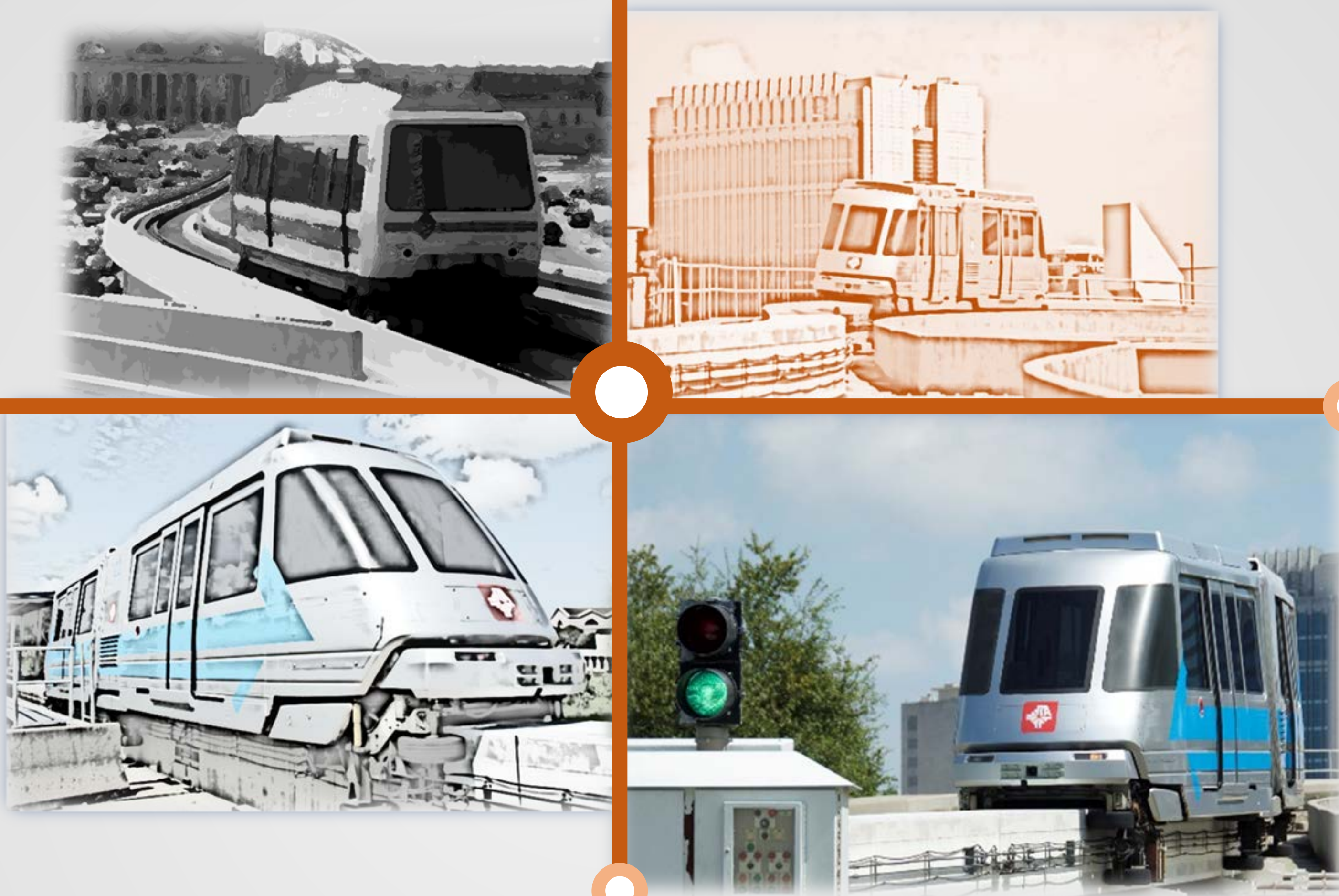
Jacksonville
Transportation
Authority



JTA Skyway Modernization Program

Technical Memorandum III: Skyway Technology Options & Evaluation

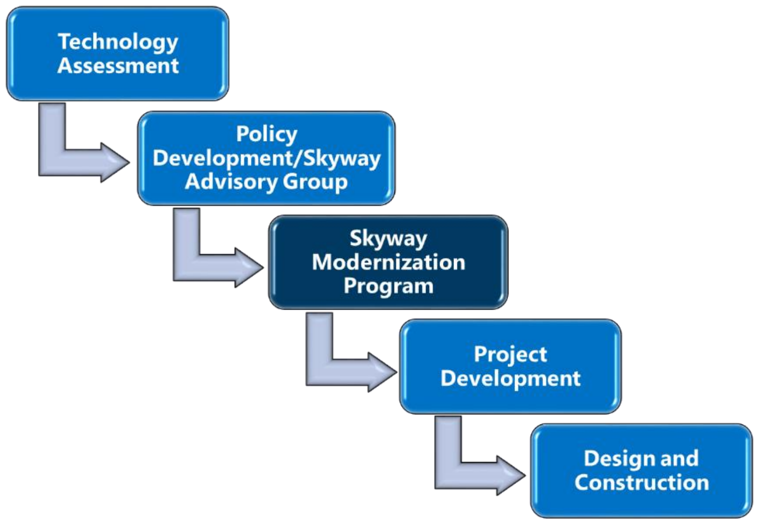
Final Report, April 2017

Table of Contents

List of Tables

Executive Summary

Technical Memorandum No. 3 – Skyway Technology Option Evaluation of the **JTA Skyway Modernization Program** provides for a discussion and evaluation on the refined list of technology options available for replacement and expansion of the existing Skyway system. The initial review included all potential classes of transit solutions: Personal Rapid Transit (PRT), Small and Large Monorails, Cable-Propelled Automated People Mover (APM) Systems, Self-Propelled APM Systems, Automated Light Rail Transit Systems (ALRT), and Light Rail Transit / Streetcar Technologies.



Prior to initiating the Skyway Modernization Program, a Skyway Technology Assessment was undertaken to provide an initial assessment of the Skyway's operating systems, vehicles and infrastructure. During the initial review and assessment phases, the list of potential technologies was refined to the following:

- Overhaul Vehicles
- New Vehicles
- Decommission Skyway: Streetcar, BRT, or Bus Circulator
- Repurpose Skyway: Streetcar, BRT, or Bus Circulator

