assistant conductors/trainmen: will be assigned, with the same work duty ratio as the rest of the train crew, depending on train length (see Section 4).

- Manager, Central Traffic Control (CTC): manages the traffic control operation. He will be supported by CTC supervisors, train dispatchers, power supply managers and their assistants. He is assigned a secretary.

- One CTC supervisor, train dispatcher, and power supply manager: assigned on each eight hour shift (three shifts) with the CTC operational 24 hours daily.

- One CTC assistant: works with the train dispatcher and one with the power supply manager on the first two shifts (primary periods of service). One assistant is assigned to support both positions on the third shift.

- A yardmaster and yardmen: assigned on the first and second shifts at the main storage yard. One yardman is assigned on the third shift.

B. The director of stations is responsible for station operations and management of security. He is supported by a security chief and a secretary. It is assumed that:

- Station masters work 10-hour shifts to support up to 20 hour/day revenue service. Full time coverage is provided 365 days per year.

- Ticket agents work the same shifts as the station masters -- one per shift at small and intermediate stations; two per shift at major city stations.

- Baggage handlers work the same shifts as ticket agents--two per shift at small and intermediate stations; four per shift at major city stations.

- Security guards work 8-hour shifts with 24-hour security provided at each of the stations. A guard will also be assigned on all three shifts at the Administration Building and at the yard and shops. Security of the right-of-way and unmanned facilities would be coordinated with local law enforcement agencies.

3.3.3.2 Assistant Vice President for Engineering and Maintenance

The assistant vice president of engineering and maintenance supervises the maintenance of equipment and the maintenance-of-way operations. He is assisted by two directors and a secretary.

A. The director of equipment maintenance will supervise all maintenance of equipment (M.O.E.) activities, and will be supported by a secretary.

- M.O.E. facility staff: The main maintenance of equipment facility staff will be supervised by a manager, supported by a secretary. Staff size will depend on the fleet size and maintenance-hours per vehicle per year.

- Service & Inspection (S&I) facility staffing: S&I facility staff will be supervised by a manager at each facility supported by a secretary at each. Staff size will depend on the fleet size and S&I hours-per-vehicle required. In addition, a cleaning crew will be required for light cleaning of the trains on trip turnarounds at each S&I facility. (Two personnel per S&I facility full-time, around the clock, 365 days per year.)

B. The director, maintenance-of-way supervises and coordinates the maintenance of all fixed facilities. He is supported by two assistant directors--one for Way and Structures and one for Systemwide Electrical and Communications--and by a secretary. The assistant directors will be supported by field crews stationed at the M.O.W. bases.

- Assistant directors: with the support of the M.O.W. base supervisors, the two assistant directors are responsible for the inspection and maintenance in their respective areas.

    - Way and Structures: all fixed facilities including stations, other buildings and facilities, guideways and switches (except for the power and control portions of the switches).

    - Systemwide Electrical and Communications: all electric power, control, and communications systems.

- Supervisors: Each M.O.W. base supervisor will be responsible for two right-of-way (R.O.W.) maintenance facilities.

- Foremen: A senior M.O.W. foreman will be assigned on all three shifts (1st, 2nd and 3rd) at each R.O.W. maintenance center.

- Guideway inspection and maintenance personnel: Staff requirements for the guideway inspection and maintenance crews are estimated at on a labor-hours-per-guideway-mile-per-year basis. It is assumed that guideway staff will work three shifts per day, seven days a week on a rotating basis. This labor category covers all guideway structural inspections and repairs and incidental M.O.W. functions such as vegetation control, repair of drainage systems, access roads, fences and other ancillary facilities.

- Guideway switch inspection and maintenance personnel: Because of the nature and complexity of this vital guideway element, and of its importance in supporting safe and reliable operations, a dedicated switch inspection and maintenance staff will be required, sized on the basis of required maintenance-hours-per-switch and the number of switches.

- Systemwide electrical and communications inspection and maintenance personnel: Staff requirements for inspection and maintenance crews are estimated on a labor-hours-per-guideway-mile-per-year basis.

C. The director of engineering supervises the design and construction of facility and system improvements and provides technical support to the rest of the organization. He is supported by an engineering staff of senior engineers and construction managers, and a secretary. During the initial system design, construction, and start-up this group will be quite large; but, once it is in operation, the engineering staff can be reduced to a small cadre of senior engineers.

4.0 ASSUMPTIONS AND ESTIMATES

Annual O&M labor costs are estimated on the basis of the prototypical maglev operating organization described in Section 3.3.

A simplified maglev train operation scheme, shown in Figure 4-1, was developed for the purposes of computing representative transportation statistics. Direct labor rates are estimated based on an analysis of U.S. transit workers salaries and on professional judgement. Material costs are computed on the basis of estimated renewal rates and on capital cost estimates. Equipment costs are computed on the basis of staff size, equipment requirements, and estimated equipment costs. Consumable supplies costs are estimated on the basis of professional judgement.

Table 4-1 lists estimated staff requirements, average base salary costs, and burdened labor costs for the prototypical operating organization. The subsections which follow describe further assumptions made in arriving at these estimates. In computing burdened labor, a thirty percent employee fringe benefit rate is assumed, which includes an allowance for:

- FICA (or equivalent)
- Pension
- Hospital/Medical/Dental
- Life Insurance
- Short-term Disability
- Unemployment Insurance
- Workman's Compensation
- Uniforms

Sick leave, holidays and vacation costs are included in the base salaries.

Assumptions made in computing staff size and salary rates shown in Table 4-1 are described in the text below and in the footnotes to the table. The prototypical O&M organization is based on a 400+ mile long system with 10 stations and approximately 38 trains per day--based conceptually on the New York State corridor. Train size and frequency depend on ridership figures which were not available to the authors; therefore, estimated numbers were used for illustration purposes to generate the figures shown.

4.1 Maintenance Costs

Maintenance costs are broken down into three categories: guideway maintenance, vehicle maintenance, and other fixed facility maintenance. The assumptions and estimates made in these areas are discussed below.

