

# ADVANCED GUIDEWAY SYSTEM (AGS) FEASIBILITY STUDY

## CHAPTER 4 COST ESTIMATION

## Chapter 4 Cost Estimation

### 4.1 Introduction

The cost of the design and construction of the AGS is an important means of comparing alternatives and determining the affordability of the investment. This section describes the capital cost components and estimates for the four alignment/technology pairs operating on a Full System from Eagle County Regional Airport to I-70/C-470.

### 4.2 Overview

The AGS Study Team developed detailed costs for these four alignment/technology pairs:

- Hybrid Alignment with 120 mph Maglev
- Hybrid Alignment with High Speed Maglev
- High Speed Maglev Alignment
- High Speed Rail Alignment

Appendix D documents these estimates. Maps of these alignments can be found in Appendix E.

The cost estimates included direct costs (costs associated directly with building the capital infrastructure associated with the AGS) and indirect costs (contingencies, professional services, environmental mitigation, and utility relocations). Indirect costs are expressed as a percentage of the direct costs.

#### 4.2.1 Direct Costs

**Vehicles** – The number of vehicles was estimated based on the operating scenario and round-trip time for technology and alignment, the 30-minute service headway, the capacity of the standard consist for the technology, and the peak passenger load.

- For the Hybrid/120 mph Maglev, the standard consist is a two-car “married pair.” The total estimate for this technology is 18 pairs (or 36 total single vehicles), including spares.
- For High Speed Maglev, the standard consist is five cars coupled semi-permanently. Five High Speed Maglev consists were estimated.
- For High Speed Rail, high-speed trains are multi-car consists, including locomotive units and passenger cars. Six multi-car consists were estimated, including a spare.

**Propulsion System** – This includes such items as substation civil structures, substation propulsion blocks, wayside equipment, power

#### *Direct costs included:*

- *Vehicles*
- *Propulsion Systems*
- *Energy Supply*
- *Operational Control Technology*
- *Communication/Control Technology*
- *Guideway/Track Infrastructure*
- *Stations*
- *Operations and Maintenance Facilities*
- *Construction Support*
- *Right-of-Way and Utilities*

systems, and similar items. This cost area is unique to maglev technology and each maglev technology provider since the propulsion systems for rail systems are integral in the locomotive units.

**Energy Supply** – This includes such items as energy supply substations, operating facilities, wayside equipment, energy supply at passenger stations, and similar items. This cost area was used for high-speed maglev technology and high-speed rail systems. For high-speed rail, it includes overhead contact systems, third rail, or other power transfer systems. For high-speed maglev, it includes the equipment necessary to power the linear synchronous motor (LSM) that is part of the guideway. For 120-mph maglev, the energy systems are integral in the on-board linear induction motor (LIM) propulsion and vehicle systems.



Hybrid/High Speed Hybrid  
LSM on Guideway

**Operation Control Technology** – This is the safety-related portion of the operation control system. The operation control technology includes operation control/safety technology, stationary data transmission, radio data transmission, and vehicle location components (guideway mounted digital flags).

**Communication/Control Technology** – This includes the emergency system, closed circuit television, public information and address systems, and other monitoring and detection devices needed for safe and efficient operation.

#### **Guideway/Track Infrastructure**

- **Guideway/Track** – The major guideway infrastructure elements for maglev technologies are guideway beams, guideway switches, and guideway equipment. The guideway costs were estimated for a double-track guideway (with some single-guideway areas, including stations), based on an average for guideway superstructures, assuming the Transrapid design for guideway beams (Type I beams) and for concrete elements (Type III on bridges and in tunnels). High-speed rail track items include ballast; rails; ties; fasteners; and special track work, such as sidings and turnouts. All track costs are for dual-tracked alignment. Direct fixation track was assumed for elevated and tunnel areas, while ballasted track was used for at-grade sections. Sound walls along the outside of the guideway are intended to reduce noise from passing train sets. An allowance for sound walls was included to cover areas where the alignment travels through residential areas, such as Idaho Springs, Eagle, Avon and Vail. Safety fencing was assumed along the full length of the alignments (surface and elevated sections, and at stations and facilities). Landscaping would be provided in developed areas.
- **Bridges and Viaducts** – The system infrastructure includes structures that carry guideways, straddle bent crossings of I-70, special foundations/caissons, support columns, bridges, and viaducts. The costs for guideway structures were estimated for a double- and single-track guideway. The structure cost per route length for track was based on column height and construction complexity. The AGS Study Team

developed 28 different bridge and viaduct options for costing maglev structures, including viaduct, high viaduct, and long span. The team developed 16 different bridge and viaduct options for costing high-speed rail structures.