The above refined options were then evaluated through the Life Cycle Cost Analysis (LCCA) process and the results were presented to the Skyway Advisory Group (SAG) for further review. Based on the results of these reviews, several suppliers were contacted to provide details on potential technology solutions and determine the industry's likelihood of responding to a solicitation for various rehabilitation and/or replacement options. The following suppliers/vendors provided responses:

- Bombardier
- Schwager Davis (SDI)
- Skyweb Express (Taxi 2000)
- 2getthere
- Leitner Poma
- Mitsubishi Heavy industries – Sumitomo
- Woojin IS America Inc.

Based on the results from the industry response and the LCCA, the technology options were finalized and evaluated based on a weighted set of 15 criteria. The results of the scoring the final rankings for the Technology Options were:

1. New Technology - Autonomous Vehicles (score of 3.45)
2. Replace the system with a same type of vehicle on the guidebeam (score of 3.0)
3. Personal Rapid Transit (score of 2.85)
4. Replace the system with a vehicle without guidebeam (score of 2.75)

The above process and associated findings including the recommended / preferred technology approach to further evaluate Autonomous Vehicle technologies as a replacement option for the existing Skyway were presented to the JTA Board on December 8, 2016. At that time the JTA Board approved the plan to move forward with further evaluating Autonomous Vehicle technology.