TABLE 4-1

Staff Requirements and Salary Costs for Prototypical Maglev O&M Organization

Staffing Requirements	Shifts			Total Personnel	Average Base Salary(1)	Burdened Salary(2)
	1st	2nd	3rd			
President	1			1	$100,000	$130,000
Asst. to President	1			1	$70,000	$91,000
Exec. Secretary	1			1	$35,000	$45,500
Total Office of President	3	0	0	3	$205,000	$266,500
Administration						
V.P. Administration	1			1	$80,000	$104,000
Director of Personnel	1			1	$60,000	$78,000
Personnel/Benefits Analysts	2			2	$40,000	$104,000
Director of Procurement	1			1	$60,000	$78,000
Buyers/Procurement Specialists	4			4	$40,000	$208,000
Director of Finance	1			1	$60,000	$78,000
Accounting/Payroll/MIS Specialists	10			10	$35,000	$455,000
Revenue Collectors	8			8	$30,000	$312,000
Director of Sales/Marketing	1			1	$60,000	$78,000
Sales and Adv. Manager	1			1	$50,000	$65,000
Sales/Marketing Specialists	2			2	$40,000	$104,000
Manager of Catering Services	1			1	$50,000	$65,000
Catering Staff (not computed)						
Director of Labor Relations	1			1	$60,000	$78,000
Labor Relations Specialists	2	1	1	4	$40,000	$210,600
Director of Training/Safety	1			1	$60,000	$78,000
Training/Safety Specialists	2	1	1	4	$40,000	$210,600
Secretaries	7			7	$22,000	$200,200
Total Administration	46	2	2	50	$1,928,000	$2,506,400
Operations/Transportation(3)						
V.P. of Operations	1			1	$80,000	$104,000
AVP Transportation	1			1	$70,000	$91,000
General Superintendent	1			1	$65,000	$84,500
Road Foremen	4	4		8	$55,000	$572,000
Operators	16	16		32	$50,000	$2,080,000
Conductors	16	16		32	$40,000	$1,664,000
Assistant Conductors	24	24		48	$35,000	$2,184,000
Yardmasters	2	2		4	$40,000	$208,000
Yardmen	2	2	2	6	$25,000	$198,250
CTC Manager	1			1	$60,000	$78,000
CTC Supervisors	2	2	2	6	$50,000	$396,500
Train Dispatchers	2	2	2	6	$45,000	$356,850
Power Supply Managers	2	2	2	6	$45,000	$356,850
Traffic/Power Assistants	4	4	2	10	$35,000	$459,550
Director of Stations	1			1	$60,000	$78,000
Station Masters	20	20		40	$45,000	$2,340,000
Ticket Agents	22	22		44	$25,000	$1,430,000
Baggage Handlers	44	44		88	$15,000	$1,716,000
Security Chief	1			1	$45,000	$58,500
Security Guards	22	22	22	66	$25,000	$2,180,750
Secretaries	5			5	$22,000	$143,000
Total Operations/Transportation	193	182	32	407	$12,907,500	$16,779,750

TABLE 4-1 (cont'd)

Staffing Requirements	Shifts 1st	2nd	3rd	Total Personnel	Average Base Salary(1)	Burdened Salary(2)
Engineering and Maintenance(4)						
AVP Engr. and Maintenance	1			1	$70,000	$91,000
Director, M.O.E.	1			1	$65,000	$84,500
Managers S&I Facility	3			3	$55,000	$214,500
S&I Facility Staff	28	28	28	84	$35,000	$3,885,700
Car Cleaners	10	10	10	30	$22,000	$872,300
Manager, Main Repair Facility	1			1	$60,000	$78,000
M.O.E. Facility Staff	45	28		73	$35,000	$3,321,500
Director, M.O.W.	1			1	$65,000	$84,500
A.D. Way & Structures	1			1	$60,000	$78,000
M.O.W. Supervisers	4			4	$45,000	$234,000
M.O.W. Senior Foremen	8	8	8	24	$40,000	$1,268,800
M.O.W. Foreman	2	2	8	12	$35,000	$564,200
M.O.W. Inspectors/Maintainers	10	10	76	96	$30,000	$3,892,200
Switch Maintainers	8	8	42	58	$35,000	$2,734,550
A.D. Systemwide Elec. & Comm.	1			1	$60,000	$78,000
Manager, Power Systems	1			1	$50,000	$65,000
Manager, Comm. & Control Systems	1			1	$50,000	$65,000
Electrical Foremen	2	2	8	12	$38,000	$612,560
Electrical Inspectors/Maintainers	36	36	72	144	$35,000	$6,715,800
Director of Engineering	1			1	$65,000	$84,500
Engineering Staff	8			8	$55,000	$572,000
Secretaries	20			20	$22,000	$572,000
Total Engineering and Maintenance	193	132	252	577	$20,129,700	$26,168,610
GRAND TOTAL PERSONNEL/SALARIES	**435**	**316**	**286**	**1037**	**$35,170,200**	**$45,721,260**

NOTES:

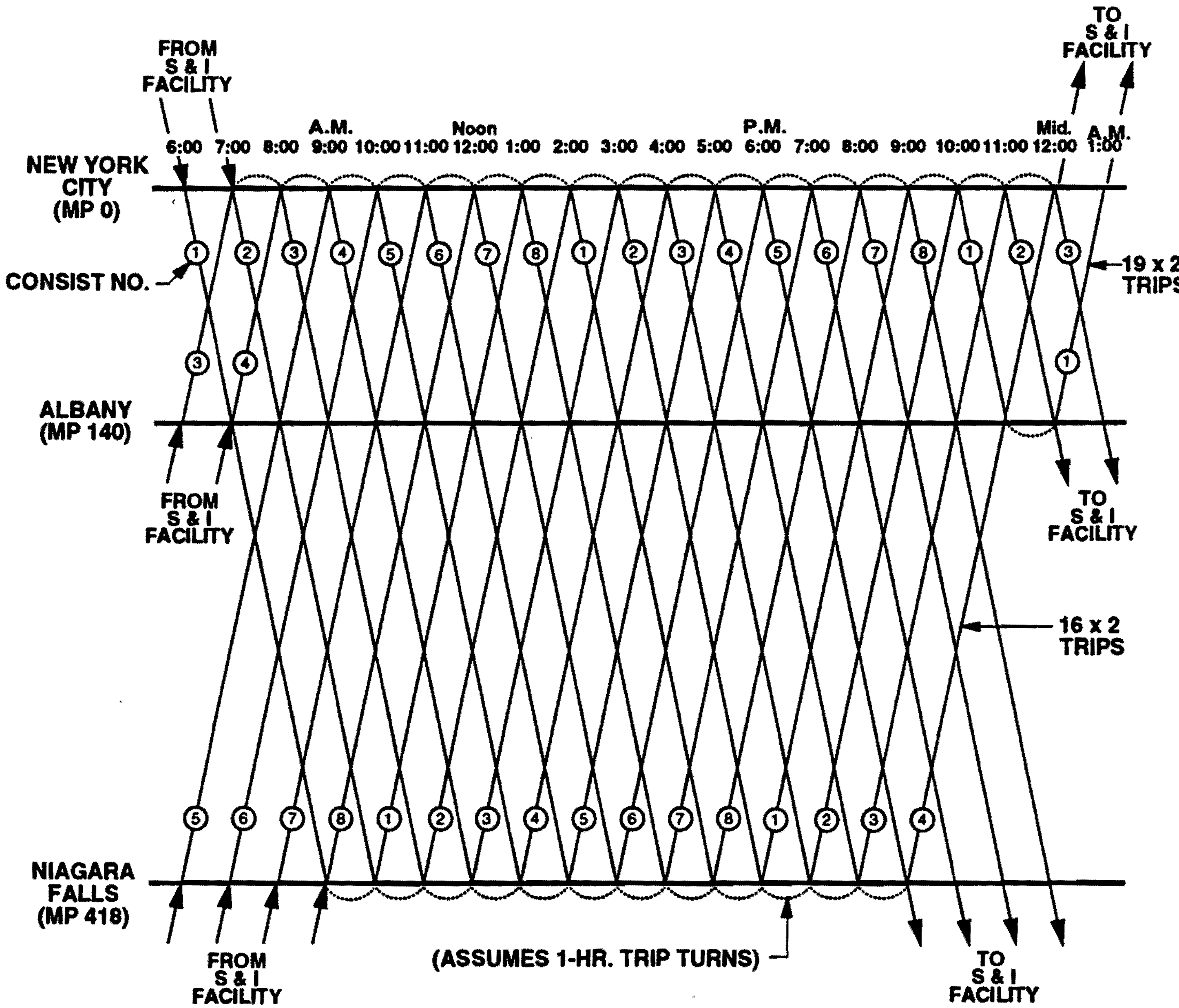
(1) Average Base Salary excludes shift differential costs. Totals (by department and grand total) include shift differential costs, i.e., they represent total direct labor costs. Base Salary includes holidays, vacation, and sick leave, i.e., is based on 40 hr. weeks 52 weeks per year.