- **Tunnels** – Tunnel structure work includes boring/drilling/digging costs, ventilation systems, limited spoils disposal, and tunnel electrical systems (lighting, fans, etc.). Twelve tunnel options were developed, including a cut-and-cover option for both high-speed rail and maglev systems.
- **Other** – This item includes drainage and earthwork.

**Stations** – Each station includes platforms, circulation, lighting, security measures, and auxiliary spaces for ticket sales, passenger information, station administration, baggage handling, and commercial use. Many station designs show a two-story building with circulation on the ground floor and transport platforms. However, station designs differ, depending on demand and terrain.

**Operations and Maintenance Facilities** – These include the operation control center, maintenance facilities, and maintenance vehicles required for the operation and maintenance of the system. The Central Maintenance Facility is assumed to be near I-70/C-470 and would house an Operations Control Center. A secondary maintenance facility is assumed near Eagle County Regional Airport.

**Construction Support** – This includes special construction equipment, such as gantries and one-time beam fabrication facilities that are beyond the normal requirements of commercial construction or fabrication vendors.

**Right-of-Way and Utilities** – This includes costs associated with the purchase of land or easement rights, including relocation assistance, demolition costs, acquisition services, and the purchase cost. It also includes costs for utility relocation based on the land use categories from the right-of-way estimates. More densely built-up areas would be expected to have more utility conflicts with a new transportation system. This cost is the actual cost related to moving utilities, and not professional services.

#### 4.2.2 Indirect Costs

**Contingencies** – These are allowances added to construction cost estimates at the conceptual planning/engineering stage to account for design details not yet determined, and to accommodate quantity and unit cost variances that would arise during later phases of project development.

- **Standard** – A standard 10 percent contingency related to project elements that have uncertainties and mountain construction (except switches).
- **Switch** – A special 20 percent contingency related to maglev switches because of the uncertainty in these items.

##### *Indirect costs included:*

- *Contingencies*
- *Professional Services*
- *Utility Relocation*
- *Environmental Impact Mitigation*

- **Right-of-Way** – A special 20 percent contingency related to right-of-way and the uncertainty in land prices across lengthy corridor segments.
- **Tunnel** – A special 30 percent contingency related to tunnel construction because of the uncertainty in preliminary design, geology, and other risk items.
- **Emergency Tunnel** – A special 20 percent contingency related to tunnel construction of escape shafts and corridors and other emergency items that will be detailed during the design phase.
- **Overall** – A special 30 percent contingency added to the entire cost estimate until more details are determined in the design and construction phases and costs are dramatically refined.

**Professional Services** – These costs cover the management, procurement, oversight, and overhead costs associated with planning, engineering, and implementation of the project. They include the cost for the technical planning and approval of the project prior to and during construction, manufacturing, installation, commissioning, certification, and acceptance.

**Utility Relocation** – The cost for professional services related to planning, design, and implementation of utilities relocation.

**Environmental Impact Mitigation** – This accounts for environmental impact mitigation measures that would be identified during a formal environmental study process. These measures would mitigate site-specific environmental impacts and include such items as replacement of displaced natural, recreational, or cultural resources; removal of hazardous materials; and replacement of habitat.

### 4.3 Capital Cost Estimates

Table 4-1 shows the capital cost estimates for each of the alignment/technology pairs for the Full System AGS from Eagle County Regional Airport to I-70/C-470. Complete cost estimate spreadsheets and a complete explanation of how capital costs were determined are included in Appendix F.

**Table 4-1: Capital Cost Estimates for Full System AGS**

	Hybrid/ 120 mph Maglev (\$)	Hybrid/ High Speed Maglev (\$)	High Speed Maglev (\$)	High Speed Rail (\$)
<b>Direct Costs</b>				
Vehicles	240,000,000	240,200,000	240,200,000	180,000,000
Propulsion System	156,000,000	748,300,000	748,300,000	0
Energy Supply	Included in Propulsion System	235,000,000	235,000,000	280,463,479
Operation Control Technology	198,000,000	115,557,991	114,701,631	219,112,093
Communication/ Control Technology	Included in Operation Control Technology	7,653,800	7,653,800	61,351,386
Guideway/Track	1,065,325,171	1,558,715,098	1,711,594,292	1,032,256,862

