**Proven, Reliable Technology**

Straddle-type Monorails have been Refined and Improved for Over 60 Years

If transit "experts" say SkyRail is not a "proven" urban transit technology fully capable of meeting day-t-day high capacity operation, they simply must not be aware of the facts. In this context, it is very important to note that modern transportation technology has evolved tremendously through the years -- from the first private inventions to becoming the backbone of modern civilization. Cars, trucks and buses have been modernized and improved for more than 100 years since they were invented; trains have been modernized and improved over nearly 200 years since the first steam trains.


Similarly, surface light rail has been modernized and improved for over 100 years since the first trams and streetcars. And in a highly analogous manner, straddle type monorail technology has been incrementally improved and modernized for more than 60 years.

Monorail's Steady Development Progress has paralleled that of Light Rail Transit

Straddle monorail's steady development started with a test track in Europe and the first Disneyland Monorail in the 1950s, the initial urban systems in Japan starting in the 1960s with the Haneda Tokyo Airport line, and Walt Disney World in the 1970s. This trend of ongoing development and improvement has continued to this day.

PCC Streetcar and Disneyland Monorail of the 1950's

Along the way, Monorail's steady path toward reliable urban transit service followed very much the same path that light rail's evolution also followed, from slow, manually operated, uni-directional streetcar and tram lines with loops at the ends of the lines -- to modern light rail and monorail lines with bi-directional trains and active track or guide beam switching.

San Diego Trolley 1981

Disney World Monorail 1971

This steady improvement included many public monorail lines being implemented through the first 50 years of monorail development (not just amusement park systems, systems that contained virtually the same basic elements as improved light rail systems) – and these lines have been operated over millions of train miles and hours. These parallel developments in light rail and monorail technology from the 1970s through the Year 2000 continued, including, but not limited to, the following key features:

- High voltage (750 VDC and 1500 VDC) electric power distribution
- Reliable AC propulsion motors and solid state motor controllers
- Bi-directional vehicles
- "Pinched loop" operation to eliminate loops through frequent switching that is fully interlocked with the train protection system
- Automatic or operator-initiated door operation using transit grade equipment
- Full standing height interiors
- Semi-permanent coupling into higher capacity trains
- Level boarding at stations (for monorails and some light rail lines)
- Proven fixed block train protection (for monorail, and for light rail lines operating in exclusive rights of way)

London Docklands Light Rail 1987

Chongqing Monorail 2004

Unfortunately, with only one exception (in Las Vegas), improved and modernized straddle type monorail technology was not implemented in urban settings in this country over this time period, such that there are relatively few transit "experts" who are aware of these facts. At the same time, light rail systems were being implemented in many United States cities, such that by the end of this period, there were many light rail practitioners based here with first (or second) hand light rail knowledge. Now, however, as most low cost at-grade rights of way for light rail systems already have been taken, transit leaders are turning to fully grade separated options and are very seriously investigating straddle monorails for other right of way types, including freeways and high volume arterial roadways where at-grade operation can't function, to parkways, utility corridors, and waterways.

**SkyRail Technology Development: Evolutionary to Revolutionary**

Therefore, following tens of thousands of hours of high level engineering progress and hundreds of millions of dollars of research and development, BYD's SkyRail is being implemented around the world at a record pace. BYD's holistic approach to the technology has not only been applied to the monorail trains – it has included all of the major elements of what is arguably the world's most fully integrated urban transit technology.


Through this multi-year development program, BYD's SkyRail includes all of the 1950s through the year 2000 evolutionary features of urban rail transit systems mentioned above, plus all of the following state-of-the-art features:

- Increased safety and reliability through driverless, communications based, positive train control technology, enabling operating headways as low as two minutes in each direction

