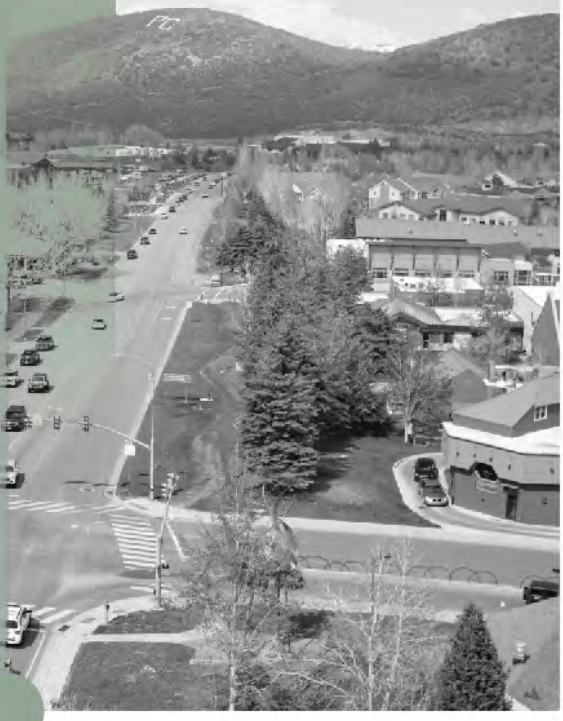
Re·create 248

AUTOMATED GUIDEWAY TRANSIT WHITE PAPER

January 2025



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1 INTRODUCTION

This white paper was developed as part of the Re-create 248 Transit Study to research and compile information related to Automated Guideway Transit (AGT) industry. As a potential transit alternative for the study area, a clearer definition for this mode is required to understand how to evaluate the effectiveness and feasibility of AGT as a viable public transit option. Various AGT systems and technologies, both nationally and internationally, were reviewed to determine the potential competitiveness of this mode as compared to more conventional in-use transit services like high frequency bus or light rail.

This white paper aims to provide information about this technology to define AGT as a public transit mode to inform the alternatives evaluation process of the Re-create 248 study, and addresses the following questions:

Definition: AGT is defined as a driverless transit service on an elevated fixed guideway, on which vehicles will balance or be suspended, using electric motors for propulsion.

- What are the range of automated guideway transit technologies available?
- What is the most appropriate technology that could be applied to the Re-create 248 corridor for the purpose of completing the Level 1 (preliminary) alternatives evaluation?
- What are the key characteristics of the selected technology, such as passenger capacity, service frequency, turning radii, and maintenance facility needs?
    - In what contexts might this technology be justified?
    - What are the primary concerns and considerations associated with the selected technology?

The following sections provide an overview of the history and background of AGT systems and reviews of relevant case studies highlighting key characteristics. Additionally, a summary of design criteria such as alignment, capacity, and costs are provided. Finally, the paper outlines contexts in which AGT system may be viable and lists concerns or considerations associated with the implementation.

2 AGT TYPES AND BACKGROUND

AGT is a term that includes several different types of elevated guideway-based transportation systems. Any driverless transportation system operating on a dedicated guideway falls under the AGT umbrella. AGT systems can be categorized into two types based on their capacity and performance:

AGT Type A utilizes small vehicles designed to transport people on demand, addressing first- and last-mile transportation gaps. Passenger capacities typically range from 4 to 25 per vehicle. This type of AGT is also known as Automated Transit Network (ATN), which includes several

subcategories: Personal Rapid Transit (PRT), Group Rapid Transit (GRT), and emerging technologies such as ConnX Autonomous Driverless Transport and Whoosh On-Demand Autonomous Guideway Transit. Details about these variations are provided in Table 1.

AGT Type B uses trains to transport passengers, operating on fixed schedules with dedicated stations. This type includes three variations: Automated People Mover (APM), Automated Light Metro (ALM), and Monorail. Although all three technologies share a similar concept; using trains on elevated guideways and look almost identical in design and operation, the terminology used varies by region, with some referring to these systems as APMs, others as ALMs, and the most common term being monorail. One key distinction is that ALM and monorail systems often offer higher passenger capacities due to their ability to couple multiple trains, which is less common in APMs. APMs have mostly been utilized at airports.

AGT Type B is more comparable with other service-proven transit systems and more likely to meet the Re-create 248 Purpose and Need statements as defined for this study. Additionally, the term “monorail” is more widely recognized in the industry and among manufacturers when referring to AGT Type B. Therefore, in this report, the term “monorail” will be used to describe AGT Type B, and the following sections of this report focus mainly on the monorail technology as a potential viable transit alternative.

Table 1 provides a summary of the different forms of AGT. Detailed information and design standards for various AGT types, such as service frequency and station spacing, are limited and inconsistent between services in operation. To address this, a built example was reviewed for each AGT type (with the exception of emerging technologies) to determine service frequency and station spacing. The station spacing measurements are based on Google Earth and are intended for planning-level purposes.

Table 1. Different Variations of AGT

	MODE	DESCRIPTION	TYPICAL PASSENGER CAPACITY	BUILT EXAMPLE	FREQUENCY	STATION SPACING
AGT Type A/ Automated Transit Network (ATN)	Personal Rapid Transit (PRT) (Zatran, n.d.)	Used for individual or small group travel needs. Passengers can bypass unnecessary stops making travel more efficient.	10 per car	Morgantown PRT, Morgantown, United States	Varies, PRT can operate on-demand and provide non-stop, point-to-point service between origin and destination stations.	Morgantown PRT station spacing varies from 0.3 miles to 1.5 miles.
	Group Rapid Transit (GRT) (City of San Jose, 2017)	Utilizes small vehicles to transport people and operates service on demand to close first-last-mile gaps.	10-25 per car	London Heathrow Airport ATN, London, United Kingdom	Varies like the PRT system. Heathrow Airport ATN frequency is every 15 minutes.	NA
	Emerging Technology: ConnX Autonomous Driverless Transport (Leitner-Poma, n.d.)	Provides a hybrid solution based on a ropeway, in which the cabin is transferred to an autonomous vehicle in the station, which then continues traveling on its own route.	4 per car	NA	Varies. Like the PRT system, the ConnX system can operate on-demand and provide non-stop, point-to-point service between origin and destination stations.	NA
	Emerging Technology: Whoosh On-Demand Autonomous Guideway Transit (Whoosh, n.d.)	Designed for direct point-to-point service for individuals or small groups.	5 per car	Remarkables Park Whoosh Pilot Project (currently underway), Queenstown, New Zealand	Varies. Like the PRT system, the Whoosh system can operate on-demand and provide non-stop, point-to-point service between origin and destination stations.	NA
AGT Type B	Automated People Mover (APM) (Wikipedia, 2024)	Serve small populations, generally utilized in theme parks or airports.	~150 per car	LAX Automated People Mover (under construction), Los Angeles, United States	LAX APM will operate every two minutes, the line will have a ten-minute end-to-end travel time.	LAX APM station spacing will be 0.3 miles to 1 mile.

	MODE	DESCRIPTION	TYPICAL PASSENGER CAPACITY	BUILT EXAMPLE	FREQUENCY	STATION SPACING
	Automated Light Metro (ALM) (Rem, n.d.)	ALM functions similarly to light rail and requires robust infrastructure for guideways and stations.	~400 per train (varies greatly depending on the manufacturer)	Vancouver's Sky Train Automated Metro, Vancouver Canada	Vancouver's Sky Train operates 2-5 minutes during peak hours and 6-12 minutes during off-peak hours.	Vancouver's Sky Train station spacing varies from 0.5 miles to 1.5 miles.
	Monorail (Wikipedia, 2024)	Generally used to define any elevated AGT but encompasses higher capacity variations of the technology.	~<500 per train (may use the same cars as an APM, but can connect more cars together for a longer train)	Las Vegas Monorail, Las Vegas, United States	Las Vegas Monorail operates every 4-8 minutes.	Las Vegas Monorail station spacing varies from 0.5 miles to 1.5 miles.

Several monorail systems currently operate in the United States, as shown in Figure 1. Recognizable systems include the Walt Disney World Resort in Orlando, Florida, and the Disneyland Amusement Park in Anaheim, California. The 14-mile system in Orlando provides transportation for the park's 50 million annual visitors, accommodating approximately 150,000 daily passenger trips (MDOT, 2020). The Tampa monorail line has been decommissioned since the time of the report.

Source: Monorail Global Scan and Assessment (MDOT, 2020)

Figure 1. Map of Existing Monorails in the United States

To better understand monorail technology several operational systems were reviewed with the findings summarized in Table 2. The review focused on key criteria such as speed, travel time, ridership, cost, station citing, and other factors to provide an overview of the performance and characteristics of monorail systems.

The case studies were selected based on their functionality and relevance to the Re-create 248 study, focusing on systems that operate most like public transit, are at least three (3) miles long, and operate in urban and/or suburban areas. While the case studies review focused on U.S. examples, most monorails in the country are limited to specialized applications, such as serving airports or theme parks, rather than functioning as public transit systems. The Las Vegas, Nevada monorail may be the most relevant example of a monorail currently operating as public transit in an urban setting in the U.S. Other case studies are from outside the country.

Table 2. Monorail Case Studies Key Characteristics

CASE STUDY	AVERAGE SPEED	TRAVEL TIME	HEADWAY	LENGTH & # OF STATIONS	RIDERSHIP	CONSTRUCTION COST	OPERATION COST	FARE STRUCTURE
Las Vegas, Nevada, U.S.	50 MPH	~15 min total length	4-8 min	3.9 miles, 7 stations	13,500 daily, 2.9 million annually	$650 million (2004)	$38.7 million annually	$13.45 for a 24-hour pass up to $57.50 for a 7-day pass. Discounts are available for local residents.
Tama, Japan	40 MPH	~24 min	5 min	10 miles, 19 stations	120,000 daily 50.5 million annually	$2.4 billion (2000)	$645,000 annually	Distance-based $1-3.75 USD (.05 miles-10 miles)
Sao Paulo, Brazil	50 MPH	~12 minutes,	N/A	4.7 miles, 10 stations	N/A	$1.6 billion (estimate includes the future phases of the project, research was unclear on if this includes planning, design, or other operational costs)	N/A	Trip based: $1.03
Wuppertal, Germany	17.1 MPH	~30 minutes full trip	4-6 min	8.26 miles, 20 stations	65,000 daily, 80,000 annually	$4.2 million (1901) Additional renovation cost of $658 million (2016)	N/A	Trip based: $3.18 USD

3 MONORAIL TECHNOLOGY OVERVIEW

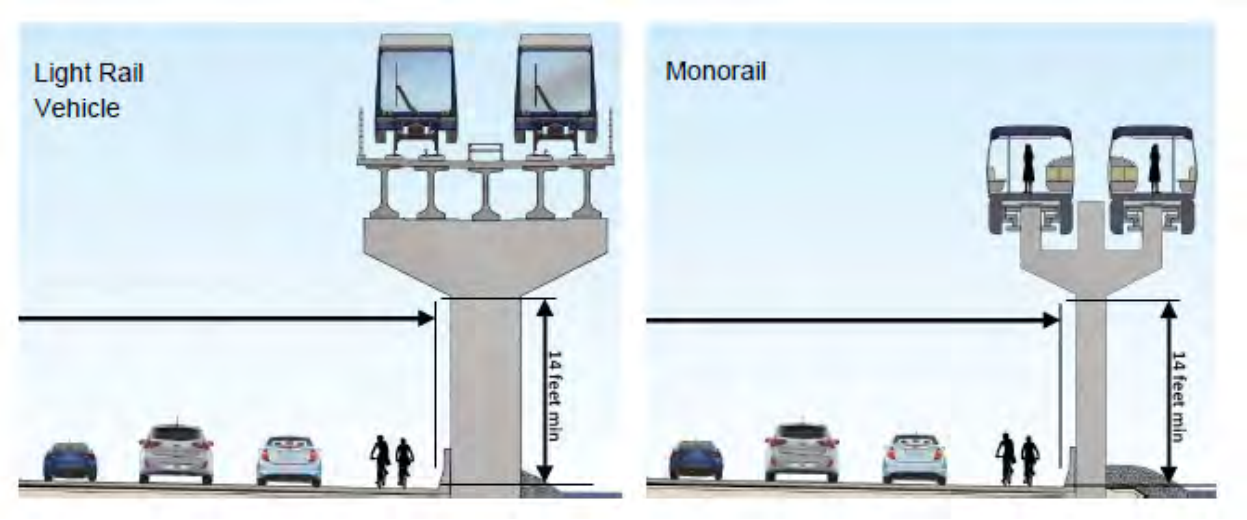
This section provides information on monorail variations including service, vehicles, alignment, market considerations, design criteria, and the contexts in which monorail is most effective as a transit solution.

3.1 MONORAIL TYPES

Monorail is an elevated fixed guideway based on a single- or dual-beam. Monorail systems generally have two main configurations: straddle beam and suspended rail (MDOT, 2021). Figure 2 shows the two monorail configurations. For the straddle beam, the car straddles a metal or concrete beam, and for the suspended configuration, wheels above the car ride on a steel rail while the car hangs underneath. The suspended rail system has seen just a few iterations with no broad market support, and the current manufacturers of monorail systems exclusively develop straddle beam technology (MDOT, 2021). Unless mentioned otherwise, this paper refers primarily to the straddle monorail.

Figure 2. Suspended Monorail Wuppertal, Germany (left) and Straddle Monorail Las Vegas, United States (right)

Narrow guide beams, typically between 27 and 36 inches wide and made of pre-cast reinforced concrete, are unique in that they both guide and structurally support the vehicles. This is a major factor that can reduce the construction cost and visual impacts of the technology, as compared to other grade-separated transit modes (MDOT, 2021). Figure 3 shows both monorail and elevated light rail vehicles. As shown, monorails can have a lower profile and smaller footprint compared to typical light rail vehicles. Monorail systems generally have a smaller footprint on the environment and the narrow guide beams are less obtrusive than conventional through-type guideways that can resemble aerial road structures (MDOT, 2020).



Source: Monorail Global Scan and Assessment (MDOT, 2020)

Figure 3. Monorail Guideway Comparison

3.2 MONORAIL ALIGNMENT

Monorail operates solely on exclusive right-of–way and cannot operate in mixed traffic as buses or trams do, because the guideway beams cannot be crossed by other vehicular or pedestrian traffic at ground level, unlike rail tracks which can be embedded into the street (Kennedy, R, 2012). Although straddle monorail systems are generally built in an aerial guideway configuration, some monorail systems also operate in underground sections, or close to ground level, with adequate fencing to prevent unauthorized access to the guideway (MDOT, 2021).

Monorails often have slope or grade changes in their route which provide design flexibility - straddle systems have a maximum grade of ten percent, although six percent is the maximum grade typically used in practice (MDOT, 2020).

Monorails are typically seen as alternatives to subway or metro systems when the system performance (passenger transport capacity) dictates that the transit solution be grade-separated. Transit solutions that intermix with road traffic have limited capacity, whereas grade or guideway separated solutions (subway or elevated) inherently eliminate the constraints of being mixed with traffic (MDOT, 2020).

3.3 MONORAIL MARKET AND DESIGN CRITERIA

There are four manufacturing companies worldwide that provide monorail systems: Bombardier, Build Your Dreams (BYD), China Railway Rolling Stock Corporation Limited (CRRC), and Hitachi. All these companies have significant interest in supplying the U.S. with transit vehicles. Bombardier is active in the supply of steel wheel subway and intercity rolling stock, as well as rubber-tired People Movers in the U.S. CRRC is constructing Metro cars for Chicago, Illinois and Boston, Massachusetts. Hitachi is building Metro cars for Miami, Florida and Baltimore,

Maryland. BYD is the only company significantly invested in the U.S. transit bus market, and they do not supply the U.S. with rail rolling stock. Over recent years, these multi-billion-dollar companies have shown they have the resources and ability to contract with and deliver large transit solutions to large cities (MDOT, 2020). The marketing material from each manufacturer is included in the **Appendix A**.