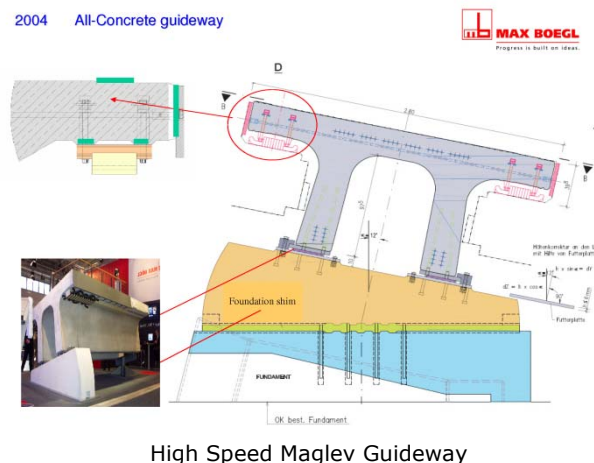


**Table 4-1: Capital Cost Estimates for Full System AGS**

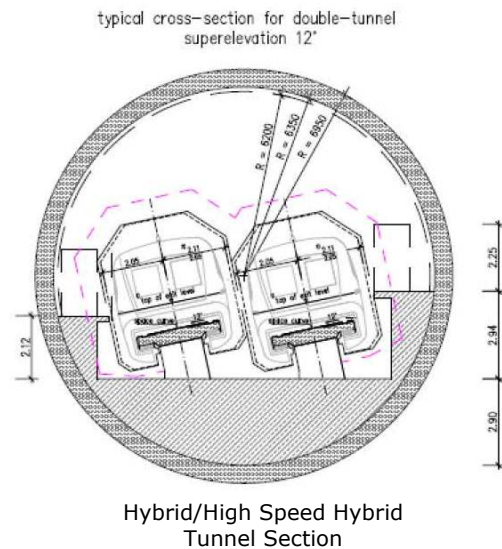
	Hybrid/ 120 mph Maglev (\$)	Hybrid/ High Speed Maglev (\$)	High Speed Maglev (\$)	High Speed Rail (\$)
Bridges and Viaducts	208,721,824	208,721,824	118,329,180	652,490,948
Tunnels	2,227,678,781	2,227,678,781	6,636,376,201	9,743,773,973
Other	221,962,502	221,962,502	217,232,268	338,009,250
Stations	140,000,000	140,000,000	140,000,000	110,000,000
Operations and Maintenance Facilities	15,200,000	49,000,000	49,250,000	49,250,000
Construction Support	50,000,000	50,000,000	50,000,000	50,000,000
Right-of-Way and Utilities	329,494,912	329,494,912	223,904,348	268,005,695
<b>Subtotal Direct Costs</b>	<b>4,852,383,191</b>	<b>6,132,284,908</b>	<b>10,492,541,720</b>	<b>12,984,713,687</b>
<b>Indirect Costs</b>				
Professional Services	1,581,270,000	1,940,000,000	3,681,480,000	4,711,680,000
Utility Relocation	547,360,000	671,540,000	1,274,360,000	1,630,970,000
Environmental Mitigation	152,050,000	186,540,000	353,990,000	453,050,000
Other Contingencies	1,229,422,402	1,329,253,581	3,666,979,980	5,137,127,519
Overall Contingency	2,508,740,000	3,077,880,000	5,840,810,000	7,475,260,000
<b>Subtotal Indirect Costs</b>	<b>6,018,842,402</b>	<b>7,205,213,581</b>	<b>14,817,619,980</b>	<b>19,408,087,519</b>
<b>Total Costs</b>	<b>10,871,225,593</b>	<b>13,337,498,489</b>	<b>25,310,161,700</b>	<b>32,392,801,206</b>
<b>Cost Per Mile</b>	<b>90,217,640</b>	<b>110,684,635</b>	<b>213,587,862</b>	<b>297,454,557</b>

The following conclusions can be drawn from the capital cost estimates:

- The indirect costs contribute more to the total cost than the direct costs. This is not unusual at this preliminary level of alignment design. As the design progresses and more unknowns become known, the percentage of indirect costs will drop.
- The Hybrid/120 mph Maglev represents the least costly alternative. A Hybrid/High Speed Maglev is more costly, but comparable at this stage of the analysis.