- Higher speed, fully grade-separated operation, from 50 mph to 75 mph cruise speeds
- Automatic coupling into longer trains, up to 8 car trains, to meet high demand periods by providing peak capacity of at least 18,000 passengers per hour per direction (pphpd) at American standing space specifications, not European or Asian levels of standee crowding, where the peak line capacity can reach 40,000 pphpd.
- Walk-through trains to enhance passenger boarding and de-boarding, more evenly distribute the passenger load, and facilitate emergency evacuation
- Transit-grade, state-of-the-art components throughout, such as reliable door operators, HVAC systems, variable message signs, public address systems with battery backup, facial recognition systems, closed circuit monitoring systems, smoke detection systems, etc.
- Permanent magnet synchronous AC motors, which typically have 30%-60% higher torque capacity and 30% better torque utilization with faster acceleration and deceleration, and much lower heat generation -- and as a result, these motors are showing a significantly longer life.
- Flexible seating arrangements consistent with the North American practice of maximizing seating
- Emergency evacuation walkways throughout the network that provide a safe path to code-compliant evacuation facilities located at stations and along the route
- Improved and higher speed guideway switching that provides all of the same functions as rail switches
- Code-compliant trains that minimize the potential for fires and toxic smoke
- ADA compliance, including level boarding wheelchair access resulting from automatic height adjustment, based upon passenger load
- Fully integrated, "top down" energy conservation and management, including regenerative braking and wayside energy storage
- Backup on-board batteries that can move the train to the nearest station in the event of a regional power outage
- Reliable, efficient, low energy consuming LED lighting throughout
- Sleek, modern, dynamic design, both inside and out, using high quality materials (aluminum exteriors and composite interiors), large windows, and a very comfortable and quiet ride.
- Longer span structures and special structures for unique situations
- Seismic requirements fully integrated into the structural design
- Smaller, lighter weight, pre-cast columns and beams that greatly reduce costs and accelerate construction, while minimizing construction disruption
- Shorter turning radius, down to as small as 150 feet, to facilitate urban integration

SkyRail is built with transit grade components throughout, including the guide beam switches. BYD has developed or improved six types of switches that can be used in a variety of routing situations to improve operational flexibility while remaining high reliability, with operational availability greater than 99.97%.

BYD also has spent considerable time on research and development in cold climates and is delivering projects where snow and ice buildup can occur. For SkyRail, several systems including train mounted brushes, anti-frost coatings and switch and beam heating, have been developed to mitigate the effects of snow and ice during in cold environments.

This combination of evolutionary and revolutionary technology has led to BYD becoming the world's largest supplier of urban monorail systems.

**Service Proven Technology**

BYD has over 210 miles of new SkyRail systems already in planning and design, construction, or operation, starting in China and the Philippines, and now expanding to systems in the detailed planning stage for several major cities in North and South America and Africa. The latest award is for an urban system in Savador, Brazil. And there are dozens of earlier generation straddle type urban transit systems provided by others in 42 cities already in full operation around the world (totaling 269 miles and over 400 stations), plus new systems underway in some of the very largest cities, including Bangkok, Thailand, and Wuhu, China.

*BYD SkyRail Projects - In Planning, Construction, or Delivered*

| Number | Project | Location | Length (mi) | # of Stations/status |
|---|---|---|---|---|
| 1 | BYD Garden Line | Shenzhen, China | 3.1 | 7 |
| 2 | Pingshan Demonstration Line | Shenzhen, China | 4.7 | on hold |
| 3 | Dapeng Demonstration Line | Dapeng, China | 12.4 | on hold |
| 4 | Shantou Line | Shantou, China | 12.2 | 18/testing |
| 5 | Xi'an Line | Xi'an, China | 13.7 | in Planning |
| 6 | Huashan Line | Huashan, China | 4.4 | in Planning |
| 7 | Bengbu Line | Bengbu, China | 12.4 | on hold |
| 8 | Guang'an Line | Guang'an, China | 6.2 | 8/testing |
| 9 | Jilin Line 1 | Jilin, China | 13.4 | on hold |
| 10 | Jilin Line 2 | Jilin, China | 11.3 | on hold |
| 11 | Tianjin Line | Tianjin, China | 18.6 | in Planning |
| 12 | Zhongshan Line | Zhongshan, China | 7.7 | in Planning |
| 13 | Shaoguan Line | Shaoguan, China | 10.1 | in Planning |
| 14 | Fenghua Line | Fenghua, China | 16.1 | in Planning |
| 15 | Yinchuan Line | Yinchuan, China | 3.5 | 8 |
| 16 | Anyang Line | Anyang, China | 2.9 | on hold |
| 17 | Jining Line | Jining, China | 23.3 | 7/testing |
| 18 | Jiuzhaigou Line | Jiuzhaigou, China | 34.2 | in Planning |
| 19 | Guilin Line | Guilin, China | Still in Planning Phase | in Planning |
| Total | | | 210+ | 123+ |

