Wireless Streetcar Systems Estimated Cost Savings

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Wireless Streetcar Systems

The age of wireless streetcars has arrived. Recent advancements in battery technology have made the dream of wireless systems a reality. Storage devices are smaller, smarter and more efficient than ever before. They fit easily into modern streetcar shells and work seamlessly with the car's other systems. Car frames, trucks, motors, doors, heating and air conditioning systems remain unchanged. Pantographs and power routing systems can be totally eliminated in small systems and optimized in larger systems. And the only new addition is the battery management system. This seamless evolution in power supply provides a number of improvements while preserving the proven performance of time tested systems.

Wireless technology is most suitable for streetcar systems up to 5 miles in length, or where constraints like historic district restrictions must be considered. They are safer, cheaper to build, cheaper to operate, aesthetically more pleasing and have less environmental impact. And construction is faster and less disruptive. Wireless systems minimize property requirements, nearly eliminate the cost of electrical infrastructure, reduce the cost of bridges and tunnels, shorten construction schedules, reduce construction impacts, reduce maintenance costs, improve safety, and improve yard and shop operations. The result is a system that delivers all of the advantages of a modern streetcar without the complications and traditional clutter of poles and wires. Some of the advantages of wireless streetcar systems are:

Property: Assembling the right of way for new streetcar system is a difficult proposition. Property is always at a premium. New lines are often built in abandoned or underused freight rail corridors that were originally constructed with narrow track centers and little, if any, room for expansion. Squeezing in a modern streetcar line, complete with catenary poles and duct banks for power distribution, becomes problematic and expensive. It is not uncommon for the right of way to cost more than \$2M per mile.



Pole & wire clutter in urban environment

Urban environments are even more difficult, especially in older, densely developed neighborhoods where the streets and sidewalks are narrow. Catenary poles must either occupy space between the tracks, adding as much as 3' to the width of the track system, or they must be located on narrow sidewalks where they take up precious pedestrian space and add to the urban clutter of poles. Eliminating wires and poles enhances the prospects of neighborhood acceptance and reduces the cost and time required for

environmental clearance. Catenary systems also require power distribution cables and negative return cables. That means a considerable amount of street excavation to build the duct banks, and it adds significant cost, time, and construction impacts to already expensive projects.



Locating substations is a particularly difficult property issue. Streetcar systems need substations about every mile. Typically, the substation footprint is about 1,000 SF. In an urban setting, that means finding an empty lot, locating them in a park, or purchasing existing commercial or residential property and converting it to an industrial application. Needless to say, this is a difficult and expensive proposition and generally meets with considerable resistance from the neighborhood,

especially in a residential area. Even in an ideal setting, the underlying substation property could cost more than \$500K. Substations also need power from the local electric utility. These are generally new underground cables that also add to the cost and impact of construction.

Power Infrastructure: The savings associated with wireless technology are substantial. Overhead catenary systems are expensive. Wireless technology eliminates all of the infrastructure and hardware associated with the distribution of power. It also eliminates the long term problems of stray current, and the cost of cathodic protection for underground utilities. At a minimum, wireless streetcar technology will eliminate:

- Overhead wires
- Line poles
- Tie offs and guy wires at curves
- Tensioning devices
- Sectionalizing switches and associated hardware
- Substations and substation feeds
- Power distribution and negative return cables
- Cathodic protection for buried utilities
- Utility relocation associated with underground construction
- Electrical isolation of the rail