(2) Burdened Salary = Average Base Salary plus shift differential salary (@ 5% of 3rd shift) times 1.30 (reflecting a 30% fringe benefit rate).

(3) Train crew staffing is based on 38 trains per day (avg. 6 cars long) requiring 19 crews factored for 365 days/year operation (16 round trips NYC – Niagara Falls + 3 round trips NYC – Albany).

(4) Equipment maintenance and S&I cost is based on a fleet size of 66 vehicles (48 active vehicles + 18 spares) operating 31 million car miles (5.2 million train miles) per year. (Refer to Figure 4-1 for details.)

FIGURE 4-1
SIMPLIFIED MAGLEV TRAIN OPERATION
NEW YORK CITY TO NIAGARA FALLS, N.Y.
(Developed for purposes of computing representative transportation statistics only)



REPRESENTATIVE TRANSPORTATION STATISTICS
• 38 trains/day (average 6-car consist)
• 14,216 t.m./day
• 85,296 car/miles/day
• 8 train consists + 2 operational spares + 1 shop consist = 66 cars
• 19± crews/day (average) 32 crews for 365-day operation

4.1.1 Guideway Maintenance Costs

Guideway maintenance costs are estimated on the basis of labor, material, equipment, and supply costs, as follows.

4.1.1.1 *Labor Costs*

Labor costs are computed on the basis of the prototypical operating and maintenance organization described earlier. (Refer to the discussion on the director, maintenance-of-way, for a description of the overall organizational element that is responsible for carrying out guideway and systemwide electrical maintenance.) A complete computation of labor cost is contained in Table 4-1 and in Sections 5, 6, and 7. Whenever workers are required to work on a 3rd shift, (e.g., 11:00 p.m. – 6:00 a.m.), a five (5) percent pay differential will apply.

Within the M.O.W. organization, it is assumed that each M.O.W. base supervisor ($45k) will be responsible for two right-of-way (R.O.W.) maintenance facilities[1]. The capital cost model estimates R.O.W. maintenance centers will be located every 50 miles along the R.O.W.; therefore, the number of M.O.W. supervisors required would be computed as follows: corridor route length divided by 100, rounded to the nearest whole number. (In the case of the New York State corridor, this figure would be four (4) M.O.W. supervisors.) Supervisors will work a 225-day work year. It is assumed that their responsibilities will be covered by senior foremen when they are not present; therefore, there is no need for second or third shift, weekend or holiday/vacation supervisory positions to be created. A receptionist/secretary will be assigned to each M.O.W. base.

A senior M.O.W. foreman ($40k) will be assigned on all three shifts (1st, 2nd and 3rd) at each R.O.W. maintenance center. The number of M.O.W. foremen required is computed as follows: corridor route length divided by 50 miles (truncated to the nearest whole number) times three (3) shifts per day. (In the case of the New York State corridor 24 M.O.W. foremen would be required.) Foremen will work a 225-day work year. It is assumed that their senior foremen from adjacent R.O.W. maintenance centers when they are not present, and that they will be on-call for emergency situations, e.g., on weekends holidays, etc. Therefore, no additional foreman positions will be required other than those discussed above.

Staff requirements for the guideway inspection and maintenance crews ($30k) are estimated at 200 labor-hours per guideway-mile per year plus an additional 8 percent for foremen ($35k). For the New York State corridor this would amount to a guideway maintenance staff of 96 employee equivalents plus eight

1. *Figures in parentheses represent estimated annual base salary costs for the positions indicated.*

(8) foremen. (862 s.g.m. x 200 hrs/mile ÷ 1800 hrs per year = 96) Guideway staff will work three shifts per day, seven days a week on a rotating basis. Since virtually all guideway maintenance requiring guideway occupancy will be overnight, the third shift (11:00 p.m. - 7:00 a.m.) will have the predominantly biggest staff, say 80 percent, with first and second shifts staffed at a nominal 10 percent each. (In the New York State corridor, this would amount to 76 inspectors/maintainers on 3rd shift and ten (10) each 1st and 2nd shifts.) Foremen will supervise the 3rd shift.

This labor category covers all guideway structural inspections and repairs and incidental M.O.W. functions such as vegetation control, repair of drainage systems, access roads, fences and other ancillary facilities. The estimate presumes a low-maintenance guideway design and excludes extraordinary retrofits or extensive painting of structures, i.e., it covers only normal (routine) guideway structural inspection adjustment and minor repairs.

Because of the nature and complexity of guideway switches, and of their importance in supporting safe and reliable operations, a dedicated switch inspection and maintenance staff is assumed. The equivalent of 900 labor-hours per year per switch is estimated to be required for inspection and maintenance. This is for a movable-guideway type switch such as for the Transrapid system. Other technologies using simpler electronic switching mechanisms would require less intensive maintenance.

This would amount to 58 switch maintainers ($35k) (i.e., 116 x 900 ÷ 1800 = 58) in the New York corridor. It is presumed that mainline switch maintenance will be carried out primarily on 3rd shift, with a token force of maintainers on duty at other times for emergencies. Again, an eight percent foreman coverage will apply. (A switch maintenance crew would typically comprise Way and Structures personnel and Electrical personnel.)

Staff requirements for Systemwide Electrical and Communications inspection and maintenance personnel: are estimated that 300 labor-hours per guideway-mile per year plus an additional 8 percent for foreman. For the New York State Corridor this would amount to a systemwide electrical and communications maintenance staff of 144 employee equivalents ($35k) plus 12 foremen ($38k). (862 s.g.m x 30 hrs/mile ÷ 1800 labor hours per year = 144) this category covers all traffic control, electrification and telecommunications systems inspection and maintenance.

As with guideway maintenance, all guideway-occupying electrical and communications inspection and maintenance activities, will have to be performed in non-revenue service hours, i.e., at night. It is estimated that roughly 50 percent of the systemwide electrical and communications inspection and maintenance tasks will be performed on 3rd shift and 25 percent each on 1st and 2nd shifts.

The labor-hour per guideway-mile figures indicated were estimated on the basis of a review of estimates made by others for feasibility studies, recent HSR and Maglev system franchise proposals and maintenance-of-way plans, and considering actual experience in the M.O.W. of the French TGV system and Amtrak's Northeast Corridor. (These latter estimated costs provide a rough frame of reference if not a directly relevant cost basis.) The switch maintenance estimate provided is an independent estimate prepared by PBQD. The computation of total guideway maintenance labor costs is included in Section 7.