- The High Speed Maglev and High Speed Rail are significantly higher in cost. This is due primarily to higher tunnel costs and related contingencies, as well as technology-related costs (e.g., energy supply, communications, etc.).
- The High Speed Maglev and High Speed Rail capital costs are consistently higher because of their greater complexity. These technologies have ten or more years of commercial service. The 120 mph Maglev technology is theoretical at this point. Therefore, costs for the high-speed technologies have more credibility.
- The costs separate out the individual contingencies and indirect costs. This makes clear that the Hybrid/120 mph Maglev and the Hybrid/High Speed Maglev are fairly close in cost. Their costs per mile are similar to those of urban light rail systems in the United States. In each case, the indirect costs represent over 50% percent of the total capital investment. Within those, contingencies are high, but will decrease as the design is refined and construction estimates, right-of-way needs, and procurement costs are finalized.
- Maglev guideways have a substantial concrete section around which the vehicle wraps; therefore, a large percentage of the maglev guideway cost is associated with structures (Guideway/Track and Bridges and Viaducts). Rail tracks are not as complex, so a greater percentage of the high-speed rail cost is in Bridges and Viaducts and Tunnels.
- A single maglev vehicle is more expensive than a single high-speed rail vehicle, but has higher capacity.
- High-speed rail stations could be longer than maglev stations because the trains need to be longer to accommodate the same capacity as maglev vehicles.



#### 4.4 Key Cost Drivers

Table 4-2 illustrates the key cost drivers for the alignment/technology pairs as a percentage of the total of direct costs and indirect costs. The direct cost for Tunnels and Guideway/Track is the highest cost driver for all alignment/technology pairs.

**Table 4-2: Key Cost Drivers by Alignment/Technology Pair**

	Hybrid/ 120 mph Maglev	Hybrid/ High Speed Maglev	High Speed Maglev	High Speed Rail
<b>Direct Costs</b>				
Tunnels	46%	36%	63%	75%
Guideway/Track	22%	25%	16%	8%
Right-of-Way and Utilities	7%	5%	2%	2%

**Table 4-2: Key Cost Drivers by Alignment/Technology Pair**

	Hybrid/ 120 mph Maglev	Hybrid/ High Speed Maglev	High Speed Maglev	High Speed Rail
<b>Direct Costs</b>				
Vehicles	5%	4%	2%	1%
Other	5%	4%	2%	3%
Operation Control Technology	4%	2%	1%	2%
Bridges and Viaducts	4%	3%	1%	<b>5%</b>
Propulsion System	3%	<b>12%</b>	<b>7%</b>	0%
Stations	3%	2%	1%	1%
Construction Support	1%	1%	0%	0%
Energy Supply	0%	4%	2%	2%
Communication/Control Technology	0%	0%	0%	0%
Operations and Maintenance Facilities	0%	1%	0%	0%
<b>Subtotal</b>	100%	100%	100%	100%
<b>Indirect Costs</b>				
Overall Contingency	42%	43%	39%	39%
Professional Services	26%	27%	25%	24%
Other Contingencies	20%	18%	25%	26%
Utility Relocation	9%	9%	9%	8%
Environmental Mitigation	3%	3%	2%	2%
<b>Subtotal</b>	100%	100%	100%	100%

**Bold** = the highest cost drivers based on direct costs of each alignment/technology pair.

Note: Percentages represent the percentage of the cost drivers of the total of direct and indirect costs.

#### 4.4.1 Tunnels

The most costly element for all alignment/technologies is Tunnels. The degree to which tunnels are key cost drivers varies with the number and length of the tunnels associated with the alignment. Table 4-3 compares the tunnel data of each alignment.

**Table 4-3: Tunnel Data by Alignment**

Alignment/ Technology	System Length (ft.)	System Length (mi.)	Tunnel Length (ft.)	Tunnel Length (mi.)	Tunnel Length as % of Total System Length	Number of Tunnels
Hybrid/120 mph Maglev*	636,401	120.5	82,737	15.7	13%	15
Hybrid/ High Speed Maglev*	636,401	120.5	82,737	15.7	13%	15
High Speed Maglev*	625,538	118.5	211,956	40.1	34%	31
High Speed Rail**	575,097	108.9	343,045	65.0	60%	25

\* Single bore tunnel was assumed for all maglev alignments.

\*\* Twin bores were assumed for high-speed rail, except for tunnels less than 500 feet long.



Tunnel lengths compared to the total alignment lengths are greater for the High Speed Maglev and High Speed Rail Alignments. Longer-length tunnels are required to accommodate the desired straighter alignments and less significant grades (and grade changes). These tunnels are costly, and having 34 to 60 percent of the system length underground may not be desirable for passengers who want to view the Colorado scenery.

Table 4-4 compares the tunnel costs by alignment. It should be noted that for all maglev tunnels, it was assumed that a single bore would suffice.