1.0 Skyway Modernization Program Introduction

In an effort to bolster transportation service in downtown Jacksonville, the Jacksonville Transportation Authority (JTA) has undertaken the Skyway Modernization Program. The goal of this program is to identify a path forward regarding the existing skyway and determine the future transportation solutions for the City of Jacksonville. Integral to this task has been the review and analysis of possible technologies available to either refurbish or replace the existing Skyway Automated People Mover (APM) system. The ongoing analysis has included:

- Condition Assessment of:
  - Skyway Operating System
  - Skyway Infrastructure (including Load Rating of a typical span).
- Technology Assessment
- Evaluation of Alternatives:
  - Retained alternatives were examined at a concept level to establish its viability and implications.
  - Retained alternatives included a concept level description/discussion of:
    - The category of modifications (system and infrastructure) required;
    - Policy considerations and implications; and
    - Cost per mile

Throughout the process each alternative has been vetted through varying review committees, life cycle cost analysis, and the industry reviews with suppliers and vendors. This resulted in a refined list of possible solutions:

- Replace the system with a same type of vehicle on the guidebeam
- Replace the system with a vehicle without guidebeam
- New Technology - Autonomous Vehicles
- Personal Rapid Transit

1.1 Purpose

The purpose of this document, *Technical Memorandum # 3*, is to summarize the findings of the Skyway Modernization Program; provide an analysis of the retained technology options; and identify the preferred technology for further evaluation, thus leading into the project development.

2.0 Skyway Technology Assessment

This section includes a discussion of transit technologies, including PRT, Group Rapid Transit (GRT), Automated People Mover (APM) systems, Monorail systems, Automated Light Rail Transit (ALRT), and LRT / Streetcar systems examined as potential replacement options for the Skyway. The purpose of this is to establish the technology or technologies that are most appropriate as a candidate for the JTA's replacement of the existing System with a new, high-quality, state-of-the-art public transport technology.

2.1 Candidate/Universe of Technologies

The intention of the System will be a fully automated driverless technology. These technologies are proprietary and there are only a few, known suppliers in the market place. Some suppliers have multiple classes of technologies (for example: self-propelled rubber tired and large steel wheel-rail technologies) and they typically propose a technology for a project based on its cost competitiveness and best fit to the requirements in response to a solicitation. The range of such technologies is:

- Personal Rapid Transit (PRT)
- Monorails
- Cable-propelled APMs
- Self-propelled Rubber-Tired APMs
- Large Steel Wheel-Rail APMs
- LRT Streetcars

All of these technologies operate in a fully automated, driver-less mode. The site-specific application of the technology is based on proprietary "off the shelf" equipment designs that are customized to satisfy site-specific constraints. For technology assessment purposes, the recommended screening criteria considered include:

- Technical maturity
- Safety
- Reliability
- Right of way requirements
- Ability to meet operational requirements
- Ability to meet ridership demands
- Opportunities for competitive procurement.

For more detailed descriptions of the candidate/universe of technologies, refer to the Final Skyway Technology Assessment Report issued in August 2015. A general summary of the information contained within that report can be found in Appendix 4 (A-4).

2.2 Technology Evaluation/Operational Assessment

Available APM technologies were evaluated against the project specific requirements utilizing the following criteria:

- Performance
  - Capacity (pphpd) / Ability to Meet Passenger Demand
  - Speed
  - Geometry / Configuration
  - Expandability
  - Operating Range
  - Failure Management / Availability
- Level of Service
  - Trip Times
  - Headways / Wait Times
  - Direct Connectivity
  - Safety / Security
- Urban Insertion Impact
  - Acceptable Noise or Vibration Levels
  - Visually Acceptable Infrastructure
  - Impacts to Existing Infrastructure
  - Fixed Facilities Space Requirements
- Cost
  - Capital Cost Comparison
  - O&M Cost Comparison
- Technology Maturity
  - Service-Proven Technology
  - Supply and Manufacturing Capability
  - Operations & Maintenance Capability
  - Corporate Organizational and Commercial Considerations

2.3 Preliminary Options

At the conclusion of the *Skyway Technology Assessment* (refer to the report submitted in November 2014), a preliminary set of options was discussed with the JTA project team.