4.1.1.2 Guideway and Systemwide Electrical Materiel Cost

The annual materiel cost for M.O.W. operations is computed as a percentage of the initial capital cost. The materiel cost estimate is based on the expected service life for each component of the infrastructure, the percentage of each component projected to be renewed during its projected service life, and a factor for the material content of the component. The following factors are estimated for guideway and systemwide electrical material costs based on the initial capital costs of each category:

	Service Life (years)	Percent Renewed (%)	Material Content Factor	Annual Maintenance Material Cost Factor
Guideway Structures	80	10	0.5	0.000625
Systemwide Electrical Components	35	25	0.75	0.00536
Switches	50	50	0.5	0.0050

For the Transrapid 07 system, the estimated capital costs per single guideway mile (s.g.m.) is as follows:

Guideway Structure (items subject to maintenance)	
Guideway Beam (avg. of at-grade & elevated)	$2 million / s.g.m
Glide Plates & Vertical Guide Plates	$1.5 million / s.g.m.
Bearings	$0.25 million / s.g.m
Columns	$0.5 million / s.g.m
Total Guideway Structure (subject to maintenance)	$4.25 million / s.g.m

Systemwide Electrical	
Substations	$0.33 million / s.g.m.
Feeder Lines	$0.97 million / s.g.m.
Motor Switches	$0.48 million / s.g.m.
Long Stators	$0.42 million / s.g.m.
Command & Communications	$0.70 million / s.g.m.
Total Systemwide Electrical	$2.9 million / s.g.m.

Switches	$1.9 million each

Based on the above capital cost estimates and cost factors the annual maintenance material estimates are as follows:

Maintenance Item	Estimated Annual Material Cost
Guideway Structures	$2,650 / s.g.m
Systemwide Electrical	$15,500 / s.g.m
Switches	$9,500 each

Each R.O.W. maintenance base will be equipped with a small fleet of non-revenue mobile vehicles e.g., automobiles, vans, light trucks, and utility vehicles for the use and support of the resident staff. In addition, there will be special equipment needed systemwide for inspection and maintenance of the guideway structures and electrical and communications systems (as described in the capital cost report). Other special equipment needed only occasionally, i.e., not in normal everyday operations, will be leased as required (e.g., heavy lift equipment, such as cranes).

The estimated annual cost of leasing, operating and maintaining the non-revenue vehicles and of operating/maintaining the systemwide special equipment is as follows:

Mobile Vehicle Fleet Per R.O.W. Maintenance Base (except systemwide equipment)	**Total Annual Lease Cost ($)**	**Total Annual Operating and Maintenance Cost ($)**
5 automobiles	$25k	$50k
2 vans	15k	20k
3 light trucks and utility vehicles	25k	30k
L.S. mobile equipment rentals	20k	10k
	$85k	$110k
Annual systemwide specialized equipment	N.A.	$500k

Total Annual Equipment Cost: $195k per R.O.W. base + $500k

Tools and consumable supplies are estimated at a lump sum of $50,000 per R.O.W. maintenance base per year.

4.1.2 Vehicle Maintenance Cost

As with guideway maintenance, vehicle maintenance costs are estimated on the basis of labor, material, equipment, and supply costs as follows.

4.1.2.1 Labor Cost

Labor costs are computed on the basis of the prototypical operating and maintenance organization described earlier. (Refer to the discussion on the director of equipment maintenance for a description of the overall organizational element that is responsible for carrying out vehicle maintenance.) Within this organization, it is assumed that the main maintenance of equipment facility staff will be supervised by a manager ($60k), supported by a secretary ($22k). Staff requirements are estimated to be 2,000 hours inspection and maintenance per vehicle per year, including foremen. The main shop will be staffed on a two-shift basis, 260 days per year. The average M.O.E. facility staff salary including foreman is estimated at $35,000 per year. Staff cost would be computed as follows:

$$\frac{\text{No. of Vehicles} \times 2{,}000 \text{ hrs.}}{1{,}800 \text{ hrs/employee}} \times \$35{,}000$$

The 2,000-hour figure is based on engineering judgement and on reference to estimates made by others in other recent studies and franchise proposals listed in Appendix A.

S&I facility staff will be supervised by a manager ($55k) at each facility supported by a secretary ($22k) at each. Staff requirements are computed on the basis of an estimated 5 labor-hours per vehicle for service and inspection including foremen per 1,000 vehicle-miles. The average S&I staff salary is estimated at $35,000 per year including foremen. S&I facilities would operate 24 hours per day 365 days per year.

In addition, a cleaning crew of two persons per shift, seven days per week, will be required for light cleaning of the trains on trip turnarounds at each S&I facility (1st and 2nd shifts) and on overnight train layovers (3rd shift). The number of full-time employee equivalents per S&I facility for vehicle cleaning would be ten (10) (2 x 24 x 365 ÷ 1800). For this unskilled labor category, an annual direct labor cost per person is estimated at $22,000. Refer to Table 4-1 for a complete tally of M.O.E. labor costs.

4.1.2.2 Vehicle Material Cost

Material costs are estimated at 0.005 percent of the purchase cost of the rolling stock per 1,000 miles of operation plus one (1) percent of the revenue fleet purchase cost per year for heavy repairs and overhaul. For the Transrapid 07 vehicle, this is estimated at $250 per 1,000 miles plus $50,000 per vehicle per year.

4.1.2.3 *Equipment and Supply Cost*

Shop equipment maintenance is included in the facility maintenance cost. Mobile vehicles for shop staff are estimated as follows:

M.O.E. Main Shop	**Total Annual Lease Cost ($)**	**Total Annual Operating and Maintenance Cost ($)**
3 automobiles	$15k	$30k
2 light trucks	15k	30k
3 forklift vehicles	5k	5k
	$35k	$65k
	Total:	**$100k/yr**
S&I Facilities (each)		
2 automobiles	$10k	$15k
1 forklift vehicle	2k	2k
1 light truck	8k	13k
	$20k	$30k
	Total:	**$50k/yr**

Tools and consumable supplies are estimated at a lump sum of $500,000 per year for the main maintenance facility and $200,000 per year per S&I facility (including train cleaning supplies).

4.1.3 Other Fixed Facility Maintenance Costs

In addition to the foregoing guideway, systemwide electrical, and vehicle inspection and maintenance costs, all other maglev system facilities--stations, maintenance facilities, substations, administrative offices, and the central control facility--will also require regular upkeep and maintenance. An annual unit cost per square foot of facility is estimated as follows:

Facility	**Annual Repair/ Maintenance Cost ($ / Sq. Ft.)**	**Annual Cleaning/ Janitorial Services ($ / Sq. Ft.)**
Stations (incl. platforms)		
Major City Station	$0.80	$1.00
Intermediate Station	$1.00	$0.80
Small Station	$1.25	$0.85

Facility	Annual Repair/ Maintenance Cost ($ / Sq. Ft.)	Annual Cleaning/ Janitorial Services ($ / Sq. Ft.)
Maintenance Shop and Offices	$0.50	$0.75
Service & Inspection Facilities	$0.50	$0.75
Yard and Vehicle Storage Area	$0.10	N.A.
R.O.W. Maintenance Facilities	$0.70	$0.80
Substations	$0.30	N.A.
Central Control Facility	$0.50	$0.80
Administrative Offices	$0.45	(incl. in rent)

Annual repair/maintenance includes all required labor materials, and equipment, presumably using operating authority labor forces exclusive of contract services for elevators, escalators and other mechanical equipment estimated separately. Janitorial services would presumably be performed on a contract basis by an outside agency. In order to determine the total employee equivalents required for building maintenance, divide the total building maintenance, cost computed using the $/sq.ft. costs above, by $75,000 ($35,000 direct labor per employee x 1.5 fringes x 1.428 factor for material and equipment) and round it to the nearest whole number.