Due to the technical complexity of monorail systems, many aspects are proprietary to the private enterprises that manufacture or license designs. As a result, publicly available information is less detailed, however, designs are more unique to each system than other forms of transit (i.e. no standardized design criteria).

Table 3 shows the design criteria for Bombardier's INNOVIA 300 and BYD's SkyRail systems. These straddle beam systems feature bi-directional, fully automated driverless trains, operating on a grade-separated dual-track alignment. The Las Vegas Monorail uses Bombardier technology, and the Utah Transit Authority's (UTA) FrontRunner commuter rail cars are supplied by Bombardier.

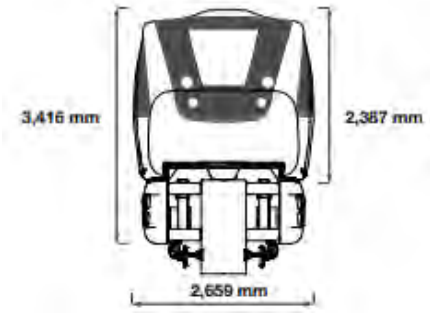
Table 3, Monorail Design Criteria

DESIGN CRITERIA	BYD "SKYRAIL"	BOMBARDIER "INNOVIA 300"
Car Length	39.3'	End Car: 43.3' Mid Car: 38.9'
Car Width	10.3'	10.3'
Capacity	80 / end car 93 / mid car	76 pass / car average
Speed	75 mph	50 mph
Number of Cars	2 to 8 cars	2 to 8 cars
Maximum Grade	10%	10%
Maximum Grade in Service	6%	6%
Minimum Turning Radius	148'	150'
Rail Beam Width	2.3'	2.3'

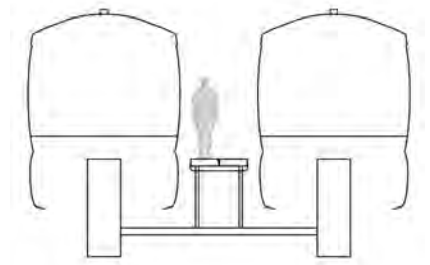
Monorail footprints can vary depending on the alignment and station type. A single-beam alignment with a side platform typically has the smallest footprint, while a dual-beam alignment with a center platform generally has the largest. The width of the train and beam also varies based on the manufacturer and type of technology. Currently, no published standards or guidance are available online that describe platform dimensions and specifications. To better understand the footprint, a review of existing monorails and studies involving platform designs and car widths was conducted. Table 4 shows the dimensions and key design criteria for the Las Vegas monorail which operates on a dual-beam alignment with center platforms.

Table 4, Train, Guideway, and Platform Dimensions of Las Vegas Monorail

DESIGN CRITERIA	LAS VEGAS MONORAIL "INNOVIA 200'	TYPICAL CROSS SECTION
Train Width	8' 8"	
Train Height	7' 8"	
Length of 4-car Train (over nose cone)	138'	
Length of 4-car Train (over face of couplers)	136' 10"	
Train + Beam Height	11' 2"	
Beam Underpass	16' 9"	
Typical Elevated Guideway Span	100'	
Maximum Elevated Guideway Span	120'	
Guideway Running Surface Width	26'	
Maximum Guideway Elevation	~60' above grade	
Average Guideway Elevation	30'	
Average Station Spacing	0.5 miles	
Platform Length	243'	
Alignment Width with Platform*	~80-100'	
Alignment Width with No Platform*	~18-20'	



Train Dimensions


Dual-Beam Alignment with Canter Platform

* The width was measured using Google Earth.
Source: Bombardier INNOVIA 200 Monorail Technology (Bombardier, 2010)

Table 5 shows the design criteria that were developed for the alignment evaluation as part of the I-270 Monorail Feasibility Study (MDOT, 2021).

Table 5. Train, Guideway, and Platform Dimensions Designed through 1-270 Monorail Feasibility Study

DESIGN CRITERIA	I-270 MONORAIL FEASIBILITY STUDY
Center Platform Width	18'
Side Platform Width	14'
Platform Length (One 3-car train)	150'
Platform Length (Two 3-car trains)	300'
Tangent Center to Center	14' 3" at 50 mph
Tangent to Fence	7' 3"
Vertical from Beam Top	17'

DESIGN CRITERIA	I-270 MONORAIL FEASIBILITY STUDY
2-Track Envelope	26’
Beam Underpass	16’9”

3.4 CONTEXT FOR SUCCESS

Some cities are considering monorails as a cost-effective transit option due to potentially lower construction cost, shorter construction times, and design flexibility. However, not all monorail systems have been successful. Monorails serving less urban or sparsely populated areas and/or not integrating seamlessly with the existing transit networks have not seen strong success in garnering ridership. Most successful monorail systems around the world are located in high-density areas with walkable stations that serve highly frequented destinations, such as airports and amusement parks.

Monorail may have the ability to provide unique transportation solutions through constrained areas, but requires the following characteristics to be successful:

- Serve a large population base
- Traverse a dense urban environment
- Have transit-oriented development patterns at station locations
- Have frequent headways
- Have a reasonable fare structure
- Be easily accessible by car and on foot
- Be integrated with other transit networks

4 OTHER CONSIDERATIONS

General concerns regarding monorail technologies are listed below. It is important to note that monorail systems have been implemented less frequently than other service-proven transit modes, such as Bus Rapid Transit (BRT) or Light Rail, resulting in limited evidence and resources addressing operational concerns.

FTA Funding Eligibility: It is unclear whether monorail technology would qualify for Federal Transit Administration (FTA) Capital Investment Grants (CIG) funding. According to the FTA, “other fixed guideway modes such as gondola, inclined plane, cable car, monorail, etc. are seldom proposed to FTA for CIG funding. Therefore, FTA has not implemented Core Capacity eligibility calculations for these types of proposed projects. FTA intends to work with project sponsors of these modes on a case-by-case basis as necessary to determine Core Capacity

eligibility". This suggests that monorail systems may face additional uncertainty or challenges when seeking CIG funding, as their eligibility would require case-by-case evaluation by the FTA.

Proprietary Nature of Monorail Technology: The operator of a monorail system is tied to the supplier or manufacturer. The specialized components required for monorails may be harder to source, have long lead times for manufacturing, or are only available from a limited number of manufacturers. If federal funding is used for the project, strict Buy America and Davis-Bacon Act regulations may be difficult to meet.

Monorail technology is changing rapidly, and deviates from other service-proven technologies. New operations and maintenance facilities would be required to service the system and require a separate federal environmental study. Additionally, introducing a new transit system in the area requires a specialized work force or additional training for existing workers (TDOT, 2015).

Safety and Reliability: The safety and reliability of monorail systems remain largely unproven. Concerns include the ability of monorail trains to execute track switches and the implications for passenger safety during emergencies or vehicle breakdowns. Monorail systems must comply with standards such as the National Fire Protection Association (NFPA) 130: Standard for Fixed Guideway Transit and Passenger Rail Systems, among others, to operate in the United States (TDOT, 2015).

Evacuation Procedure: Monorail vehicles and guideways must facilitate passenger evacuation during emergencies. This is particularly critical for automated systems, as transit personnel may not be onboard during the time of an accident (TDOT, 2015).

Maintenance Considerations: Maintenance equipment for monorail systems are specialized items built specifically for monorail activities. These material handling solutions target key issues monorail maintenance and repair facilities face day to day. In order to perform maintenance and repair operations on monorail cars, custom material handling equipment is required (Handling Specialty, 2022) which can make the maintenance process longer and more complicated. For example, the monorail in Seattle had maintenance issues in 2006, and the system was shut down for a longer time than expected (Lange, 2006). Another shutdown happened in 2004 and the system was closed for months after being damaged by fire on Memorial Day (Le, 2006). City Cast Las Vegas news reported Las Vegas monorail is having financial and maintenance issues as the system ages; replacement parts are becoming scarcer and more costly, and it will become harder, if not impossible to make repairs (Kachelriess, 2024). However, these claims have not been verified by the Las Vegas Monorail website.

It is important to note that information on monorail operations and maintenance requirements in snowy conditions like the SR-248 study area have not been reviewed due to limited online sources. It is unclear at this time how to plow or maintain the elevated tracks in inclement weather, but likely would require specialized equipment.

Alignment: Monorail operates solely on exclusive right-of–way on mostly on the elevated structure which is more expensive than conventional rail modes such as light rail that has the

flexibility to operate at grade. At-grade rail technology is simpler and cheaper to implement than an elevated structure. Also, monorail-specific alignments cannot easily accommodate other transit or freight modes, unlike some Light Rail alignments (Umich.edu, 2006).

Visual Impact: Considering the monorail operates on the elevated track it will have a much higher visual impact compared to transit facilities operating at-grade. Among elevated systems, monorails generally produce the least visual and noise impact. Stations are intended to be elevated, with passengers traveling up and down to access them. Additionally, modern safety requirements for evacuation catwalks (bridged structures over and adjacent to the corridor) make their structures comparable in width to two-track elevated systems (Umich.edu, 2006).

Public Support: Since monorail technology is less utilized compared to other public transit services obtaining public support may be challenging, for example, as part of the Sepulveda Transit Corridor Project in Los Angeles monorail was selected in the initial range of alternatives (Metro, n.d.). However, during the public meeting and the survey held in 2024, 85% of participants were opposed to the monorail alternative and Metro, the regional transit service, eliminated this alternative as an option for the Sepulveda Transit Study (WyndiMan, 2024).

Parts Delivery and Assembling: There is limited public information on the timeline for manufacturing and delivering monorail components after a contract is signed. The only example found online is from the Las Vegas Monorail project, the contract was awarded in September 2000, the first vehicle was delivered in January 2003, and revenue service began in July 2004 (Bombardier, 2010).

The Federal Transit Administration's (FTA) Buy America requirements will apply to any transit vehicle procurement that uses federal funding, including monorail. These requirements stipulate that "the steel, iron, and manufactured goods used in the project are produced in the United States," (49 U.S.C. § 5323(j)(1)). These requirements apply to rolling stock, train control systems, communication, and traction power, and require that the final assembly for the rolling stock must occur in the United States. Compliance with Buy America requirements could potentially be very challenging.

5 CONCLUSION

This white paper provides a review of AGT systems, with a particular focus on defining the technology as a potential transit solution for the SR-248 corridor for the Level 1 alternatives evaluation. The Level 1 evaluation will compare different transit modes against each other to determine which mode best meets the corridor's needs using preliminary design footprints, potential impacts, and the ability of the alternative to provide access.

Monorail offers several benefits, including elevated design flexibility, reduced construction impact (compared to other elevated technologies), and comparability with other transit modes in terms of capacity. However, they also present unique challenges, such as proprietary technology, higher construction costs for elevated structures, maintenance complexities, and more. The viability of monorail systems depends on specific factors such as population density,

transit-oriented development, integration with existing networks, and public support. While monorail systems have been successfully implemented in various urban and suburban contexts worldwide, their application in the SR-248 corridor would require careful consideration of alignment, accessibility, and maintenance strategies.

REFERENCES

Bombardier (2010). Bombardier INNOVIA 200 Monorail Technology.

https://www.monorails.org/pdfs/INNOVIA%20200.pdf

City of San Jose. (2017). Automated Guideway Transit Study Final Report. https://www.sanjoseca.gov/home/showpublisheddocument/2586/636633570996530000

Maryland Department of Transportation. (2020). Monorail Global Scan and Assessment. https://www.mdot.maryland.gov/OPCP/Monorail_Global_Scan_and_Assessment_November_2020.pdf

Maryland Department of Transportation. (2021). I-270 Monorail Feasibility Study. I-270_MFS_Report_2021-2_23.pdf

Réseau express métropolitain. (2020, November 16). Five Things to Keep in Mind Regarding REM Cars. https://rem.info/en/news/five-things-keep-mind-regarding-rem-cars

Tennessee Department of Transportation. (2015). Monorail Assessment Report for the I-24 Southeast Corridor Final Report. https://www.tn.gov/content/dam/tn/tdot/documents/government-how-do-i-documents/Studies/I-24/SE_Corridor_Monorail_Revised_Final_Report_020215.pdf

Handling Specialty. (2022, September 7). Maintenance Equipment for Monorail Systems. https://handling.com/blog/railways/maintenance-equipment-for-monorail-systems/

Kachelriess, R. (2024, March 27). The Las Vegas Monorail is Going Away. City Cast Las Vegas. https://lasvegas.citycast.fm/explainers/las-vegas-monorail-going-away

Kennedy, R. (2012). Considering Monorail Rapid Transit for North American Cities

https://www.monorails.org/webpix%202/RyanRKennedy.pdf

Lange, L. (2006, July 18). Monorail Buildup Becomes Letdown over Safety Issues. Seattle Post-Intelligencer. https://www.seattlepi.com/seattlenews/article/monorail-buildup-becomes-letdown-over-safety-1209256.php

Leitner-Poma. (n.d.). ConnX Driverless Transport. https://leitner-poma.com/products/connx-driverless-transport

Le, P.C. (2006, August 11). Seattle Center Monorail Back in Action. Seattle Post-Intelligencer. https://www.seattlepi.com/local/transportation/article/seattle-center-monorail-back-in-action-1211525.php

Metro. (n.d.). Sepulveda Transit Corridor Project. https://www.metro.net/projects/sepulvedacorridor/

Umich.edu. (2006). Monorail vs. Light Rail. https://websites.umich.edu/~yopopov/rail_modes/monorail.html

Whoosh. (n.d.) Whoosh – Introducing a New Transportation Solution. https://whoosh.solutions/index.html#section-about

Wikipedia. (n.d.) People Mover. Retrieved January 10, 2024, from https://en.wikipedia.org/wiki/People_mover

Wikipedia. (n.d.) Seattle Center Monorail. Retrieved January 10, 2024, from https://en.wikipedia.org/wiki/Seattle_Center_Monorail

WyndiMan. (2024). In Reddit. Metro Has Eliminated Monorail Alternative 2 as an Option for the Sepulveda Transit Corridor. https://www.reddit.com/r/LosAngeles/comments/1dyiha6/metro_has_eliminated_monorail_alternative_2_as_an/?rdt=52986

Zatran. (n.d.). Personal Rapid Transit (PRT) | Group Rapid Transit (GRT). https://www.zatran.com/en/technology/personal-rapid-transit-prt/

APPENDIX A: MANUFACTURER'S MARKETING MATERIALS

INNOVIA Monorail 300 system

Transportation Systems

BOMBARDIER
the evolution of mobility

TOP SUPPLIER AROUND THE WORLD

Driverless monorail systems

Bombardier is a world leader in the monorail systems segment:

- **Over two decades of experience**
- **Flagship performance in urban transportation**
- **Over 600 vehicles ordered or in operation in six cities and airports**
- **Industry-leading system availability levels as high as 99.02%**

BOMBARDIER
the evolution of mobility

THE EVOLUTION OF THE MONORAIL TECHNOLOGY

Technology background

Monorails originated in early 1900s with two different technologies:

Suspended technologies

Schwebebahn Wuppertal, Germany, in operation since 1901

Straddle beam

1950s ALWEG monorail test track in Germany

1st ALWEG monorail in commercial operation, Disneyland 1959

- **ALWEG design attracted attention of Disney**
  - Installed globally in Disney parks
  - Popularised as theme park application
- **ALWEG design is basis for:**
  - Disney, Bombardier Las Vegas, Hitachi

Today, over 50 monorail systems are in operation around the world[1]