Duct bank construction

The cost of catenary systems in an urban environment is typically about \$2.5M per mile. That includes the poles, pole foundations, wires, and hardware. Tie-offs, guy wires, tensioning devices and sectionalizing switches adds another 10%, or \$250,000 per mile. The average cost of a substation is approximately \$1.25M and they are located about every mile. And the average cost of a utility feed to each substation can be taken as \$500,000. The excavation and duct bank construction associated with

the power distribution will cost, on average, \$300,000 per mile. A major problem with "wired" systems is stray current and the resulting damage to buried utilities. Controlling stray current requires that the rails are wrapped in a special insulating material called a "boot". This is a laborious and costly element of work that is necessary to control stray currents. Wireless technology eliminates the need to "boot" the rail. Eliminating this element of work will save approximately \$250,000 per mile. Stray current is also controlled through cathodic protection. Cathodic protection employs a suite of electrical devices attached to adjacent utilities and structures to counteract the effects of stray current. It is difficult to assign a cost to cathodic protection as it varies greatly from project to project. However, the cost can be substantial and it is reasonable to assign an

average cost of \$200,000 per mile. Lastly, utility relocation associated with the construction of the power distribution duct banks, substations, and catenary pole foundations will add another \$500,000 per mile. Taken together, the capital cost savings of wireless technology is approximately \$5.75M per mile. For a short urban circulator approximately 5 miles long, the total savings in capital costs is nearly \$29M. These savings are substantial, and could offset nearly 100% of the cost of the vehicle fleet.

Wireless Streetcar Cost Savings:		
	Cost per Mile	
Poles & wires	2,500,000	
Special hardware	250,000	
Substations	1,250,000	
Utility power feeds	500,000	
Duct banks	300,000	
Special rail isolation	250,000	
Cathodic protection	200,000	
Utility relocation	500,000	
Savings per mile:	\$5,750,000	

Bridge and Tunnel Costs: There are other savings in systems with bridges and tunnels. These savings can only be quantified on a project specific basis, but they are easy to identify. Bridge widths can be reduced by 3 to 4 feet simply by eliminating the poles and wires. And accommodations for the power distribution cables are eliminated. At nearly \$500 per square foot, bridge costs may be reduced by nearly \$2,000 per linear foot. A wireless system also means less overhead clearance, which could eliminate the need to raise existing overhead bridges and the need for additional bridge safety and maintenance considerations.

In twin bore (single track) tunnels, the tunnel diameter is generally determined by the combined height of the track, vehicle, and the overhead wire system. Eliminating the overhead wires, and the operating clearance for a raised pantograph, may allow for a smaller tunnel bore. Large bore (double track) tunnel diameters are generally dictated by the width of the track system, so tunnel bores for a wireless system may be nearly identical to a system with wires. But space in a tunnel is always at a premium and construction and maintenance in a tunnel is expensive, so eliminating the wires and power distribution cables may still result in significant savings. And locating substations in a tunnel is also expensive. They must either be housed in the passenger facilities or somewhere along the tunnel. Either way, the amount of cavern excavation required for their construction and maintenance is significant.

Construction Impacts: Wireless technology reduces construction impacts. It improves access to homes and reduces disruptions to businesses. The most disruptive elements of streetcar construction are the pole foundations, construction of the duct banks, and the

relocation of utilities. All of these require excavation. The work is time consuming, noisy, and creates a considerable amount dirt and dust. It often requires detours, including pedestrian barriers, and sometimes the work is immediately in front of homes or commercial establishments. This work is greatly reduced with wireless technology, and the quality of life within the construction corridor is easier to maintain.



Urban construction

Streetcar Construction Schedule:



Construction durations are also reduced. In general, "stringing" the wire, powering the substations, and testing the electrical systems are among the last elements of work. This work requires specialized equipment and unencumbered access to the work

site. Consequently, these tasks are only started when construction of the track and stations is nearly complete. Eliminating the electrical systems would reduce construction durations, and just as importantly, greatly simplify start up and commissioning of the Streetcar. A typical streetcar construction project that normally takes more than 3 years to complete could easily be reduced by more than 6 months. This also lowers costs by reducing the expenses related to overhead and financing.