The cost of operating, cleaning, and maintaining the parking facilities at the stations is assumed to be paid for and offset by the revenue from these facilities and is not included in this estimate.

Contract services will be used for maintenance of elevators, escalators and other mechanical equipment. An allowance of $25,000 per station per year is estimated to be required for small stations, $50,000 per year for intermediate stations, and $100,000 per year for major city stations.

4.2 Energy Costs

This cost category is broken down into trainset energy and fixed facility energy requirements.

4.2.1 Trainset Energy Costs

Trainset energy cost is computed on the basis of estimated consumption and approximate electrical energy rates and demand charges.

4.2.1.1 *Energy Consumption*

Experience to date with Transrapid 07 operating requirements for electrical energy and power is based on observations at the German test track at Emsland. No revenue service utilizing TR-07 technology yet exists anywhere in the world.

Observations at the Emsland facility have been limited to single (two-car) trains. Observed power requirements for a single train will not resemble a revenue service operation, in which multiple trains will simultaneously traverse a given section of guideway, resulting in very different power demands and energy requirements from those observed at Emsland. (A "section" of guideway means a length of guideway fed by a single substation, on the order of twenty miles long.)

Energy usage and power demand of trains in revenue service will depend on route characteristics (grades and curves), length and frequency of trains, top speed, number of station stops, extent of regenerative braking used (where the kinetic energy of a train is converted back into electrical energy and reused by other trains or potentially fed back to the utility), and other factors.

Estimates of energy consumption for the Transrapid 07 vehicle vary. The technology supplier has estimated an average energy consumption of 61 Watt-hours per seat-kilometer for a typical intercity application, assuming a 250 mph top speed and 75-mile station spacing. Bechtel's California-Nevada Super-Speed Ground Transportation franchise proposal (July 1990) calculated traction energy consumption for the 262-mile Anaheim-Las Vegas run at 18 MWh for an 8-car consist operating at a maximum speed of 250 mph. This works out to 68 kWh/train-mile or about 51 Wh/seat-kilometer. Each corridor route will have its own unique energy consumption requirement. Simulations are needed to estimate energy consumption and peak power requirements accurately.

Peak demand for a single two-car Transrapid 07 train is on the order of 40 MW, but peak demand is not likely to be sustained more than for a few minutes in any one guideway section. Therefore, the integrated peak (over time) will be less than this value.

4.2.1.2 Energy Costs

The cost of producing and delivering electricity on a large scale by a utility is made up of the costs of capital, fuel, operational activities and maintenance. Those costs of electrical production and distribution vary from utility to utility and region to region depending on costs to the utility (price of fuel, existing infrastructure capacity, etc.) and the utility rate structure for a given electricity use category (residential, commercial, special, etc.)

A maglev service, like an electrified railroad, will create unique loads on a utility, which require specialized rate structures. It is difficult to anticipate the exact structure a utility contract with a maglev operator would take, and the costs which would result therefrom. For that reason, various simplifying assumptions must be made here.

Industrial customers, including electrified railroads, are typically billed on the basis of demand charges ($/kW per month) and energy charges (per kWh) during each rating period. Demand is measured on an integrated basis (meter has an "x" minute time constant); demand intervals can vary from 15-60 minutes. Typically utility companies have different charges for summer vs. non-summer electrical usage, for on-peak, intermediate-peak, and off-peak, for excess demand (beyond contract amount), for fuel rates, and so forth. A maglev route may be served by several utility companies which further complicates the computations.

Given the high number of unknown variables, it is impossible to estimate with any certainty what the energy cost will be for any particular corridor application without a great deal of study. Nevertheless, for the purpose of estimating energy cost for the AOMC model the following approximate values are proposed:

Average Demand Charge (per month)	$7.50 per kW
Average Energy Charge (per month)	$0.034 per kWh
Peak System Demand (15 min.)	25 MW
Average Energy Consumption (6 - car train)	51kWh/train-mile

This would equate to an annual demand charge of $2.25 million plus $1.73 per train mile for energy.

4.2.2 Fixed Facility Power and Other Utility Costs

Electrical power for buildings (light, HVAC and other equipment) is estimated at $1.50 per sq. ft. per year. Gas, water, sewer and other utilities are estimated at $0.25 per sq. ft., for a total utility bill of $1.75 per sq. ft., per year.

4.3 On-Board Operating Costs

On-board operating costs are broken down into train crew and food service attendant (personnel) costs and services costs.

4.3.1 On-Board Personnel Costs

As outlined in Section 3, on-board personnel will consist of road foremen, train operators, conductors, assistant conductors/trainmen, and food service attendants. Staffing will depend on train frequency, length of trains, and extent of food service provided. A general set of assumptions used in estimating on-board personnel costs follows.

Road foremen ($55k) will be used on a roving systemwide basis--two per 10-hour shift, 7 days per week, 365 days per year requiring eight (8) total. The number of road foremen required is relatively insensitive to the size of the operation, i.e., even a small system would require some road foremen, and a system could be quite large before the number of road foremen would have to increase substantially. For purposes of the AOMC model, assume it is a fixed requirement regardless of route length or number of trains operated.

A train operator ($50k) will be assigned to each train with a duty ratio that will vary with trip times and frequency of service. Ideally each operator will make at least one roundtrip of six hours or more per day starting and ending at home stations to avoid overnight accommodations, per diem, or deadheading. It is necessary to establish a train schedule before computing the number of train operators required. A conductor ($40k) will be assigned per train with the same work/duty ratio as the train operators. Assistant conductors/trainmen ($35k) will be assigned, with the same work duty ration as the rest of the train crew, as follows:

Train Length	No. of Assistant Conductors/Train
2 cars	0
3 - 6 cars	1
7 - 10 cars	2

On-board food service attendants ($25k) will be assigned as follows: One each per food service car, with up to two food service cars per train, with the same work/duty ratio as the train crew. Assume trains of six cars or less will have a single food service car; trains of seven or more cars will have two food service cars each.

4.3.2 On-Board Services Cost

The cost of on-board food service will be largely offset by food service revenues. If operated on a close-to-breakeven basis, (possibly contracted out to a food service company), this cost category should not enter into the net operating cost or revenue, and, therefore, should not be considered in evaluating competing technologies. The cost of non-food item consumables (e.g., lavatory supplies, drinking water) is estimated at $100 per train trip.

4.4 Other Fixed Facility Operating Costs

Other fixed facility operating costs consist of traffic control, station operations, annual R.O.W. land use fee, and mobile equipment costs.