[1] The Monorail Society www.monorail.org

BOMBARDIER
the evolution of mobility

YESTERDAY'S PERSPECTIVE OF RAIL SYSTEMS

Technology background

Mass transit systems:

- Underground
- Congested and heavy
- Metro system only option for high capacity service

Monorail systems:

- Elevated
- Futuristic and impractical
- Only suitable for low capacity service; such as amusement parks

GAME CHANGING URBAN TRANSPORTATION SOLUTION

INNOVIA Monorail 300 system

The *INNOVIA* Monorail 300 system incorporates the design and operational features required for rigorous urban line-haul service

- Fully automated and driverless mass transit solution
- Futuristic appearance and aerodynamic design
- Speeds up to 80 km/h
- Minimised headways for highest frequency of service
- Energy efficient technologies
- High passenger capacity
- Superb comfort and ride quality

BOMBARDIER
the evolution of mobility

SUITABLE FOR A RANGE OF APPLICATIONS

Tomorrow's technology today

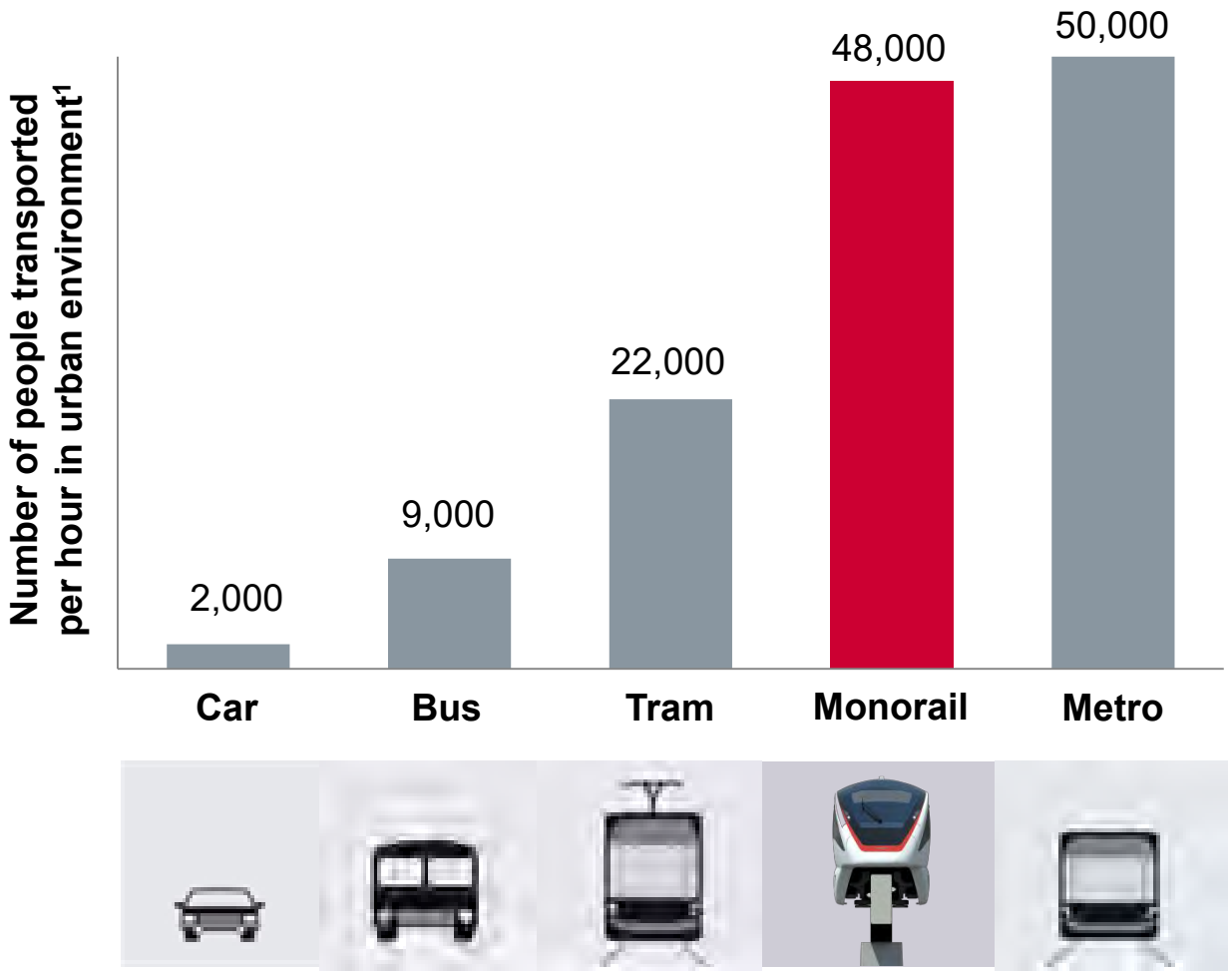
The *INNOVIA* Monorail 300 technology combines the high capacity of mass transit systems with monorail's sleek look and elevated operation

- **Collector distributor**
  - 2,000 to 10,000 pphpd
  - feeder system to mass transit network
  - seamless integration into urban environment (including through buildings and structures)

- **Line haul (medium to high capacity)**
  - 5,000 to 48,000 pphpd
  - frequent and reliable passenger service
  - dedicated right-of-way provides unrestricted operation

A COMPETITIVE SOLUTION

Mass transit capacity



[1] International Association of Public Transport (UITP); Institute for Sustainability and Technology Policy, Murdoch University. Number of people crossing a 3 to 5 metre-wide space in an hour in an urban environment (Monorail added by BT)

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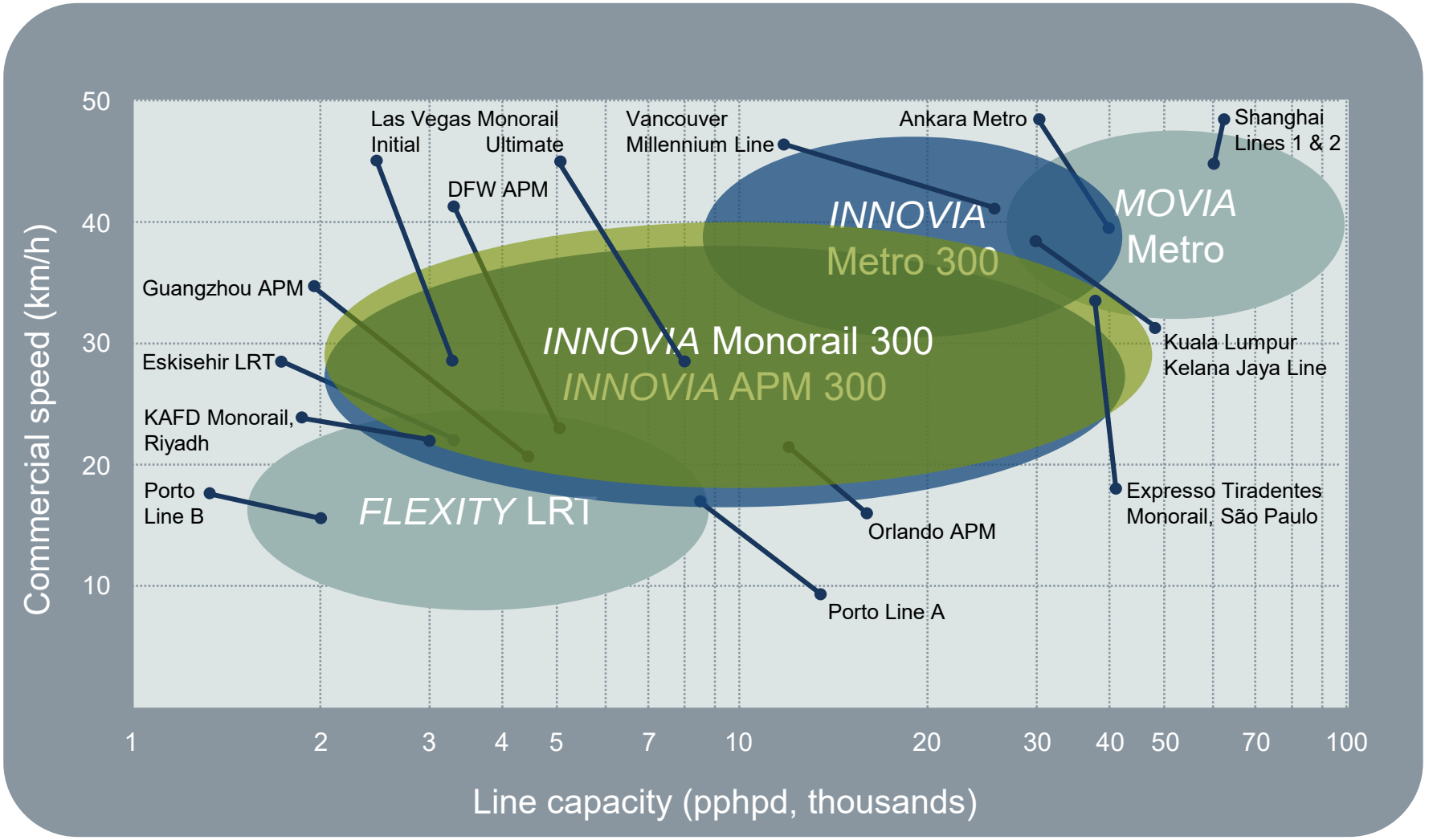
HIGHLY FLEXIBLE CONFIGURATIONS AND CAPACITIES

Top performers



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CAPACITY COMPARISON

INNOVIA Monorail 300 vs. other transit solutions

			Capacity at 6 passenger / m^2		
TECHNOLOGY	DESCRIPTION	NUMBER OF CARS	VEHICLE CAPACITY	120 SECOND HEADWAY	90 SECOND HEADWAY
Heavy metro	Smaller size (Rc+M+M x 2)	6	1,016	30,500	40,600
	Medium size (Rc+M+M x 2)	6	1,508	45,200	60,300
	Large size (Rc+M+M x 2)	6	1,736	52,100	69,400
Monorail	7-car train	7	1,002	30,080	40,000
Tramway	30 metre	1	270	8,100	10,800
	2 coupled 30 metres	2			21,600
	40 metre	1	380	11,400	15,200
	2 coupled 40 metres	2			30,400
Standard bus	With 2 axles	1	85	2,550	3,400
	Articulated	1	121	3,650	4,840
	Bi-articulated	1	173	5,200	6,920
Bus in segregated line	Type milenio Bogota	1	160	22,400	30,000

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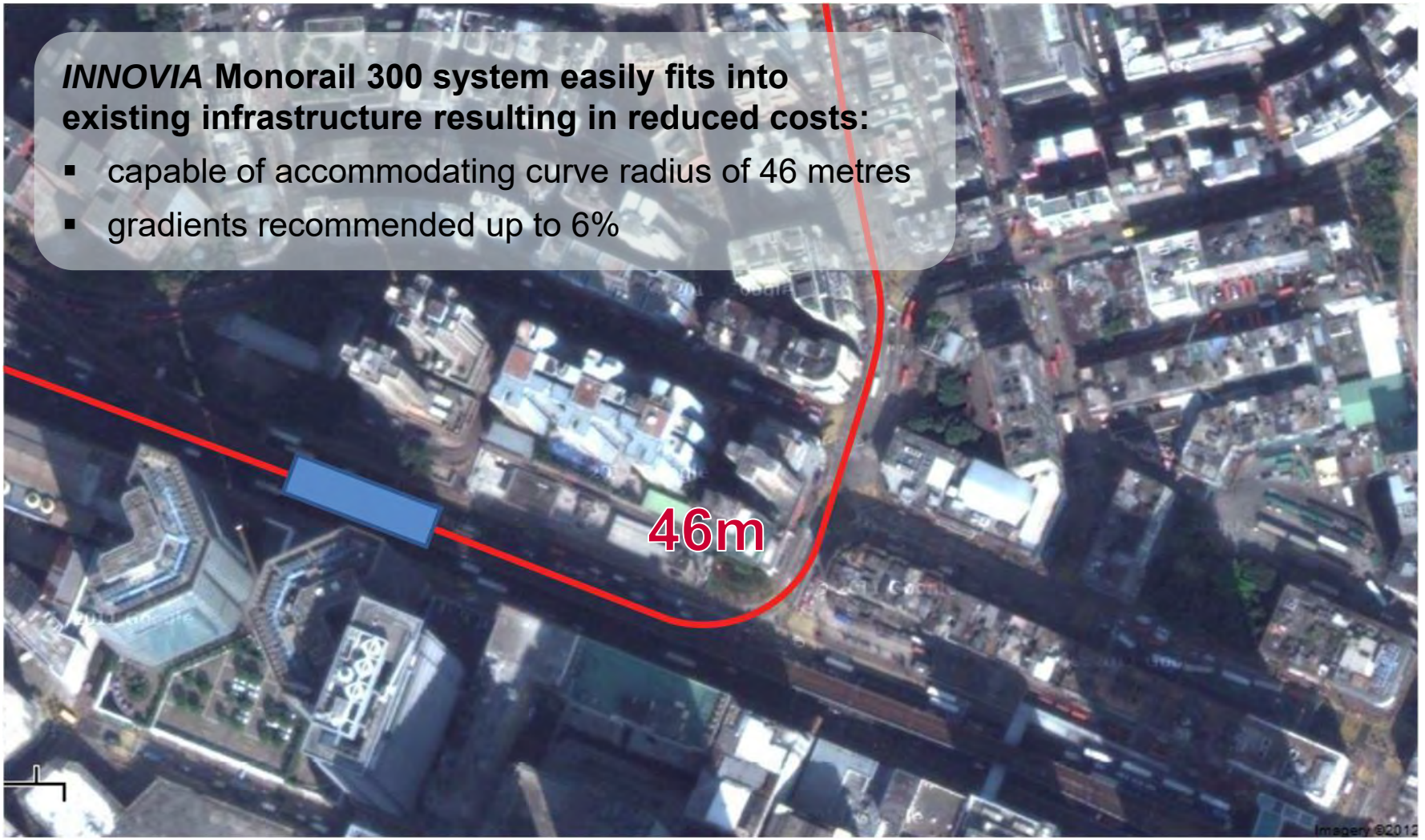
SEAMLESS INTEGRATION AND ROUTE FLEXIBILITY

Urban fit

- Slender guideways are easily integrated into different environments
- Low profile sleek vehicles
- Infrastructure requires minimal land expropriation
- Flexible route alignment
- Sharp curve radii and steep grades
- Designed for seamless integration with buildings and structures
- Unobtrusive stations
- Quiet vehicle operation

ALIGNMENT CAPABILITIES

Urban fit



Satellite picture © Google 2012

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GOOD NEIGHBOUR

Urban fit

TURNKEY APPROACH

Integrated mobility solution

***INNOVIA* Monorail 300 systems were developed as turnkey systems for:**

- integrated system operation
- minimised civil cost impact
- optimised for total lifecycle cost

Key advantages of a turnkey approach:

- one fixed price
- one party responsible
- one source for skilled people
- shorter, more reliable delivery schedule

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FULLY AUTOMATED DRIVERLESS OPERATION

CITYFLO 650 technology

- **Proven technology**
- **Reduces cost of operation**
- **Reduces system maintenance costs**
- **Minimises energy consumption**
- **Allows for very short headways, which enable:**
  - maximum train speed
  - minimum train lengths
  - minimum platform length and civil station costs
  - optimum fleet size
  - minimum wait times (higher frequency of service)
  - high ridership levels

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OPTIMISED SYSTEM FOR MASS TRANSIT APPLICATIONS

Vehicle overview

Train configuration	2- to 8- car trains
Car empty weight	14,000 kg
Maximum gradient	6%
Minimum horizontal curve radius	46 m
Maximum speed	80 km/h
Power distribution	750 Vdc
Propulsion system	Permanent Magnet Motor
Design capacity	
▪ 2-car trains	9,680 pphpd[1]
▪ 4-car trains	20,400 pphpd
▪ 8-car trains	41,840 pphpd