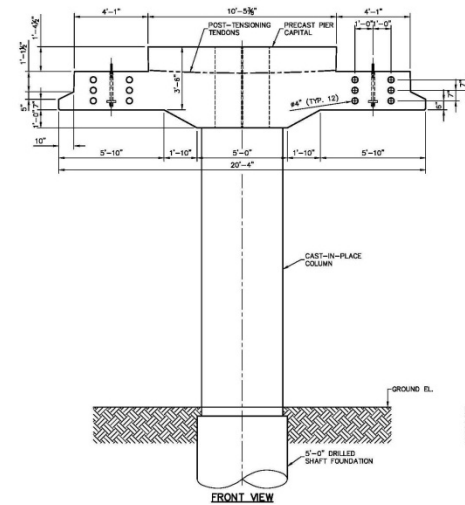
**Table 4-4: Tunnel Costs by Alignment/Technology Pair**

	Hybrid/ 120 mph Maglev	Hybrid/ High Speed Maglev	High Speed Maglev	High Speed Rail
	\$2,227,678,781	\$2,227,678,781	\$6,636,376,201	\$9,743,773,973
Tunnel Contingency	\$668,303,634	\$668,303,634	\$1,990,912,860	\$2,923,132,192
Emergency Tunnel Contingency	\$445,535,756	\$445,535,756	\$1,327,275,240	\$1,948,754,795
<b>Total Tunnel Cost</b>	<b>\$3,341,518,172</b>	<b>\$3,341,518,172</b>	<b>\$9,954,564,302</b>	<b>\$14,615,660,960</b>
<b>Tunnel Cost as Percentage of Total Cost as shown in Table 4-1</b>	<b>30.7%</b>	<b>25.1%</b>	<b>39.3%</b>	<b>45.1%</b>

**4.4.2 Guideway/Track**

The second most costly element for all alignment/technology pairs is the Guideway/Track. Both the 120 mph Maglev and the High Speed Maglev have proprietary guideways specific to their system. For instance, Transrapid and General Atomics use an LSM where the stator is incorporated in the guideway; American Maglev uses an LIM where the stator is onboard the vehicle. This results in different designs for the guideway. In general, the LIM guideway is simpler and less expensive.

High-speed rail uses slab track with special concrete ties for the slab track and rail. Because of its relative simplicity, the costs for Guideway/Track for the High Speed Rail Alignment are lower than for either of the maglev alignments and are a lower percentage of overall costs. Table 4-5 compares Guideway/Track costs by alignment/technology pair.



AMT Guideway

**Table 4-5: Guideway/Track Costs by Alignment/Technology Pair**

	Hybrid/ 120 mph Maglev	Hybrid/ High Speed Maglev	High Speed Maglev	High Speed Rail
Guideway/Track	\$1,065,325,171	\$1,558,715,098	\$1,711,594,292	\$1,032,256,862
% of Direct Costs	22.0	25.4	16.3	7.9
% of Total Cost	9.8	11.7	6.8	3.2

#### 4.4.3 Right-of-Way and Utilities

Right-of-way and Utilities is a key cost driver for the Hybrid Alignment. Each alignment has a different breakdown of public versus private lands. Each alignment also has a different breakdown of tunnel segments versus elevated and surface guideway/track segments. These factors directly affect the cost of right-of-way.

Cost estimates used \$1 per square foot for all public land (tunnel or surface or elevated), \$5 per square foot for private subsurface rights, and \$22 per square foot for private surface and elevated segments. The High Speed Rail Alignment right-of-way cost is higher than for the Hybrid or High Speed Maglev Alignments because it has a wider footprint, even though the High Speed Rail Alignment has a greater tunnel length (i.e., more subsurface length). The analysis was done by system segment for each alignment. Table 4-6 provides the right-of-way requirements for each alignment/technology pair.

**Table 4-6: Right-of-Way Requirements by Alignment/Technology**

Alignment	% on Private Properties	% on Public Lands
Hybrid (AMT and TRI)	42.30	57.70
High Speed Maglev (Transrapid - TRI)	55.20	44.80
High Speed Rail (Talgo 250)	57.70	42.30
High Speed Rail Spur (to Breckenridge)	60.50	39.50
<b>Right-of-Way Width</b>		
Maglev (AMT and TRI)	40 feet wide	
High Speed Rail (Talgo 250)	75 feet wide	

Major utility relocations include overhead power lines and underground facilities, such as pipelines, water and sewer mains, and underground duct banks and vaults. Costs for utility relocation were estimated using the land use categories from the right-of-way estimates. More densely built-up areas would be expected to have more utility conflicts with a new transportation system.

Table 4-7 shows the Right-of-Way and Utilities costs of each alignment/technology pair and the percentage they are of the total costs.