4.4.1 Traffic Control Costs

Manager, Central Traffic Control (CTC) ($60k) will manage the traffic control operation. He will be supported by CTC supervisors ($50k), train dispatchers ($45k), power supply managers ($45k) and their assistants ($35k) and a secretary ($22k). One CTC supervisor, train dispatcher and power supply manager will be assigned on each eight hour shift (three shifts) with the CTC operational 24 hours daily. Five personnel are required for each position for 365 day operations. One CTC assistant will work with the train dispatch and one with the power supply manager on the first two shifts (primary periods of service). One assistant is assigned to support both positions on the third shift. Ten assistants are required for 365 day operations. A yardmaster ($40k) will be assigned on the first and second shifts at the main storage yard, 365 days per year. One yardman ($25k) will be assigned all three shifts 365 days per year.

4.4.2 Station Operation Costs

The director of Stations ($60k) is responsible for station operations and management of security. He is supported by a secretary ($22k). Station masters ($45k) work 10-hour shifts to support up to 20 hour/day revenue service. For the New York State Corridor with 10 stations, forty (40) station masters would be required for 365-day operations ($10 \times 20 \times 365 \div 1800 = 40$). Ticket agents ($25k) work the same shifts as the station masters. Forty-four ticket agents would be required at a minimum for a ten-station system (such as NYS) for 365-day operations. (Spot checking of tickets would be performed by the station masters, ticket agents, and guards as well as by conductors and assistant conductors on the trains.) A security chief ($45k) will supervise systemwide security. Security guards ($25k) will work 8-hour shifts with 24-hour security provided at each of the stations. Approximately fifty guards would be required to provide station security 365 days per year for a ten-station system. A guard will also be assigned on all three shifts at the Administration Building and at the yard and shops. Sixteen guards would be required to provide security 365 days per year. In sum, approximately 66 security guards are required to provide coverage 365 days per year for a prototypical system. Security of the right-of-way and unmanned facilities would be coordinated with local law enforcement agencies. Baggage handlers ($15k) will be assigned as follows: two per 1st and 2nd 10-hour shifts 365 days per year at small and intermediate stations (8 employees total per station) and four per 1st and 2nd 10-hour shifts 365 days per year (16 employees total).

4.4.3 Annual R.O.W. Land Use Fees

Right-of-Way land use fees are estimated on the basis of the percentage of right-of-way leased by type times a unit land use (easement) fee for each category of land--urban suburban, rural, Interstate and other R.O.W. Land costs will vary by order of magnitude depending on where and when acquired. Urban costs should probably be computed on a sq.-ft.-basis. An allowance should also be included for acquisition of what are referred to as "X" parcels. These are parcels of land that become non-viable economically due to the proposed R.O.W. taking. It is proposed that the Regional Land Lease Multiplier be used to cover these extra costs, estimated at 20% of the base lease value. (No other regional variation has been systematically identified for use in the model.)

4.4.3.1 *Urban R.O.W. Land Use Fees*

It is postulated that all urban tunnel construction would be within easements, and the remainder of urban R.O.W. would be purchased. The capital cost model should compute a ratio of urban tunnel guideway to total urban guideway--with the result, expressed as a percentage used to calculate a length of urban R.O.W. in easement (in miles) times an annual use fee in dollars per mile. For Urban R.O.W. this annual use fee is estimated at $20,000 per mile.

4.4.3.2 *Suburban R.O.W. Land Use Fee*

It is postulated that all suburban tunnel construction would be within easements, and the remainder of suburban R.O.W. would be purchased. The capital cost model should compute a ratio of suburban tunnel guideway to total suburban guideway--with the result expressed as a percentage, used to calculate a length of suburban R.O.W. in easement (in miles) times an annual use fee in dollars per mile. For suburban R.O.W. this annual use fee is estimated at $7,000 per mile.

4.4.3.3 *Rural R.O.W. Land Use Fee*

It is postulated that all rural tunnel construction would be within easements, and the remainder of rural R.O.W. would be purchased. The capital cost model should compute a ratio of suburban tunnel guideway to total suburban guideway--with the result expressed as a percentage, used to calculate a length of rural R.O.W. in easement (in miles) times an annual use fee in dollars per mile. For rural R.O.W. this annual use fee is estimated at $3,000 per mile.

4.4.3.4 *Interstate R.O.W. Land Use Fee*

Interstate R.O.W. would be either entirely leased or provided at no cost to the project by the governmental sponsor of the project. It is suggested using 100% leased land as the default, with the option of using $0 as the Interstate R.O.W. lease cost.

4.4.3.5 Other R.O.W. Land Use Fee

It is postulated that 100% of "Other R.O.W." land would be leased. For other R.O.W. this annual use fee is estimated at $7,000 per mile.

4.4.4 Mobile Equipment Costs

Mobile equipment cost assumptions each department are discussed in each section and are summarized in Table 4-2.

Table 4-2

Annual Mobile Equipment Cost Summary

	Annual Equip. Lease Cost	Annual Equip. Lease Cost
R.O.W. Maintenance Vehicles		
(per M.O.W. base)	$85,000	$110,000
Systemwide Specialized Equipment	N.A.	$500,000
M.O.E. Facilities Vehicles		
Main Shop	$35,000	$65,000
S&I Facilities (each)	$20,000	$30,000
Other Mobile Vehicles (Staff Cars)		
Office of President (1 car)	$5,000	$5,000
Administration Dept. (8 cars)	$40,000	$40,000
Operations/Transp. Dept. (8 cars)	$40,000	$40,000
Engineering & Maint. Dept. (8 cars)	$40,000	$40,000
	$125,000	$125,000
Total for Prototypical Corridor (400 + miles long, w/8 M.O.W. bases and 3 S&I Fac.)	**$900,000**	**$1,660,000**

4.5 General Sales and Administrative Costs

This category consists of sales and marketing, insurance and administration costs.

4.5.1 Sales/Marketing Costs

The director of sales/marketing ($60k) supervises public information, advertising, the sale of advertising space in the stations, and coordination of ticket sales by travel agents. He also supervises the catering operations. He is assisted by a sales and advertising manager ($50k), sales and marketing specialists ($40k), a manager for catering services ($50k), and a secretary ($22k).

The sales and advertising manager will supervise printing and distribution of timetables, pocket maps, brochures, posters and other space advertising, as well as the sale of outside advertising space in stations and coordination of ticket sales by travel agents. He will be assisted by two sales and marketing specialists.

The manager for catering services will supervise the catering staff on the trains and the operation of the support/provision facilities at the terminal stations. (On-board catering is discussed above.) Ten food service personnel ($25k) are estimated to be required to staff three prototypical catering support facilities. It is projected that the caterers and support staff will be paid from the profits of the food service operation and therefore should not be included in the O&M cost calculation.

4.5.2 Insurance Costs

Public liability and property damage insurance is estimated at $10 million per year for the New York State corridor.

4.5.3 Administration Costs

Administration costs are relatively insensitive to the extent of the operation. The department heads and their immediate support staff will be required regardless how large the supporting O&M organization is below them. this staff consists of the office of the president; the VP for administration ($80k) and his directors for personnel, procurement, finance, sales and marketing and stations (all $60k); the VP for operations, his AVPs for transportation and engineering and maintenance, and their first line supervisors (general superintendent ($65k) and directors of labor relations, and training/safety, equipment maintenance, and maintenance of way (all $60k).