*Other Straddle Beam Monorail Systems Around The World*

| Number | Project | Location | Length (mi) | # of Stations |
|---|---|---|---|---|
| 1 | Window of the World | Shenzhen, China | 1.06 | 3 |
| 2 | Happy Line Monorail | Shenzhen, China | 2.41 | 7 |
| 3 | KL Monorail | Kuala Limpur, Malaysia | 5.34 | 11 |
| 4 | Chongqing Monorail | Chongqing, China | 61.18 | 70 |
| 5 | Chiang Mai Zoo | Bangkok, Thailand | 1.24 | 4 |
| 6 | Sentosa Express | Sentosa Singapore | 1.3 | 4 |
| 7 | Palm Jumeirah Monorail | Palm Jumeirah, UAE | 3.35 | 4 |
| 8 | Mumbai Monorail | Mubai, India | 12.42 | 18 |
| 9 | Xi'an Monorail | Xi'an, China | 5.96 | 11 |
| 10 | Daegu Monorail | Daegu, South Korea | 14.91 | 30 |
| 11 | Asia Park | Da Nang, Vietnam | 1.86 | 3 |
| 12 | QOM Monorail | Tehran, Iran | 4.22 | 8 |
| 13 | Financial District Monorail | Saudi Arabia | 2.24 mi | 6 |
| 14 | The Rivers Monorail | Port Harcourt, Nigeria | 11.86 | 14 |
| 15 | Calabar Monorail | Calabar, Nigeria | 0.69 | 3 |
| 16 | SeaWorld Monorail | Gold Coast, Australia | 1.24 | 3 |
| 17 | Oasis-Jupiter Monorail | Broadbeach, Australia | 0.81 | 3 |
| 18 | Alton Towers Monorail | Alton Towers, England | 1.99 | 2 |
| 19 | Chester Zoo Monorail | Chester Zoo, England | 0.93 | 2 |
| 20 | E.P. Express Monorail | Europa Park, Germany | 1.55 | 3 |
| 21 | Mirabilandia Ravenna Monorail | Savio, Italy | 1.24 | 2 |
| 22 | Moscow Monorail | Moscow, Russia | 2.92 | 6 |
| 23 | Plaza Imperial Monorail | Zaragoza, Spain | 0.37 | 2 |
| 24 | Atlantis City | Ankara, Turkey | 0.31 | 3 |
| 25 | Marconi Express | Bologna, Italy | 3.11 | 3 |
| 26 | Tokyo Monorail | Haneda, Japan | 11.06 | 11 |
| 27 | Higashiyama Monorail | Nagoya, Japan | 1.24 | 2 |
| 28 | Kitakyushu Monorail | Kitakyushu, Japan | 5.47 | 13 |
| 29 | Osaka Monorail | Osaka, Japan | 17.39 | 18 |
| 30 | Tama Monorail | Tokyo, Japan | 9.94 | 19 |
| 31 | Tokyo Disneyland | Tokyo, Japan | 2.98 | 4 |
| 32 | Okinawa Urban Monorail | Okinawa, Japan | 7.95 | 15 |
| 33 | Disneyland | Anaheim, California | 2.50 | 2 |
| 34 | Seattle Monorail | Seattle, Washington | 0.93 | 2 |
| 35 | Disney World | Orlando, Florida | 14.66 | 6 |
| 36 | Hawaii Monorail | Pearlridge, Hawaii | 0.31 | 1 |
| 37 | Miami MetroZoo | Miami, Florida | 1.99 | 4 |
| 38 | Tampa Airport Monorail | Tampa, Florida | 0.62 | 8 |
| 39 | Newark SkyTrain | Newark, New Jersey | 2.98 | 8 |
| 40 | Jacksonville Skyway | Jacksonville, Florida | 2.50 | 8 |
| 41 | Las Vegas Monorail | Las Vegas, Nevada | 3.91 | 7 |
| 42 | Sao Paulo Monorail | Sao Paulo, Brazil | 40.37 | 49 |
| Total | | | 269 | 402 |

**Long Term Product Support**

As the world's largest supplier of monorail systems, BYD is demonstrating its commitment and ability to provide long term support of SkyRail around the world – and especially in the United States. As a truly global, private company with 60 percent of our trading stockholders being Americans (including nearly 10% company ownership by Berkshire Hathaway under the leadership of Warren Buffett), we are here for the long run. BYD already is present in over seven North American cities, has annual revenues of $17 billion (US), global leadership in renewable energy generation and storage, and a core business led by virtue of being the world's largest producer of zero emission vehicles. Thus, BYD obviously has the unmatched resources, engineering know-how, and advanced technology base required to provide long term, environmentally sustainable support to SkyRail cities throughout the country and the world.