[1] pphpd : passengers per hour per direction

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BUILT TO THE HIGHEST QUALITY STANDARDS

Vehicle overview

- **Aluminium carbody, steel underframe, composite end cap**
- **Independent bogie with secondary suspension**
- **Tinted windows with laminated safety glass**
- **2 bi-parting doors per side of car**
- **Roof-mounted air conditioning units with containing twin HVACs**
- **Complies with NFPA for fire safety**

[1] NFPA

FOCUS ON PASSENGERS

Vehicle interior

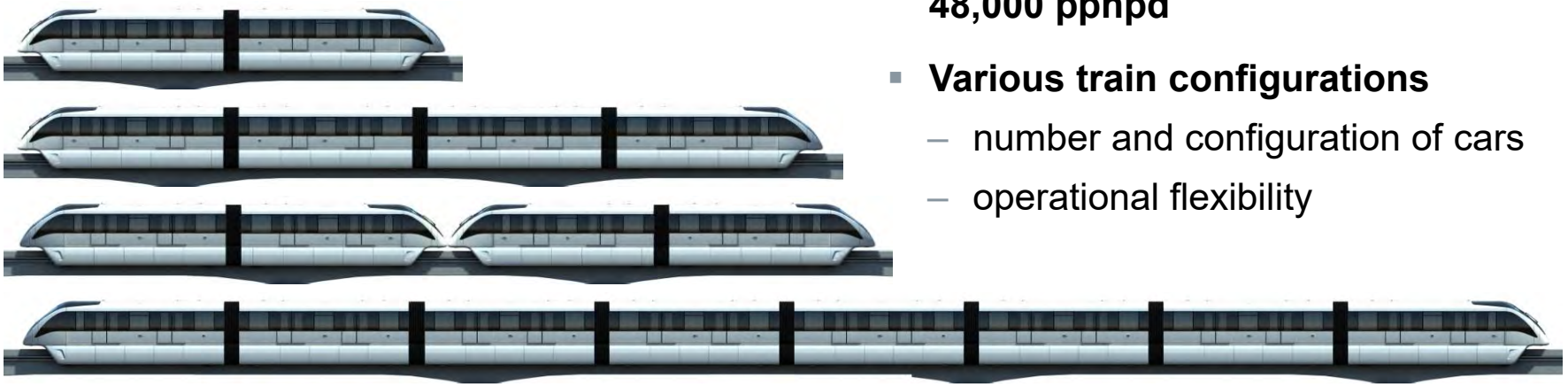
- **Spacious and open vehicle increase passenger comfort**
- **Superior ride quality through independent bogies**
- **Inter-car walk-through provides free passenger flow and enhanced safety**
- **Large windows create bright atmosphere and unique view of city**
- **Low interior noise enhances the ride experience**
- **Passenger information system for clear and timely instruction**
- **Accessible for passengers with disabilities**

HIGH FLEXIBILITY AND CUSTOMISATION

Tailor-made vehicles

- **Customisable exterior design**
- **Flexible interior arrangements**
  - wide choice of colors and materials
  - configurable seating
  - spacious interiors and gangway
- **Customisable static and dynamic signage**

- **Solutions from 2,000 to 48,000 pphpd**
- **Various train configurations**
  - number and configuration of cars
  - operational flexibility



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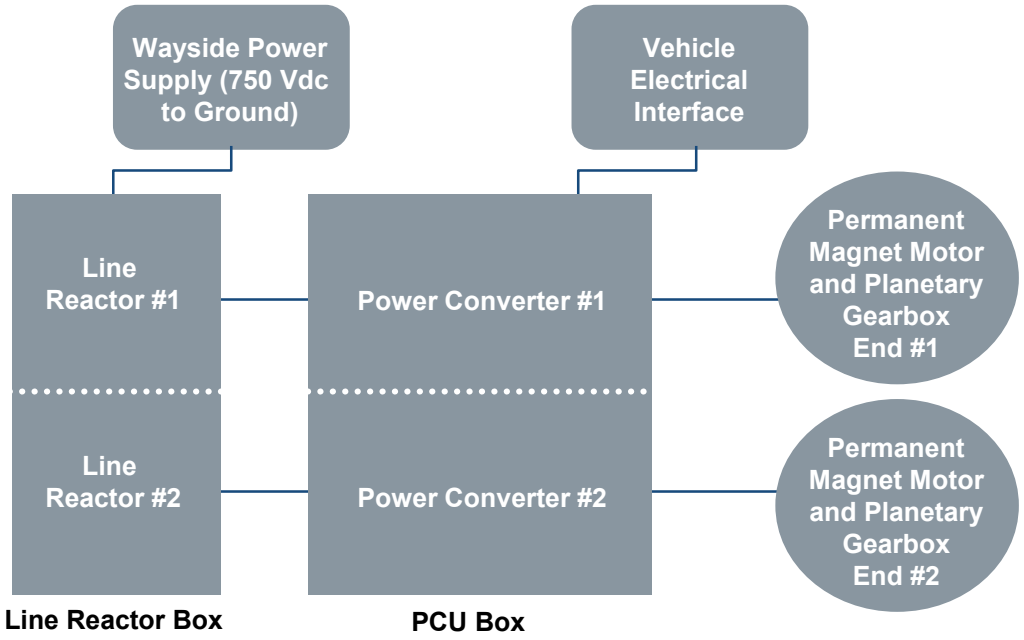
DRIVEN BY INNOVATION AND INGENUITY

Propulsion technology

- **Permanent magnet motor (PMM) designed for *INNOVIA* Monorail 300 system**
- **Rotor creating its own flux by incorporating magnets**
- **Propulsion system maximizing regenerative dynamic braking to minimise use of friction brake**



- **Speeds up to 80 km/h**
- **High capacity transit**
- **Low noise**

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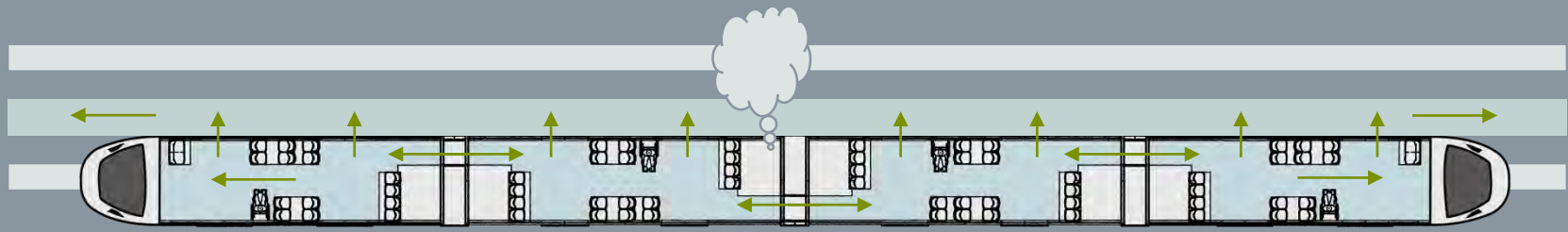
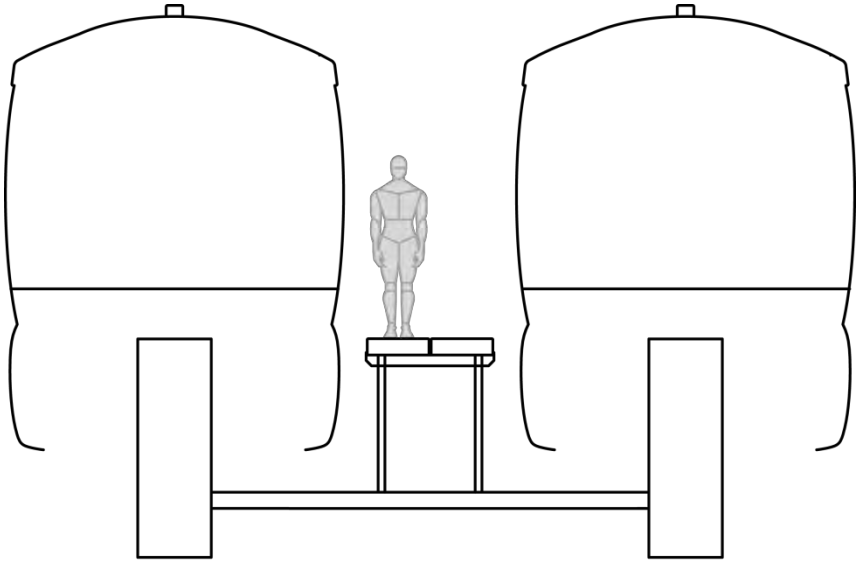
ENHANCED SAFETY WITH UNCOMPROMISED AESTHETICS

Evacuation walkway

Immediate, rapid passenger initiated evacuation from a hazardous situation





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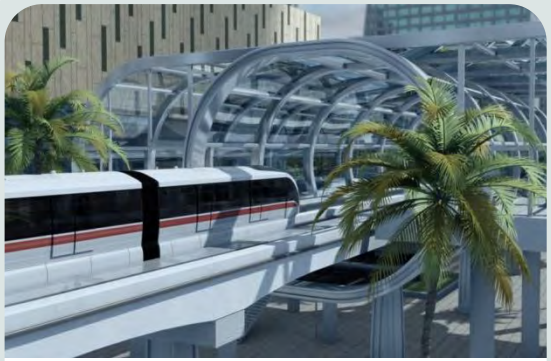
FLEXIBLE ALIGNMENT WITH MINIMUM VISUAL IMPACT

Guidebeams



Concrete structures provide elegant strength and durability as well as:

- **Fast and efficient construction**
- **Affordability**
- **Fire-resistance**
- **Low maintenance**
- **Full compliance to all norms and standards**

Exclusive guidebeams ensure:

- **Dedicated right-of-way unrestricted operation**
- **Accidents with surface traffic are impossible**
- **Derailment virtually impossible**

Unobtrusive evacuation walkway, always recommended for safe egress, allow for:

- **Passenger safety**
- **Easy access for system maintenance**
- **No need for active intervention in an emergency**

COST EFFECTIVE AND EASY INSTALLATION

Guidebeams

- **Infrastructure developed to minimise the cost and disruption of civil construction**
- **Pre-cast lightweight guideway structures built off-site allow rapid assembly on site**
- **Low land intake / low expropriation costs reduce delays and allow for quick progress**
- **Elevated guideway eliminates the need for expensive and time-consuming tunnelling**
- **Easy implementation into different environments (suitable for both greenfield and brownfield)**

FAST AND SMOOTH SWITCHES

Guidebeams

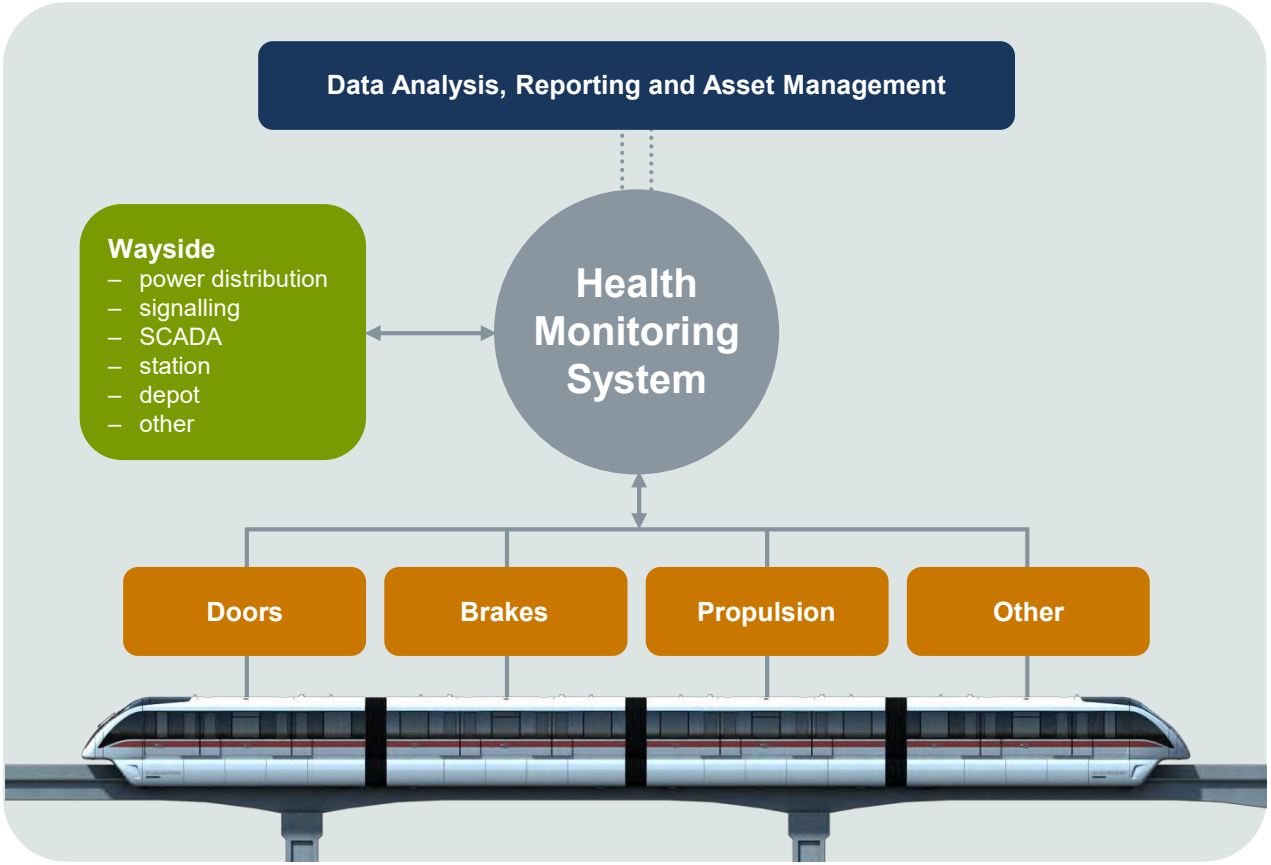
- **Beam replacement or multi-position pivot switches**
  - beam replacement switches are used on the mainline
  - multi-position pivot switches are used in storage yard areas
- **No restriction of system capacity or operating speed**

High speed beam replacement turn out switch

Multi-position pivot switch

New developments in embedded diagnostic systems for vehicle subsystems and wayside systems

- **Collect and analyse data**
- **Data trending and visualisation**
- **Deep visibility into performance**
- **Fast fault finding and resolution**



PREDICTIVE MAINTENANCE

Operation and maintenance (O&M)