Support staffs within the VPs, AVPs, and directors' offices will vary somewhat depending on the extent of the enterprise (e.g., numbers of procurement specialists or revenue collectors) as discussed in Section 3.3. Staff salaries and fringes and computed and summarized by department in Table 4-1.

In addition to administrative salaries, fringe benefits, vehicles, and insurance costs discussed above, there are other overhead costs associated with running the enterprise, including:

- administrative travel
- computer and other office equipment leases
- furniture rental/office furnishings

- office supplies
- telephone/fax/communications
- reproduction and printing
- postage and express mail
- employee training
- professional association membership dues, conferences, and seminars
- publication subscriptions
- outside agency and professional fees (employment, advertising, accounting, legal)
- taxes
- other miscellaneous expenses

It is not possible to compute an accurate cost for each of these other expenses. It is recommended that an overhead allowance be included in the AOMC model at twenty-five (25) percent of direct labor costs (i.e., base salary) cost to cover these indirect and other expenses.

5.0 TECHNOLOGY VARIABLES (TECH)

Technology (TECH) variables are based on the characteristics of a given maglev technology and will vary with different technologies studied. The estimated TECH default values listed in Table 5-1 are based on the Transrapid 07 technology. Refer to Sections 4.1 through 4-4 for a discussion of the underlying assumptions made in computing these estimates.

Table 5-1

Annual O & M Costs
Technology Variables

Maintenance Costs	Direct Labor Hours	Foremen @ 8% DL	Total Labor Hours
Labor Hours			
Guideway Structure (per mile)	200	16	216
Systemwide Electrical & Comm. (per mile)	300	24	324
Switches (per each)	900	72	972
Vehicles (per each)	2,000	incl. in D.L.	2,000

Material	
Guideway Structure (per single guideway mile)	(0.000625) ($4.25 million) = $2,650
Systemwide Electrical & Comm. (per single guideway mile)	(0.00536) ($2.9 million) = $15,500
Switches (per each)	(0.0050)($1.9 million) = $9,500
Vehicles (per each)	(0.01 + 0.00005/1000 miles)($5 million) = $50,000 + $250/1,000 miles

Energy Consumption	
Power Consumption Rate per Trainset (6 - car consist)	51 kWh/mile
On-Board Operating Personnel (exclusive of food service personnel)	
No. of Operators	1
No. of Conductors	1
No. of Assistant Conductors (by train length)	
2 cars	0
3 - cars	1
7 - 10 cars	2
Other Fixed Facility Operating Costs	
No. Non. Supervisory CTC personnel	22
No. Mobile Equipment Vehicles Leased	125

6.0 CORRIDOR VARIABLES (COR)

6.1 Maintenance Costs (1 Element)

6.1.1 Regional Labor Multiplier

Upon a fairly rigorous investigation of the subject of regional variations in labor rates, no discernable basis could be identified for establishing a regional labor multiplier. An analysis of U.S. transit system, Amtrak and airline employee wages revealed no significant regional variation in labor costs, with the possible exception of the Northeast Corridor, and in particular the New York metropolitan area, which has somewhat higher than average wage costs than other large metropolitan areas (with the exception of the San Francisco Bay Area). Wage rates appear to be more a function of the overall population of the metropolitan area than of its geographical location.

Unless and until such a regional variation is identified, it is suggested that the regional labor multiplier be kept at 1.0. (Cases may arise, however, where it would be useful to test variations in labor rates, which could most easily be accomplished by just changing this factor; therefore it is suggested that it be kept in the cost estimating model, just not changed under most circumstances.)

6.2 Energy Costs (1 Element)

6.2.1 Cost per Energy Unit

It is not practical to compute energy per trainset-hour (as currently called for in the AOMC model). It is recommended that the model be modified to incorporate the energy cost factors discussed in Section 4.2.1.2.

6.3 Other Fixed Facility Operating Cost (7 Elements)

6.3.1 Hours per Day of Operation for Traffic Control Center

Twenty-four (24) hours per day, 365 days per year.

6.3.2 Days per Week of Operation: 7

6.3.3 Percent of Urban R.O.W. Leased

It is postulated that all urban tunnel construction would be within easements, and the remainder of urban R.O.W. would be purchased. (The capital cost model should compute a ratio of urban tunnel guideway to total urban guideway--with the result, expressed as a percentage used here.)

6.3.4 Percent of Suburban R.O.W. Leased

It is postulated that all suburban tunnel construction would be within easements, and the remainder of suburban R.O.W. would be purchased. (The capital cost model should compute a ratio of suburban tunnel guideway to total suburban guideway--with the result expressed as a percentage, used here.)

6.3.5 Percent of Rural R.O.W. Leased

It is postulated that all rural tunnel construction would be within easements, and the remainder of rural R.O.W. would be purchased. (The capital cost model should compute a ratio of rural tunnel guideway to total rural guideway--with the result, expressed as percentage, used here.)

6.3.6 Percent of Interstate R.O.W. Leased

Interstate R.O.W. would be either entirely leased or provided at no cost to the project by the governmental sponsor of the project. (It is suggested using 100% leased land as the default, with the option of using $0 as the Interstate R.O.W. lease cost.)

6.3.7 Percent of Other R.O.W. Leased

It is postulated that 100% of "Other R.O.W." land would be leased.

6.4 General Sales and Administrative Costs (3 elements)

(It is unclear why this category of annual O&M cost is included in COR rather than PARA, since the rest of the sales and advertising, liability coverage, and other insurance cost is included there. Except for the number of revenue collectors required, the costs in this category seem relatively unaffected by the corridor characteristics).

6.4.1 Required Number of Sales and Marketing Support Personnel. (suggest combining with PARA elements under general sales and administrative costs.)

The sales and marketing staff has been estimated at five people, including a director of sales/marketing, a manager of sales and advertising, two sales/marketing specialists and a secretary.

It is assumed that one-third of all passenger tickets will be purchased through ticket agents. An agent fee of 10% of the value of tickets written is assumed as a normal commission. This results in an effective commission cost of 3.3% of intercity passenger travel revenue. A reservation system (similar to airline reservations) is estimated to cost 5% of revenue. Other sales/marketing and advertising expense is estimated at 1% of annual revenues. Therefore, the cost of sales/marketing, including reservations and ticketing exclusive of direct salary costs, is estimated to be 9.3 percent (9.3%) of annual revenue.

6.4.2 Cost for Liability Coverage

Public liability and property damage insurance is estimated at $10 million per year for the New York State corridor system.

6.4.3 Cost for Other Insurance

Included in 6.4.2 above.

7.0 PARAMETERS (PARA)

7.1 Maintenance Costs (16 Elements)

Table 7-1 summarizes the estimated AOMC maintenance cost parameters. A guideway maintenance contingency factor of ten (10) percent is assumed to cover unknown costs that cannot be specifically identified in the AOMC estimate. A fringe benefit rate of thirty (30) percent is assumed. (See Section 4.0). An overhead rate of twenty-five (25) percent covers all other indirect costs not specifically identified or estimated elsewhere. (See Section 4.5.3).