Table 2-1: Comparative Options Evaluation

Criterion \ Option	Do Nothing	Overhaul	Replace System Using Existing Infrastructure (similar vehicle)	Replace System Using Existing Infrastructure (different vehicle)	Replace System - Abandon Existing Infrastructure
Long Term Viability	◔	◕	●	●	●
Impact to Existing Infrastructure	●	●	●	◔	N/A
Urban Insertion Impact	●	●	●	◕	◔
Federal Obligation/Grant Management	●	●	◕	◕	◔
Cost	●	◕	◑ *	◔	◔
Business Case	◑	●	◑	◑	◔

●	=1,Best
◕	
◑	
◔	=4,Worst

* Sole Source

During the discussion of preliminary options, the following facts were highlighted:

- » The "Do Nothing" Option serves a baseline and may be explored further depending on the findings of the study.
- » Federal payback obligations have to be determined and included as part of the overall comparison/evaluation in case the JTA elects to proceed with an option that either requires replacing the existing vehicles with new vehicles or that replaces the Skyway with another system: PRT, Streetcar etc.
- » Business Case: Except perhaps for the Overhaul option, all options require that a business case be established by the JTA. Such business case should consider projected ridership, fare structure, operating revenues, operating costs, federal obligations etc.

The discussion led to internal JTA staff meetings and consultations aimed at the elaboration of a move-forward strategy.

2.4 Revised Options

A "Pros-Cons" comparison of the alternatives under consideration was developed. The Pros-Cons comparison was performed on a set of JTA initial options and subsequently on a set of JTA refined options. Both comparisons are included in Table 2-2 and Table 2-3 below.

Initial Options

The initial JTA options considered in this analysis are:

- Overhaul,
- Replace existing vehicle with same (new) vehicle
- Replace existing system with Alternate APM technology
- Replace the Skyway with a Light Rail (LRT) System

Table 2-2: Initial Options – Qualitative Comparison

JTA Initial Options	Overhaul	Replace with Same Vehicle	Replace with Alternate APM Technology	LRT
Pros	» Lowest relative Cost of the options » Keep/maintain existing infrastructure (Guideway/Stations/Infrastructure) » No/Minor staff Learning curve o Maintenance o MMIS o Inventory/Parts » No FTA obligation/payback » Improved System Availability	» 25 years vehicle life » Improved System Availability	» 25 years vehicle life » Vehicle in operation on other properties o Supplier support o Spare parts availability » Improved System Availability	» 25 years vehicle design Life » Appeal of a new system » Catalyst for downtown re-development
Cons	» Propulsion Replacement uncertainty » Aging Infrastructure » Unique vehicle (obsolescence)	» Mid-range Cost of the options » Unique, custom made, vehicle/long term support » Staff learning Curve o Maintenance o Maintenance Management Information System (MMIS) o Inventory, parts » Limited procurement competition (sole source), hence higher cost » Infrastructure approaching midpoint of useful design life » FTA obligation/payback	» Higher capital cost » Staff learning Curve o Maintenance o MMIS o Inventory, parts » Complete Structural Analysis of Infrastructure system required » Impact to Infrastructure o Guideway o MSF o Switches o Height of vehicle and this impact on skyway stations o Loading of new vehicles differ from existing (axle spacing, etc.) » Alignment concerns/grade (6% max, radius of curvature) » Possible reconstruction of low radius spans to accommodate new vehicle » Infrastructure approaching midpoint of useful design life » Impacts during construction » FTA obligation/payback	» Higher Capital Cost » Highest O&M Cost » FTA obligation/payback » Compete with road traffic » Decreased performance » Urban Insertion/Environmental impact » Planning consideration (BRT) » Demolition of existing infrastructure

Refined Options

The JTA options considered in this analysis are:

1. Run Skyway until it stops and replace with a Streetcar or a Bus Rapid Transit (BRT) system,
2. Overhaul the Skyway, run for 10 to 15 years and develop replacement system in the meantime
3. a) Replace vehicle with one that can run on existing infrastructure; extend the system using an elevated structure
4. b) Replace vehicle with one that can run on existing infrastructure; extend the system using an alternative mode, streetcar or BRT

Table 2-3: Refined Options – Qualitative Comparison

JTA Refined Options	**1. Run Skyway until it stops and replace with Streetcar or BRT**	**2. Overhaul vehicle and run for 10 to 15 years and develop replacement system in meantime**	**3a. Replace vehicle with one that can run on existing infrastructure Extensions using elevated structure**	**3b. Replace vehicle with one that can run on existing infrastructure Extension with alternative mode – Streetcar or BRT**
Pros	» Lowest relative cost of the options » Take time to do proper planning	» Second Lowest relative Cost of the options » Keep/maintain existing infrastructure (Guideway/Stations/Infrastructure) » No Learning curve » No FTA obligation/payback » Improved System Availability » Allows significant time for development of future transportation plan	» 25 years vehicle life » Improved System Availability » Possibility of Extensions using similar technology » Potential increased attractiveness of the Skyway using transit-oriented development » Extension Could Provide service to emission generators	» 25 years vehicle life » Improved System Availability » Integrate the Skyway with planned BRT transportation modes » Greater flexibility integrating with future transportation plan
Cons	» Planning uncertainty/ gap between skyway and Street Car/BRT operation » Impact to Passenger Service During the transition to the new replacement mode » FTA payback for vehicle and Infrastructure » Demolition of existing infrastructure-cost and impact » Skyway Operations and Maintenance costs increase with time	» Propulsion Replacement uncertainty » Infrastructure approaching midpoint of useful design life » Requires infrastructure capital investment » Unique vehicle (obsolescence) » Limited fleet -> Limited capacity of extension » Minor Passenger Service Interruption	» Higher Relative Cost » Unique, custom made, vehicle/long term support » Staff Learning Curve ○ Maintenance ○ Inventory, parts » Limited procurement competition (sole source), hence higher cost » Infrastructure approaching midpoint of useful design life » Requires infrastructure capital investment » System Operation to be considered (Y-junction) » FTA obligation/payback for vehicles » Major Passenger Service Interruption » Limited flexibility with integration with future transportation plan	» BRT costs already considered » Unique, custom made, vehicle/long term support » Staff Learning Curve ○ Maintenance ○ Inventory, parts » Limited procurement competition (sole source), hence higher cost » Infrastructure approaching midpoint of useful design life » Requires infrastructure capital investment » FTA obligation/payback for vehicles » Major Passenger Service Interruption » Transfer between modes

Summary

During the discussion it became apparent that both the "Overhaul" and the "Replace in-kind with a new vehicle" options include a non-negligible element of uncertainty. For the overhaul, the replacement of the propulsion system may prove to be challenging based on initial discussions with a major propulsion supplier (ABB), while the replacement with a new vehicle may not attract the interest of the major vehicle manufacturers, implying either that there is no interested party, or a very high sole source cost if one supplier only expresses interest. It was then suggested to the JTA to engage in discussions with Bombardier upper management and request that design information of the main propulsion controller board be provided. If such information were to be provided by Bombardier, it would give the JTA a greater assurance on the overhaul of the propulsion system, lead time and cost for repair.

2.5 Industry Feedback

Given the uncertainty surrounding some of the options, and in order to obtain more precise information, the JTA elected to issue a Request for Industry Feedback (RFIF) to 18 selected operating system suppliers/manufacturers regarding the Jacksonville Skyway Monorail Operating System. The RFIF intent was to gauge the industry interest in the following three options:

- RFIF Option 1: Overhaul of the Jacksonville Skyway Monorail System,
- RFIF Option 2: a) The Replacement in-kind of the Jacksonville Skyway Monorail vehicles and b) The overhaul of the wayside Operating System elements.
- RFIF Option 3: a) the replacement of the existing Skyway vehicles with new vehicles "allowing infrastructure modifications that do not alter the existing beam structure, with no net increase in weight stress on guideway infrastructure" and b) the replacement, as required, of the wayside Operating System (train control, power distribution, guideway switches etc.)