Increase availability

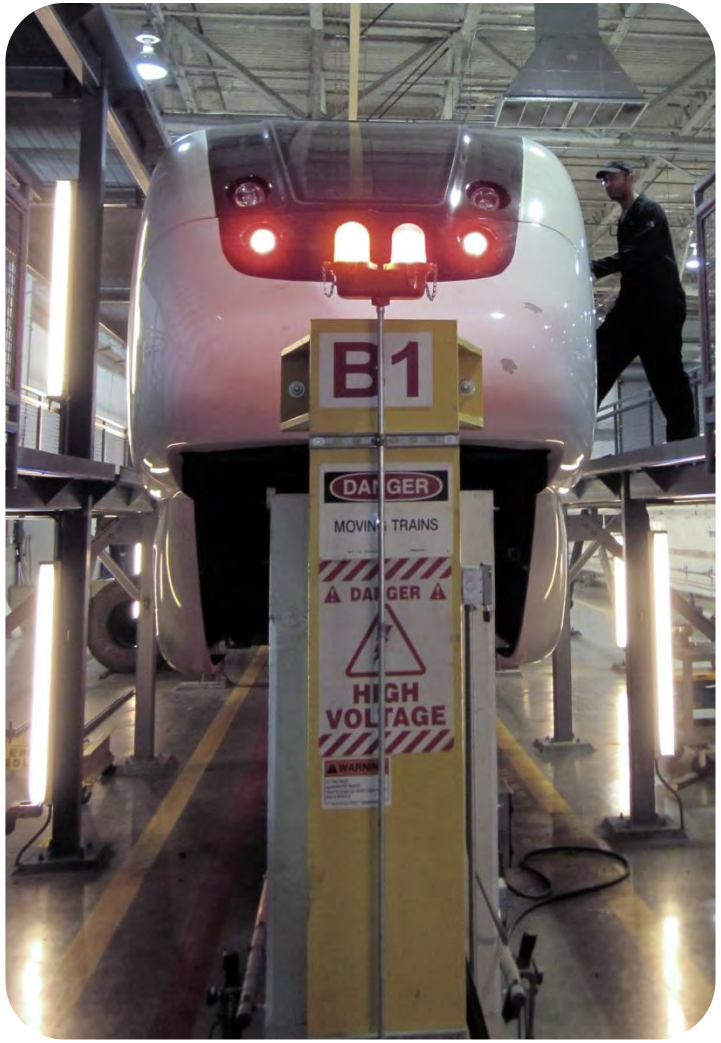
- Minimise service affecting failures
- Track failure trends and mitigate

Improve customer service

- Perform maintenance optimally
  - extends the operating life of the system
  - extends life of equipment

Reduce the total cost of ownership

- Extends maintenance intervals
- Potential elimination of daily/monthly tasks
- Automated vehicle inspections
- Reduce planned maintenance activities
- Reduce spares holdings



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PROVEN TRACK RECORD OF SAFE OPERATIONS

Safety features

- **Driverless operation eliminates risk of human error**
- **Emergency walkway along entire guideway allows safe egress for passengers and safe access to guideway for maintenance crew**
- **Inter-car walk-through enhances passenger safety**
- **Platform screen doors increase station safety, as well as provide climate control**
- **Two-way radio with central control and CCTV cameras on-board and in stations**
- ***SEKURLFO* transit security solution enables operators to protect passengers and property efficiently and cost-effectively**
- **Conservative system design with careful analysis of safe stopping distances**

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LOW SYSTEM AND FLEET COSTS

Lifecycle perspective

- **Lightweight aluminium vehicles reduce energy consumption costs**
- **Standardised for optimised operation and maintenance costs**
- **Driverless operation provide requires less staff and reduces overhead costs**
- ***CITYFLO* 650 automated train control also reduces the costs of service interruptions and corrective maintenance**

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ECO-FRIENDLY SOLUTION

Design for environment

- **Zero emissions**
- **Lightweight aluminium vehicles designed for optimal energy consumption**
- **Intelligent Power Management System**
  - energy efficency
  - optional *EnerGstor* wayside storage for enhanced energy savings
  - *EnerGplan* simulation tool for optimised energy consumption
- **Minimised consumption of construction materials**
- **Low visual impact, easily fits into existing infrastructure**
- **Low exterior noise**
- **Requirements for all suppliers**
  - maximised use of recyclable materials
  - use of environmentally friendly refrigerant

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ENERGY EFFICIENCY

Design for environment

System energy usage optimised through:

- **Aerodynamic, lightweight aluminium vehicles**
- **High percentage of recyclable materials**
- **LED lighting**
- **Automatic train control**
- **Efficient permanent magnet motor propulsion technology**
- **Improved vehicle thermal insulation system**
- **Regenerative braking**
- **Intelligent power management system**
- **Minimal consumption of construction materials**

WAYSIDE STORAGE SYSTEM

Design for environment

Based on modular supercapacitor technology for wayside, the new *EnerGstor* solution provides both economic and environmental benefits.

- Simple interface
- No house power connection required
- No communications connection required
- Only connections are to traction power +ve, -ve and ground

EnerGstor is a trademark of Bombardier Inc. or its subsidiaries.
Artist rendering does not reflect the subtly of the *EnerGstor* unit in colour or location

ENERGY OPTIMISATION SYSTEM

Design for environment

***EnerGplan* Simulation Tool allows the power supply and distribution (PS&D) engineer to optimise the power system configuration, minimise the energy consumption of the entire transit system, and overall analysis of system performance.**

- Graphical interface modelling of fleet energy consumption and operational data
- Combination of energy consumption and operational data into effective management information
- Adaptable to all kinds of vehicles and transportation systems
- Sophisticated analytical tools for comparative fleet analysis to guide

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INCREASING SYSTEM CAPACITY

Future expansions

- ***INNOVIA* Monorail 300 systems can easily accommodate future expansions**
- **Future expansions should be considered in the initial planning stage, but the flexible system design allows for unanticipated extensions and additions**
- **System expansions can be implemented without disrupting passenger service**
- **Expansions can include:**
  - adding new vehicles to an existing system
  - additional vehicles, sections of guideway and stations
  - signalling upgrades and overlays
  - spur lines
  - new operations and maintenance facilities or upgrades to the existing depot

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SUMMARY OF BENEFITS

INNOVIA Monorail 300 system

Technology	▪ **Sleek and attractive vehicles** ▪ **Slender contemporary guidebeams have a subtle presence** ▪ **Unique emergency walkway allows for safe passenger egress** ▪ **Modern solution to transportation needs**
Operation	▪ **Driverless system enhances overall efficiency** ▪ **Frequent, safe and reliable service** ▪ **High service capacity** ▪ **Cost effective transit solution**
Passenger	▪ **Modern visual appeal** ▪ **Spacious vehicle interior** ▪ **Easy access for passengers** ▪ **Comfortable rides**
Environment	▪ **Low visual impact** ▪ **Low noise** ▪ **Zero emissions** ▪ **Energy saving equipment**

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TWENTY YEARS OF URBAN MOBILITY EVOLUTION

Reference projects

Riyadh, Saudi Arabia
INNOVIA Monorail 300 System
In delivery

São Paulo, Brazil
INNOVIA Monorail 300 System
2014 (Phase 1)

Las Vegas, USA
INNOVIA Monorail 200 System
2004

Jacksonville, USA
INNOVIA Monorail 100 System
1998

Newark, USA
INNOVIA Monorail 100 System
1996

Tampa, USA
INNOVIA Monorail 100 System
1991

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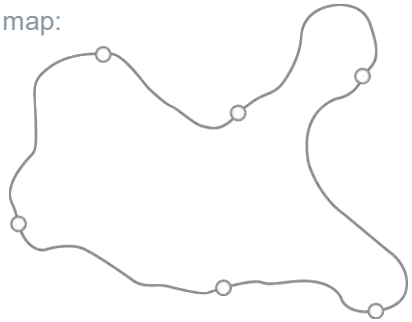
RIYADH, SAUDI ARABIA

INNOVIA Monorail 300 system

System alignment map:



Primary transportation at the new King Abdullah Financial District

In delivery

3.6 km single-beam alignment

6 stations

12 cars (6 two-car trains)

Designed to carry 3,000 pphpd

5.7% maximum grade

***CITYFLO* 650 automatic train control**

Bombardier will provide operations and maintenance services

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SÃO PAULO, BRAZIL

INNOVIA Monorail 300 system

System alignment map:

- **Vila Prudente to Cidade Tiradentes urbanization – extension of the São Paulo Metro Line 2**
- **Revenue service for Phase 1 began in 2014**
- **24 km dual-beam alignment**
- **17 stations**
- **378 cars (54 seven-car trains)**
- **Designed to carry 40,000 pphpd[1]**
- **6% maximum grade**
- ***CITYFLO* 650 automatic train control**

[1] Fleet expansion required to realise full system ridership capacity of 48,000 pphpd

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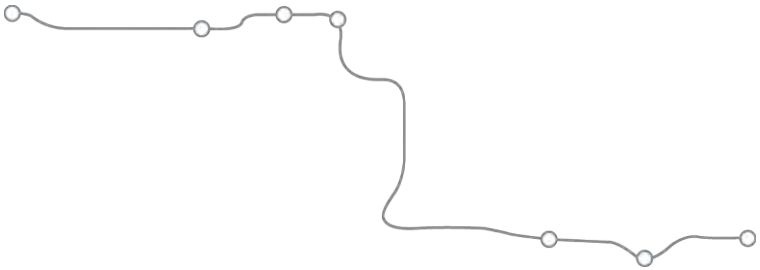
LAS VEGAS, USA

INNOVIA Monorail 200 system

System alignment map:



- **Serves the famous Las Vegas Strip – Sahara to MGM Grand, including Las Vegas Convention Center**
- **Revenue service began in 2004**
- **6.5 km dual-beam alignment**
- **7 stations**
- **36 cars (9 four-car trains)**
- **Designed to carry 3,200 pphpd**
- **6.5% maximum grade**
- **750 Vdc guideway-mounted power rails**
- **Public Private Partnership**
- **Bombardier provided 10 years of operations and maintenance services**

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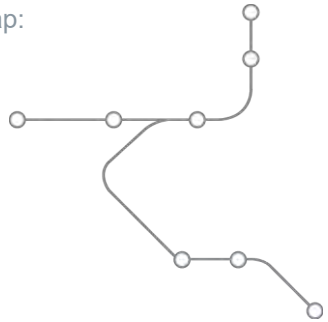
JACKSONVILLE, USA

INNOVIA Monorail 100 system

System alignment map:



- **Downtown Jacksonville – both sides of the St. Johns River**
- **Revenue service began in 1998**
- **5 km dual-beam alignment**
- **8 stations**
- **9 trains**
- **Designed to carry 900 pphpd**
- **8% maximum grade**
- **Guideway-mounted power rail**

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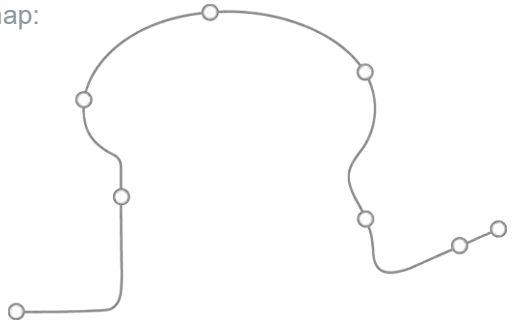
NEWARK, USA

INNOVIA Monorail 100 system

System alignment map:



- **Newark Liberty International Airport – airport terminals to northeast corridor rail line**
- **Revenue service began in 1996**
- **4.7 km dual-beam alignment**
- **8 stations**
- **108 cars (18 six-car trains)**
- **Designed to carry 3,000 pphpd**
- **3.9% maximum grade**
- **Guideway-mounted power rail**
- **System expanded in 2001**
- **Bombardier provides operations and maintenance services**

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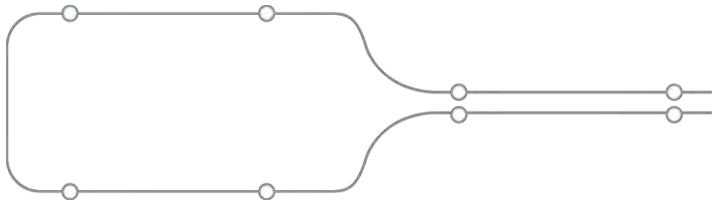
TAMPA, USA

INNOVIA Monorail 100 system

System alignment map:



- **Tampa International Airport – parking garage to main terminal**
- **Revenue service began in 1991**
- **1 km dual-beam alignment**
- **8 stations**
- **6 trains**
- **Designed to carry 680 pphpd (with luggage)**
- **Bombardier provides maintenance services**

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Build Your Dreams

BYD SKYRAIL

State-of-the-Art, Driverless Monorail

BYD's SkyRail is a fully integrated, driverless, state-of-the-art straddle type monorail system that incorporates all of the features needed for rigorous line-haul urban transit applications.

The elevated fixed guideway means there are no at-grade passenger or vehicle collisions.

SkyRail is compliant with all applicable codes and standards, including NFPA 130 and ASCE 21 specifications.

BYD's Iron phosphate batteries are installed in all trains so in the event of a regional power outage, trains can still operate to the nearest station to safely discharge passengers. It also means that power rails are not required in maintenance facilities, greatly reducing electrical arcing risk to maintenance personnel.

SkyRail can be, and already is, constructed far faster, with far less impact, and less costly than any other comparable urban transit system technology because:

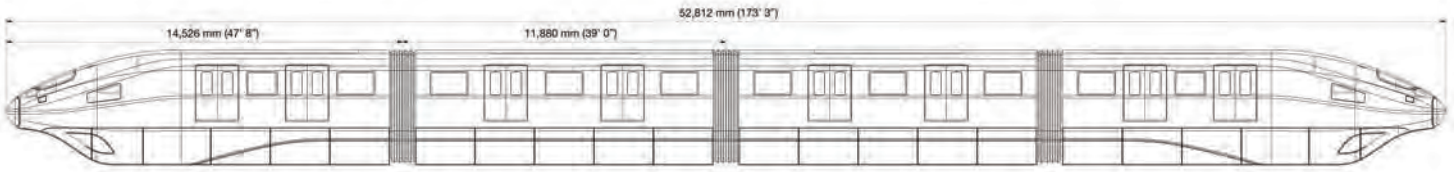
- It uses the smallest, lightest weight aerial structure
- Unlike any other comparable technology, SkyRail's aerial structure provides both the structural support as well as guidance for vehicles in a single guidebeam.
- This makes the footings much smaller and easier to fit into congested corridors with fewer utility relocations, while minimizing costly, time-consuming, and often contentious property acquisition.
- Uses pre-cast structural elements – including columns and beams – which greatly speeds the construction process and minimizes traffic and community disruption.
- As a result, SkyRail is much less costly to construct than conventional elevated technologies and a fraction of the cost of subways.

SkyRail's wide carbody and walk through design facilitates seamless ingress, egress and passenger flow through the train.

Configurable in up to an 8-car fixed consist, or smaller consists coupled automatically, SkyRail systems can move up to 37,200 people per hour per direction with trains operating on two minute scheduled headways (18,780 at U.S. standing space standards).

SkyRail incorporates the 60 years of evolutionary improvements found in other forms of rail transit, including: proven guide-beam switching utilizing transit grade components, state-of-the-art communications based, moving block train control, 5.8 GHz wireless communications, on-board Wi-Fi, and wayside battery energy storage.