Table 7-1

Annual O&M Cost
Maintenance Cost Parameters

Labor Rates	$ / hr
Guideway Maintenance Personnel	
Inspectors/Maintainers	$14.42
Foremen	16.83
Systemwide Electrical and Comm. Maint. Personnel	
Inspectors/Maintainers	$16.83
Foremen	18.27
Switch Maintenance Personnel	
Inspectors/Maintainers	$16.83
Foremen	18.27
Vehicle Maintenance Personnel	
(rate is composite of inspectors/mainteners/foremen)	$16.83

Note: Based on Average Base Salary costs from Table 4-1 divided by 2080 hours per year.

7.2 Energy Costs (3 elements)

7.2.1 Contingency Factors

Energy contingency factors of ten (10) percent are assumed for both propulsion energy and fixed facility power and other utility cost.

7.2.2 Cost per Sq. Ft. for Fixed Facilities

Electrical power for buildings (light, HVAC and other equipment) is estimated at $1.50 per sq. ft. per year. Gas, water, sewer and other utilities are estimated at $0.25 per sq. ft., for a total utility bill of $1.75 per sq. ft., per year.

7.3 On-Board Operating Costs (8 elements)

The on-board personnel contingency factor called for in the AOMC model is not believed to be necessary. Estimated value: 1.0

The labor rates for on-board personnel are summarized in Table 7-2. Revenue service will be provided 365 days per year.

Table 7-2

Annual O&M Costs
On-Board Personnel Labor Rates

Labor Category	$ / hr
Operators	$24.04
Conductors	19.23
Assistant Conductors	16.83
Food Service Personnel	12.02

Other on-board operating cost parameters are estimated as follows:

Average Hours per Day per Operator: 8

Average Hours per Day per Attendant: 8

Cost per Trip for Train Supplies: $100 (excluding food)

Days of Service per Year: 365

7.4 Other Fixed Facility Operating Costs (25 elements)

Other fixed facility operating cost parameter values are estimated as follows:

- Number of Supervisory and Support Personnel: 11 (depends on how these positions are counted.)
- Average Annual Salary for Traffic Control Center Supervisory Personnel: $50,000 x 1.3 = $65,000
- Annual Salary per Non-Supervisory Traffic Control Center Personnel: $40,000 x 1.3 = $52,000

- 40 < Hours per Week for Traffic Control Center Personnel >
- Cost per Traffic Control Center Personnel for Materiel: 0
- Number of Station Supervisory Personnel: 1 per station
- Average Annual Salary for Station Supervisory Personnel: $45,000 x 1.3 = $58,000
- Required Number of Ticketing Personnel: 1 per station during revenue hours/4.0 equivalent annually. For major city stations, double this number.
- Annual Salary per Ticketing Personnel: $25,00 x 1.3 = $32,500
- Required Number of Security Personnel: 1 per station around the clock 4.867 equivalent annually).
- Hourly Labor Rate for Security Personnel: $14.42
- Last Departure Time: 12:00 midnight (may vary)
- First Departure Time: 6:00 a.m. (may vary)
- 40 < Hours per Week for Station Operations Personnel >
- Cost per Station Operations Personnel for Materiel: 0
- Lump Sum Amount for Station Baggage Handling: (not lump sum) $15k/baggage handler/yr. x 1.3 = $19,500 each
- R.O.W. Land Use Fee Contingency Factor: 1.0
- Regional Land Lease Multiplier: 1.20 (refer to Section 4.4.3)
- Annual Lease Fee per Acre for Urban R.O.W. Leased: $20,000
- Annual Lease Fee per Acre for Suburban R.O.W. Leased: $7,000
- Annual Lease Fee per Acre for Rural Land: $3,000
- Annual Lease Fee per Acre for Interstate R.O.W. Leased: 0
- Annual Lease Fee per Acre for Other R.O.W. Leased: $7,000
- Annual Lease per Vehicle for Mobile Equipment: $7,200 (refer to Table 4-2)
- Annual Operating and Maintenance Cost per Mobile Vehicle: $9,300 excluding specialized equipment.

7.5 General Sales and Administrative Costs (26 elements)

General sales and administrative cost parameter values are estimated as follows:

- Cost per Passenger for Ticket Sales/Reservations: 9.3 percent of passenger revenue[1]
- Lump Sum Amount for Reservation Computer Operation Costs: incl. above
- Lump Sum Amount for Advertising: 1% of revenue (incl. in ticket sales cost above)
- Average Annual Salary for Sales and Marketing Support Personnel: $40k x 1.3 = $52,000
- Insurance Contingency Factor: 1.0
- Level of Liability Coverage: full coverage (limits not known)
- Level of Other Insurance: N.A.
- Number of General Management Personnel: 24 (depends on how these positions are counted.)
- Average Annual Cost per General Management Employee: $63,125 x 1.3 = $82,063
- Number of Legal Personnel: 1
- Average Annual Cost per Legal Personnel: $70,000 x 1.3 = $91,000
- Number of Financial Personnel: 10
- Average Annual Cost per Financial Personnel: 35,000 x 1.3 = $45,500
- Number of Public Affairs personnel: 0
- Average Annual Cost per Public Affairs Personnel: 0
- Number of Human Resource Personnel: 6 (incl. 4 labor relations specialists)
- Average Annual Cost per Human Resource Personnel: $40,000 x 1.3 = $52,000
- Number of Planning Personnel: (incl. w/ Engineering Personnel)
- Average Annual Cost per Planning Personnel: N.A.
- Number of Engineering Personnel: 8
- Average Annual Cost per Engineering Personnel: $55,000 x 1.3 = $71,500
- Number of Safety and Security Personnel: 70 (incl. 4 training/safety specialists)

1. *Suggest modifying the AOMC Model to compute a single cost for sales/marketing, advertising, reservations and travel agent commissions at 9.3% of ticket revenues.*

- Average Annual Cost per Safety and Security Personnel: 25,857 X 1.3 = $44,600
- Materiel Cost per Administration Personnel: 25 percent of direct labor cost
- Square Feet per Administration Personnel: 275
- Cost per Square Foot for Administration Office Rental: $18.00 / sq. ft.

8.0 SUMMARY

Development of the Annual O&M Cost component of the maglev costing model has been an iterative process. This draft interim report provides estimates of the O&M cost variables for the December 1991 version of VNTSC's model. Undoubtedly further refinements will be made both to the model and to these estimates as they are used and as additional and/or improved information becomes available.

The following further development and refinements are recommended:

1. Review AOMC model and reconcile inconsistencies between the model and the proposed estimates. (e.g., how trainset energy is estimated).

2. Review and refine prototypical maglev operating organization. Add public relations function, for example. Perhaps adjust staffing of certain other functions.

3. Review and further explain/support/justify the cost estimates in all categories, providing detailed foot or end notes and references in each section.

4. Some cost categories such as lease costs for land, for example, are particularly speculative. Easements are usually purchased up-front not amortized. We may want to consider a change in the model for this.

5. Revise Appendix A to be a true bibliography.

This effort can be completed within 2-3 weeks.

APPENDIX A

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