**Table 4-7: Right-of-Way and Utilities Costs by Alignment/Technology Pair**

	Hybrid/ 120 mph Maglev	Hybrid/ High Speed Maglev	High Speed Maglev	High Speed Rail
<b>Right-of-Way and Utilities</b>	\$329,494,912	\$329,494,912	\$223,904,348	\$268,005,695
% of Direct Costs	6.8%	5.4%	2.1%	2.1%
% of Total Cost	3.0%	2.5%	0.9%	0.8%

#### 4.4.4 Propulsion System

The Propulsion System is a key cost driver for High Speed Maglev. Since Transrapid uses an LSM, the infrastructure required to place the stator on the guideway is significant. This same system is also used for the General Atomics 120 mph Maglev. AMT has permanent magnets placed within the guideway and has its stator on board the vehicle (LIM) so propulsion costs are less.

High-speed rail is propelled by the vehicles so all costs associated with propulsion are included in the vehicle costs.

Table 4-8 compares the propulsion costs by alignment/technology pair and the percentage they are of the total costs.

**Table 4-8: Propulsion Costs by Alignment/Technology Pair**

	Hybrid/ 120 mph Maglev	Hybrid/ High Speed Maglev	High Speed Maglev	High Speed Rail
<b>Propulsion System</b>	\$156,000,000	\$748,300,000	\$748,300,000	\$0
% of Direct Costs	3.2%	12.2%	7.1%	0.0%
% of Total Cost	1.4%	5.6%	3.0%	0.0%

#### 4.4.5 Bridges and Viaducts

Bridges and Viaducts costs are a key cost driver for the High Speed Rail Alignment. This is because to maintain a flat grade, the alignment uses many tunnels connected by bridges or viaducts. This is especially true in the area east of Floyd Hill where the alignment diverges from I-70 to traverses the Clear Creek Canyon in tunnels connected by bridges. Table 4-9 compares bridge and viaduct costs by alignment/technology pair and the percentage they are of the total costs.

**Table 4-9: Bridge and Viaduct Costs by Alignment/Technology Pair**

	Hybrid/ 120 mph Maglev	Hybrid/ High Speed Maglev	High Speed Maglev	High Speed Rail
<b>Bridges and Viaducts</b>	\$208,721,824	\$208,721,824	\$118,329,180	\$652,490,948
% of Direct Costs	4.3%	3.4%	1.1%	5.0%
% of Total Cost	1.9%	1.6%	0.5%	2.0%

#### 4.4.6 Design Refinement

As the AGS proceeds through final design, many of the key cost drivers can be value-engineered to reduce costs. This includes the Tunnels, the Guideway/Track, Right-of-Way and Utilities, and Bridges and Viaducts. Many of the other costs also will be reduced through design refinement.



Major Station

#### 4.5 Station Costs

Costs for AGS stations were estimated based on past work on other high-speed rail and maglev projects. There are two classes of stations: major stations and minor stations.

Major stations were assumed to be the two end-of-line stations at Eagle County Regional Airport and at I-70/C-470. Because these stations are anticipated to have large parking structures that accommodate riders from a larger geographical area than intermediate stations, the cost for a major station was assumed to be \$25 million.

Minor stations were assumed at intermediate stations, such as Idaho Springs, Keystone, Breckenridge, Vail, Avon, etc. They will have more modest parking structures than the major stations. The cost for a minor station was assumed to be \$15 million.

Table 4-10 includes a breakdown of the costs for the two station types. These costs do not include any transit-oriented development around the station.

**Table 4-10: Station Costs**

Element	Unit Cost	Major Station	Minor Station
Terminal	\$250/square foot	12,000 square feet \$3.0 million	10,000 square feet \$2.5 million
Parking Structure	\$15,000/space	1,200 spaces \$18.0 million	600 spaces \$9.0 million
Roadway/Site Improvements	Not applicable	\$2.0 million	\$1.5 million
Miscellaneous – Furnishings, Utility Infrastructure, etc.	Not applicable	\$2.0 million	\$2.0 million
<b>Total</b>		<b>\$25.0 million</b>	<b>\$15.0 million</b>

#### 4.6 Minimum Operable Segment

The Minimum Operable Segment (MOS) is the portion of the total system that must be built to meet requirements of the *I-70 Mountain Corridor Record of Decision (ROD)*, or to effectively operate as an independent system. The *ROD* requires the evaluation of the feasibility of an AGS from the Front Range to a point west of the Continental Divide. For the

purposes of this Study, the MOS is defined as Breckenridge to I-70/C-470, which can also represent a first starter segment for the AGS.

The cost estimates prepared for the MOS for each alignment/technology pair are summarized in Table 4-11. The estimates indicate that the total represents between 51 and 59 percent of the total system capital cost, and between 49 and 56 percent of the MOS system length. This is understandable since the MOS is in the eastern part of the system where the topography is most challenging and there are higher costs for such items as tunnels and special structures.