SKYRAIL



	BYD SKY RAIL	HIGH SPEED AUTOMATED MONORAIL
Vehicle Data	Type of Vehicle	BYD SkyRail
	Maximum train consist	2-to 8-car trains
	Automatic coupling	2 to 8 car consists form 4, 6, or 8-car trains
Dimensions and Weight	Length (end car overall)	14,525 mm(47'8")
	Length (end car over coupler)	14,050 mm(46'1")
	Length (mid car)	11,880 mm (39' 0")
	Width (overall)	3,165 mm (10' 5")
	Rooftop to top of running surface	3,020 mm (9' 11")
	Doorway width (clear opening)	1,300 mm (51")
	Doorway height (at threshold)	1,850 mm (73")
	Wheelbase (centerline to centerline)	9,114 mm (29' 11")
	Vehicle weight empty (average)	14,000 kg (30,856 lb)
Technical Characteristics	Power distribution	750 Vdc or 1500 Vdc
	Propulsion system	3-phase AC permanent magnet synchronous motor, 2 per car
	Backup propulsion system/Maintentance facility propulsion	on-board rechargeable BYD iron-phosphate batteries
	Vehicle guidance	straddle beam monorail
	Vehicle operation	bi-directional
	Braking	regenerative/friction
	Energy storage	wayside containerized battery energy storage, BYD iron-phosphate batteries
	Suspension	pneumatic spring, self leveling load
	Bogies	2 single axle dual load tires per car with lateral guidance tires
	Carbody	aluminum carbody, steel underframe, composite end cap
	Windows	tinted, single glazed
	Doors	2 bi-parting doors per side per car
	Air-Conditioning	Roof-mounted module containing twin HVAC units
	Fire safety design	floor rating meets ASTM E-119, NFPA 130 compliant
Performance and Capacity	Maximum operating speed	120 km/h (75 mph)
	Nominal cruising speed	105 km/h (65 mph)
	Acceleration rate (service)	1 m/s2 (3.28 ft/s2)
	Brake rate	1 m/s2 (3.28 ft/s2)
	Minimum horizontal curve radius	46 m (150')
	Maximum sustained gradient	10%
	Recommended maximum gradient	6%
	Wheelchair locations	2 per car (flexible)
	Passenger seats per car	
	Perimeter (end car, mid car)	16, 16 (flexible)
	4-across (end car, mid car)	20, 16 (flexible)
	Vehicle capacity (standees + seated) (4-car train, 4-across seating)	
	@ 4 pass./m^2	238 + 72 = 310
	@ 9 pass./m^2	536 + 72 = 608
	Design capacity (4 standees/m^2 / 9 standees/m^2)	
	2-car trains at 2 min scheduled headways	4,560 pphpd / 8,760 pphpd
	4-car trains at 2 min scheduled headways	9,300 pphpd / 18,240 pphpd
	8-car trains at 2 min scheduled headways	18,780 pphpd / 37,200 pphpd

BYD NORTH AMERICA

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SKYRAIL

BYD Company Limited ("Build Your Dreams")

BYD COMPANY OVERVIEW

BYD is a pioneer and global leader in achieving a Zero Emission Energy Ecosystem, offering affordable solar power, reliable energy storage, and electrified transportation. Founded in February 1995, **BYD is a private (non-government owned or controlled) company** that has grown from a start-up rechargeable battery manufacturer into a company with **220 thousand employees** today and 2018 revenues of over $19.4 Billion. Throughout its 24 years of high-speed growth, BYD has established **over 30 industrial parks** across **six continents** and has played a significant role in industries related to electronics, automobiles, new energy and rapid transit. From energy generation and storage to "green" energy applications, BYD is dedicated to providing one-stop zero-emission energy solutions.

BYD is now one of the world's largest manufacturer of rechargeable batteries and battery-electric vehicles, selling more than **50,000 pure battery-electric buses, 8,000 electric trucks,** and **20,000 electric forklifts**. In addition, for four years in a row (2015-2018), BYD has been ranked **No. 1** on the global new energy vehicles (NEV) market, which includes plug-in hybrid and pure electric automobiles.

BYD's global transportation strategy is designed to address the climate crisis, increasing air pollution, and worsening traffic congestion from rapid urbanization. The universal adoption of electrified vehicles can reduce the consumption and dependence on fossil fuel, and further reduce the greenhouse gases emission. As such, BYD has focused on the mass-market adoption of zero-emission, battery-electric vehicles. BYD's initial efforts focus on transit buses, coaches, taxis, consumer vehicles, logistic vehicles, construction vehicles, and waste management vehicles; with a specific focus on vehicles in the warehouse, mining, airport, and port & terminal environments.

An ongoing innovator and investor, BYD owns **15,000+ patents**, and has applied for 24,000 patents globally. BYD's stock is publicly traded on the Hong Kong Stock Exchange, its annual reports and stock ownership are reported publicly in our annual reports, and Berkshire Hathaway, based in Nebraska, is the largest public shareholder of BYD's H-Shares. Throughout the world, we are committed to our BYD mission: **"technological innovations for a better life."**

BYD SKYRAIL

To further expand our global clean mobility initiative, BYD invested seven years and $ 2.2 billion on automated rapid transit system development, including $700+ million on SkyRail. This autonomous straddle-type monorail system is a cost-effective alternative to traditional subway and light rail systems for addressing traffic congestion problems in urban areas. It has strong advantages, including high-capacity, high-speed, driverless operation, and an iconic, progressive image that is much more compatible with the urban fabric than any other elevated alternative..

SkyRail can be constructed far faster, with far less impact, and is much less costly than any other grade-separated urban transit system, primarily because its narrow pre-cast guide beams both support and guide the vehicles, thereby requiring a fraction of the concrete and steel (and labor hours) to construct than any other elevated technology. SkyRail systems can move nearly 19,000 passengers per hour per direction (pphpd) at U.S. standing space standards, at speeds up to 75 mph, with wide, walk-through trains operating on two-minute scheduled headways. SkyRail incorporates the 60 years of evolutionary improvements found in other forms of rail transit.

To date, BYD has conducted feasibility studies in over 100 large cities and metropolitan areas around the globe. Under a single point of responsibility for project delivery, BYD aleady has constructed five SkyRail projects since publicliy announcing the technology in 2016. In 2019, BYD signed the final agreement for our newest SkyRail Project: SkyRail Bahia – a 12.4 mi SkyRail system in Salvador, Brazil; and construction will commence in Q1 2020.

BYD SKYSHUTTLE

BYD's SkyShuttle is the world's first rechargable, battery-electric, grade separated, autonomous, sustainable, and higher speed solution to the"First Mile/Last Mile" and short urban line haul challenge that all cities face in striving to create a viable mobility alternative to the private automobile. SkyShuttle was developed specifically to meet this challenge through the full integration of electric propulsion and guidance components proven in our electric bus and SkyRail programs as the world's leading provider of green, sustainable, fully integrated transportation systems.

The simple low cost, low profile, modular pre-fabricated elevated structure supports attractive small vehicles that can operate as a single car or in trains at very high frequencies (every 90 seconds), at speeds up to 50 mph (80 km/hr), providing a peak hour carrying capacity of up to 12,000 pphpd (again, at U.S. standing space standards). No costly and risky underground construction is required.

A COMMITMENT TO LOCAL MANUFACTURING AND MEANINGFUL JOBS

BYD's partnership with the City of Lancaster, California, Los Angeles County, helped launch and grow the firm's battery-electric vehicle business in North America.

- ✓ The company is now **the largest manufacturing employer in Lancaster** as well as one of the largest renewable energy employers and private sector employers in Los Angeles County.
- ✓ BYD Lancaster staff: 750 (625 production); with a **diverse workforce (comprised of 85% minorities);** includes veterans and a growing number of women and second chance employees, all achieved in cooperation with Jobs to Move America.

- ✓ The only pure electric vehicle manufacturer in the U.S. with an all-union workforce.
  - **Exceeding Buy America**, as verified by ongoing FTA audits
- ✓ First opened in 2013, our Lancaster plant's last expansion, completed in 2017, created a:
  - **Quadrupling of our manufacturing plant** size to 446,000 square feet;
  - **60% increase in jobs** from 500 to more than 750;
  - **25% increase in annual revenue for the City of Lancaster**; and
  - **35% increase in overall jobs supported annually in the area**.
- ✓ BYD North America's **state-of-the-art manufacturing plant is ISO 9001 Certified.**
- ✓ BYD's 100,000 square-foot warehouse opened in 2018 providing more space to produce and deliver our vehicles. The addition grew the **plant's overall footprint to 556,000 square feet**.

BYD'S COMMITMENT TO LOCAL MANUFACTURING FOR SKYRAIL AND SKYSHUTTLE

BYD also is fully committed to manufacturing SkyRail and Sky Shuttle vehicles in Los Angeles County.

- ✓ BYD has **purchased another 154 acres in Lancaster** for the manufacturing of SkyRail & SkyShuttle vehicles and systems. The land is in the design and permitting stage, and is estimated to create up to 1000 jobs alone, just for creation of the facilites.
- ✓ BYD is fully committed to achieving or exceeding the same minority, disadvantaged, women, and veteran participation goals it has achieved for the existing electric bus and truck plant.

BYD Transit Solutions LLC. is a wholly-owned subsidiary of BYD Company Limited. BYD SkyRail was established for the primary purpose of implementing and operating BYD SkyRail and Sky Shuttle systems in North America. Its performance is backed and guaranteed by the parent company.

Build Your Dreams®

SkyRail Project List						
No.	Name of Project	Geographic Information		Alignment		Project Status
		Country	City	Length (mi)	# of Stations	
1	Pingshan Campus	China	Shenzhen	2.7	3	In Operation
2	Yinchuan Flower Garden		Yinchuan	3.5	8	In Operation
3	Guang'an SkyRail		Guang'an	6.8	7	Final Testing & Commissioning
4	Jining SkyRail		Jining	5.9	6	Final Testing & Commissioning
5	Shantou SkyRail		Shantou	3.1 + 9.1	4 + 11	Constructed + In Planning
6	Bahia State SkyRail	Brazil	Salvador	12.4	19	Construction Starting in Mid 2020
7	Transbay Connector	United States	Undisclosed - South Florida	3.5+	3+	In Planning
8	Intermodal Multi-Venue Connector		Undisclosed - Southern California	1.9	4	In Planning
9	Intermodal Venue Connector		Undisclosed - Southern California	1.5	2	In Planning
10	Regional Mass Transit Corridor		Undisclosed - Southern California	19	8+	In Planning

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Constructed SkyRail Project Photos

Shenzhen

- 2.7 mi, operation in pinched-loop configuration
- 3 stations

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Yinchuan

- 3.5 miles, operation in open loop configuration
- 8 stations

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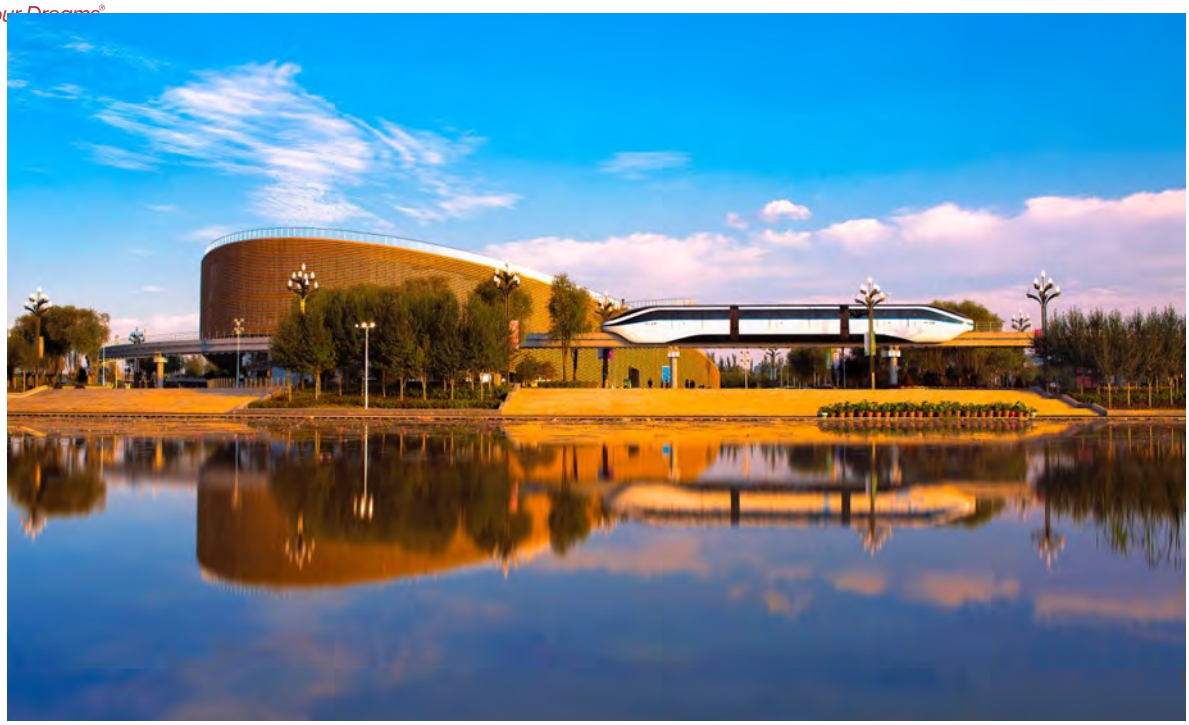


欢迎乘坐比亚迪云

Build Your Dreams®

Guang’an, China:

- 6.78 mi, pinched-loop operation
- 7 stations

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Jining, China

- 5.93 mi, pinched-loop operation
- 6 stations

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Shantou

First Phase:

- 3.1 mi, pinched loop operation
- 4 stations

Second Phase (Not Yet in Construction):

- 9.1 mi, 11 stations


汕头大学
SHANTOU UNIVERSITY

Build Your Dreams®

Salvador, Brazil

- 12.4 mi, 19 stations
- Construction starting in mid 2020
- Project involves:
    - Property development rights near stations
    - Retrofit of existing freight rail bridge over water crossing

中国中车
CRRC

Series Products of New Generation Straddle Monorail Vehicle of CRRC Changchun

中车长春轨道客车股份有限公司
CRRC CHANGCHUN RAILWAY VEHICLES CO., LTD.
重庆中车长客轨道车辆有限公司
CHONGQING CRRC RAILWAY VEHICLES CO.,LTD.

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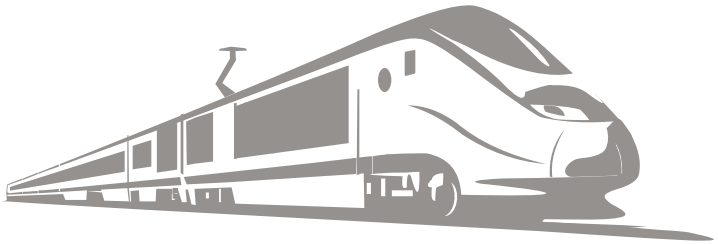


CRRC

I. Development of Straddle Monorail Vehicle

Development of Straddle Monorail Vehicle of CRRC Changchun

- First generation introduced monorail vehicle
- Structure of 4-car marshaled vehicle

Technology introduction
Digestion and absorption

2004

- Second generation large-sized monorail vehicle developed independently
- Structure of 4,6,8-car marshaled vehicle

Independent research and development
Full realization of localization

2009

- New generation Straddle monorail vehicle
- Serialized products

Serialization, intelligence and lightweight
Application of advanced technology

2016

After more than 10 years of continuous development, CRRC Changchun Monorail has undergone a process from technology introduction to completely independent innovation, and has formed a platform-based and diversified monorail vehicle product series.

I. Development of Straddle Monorail Vehicle

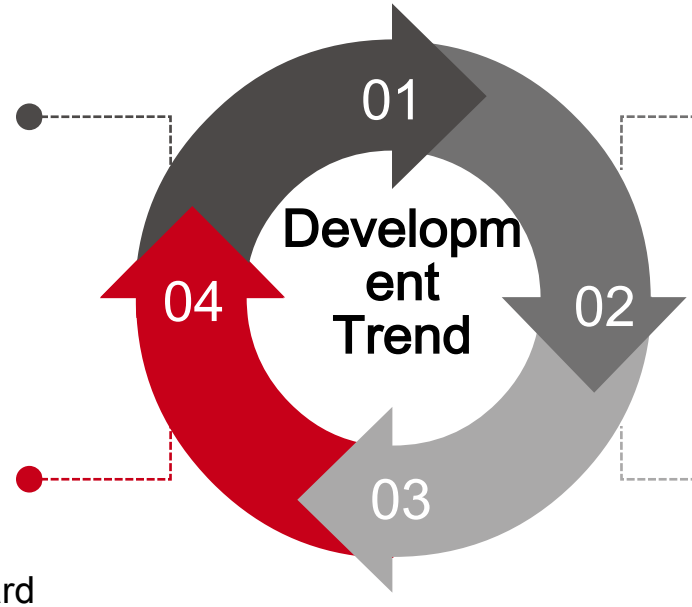
Development Trend of Straddle Monorail Vehicle

Diversification

Diversified and customized vehicle configuration and modeling design meet the different operational needs of users.