Vehicle Costs: The addition of battery equipment will result in added weight to the vehicle, resulting in added power costs. These costs, however, will be more than offset by using regenerative braking to directly recharge the batteries. Based on a fleet size of 7 cars, operating at an average of 20 hours per day and running 50,000 car miles per year, an annual savings of about \$150,000 in power consumption could be realized.



The lithium-ion batteries and associated equipment

used in Kinkisharyo's e-Brid system have proven to be very reliable and require no regular maintenance. Current life expectancy is conservatively estimated to be about 8 years. But battery technology is improving daily and batteries with a 20 year life are expected in the near future. The current cost of battery sets is approximately \$240,000. If we assume changing the batteries twice in 30 years, then the annualized maintenance costs would be about \$55,000 for a fleet of 7 vehicles.

A new 5 mile wireless system would require two charging stations at \$500,000 each and the initial cost per vehicle will be increased by about \$350,000, resulting in an added capital cost of \$3,450,000.

Operations & Maintenance: Wireless technology simplifies operations and maintenance, especially in climates with inclement weather. Winter storms play havoc with overhead

wire systems. Ice accumulation can cause "arcing" which damages the pantographs, and can even go as far as to cause "snags" which rip the pantograph off the roof of the car or pull down the wire. It is not uncommon for operators to schedule nonrevenue "ice runs" ahead of normal service just to clear the catenary system of dangerous accumulations of ice and snow. These non-revenue runs are costly, complicate service schedules, and



are not an efficient use of the revenue fleet. In older "constant length" catenary systems another problem is loose wires in the summer and wire breaks in the winter as the system tries to expand and contract with the temperature change. Even in ideal climates, catenary systems are expensive to maintain. Both the wires and the substations require regular inspection and maintenance. Substations and power feeds also require a level of security, including protective fencing and intrusion alarms, which must be inspected, tested and maintained. Wireless systems also eliminate the need for overhead wire maintenance trucks...specialized non-revenue maintenance units that are expensive to buy and can only be used efficiently on large systems. They also eliminate the spare parts and material stores of wire and catenary hardware. Even vehicle maintenance is reduced, as smooth and safe operation is dependent on the regular inspection and maintenance of the pantograph system. Wire maintenance crews are eliminated; the traditional job of

Operating Cost Savings:		
Wire & substation maintenance	460,000	
Material, parts & supplies	55,000	
Special equipment & tools	15,000	
Operating efficiencies	30,000	
3rd party support	40,000	
Annual savings:	\$600,000	

"power dispatcher" is eliminated; critical safety and proficiency training associated with overhead wires is eliminated; and substation maintenance is limited to the charging station, usually located in the shop and yard area. On a small streetcar system, these improvements and efficiencies will result in operating cost savings of approximately \$600,000 per year.

Safety: Passenger and worker safety are improved with a wireless system. In the event of a loss of power, the need for a "rescue" vehicle to ferry passengers to the nearest station is eliminated; this is especially important if power is lost to vehicles in a tunnel.

Worker safety is improved, especially in the shop and yard area where employees routinely work above the roof line of the vehicles. The vehicle maintenance shop is the most dangerous area on the system. Moving vehicles in and out of the shop can only be accomplished by powering the vehicle through overhead wires, using a "hot stick", or moving vehicles using winches or a motorized tow. Overhead wires in



the shop expose employees working above the roof line to dangerous electrical

equipment. "Hot sticks" are even more dangerous, requiring employees to handle tools with exposed electrical contacts. Winches and tow motors are much safer, but highly inefficient. Wireless technology overcomes all of those problems safely and efficiently; improving safety for employees and reducing maintenance costs.

Wireless technology also improves safety for 3rd parties working along the line. Streetcar operators must routinely provide protective services for contractors working along the right of way. Protection is required to ensure the safety of 3rd party employees performing inspection or maintenance of bridges which cross above the wires, or to ensure the safe operation of cranes and other high mast construction equipment operating near the wires. Most of the time, this protection includes a review of the contractor's operations and equipment before work is started, and an inspector at the site to ensure compliance with safety procedures. Occasionally, contractors must work very close to the overhead wires. On those occasions the wires must be de-energized and grounds applied to protect the workers. Wireless technology will not eliminate the need to protect all work above the tracks, but it will eliminate the specialized protective services for electrical safety.