**Table 4-11: Minimum Operable Segment Cost Comparison (Breckenridge to I-70/C-470)**

MOS	Hybrid/ 120 mph Maglev	Hybrid/ High Speed Maglev	High Speed Maglev	High Speed Rail
Eagle County Regional Airport to I-70/C-470 System Cost	\$10,871,220,000	\$13,337,490,000	\$25,310,170,000	\$32,392,800,000
Minimum Operable Segment (MOS) Cost	\$ 5,544,560,000	\$ 6,801,840,000	\$14,141,730,000	\$19,009,540,000
MOS as % of Total Cost	51.00%	51.00%	55.90%	58.70%
MOS as % of Total Length	50.40%	50.40%	49.20%	56.00%

The *Interregional Connectivity Study* determined that the cost to extend High Speed Maglev from I-70/C-470 to DIA along the I-76/I-70 alignment is about \$3.2 billion. If it is assumed that Hybrid/120 mph Maglev and the High Speed Rail capital costs are similar, the costs for the extended MOS of DIA to Breckenridge are shown in Table 4-12.

**Table 4-12: Extended Minimum Operable Segment Cost Comparison (Breckenridge to DIA)**

	Hybrid/ 120 mph Maglev	Hybrid/ High Speed Maglev	High Speed Maglev	High Speed Rail
Eagle County Regional Airport to DIA System Cost	\$14,071,220,000	\$16,537,490,000	\$28,510,170,000	\$35,592,800,000
Minimum Operable Segment (MOS) Cost	\$ 8,744,560,000	\$10,001,840,000	\$17,341,730,000	\$22,209,540,000
MOS as % of Total Cost	62.15%	60.48%	60.83%	62.40%
MOS as % of Total Length	62.05%	62.05%	61.76%	70.72%

#### 4.7 Operation and Maintenance Costs

Operation and maintenance (O&M) costs are the annual costs associated with operating, maintaining, and administering a system. O&M costs include employee earnings and fringe benefits, contract services, materials and supplies, utilities, and other day-to-day expenses.

The methodology for O&M costing of the alignment/technology pairs was based on the principal assumption that annual operation and maintenance costs vary according to labor productivity, consumption rates, and system characteristics related to service and facilities.



The operating scenario for costing purposes was determined to be:

- 18-hour operating days.
- 365-day operating years.
- 30-minute peak/60-minute off-peak headways between trains or vehicle consists.
- About 5-car train sets or maglev consists (with some exceptions).
- Station numbers and location determined by technology and alignment.
- For all alignment/technology pairs, the Full System east end station was at the C-470/I-70 interchange in Golden and the west end station was at Eagle County Regional Airport.
- For all alignment/technology pairs, the MOS east end station was at the C-470/I-70 interchange in Golden and the west end station was at Breckenridge.
- For the Hybrid/120 mph Maglev, an additional O&M estimate was prepared assuming 15-minute peak /60-minute off-peak headways between two-car married pair consists (due to possible need to accommodate peak demand).

Table 4-13 summarizes the O&M cost model results for the Full System and the MOS. A complete description of the O&M cost model and O&M costs for the various alignment/technology pairs can be found in Appendix G.

**Table 4-13: Operation and Maintenance Cost Estimates**

	Hybrid/ 120 mph Maglev (15-Minute Peak/60-Minute Off-Peak)	Hybrid/120 mph Maglev (30-Minute Peak/60-Minute Off Peak)	High Speed Maglev (30-Minute Peak/60- Minute Off- Peak)	High Speed Rail (30-Minute Peak/60- Minute Off- Peak)
ECRA to I-70/C-470 - Low Cost	\$52,694,000	\$45,213,000	\$47,209,000	\$55,382,000
ECRA to I-70/C-470 - High Cost	\$69,473,000	\$60,440,000	\$62,762,000	\$72,882,000
Breckenridge to I-70/ C-470 - Low Cost	\$29,485,000	\$26,072,000	\$27,258,000	\$36,191,000
Breckenridge to I-70/ C-470 - High Cost	\$39,230,000	\$35,103,000	\$36,466,000	\$47,704,000
Breckenridge to DIA - Low Cost	\$43,819,000	\$38,746,000	\$40,509,000	\$53,785,000
Breckenridge to DIA - High Cost	\$57,877,000	\$51,788,000	\$53,799,000	\$70,379,000
ECRA to DIA - Low Cost	\$65,980,000	\$56,613,000	\$59,112,000	\$69,346,000
ECRA to DIA - High Cost	\$86,873,000	\$75,577,000	\$78,481,000	\$91,136,000

ECRA = Eagle County Regional Airport.