Intelligence

Achieve unmanned vehicle driving, automatic fault diagnosis, as well as operation and maintenance analysis and management through the high-speed intelligent system.



Humanization

People-oriented high-standard safe operation configuration and selection of green vehicle materials to achieve safe and green application of vehicles.

Lightweight

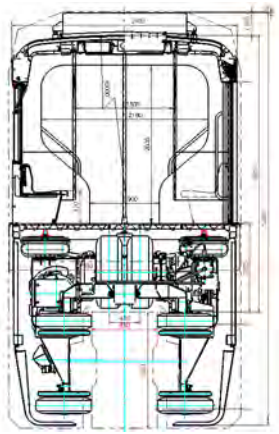
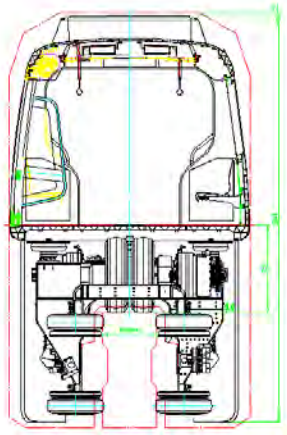
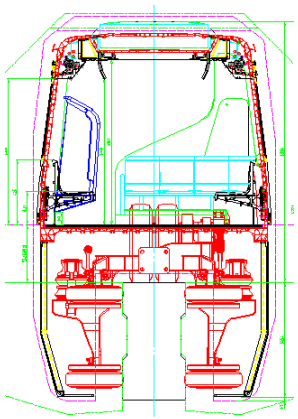
Modular and integrated design, lightweight structure construction, and selection of lightweight materials to achieve reduction of vehicle energy consumption.

II. Introduction to Straddle Monorail Vehicle of CRRC Changchun

1. Straddle Monorail Platform Series Product of CRRC Changchun

- The platforms of Straddle Monorail Technology Division of CRRC Changchun Railway Vehicles Co., Ltd. have a full range of products. Its large, Small and Medium and small vehicles can meet the selection needs of different users.



II. Introduction to Straddle Monorail Vehicle of CRRC Changchun

2. Realization of Full Transport Volume Demands of Straddle Monorail Vehicle of CRRC Changchun

1) Large Straddle Monorail

- Formation type: 4/6/8
- Passenger capacity: 962/1466/1970 persons
- Minimum radius of horizontal curve: 50m
- One-way hourly carrying capacity: 28,000~59,000 person-time/hour
- Train length (mm): 60200/89400/118600
- Acceleration: 1.0m/s^2
- Maximum operating speed: 80km/h
- Maximum gradient: 60‰

II. Introduction to Straddle Monorail Vehicle of CRRC Changchun

2. Realization of Full Transport Volume Demands of Straddle Monorail Vehicle of CRRC Changchun

2) Small and Medium Straddle Monorail

- Formation type: 2/3/4
- Passenger capacity: 386/589/792 persons
- Minimum radius of horizontal curve: 50m
- One-way hourly carrying capacity: 11,000~23,000 person-time/hour
- Train length (mm): 27300/40000/52700
- Acceleration: 1.0m/s^2
- Maximum operating speed: 80km/h
- Maximum gradient: 60‰

II. Introduction to Straddle Monorail Vehicle of CRRC Changchun

2. Realization of Full Transport Volume Demands of Straddle Monorail Vehicle of CRRC Changchun

3) Small Straddle Monorail

- Formation type: 2/3/4
- Passenger capacity: 270/411/522 persons
- Minimum radius of horizontal curve: 50m
- One-way hourly carrying capacity: 8,000~16,000 person-time/hour
- Train length (mm) : 24360/35180/46000
- Acceleration: 1.0m/s^2
- Maximum operating speed: 80km/h
- Maximum gradient: 60‰

II. Introduction to Straddle Monorail Vehicle of CRRC Changchun

2. Realization of Full Transport Volume Demands of Straddle Monorail Vehicle of CRRC Changchun

- **Comparison of Straddle Monorail Models**

	Large	Small and Medium	Small
Width of track beam (mm)	850	850/690	850/690
Vehicle dimensions (mm)	Length: Mc15500/M14600 Width: 2980 Height: 5300	Length: Mc13650/M12700 Width: 3093 Height: 5300	Length: Mc12180/M10820 Width: 2980 Height: 4412/4462
Height from rail surface to floor (mm)	1130	1130	700/450
Number of axles	4	4	2
Empty weight (ton)	≤27	≤20	≤16
Marshaling (number of cars)	4/6/8	2/3/4	2/3/4
Passenger capacity (person)	962/1466/1970 persons	386/589/792 persons	270/411/522 persons
Carrying capacity (person/hour)	28860/43980/59100 persons	11580/17670/23760 persons	8100/12330/16560 persons
Application	Branch lines and connections of first-tier cities; trunk lines of second-tier cities.	Trunk lines, branch lines or connections of second- and third-tier cities; tourist lines in scenic areas.	Tourist lines in scenic areas; trunk lines, branch lines or connections of third-tier cities.
Optional configuration	Unmanned driving, emergency traction, automatic reconnection, high-voltage direct-feed variable-frequency air conditioning, and DC750V/3000V power supply system.		

II. Introduction to Straddle Monorail Vehicle of CRRC Changchun

3. Technical Features of Straddle Monorail Vehicle of CRRC

On the basis of keeping the proven technology of the first generation and second generation monorail together with ten years of large transport volume operation experience and learning from technical advantages of monorail at home and abroad, CRRC Changchun develops the new straddle monorail vehicle with the latest urban rail transit technology.

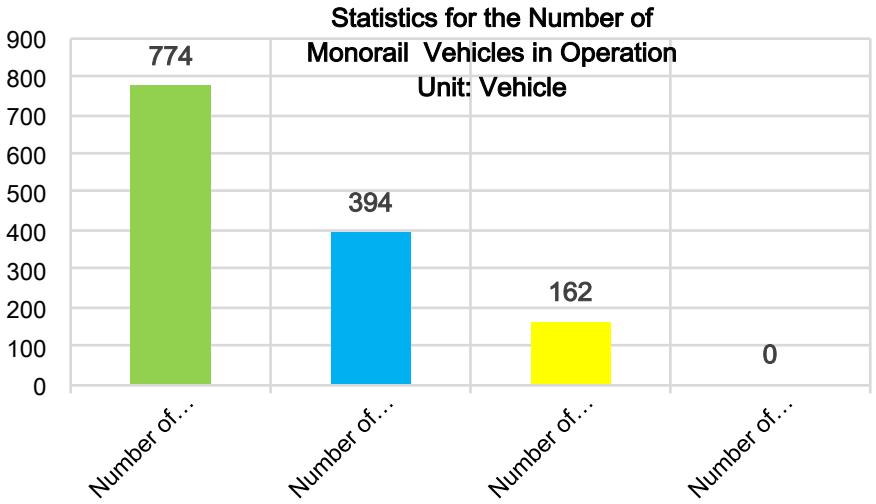
III. Introduction to Straddle Monorail Vehicle of CRRC Changchun

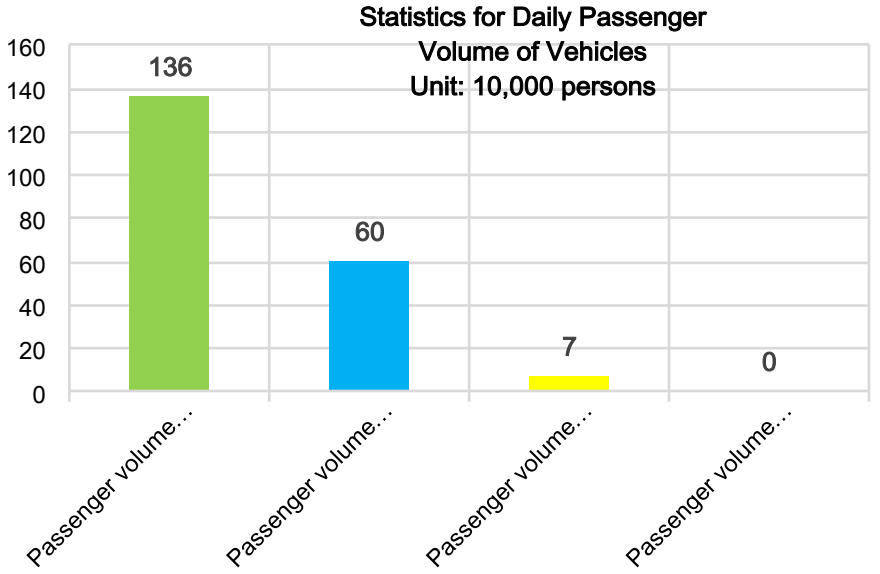
3. Technical Features of Straddle Monorail Vehicle of CRRC

- **Proven technology and rich performance**

With safe and stable operation, the vehicle technology platform has passed the operation test of large passenger flow in China;

The vehicle technology platform has the longest vehicle operation mileage opened to traffic and the largest number of in-operation vehicles in the world.

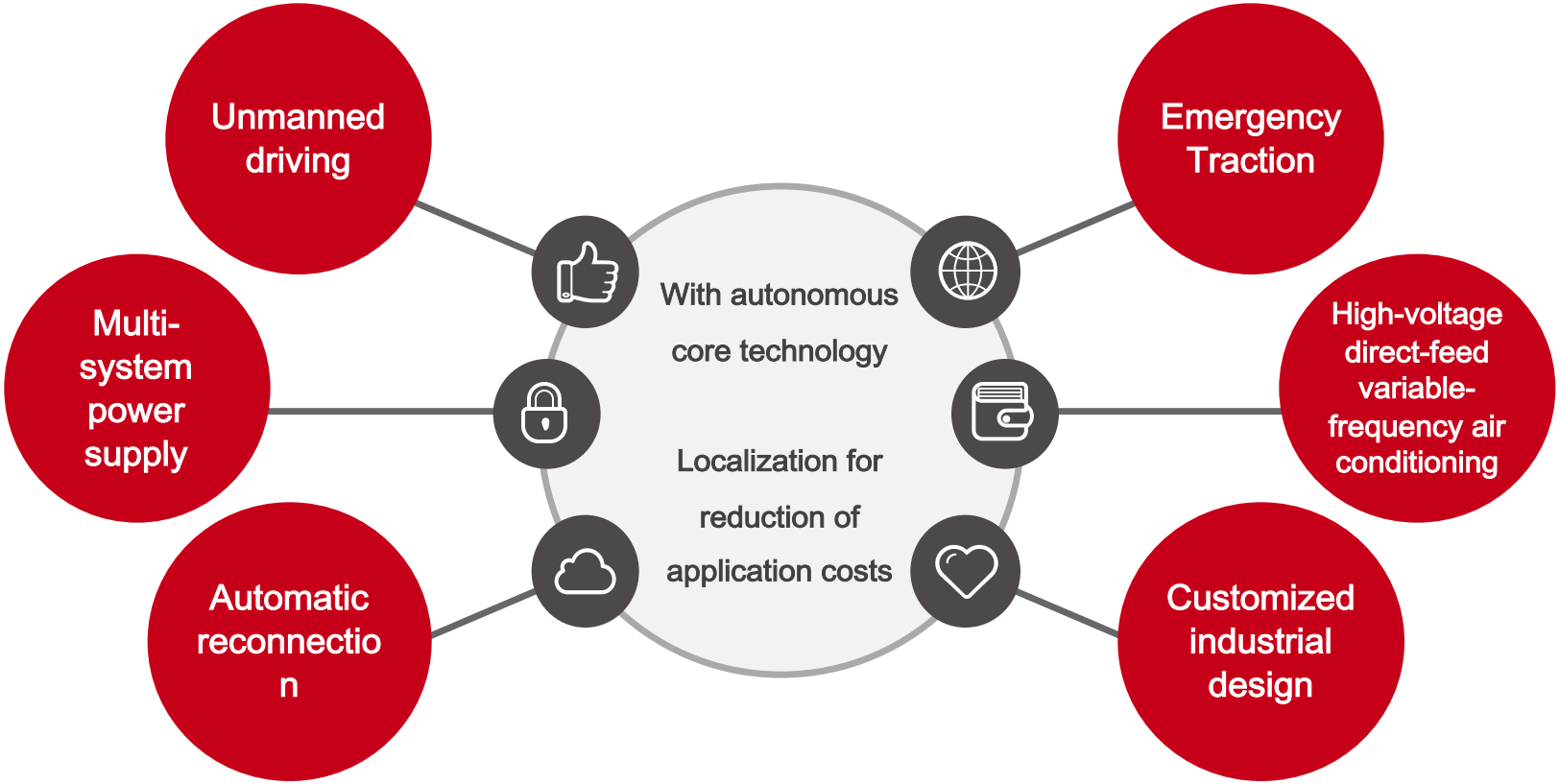




II. Introduction to Straddle Monorail Vehicle of CRRC Changchun

3. Technical Features of Straddle Monorail Vehicle of CRRC

- Personalized and customizable



II. Introduction to Straddle Monorail Vehicle of CRRC Changchun

3. Technical Features of Straddle Monorail Vehicle of CRRC

- **Modern and Stylish Art Design**

Modern shape design that keeps pace with the trend of the times

People-oriented, stylish and modern interior effects control

II. Introduction to Straddle Monorail Vehicle of CRRC Changchun

3. Technical Features of Straddle Monorail Vehicle of CRRC

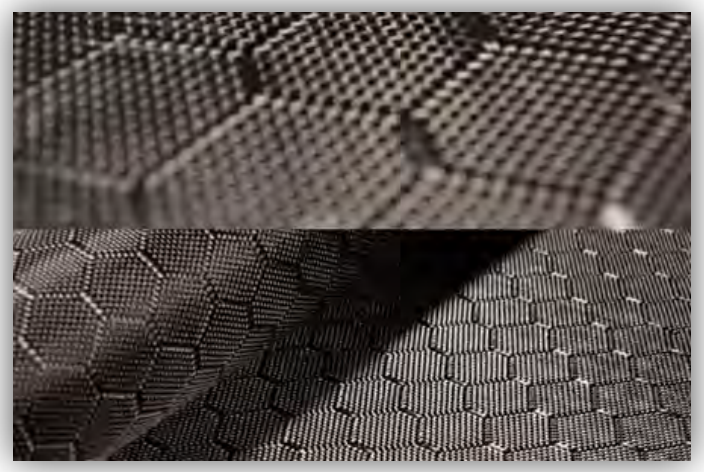
- **Energy saving and environmental protection**

Strict control of hazardous substances;

Adopt green material;

Environmentally friendly coating;

Lightweight, energy-saving and consumption reduction.



II. Introduction to Straddle Monorail Vehicle of CRRC Changchun

3. Technical Features of Straddle Monorail Vehicle of CRRC

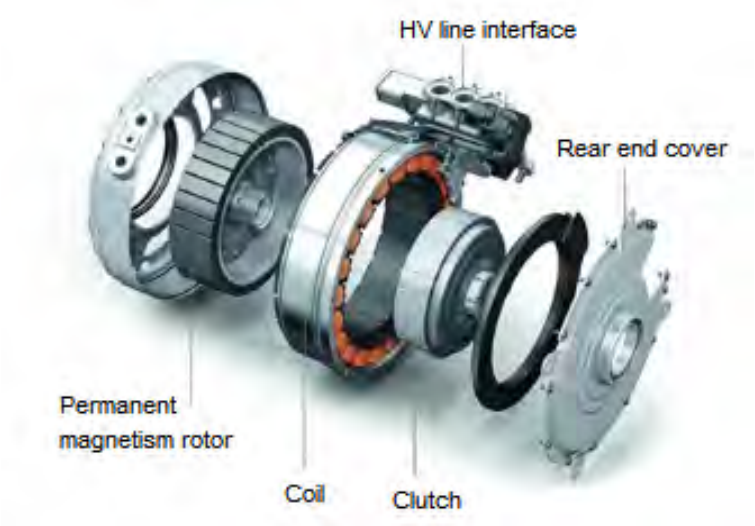
- **New Technologies and New Materials**

Permanent magnet motor technology;

Application of carbon fibercomposite;

Proven unmanned driving technology;

Automatic fault diagnosis and intelligent operation and maintenance.