Another consideration is emergency response along the transit corridor. Responding to fires along the right of way often requires the deployment of ladders and other rescue equipment in close proximity to the wires. This requires closely coordinated and diligently rehearsed emergency procedures to ensure the safety of the emergency crews. Emergency response may also require de-energizing the wires and applying grounds, which can delay response time and further threaten life and property. Wireless technology eliminates the coordination of emergency response related to the electrified systems, and eliminates the need for rescue vehicles in the event of a total loss of traction power.

Yard Operations and Storage Tracks: The yard and shop area can also be designed more effectively, without regard to pole locations or power feeds. And track geometry can be developed independent of the complications of overhead wire geometry. Storage tracks can be closer together and save space. Yard and shop construction is easier and cheaper, and yard operations are more reliable. All of the storage is available all of the time, because shut downs for wire inspection and maintenance are eliminated.



Summary: The advantages of a wireless system include significant savings in both the capital and operating cost, as well as potential savings associated with reduced rights of way, savings associated with civil works (especially bridges and tunnels), and with improved construction schedules. The disadvantages are limited to small increases in vehicle cost and battery maintenance.

Not accounting for the cost savings associated with right of way, shorter implementation

schedules or civil works benefits associated with smaller bridges and smaller bore tunnels (which can only be evaluated on a project specific basis), the system-wide savings for a 5 mile wireless streetcar system could easily be as much as:

- Project Capital Cost Savings \$25,300,000
- Annual Operating Cost Savings

E-Brid System Cost Saving Summary:		
Capital Cost Savings (5 mile system)	28,750,000	
Additional Vehicle Cost & Charging Stations	-3,450,000	
Total Capital Cost Savings:	25,300,000	
Vehicle Cost Savings (per year)	95,000	
Maintenance Cost Savings (per year)	600,000	
Total O&M Cost Savings (per year):	695,000	
Present Value of O&M Savings:	10,700,000	
Present Value - Total Savings: (5 mile system, 7 vehicles, 30 years)	\$36,000,000	

\$25,300,000 \$695,000

For a 5 mile streetcar system utilizing a fleet of 7 e-Brid vehicles, the estimated annual operating cost savings could be capitalized (at 5%) as \$10.7 Million, and when combined on a present worth basis the total cost savings could be about \$36 Million over the 30 year life of the system.

The advantages of wireless streetcars will

continue to expand. Existing battery technology limits a completely wireless system to about 5 miles. But battery storage systems will get smaller and lighter even as their capacity grows, and the range of wireless systems will be extended. Construction schedule savings together with capital and operating cost savings will make streetcar systems financially more attractive, and eliminating wires and substations will make them aesthetically and environmentally more acceptable. The improvements in electrical and passenger safety are priceless, especially when they come at no cost.

Even longer streetcar lines can benefit from wireless technology. Wireless streetcars can be especially useful in cities with historic districts that prohibit the introduction of wires. They can "bridge the gap" by running conventionally outside the historic district, then lower the pantograph and operate without wires within the district. They may also be able to lower the cost of systems with tunnels by lowering the cost of tunnel construction and maintenance.

Wireless technology is no longer experimental. It is ready for commercial use now and will quickly become the preferred solution for shorter streetcar lines and downtown circulators in an urban environment. And wireless systems offer benefits that may provide value even for longer systems. Most importantly, they are faster and cheaper to build, easier and less expensive to maintain, and they result in a more aesthetically pleasing product.

Note: The information in this report was based on typical project data and from manufacturer's data provided by Kinkisharyo. Costs for a specific project may vary depending on specific project conditions.