- O&M costs for the Full System from Eagle County Regional Airport to I-70/C-470 to range from \$45.2 million to \$72.9 million annually. The highest O&M costs are associated with the High Speed Rail alignment/technology pair.
  - O&M costs for the Full System High Speed Maglev alignment/technology pair from Eagle County Regional Airport to DIA range \$47.2 million to \$62.8 million annually because of its longer alignment and associated longer travel time.
- O&M costs for the MOS options from Breckenridge to I-70/C-470 range from \$26.1 million to \$47.7 million. Again, the highest O&M costs are associated with the High Speed Rail alignment/technology pair.
- If the MOS is extended from I-70/C-470 to DIA, the O&M costs for High Speed Maglev increases by \$11.9 million to \$15.7 million. Similar increases could be expected for the Hybrid/120 mph Maglev and High Speed Rail.

In the O&M cost model, the Hybrid/120-mph Maglev assumes the same labor rates as High Speed Maglev for vehicle and track maintenance. Information provided by AMT indicates that these rates could be significantly lower, which would reduce the O&M cost estimates for the Hybrid/120 mph Maglev.

Finally, it should be noted that O&M costs are based on a defined service plan that assumes 24 round trips per day on high-volume days. Preliminary analysis suggests that more frequent service may be needed during peak use. While much of the demand can be accommodated by scheduling more of the 24 round trips during peak periods, it may be advisable to add more trips overall, which would increase the estimated O&M costs.

#### **4.8 Conclusion**

The total capital costs for the Full System between Eagle County Regional Airport and I-70/C-470 range from \$10.8 billion to \$32.4 billion. Extending the service from I-70/C-470 to DIA adds another \$3.2 billion. Alternatives that use the Hybrid Alignment are less costly than the High Speed Alignments, principally because they have fewer tunnels than the High Speed Alignments. Contingency costs for all alignment/technology pairs are high at this point in the analysis because of the numerous uncertainties and unknown factors.

The key direct cost drivers - Tunnels, Guideway/Track, and Right-of-Way and Utilities - represent between 66 and 85 percent of the total direct costs for each of the four alignment/technology pairs. These three key cost drivers can be value engineered as design progresses. Because indirect costs were calculated as a percentage of direct costs, lowering the costs of the key direct cost drivers will also lower indirect costs, and thereby total costs.

Table 4-14 provides a breakdown of costs for the maglev alignment alternatives by segment. The segments are defined by the stations at either end of the segment. Table 4-15 provides segment costs for the High Speed Rail Alignment.

The costs for the MOS are lower, but still range from \$5.5 to \$19.1 billion. Again, as design progresses, these cost estimates will likely be lowered.

**Table 4-14: Segment Costs for Maglev Alignments**

Segment Number	Stations	Hybrid/ 120 mph Maglev	Hybrid/ High Speed Maglev	High Speed Maglev
1	Eagle County Regional Airport to Avon	\$1,590,227,527	\$2,094,427,584	\$3,772,410,843
2	Avon to Vail	\$ 693,476,591	\$ 858,226,718	\$1,572,607,724
3	Vail to Copper Mountain	\$1,607,701,781	\$2,013,023,249	\$3,979,894,250
4	Copper Mountain to Breckenridge	\$1,435,264,415	\$1,569,981,039	\$1,843,519,765
5	Breckenridge to Keystone	\$1,259,980,487	\$1,483,979,909	\$2,294,997,612*
6	Keystone to Idaho Springs/Georgetown	\$2,039,111,254	\$2,675,421,152	\$4,435,515,756*
7	Idaho Springs/Georgetown to I-70/C-470	\$2,245,465,217	\$2,642,436,323	\$7,211,233,260
<b>Total</b>		<b>\$10,871,220,000</b>	<b>\$13,337,490,000</b>	<b>\$25,310,170,000</b>

\* Differs from Appendix F because of segment quantity overlap.

**Table 4-15: Segment Costs for High Speed Rail Alignment**

Segment Number	Stations	High Speed Rail Segment
1	Eagle County Regional Airport to Vail	\$ 8,309,163,067
2	Vail to Lake Hill	\$ 5,074,098,165
3	Lake Hill to Georgetown	\$ 7,538,967,858
3b (Spur)	Lake Hill to Breckenridge	\$ 1,854,484,113
4	Georgetown to I-70/C-470	\$ 9,616,088,003
<b>Total</b>		<b>\$32,392,800,000</b>