BYD's long term commitment to SkyRail technology manifests itself through our commitment to form and lead Public/Private Partnerships (P3s) that will deliver long term project financing and implement the SkyRail system with high quality, and to do so faster and at a lower cost than conventional grade-separated rail alternatives. This long term commitment provides cities with a single point of responsibility for system performance, which in and of itself is a major motivating factor for BYD to deliver highly reliable service, high quality spare parts, and support fleet and systems rehabilitation and eventual replacement many years into the future.

This long term P3 commitment is further enhanced through BYD's demonstrated ability to form, staff, train, and lead SkyRail operations and maintenance organizations providing long term system-wide service under fixed price contracts. BYD thereby shares its primary objectives with the transit authorities with whom we partner, namely: to maintain the system diligently, and to incorporate measures and improvements over time that will ensure ongoing safe, reliable, efficient, and economical operation.

Specifically, all key elements of the SkyRail technology proposed for deployment in the United States, including the trains, systems, and switches, are fundamentally consistent with the platforms already deployed elsewhere in the world (other than local preferences such as seating, finishes, paint schemes, and so forth). This is made possible through compliance with key American and global standards and codes in all installations to the maximum extent possible. In this manner, non-recurring costs are minimized and there will be no "one-offs", no "dead-end" applications -- such that technical know-how, spare parts, and replacement vehicles and systems will be available at fair and reasonable pricing levels for the foreseeable future.

**High Capacity**

Some transit consultants question the ability of straddle monorail systems to accommodate high demand. In reality, the opposite is true: the current generation of straddle monorail systems provides medium to high capacity technology. For example, the two monorail lines in the very large city of Chongqing, China, carries approximately 1.3 million passengers per day.

Line haul, urban straddle monorail systems such as BYD's SkyRail, Bombardier/CRRC's Innovia 300, and Hitachi's large series all provide much higher peak line capacity than bus rapid transit, light rail, and automated people movers, and even many rail rapid transit (metro) systems. For example, with 8-car trains operating on 2-minute headways, BYD's SkyRail provides a peak hour capacity of nearly 19,000 passengers per hour per direction (pphpd) – at the North American standee level of 2.7 square feet per standee, plus all seats occupied. This is several times greater than the capacity provided by light rail, operating three car trains at peak frequencies of about 5 minutes (limited due to the impact of grade crossings); and it is greater than the peak hour capacity actually being operated today on many metro lines in the United States. At typical Asian and South American standee levels, the capacity reaches approximately 37,000 pphpd.

**Proprietary Technology**

Some transit consultants question such things as the pricing and availability of trains for future expansion, the availability and pricing of spare parts and specialized maintenance equipment, and other elements of straddle monorail systems due to their concerns about and the "proprietary technology" issue. There are some very relevant factors to consider that refute those arguments, including the following:

- All manufacturers of the more conventional rail vehicles and systems also consider much of their design to be proprietary – and as a result, they all protect many of their detailed drawings as "proprietary"
- As an example of this, it is important to note that cities often develop procurement specifications for replacement vehicles that are consistent with those of the supplier of their initial fleet – which often leads to selection of the same supplier of the initial fleet – especially with light rail
- That said, all rail vehicle manufacturers design vehicles to operate on standard gauge steel rail trackwork
- For monorail, there are three major straddle type monorail vehicle manufacturers world-wide, and all could supply trains that could run on the other's beam dimensions – all of which are quite close in width and depth

- For automated rail systems, the train control and communications technology also is proprietary, such that cities usually go back to the initial supplier for expansions and upgrades
- Straddle monorail systems, being fully or semi-automated, also use proprietary train control and communications technology that is the same as, or very similar to, that of the automated rail systems (such as Vancouver, B.C., Copenhagen, Kuala Lumpur System 2, HART in Honolulu – under construction, etc.) – with proprietary technology protection.
- All other parts of the systems are virtually the same as for rail systems, including traction power substations, fare collection, station platform doors, etc. – such that there are multiple suppliers for those elements.

The primary way that cities protect themselves with respect to proprietary technology, whether for rail or monorail, is to require the successful supplier to escrow the proprietary documents with the city so they can be used by the city to select another supplier if that original supplier can't or will not be able to provide fleet and systems for future expansions and upgrades – often coupling that with a requirement for open book, audited pricing if the city opts to procure anything from them in the future on a sole source, negotiated basis.

For all these reasons there are no significant differences with respect to how proprietary technology is defined and treated by the suppliers – and by their public transit authority customers.

Finally, it is very important to note in this regard that the vehicles themselves constitute only about 10 to 20% of the total cost of typical urban projects – for both rail and monorail technologies.