II. Introduction to Straddle Monorail Vehicle of CRRC Changchun

3. Technical Features of Straddle Monorail Vehicle of CRRC

- **Strong environment applicability**

Vehicle: -40℃~+50℃ all-weather adaptation;

Device configuration adapts to snowy and freezing environment.

II. Introduction to Straddle Monorail Vehicle of CRRC Changchun

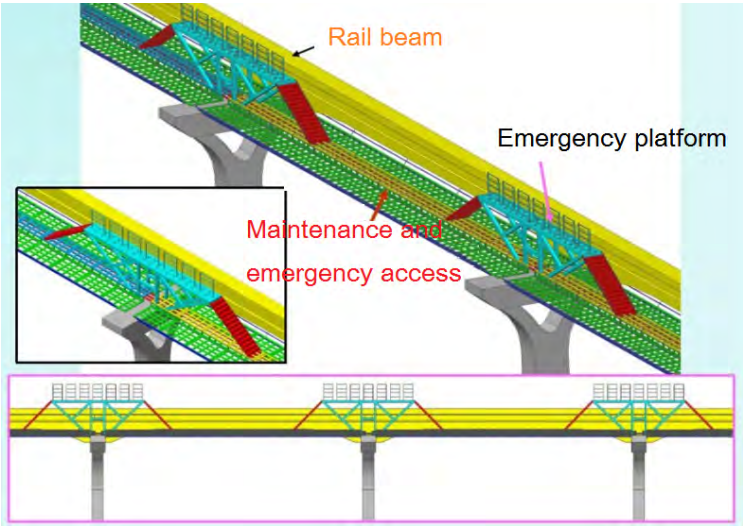
3. Technical Features of Straddle Monorail Vehicle of CRRC

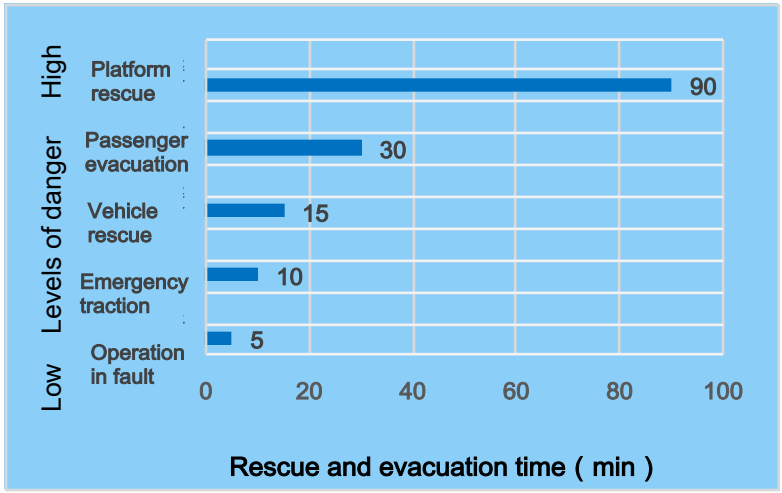
- **Safety Assurance**

Dual backup fault rapid processing;

Emergency traction emergency route disposition;

Several rescue and emergency evacuation plans.





III. Solutions

As the first domestic vehicle manufacturer to carry out research and development of the Straddle monorail, CRRC Changchun Railway Vehicles Co., Ltd. has successfully produced the first Straddle monorail train in China, and possesses a strong technical reserve.

The monorail vehicle platform of CRRC Changchun Railway Vehicles Co., Ltd. is of proven technology and rich performance and can provide different solutions to users according to city characteristics, transport capacity demand and actual environment and we look forward to your choice.

中国中车
CRRC

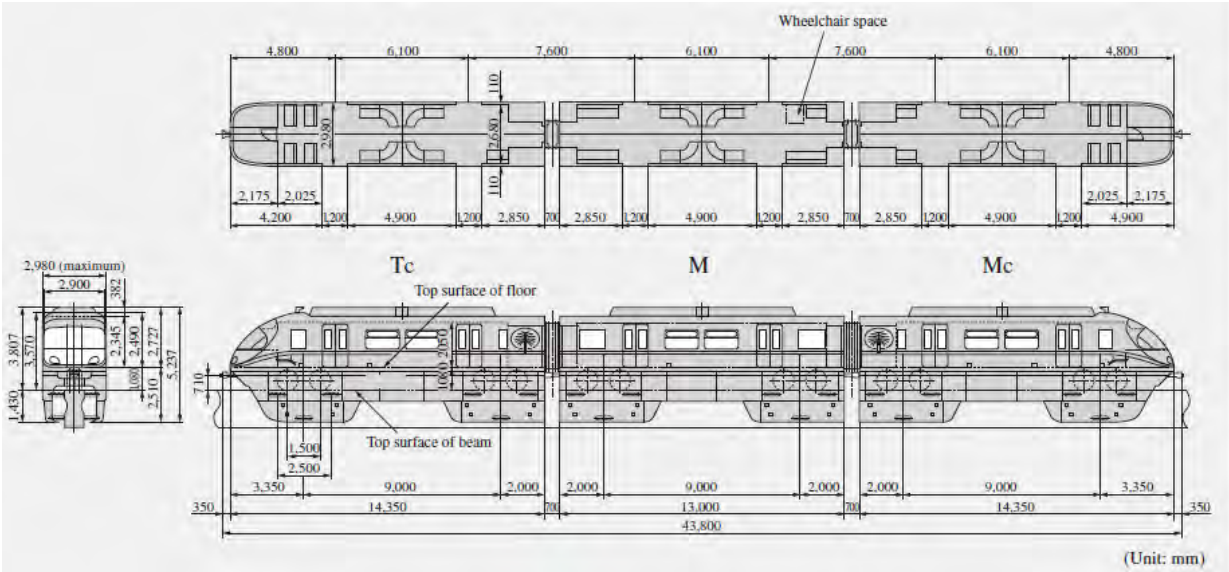
Palm Jumeirah Monorail, Dubai, UAE

HITACHI
Inspire the Next

Hitachi Monorail vehicles are available in small, middle and large sizes, each of which has different dimensions and axle loads

The monorail line (5.4km) connects the Palm Jumeirah to the mainland. The line opened on April 30, 2009 and is the first monorail in the Middle est

Item	Description
Vehicle type	Straddled Monorail
Trainset config.	3-car (Tc-M-Mc)
Passenger capacity	Tc and Mc: 98 M 106
Power feeding	DC 1500 V
Track beam width	800mm
Axle load	10t
Acceleration	1.0m/s2
Decelaration	1.11 m/s2 in normal operation 1,25 m/s2 in emergency
Maximum speed	70 km/h
Dimensions	Total lenght:43.8 m Width: 2.9 m
Operation	ATO driverless with attendant

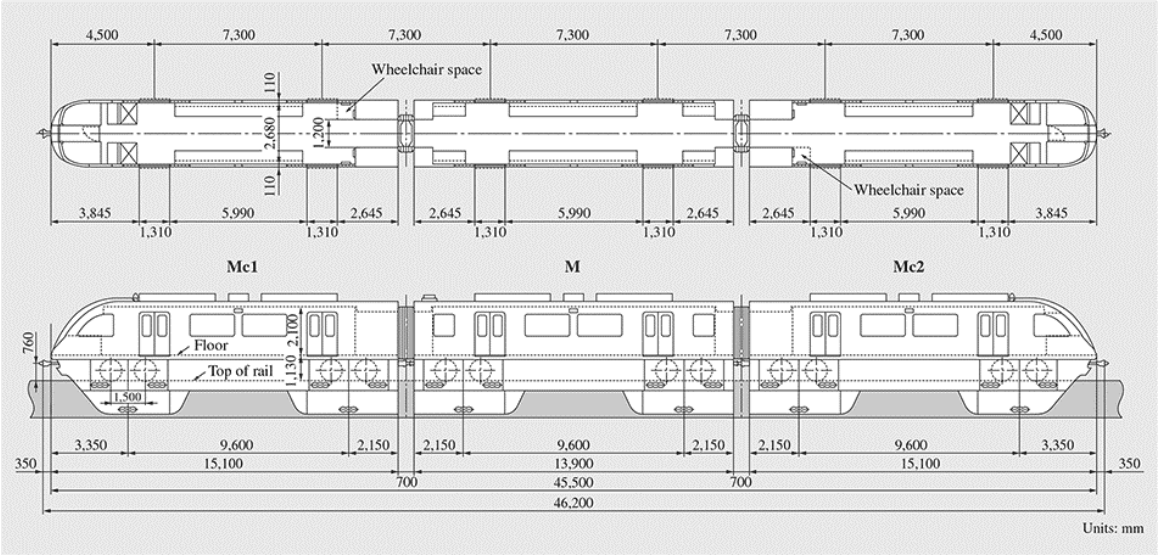


Daegu Metro Line No.3 Monorail, Korea

HITACHI
Inspire the Next

The Daegu Line 3line (24km) was opened in 2015 and is Korea's first straddle-type monorail Daegu Metro. Hitachi was contracted for the supply of monorail, track switches and signalling system.

Item	Description
Vehicle type	Straddled Monorail
Trainset Configuration	3-car (Mc1-M-Mc2)
Passenger capacity	265 (Mc1:84 Mc2: 84 M:97)
Power feeding sys.	DC1500 V
Track beam width	850mm
Axle load	11 t
Acceleration	1.0m/s2
Decelaration	1.11 m/s2 in normal operation 1,25 m/s2 in emergency
Maximum speed	70 km/h
Dimensions	Total lenght:43.8 m Width: 2.9 m
Operation	ATO driverless with attendant



Sentosa Express

HITACHI
Inspire the Next

Sentosa Express line (2.1km) was opened in 2007 and is connecting Sentosa Island to Harbourfornt on the Singapore mainland across the waters (4 stations: Vivocity, Resort World, Imbiah, Beach)

The straddle-type small monorail system was developed by Hitachi in Japan as a small, standard and cost-effective solution to the transportation needs of small to medium-sized cities. Some other features of the straddle-typed small monorail include being small in size, light and producing low noise levels; the capability of a greater passenger carrying capacity; a slim guide way structure as well as lower construction costs.

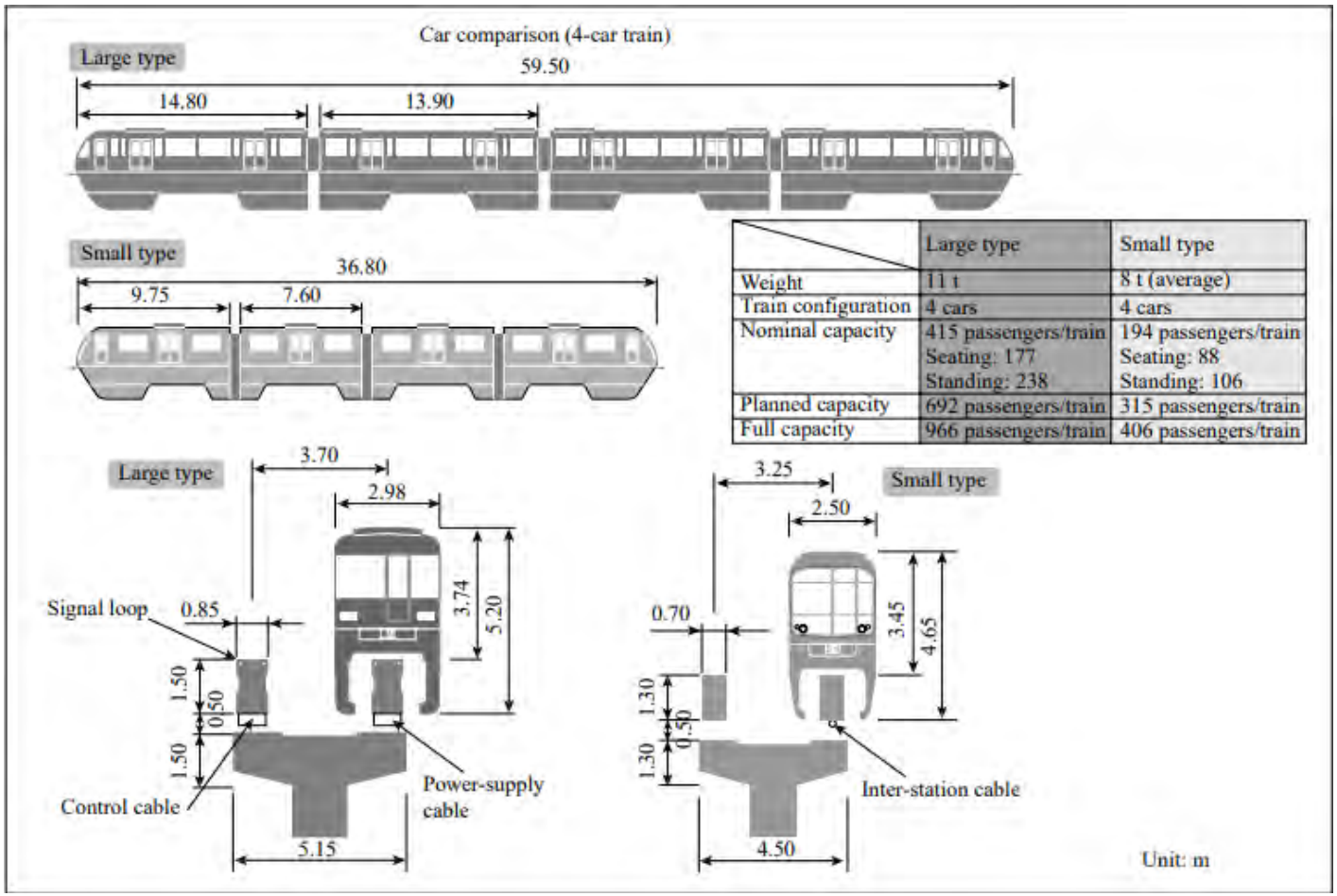
Since November 2017 Hitachi's Moving-block Wireless CBTC is in operation. The new system also includes an Automatic Train Operation (ATO) function, allowing the trains to be fully automated.

Item	Description
Vehicle type	Straddled Monorail
Trainset Configuration	2-car (Mc1-Tc)
Passenger capacity	184 (32 seated 152 standing)
Power feeding sys.	DC1500 V
Maximum speed	80 km/h
Dimensions	Total lenght:25 m Width: 2.7 m
Operation	Hitachi Moving Block Wireless CBTC ATC with Subsystem of ATO GOA 3 (DTO)

Kita-Kyushu Monorail, Japan

HITACHI
Inspire the Next

The Kitakyushu Monorail system is operating on the Kokura Line in the city of Kitakyushu in Fukuoka Prefecture, Japan, and is operated by Kitakyushu Urban Monorail Co. The line (8.8 km) connects Kokura station and Kikugaoka station, it was opened on January 9, 1985, on April 1, 1998



	Large type	Small type
Weight	11 t	8 t (average)
Train configuration	4 cars	4 cars
Nominal capacity	415 passengers/train Seating: 177 Standing: 238	194 passengers/train Seating: 88 Standing: 106
Planned capacity	692 passengers/train	315 passengers/train
Full capacity	966 passengers/train	406 passengers/train