The RFIF included a note that the Fixed Facilities (guideway, stations) overhaul (drainage, structure repair etc.) would be addressed separately by the JTA. After receipt of the RFIF responses, Lea+Elliott generated an Executive Summary and a fact sheet (see references). Additional thoughts and considerations on the RFIF responses are provided below.

The replacement with a vehicle that minimizes impact to the existing infrastructure presents its challenges as the competition is limited given that the majority of the Automated People Mover (APM) vehicles are heavier than the existing Skyway Monorail. The replacement "in-kind" also appears uncertain since it is doubtful that major APM suppliers would build a new vehicle knowing that it takes years to do so; and that it takes a few more years to attain an acceptable level of reliability.

Major APM Suppliers had recently deployed new vehicles such as the Innovia 300 APM for Bombardier or the CityVal by Siemens and would not be, in all likelihood, interested in building a new vehicle given that the fleet size for Jacksonville is small as compared to other urban systems, and the market for such small monorail may not be attractive.

To our knowledge, the most recent case of a supplier manufacturing a vehicle that fits within the physical constraints of a system built for another vehicle, would be Bombardier for the Muzha Line in Taipei, Taiwan. The original Muzha Line system was deployed by Matra Transit, since acquired by Siemens a few years ago. Bombardier was a successful bidder in the replacement of the Matra system requested by the transit authority in Taipei (DORTS) for the Muzha Line and the new extension, the Wenshan line. Bombardier car order was 202 Innovia 256 trains, in addition to the retrofit of the VAL 256 with CityFlo 650, Bombardier moving block CBTC system. The large car order, and contract value, was probably instrumental in having Bombardier compete for the project.

Building on the development of the Innovia 256, Bombardier has recently been awarded the Chicago O'Hare International Airport APM contract intended to replace the VAL 256 by Matra Transit with the Innovia APM 256.

By comparison, the differences between the Innovia Platform (100 and 200) and the VAL 256 were not as considerable, for example, as the ones between say the Innovia Monorail and the UMIII monorail. This is an important consideration in understanding the lack of response to RFIF Option 2.

RFIF responses were received by the JTA on May 6, 2015. The following includes a summary of the four responses by Schwager Davis (SDI), Bombardier, Skyweb Express and Thales.

RFIF Option 1 – Overhaul

Even though most of the overhaul elements discussed in the Operating System Condition Assessment report are feasible and manageable, the propulsion system replacements stands out as problematic.

The JTA has held discussions with ABB, a major propulsion supplier, who reviewed the existing propulsion system design, characteristics and space requirements. ABB indicated that they have identified a replacement for the brushless DC motor, but were experiencing difficulties with a) the interface between the propulsion controller and the DC motor, and b) finding space for a replacement propulsion drive. Decision was then made to widen the search and request feedback from the industry. The RFIF is obviously only a first step in assessing feasibility. Subsequent discussions, meetings and site visits may be necessary to be sure whether the propulsion system could be overhauled or replaced.

In order to increase the probability of a successful propulsion overhaul, the JTA may elect, as recommended by Lea+Elliott, to request Bombardier Transportation to provide the main propulsion controller board design details allowing the JTA to have it manufactured and tested by qualified suppliers.

Based on the RFIF responses it appears that only SDI considers this option to be viable and also points out that it could extend the service life of the system by 15 years. SDI also points out that this option would tend to be the least disruptive to the existing Skyway operations. SDI recommended that the vehicles' propulsion and braking system be upgraded to resolve the problems experienced by the Skyway (due to obsolete parts and other possible operating issues). Bombardier, on the other hand, recommends against this option citing that it would be difficult and costly to locate suppliers and vendors willing to "recreate" the very specialized components contained within the drive train and bogies of the UMIII vehicles and it would be necessary to purchase all spares with the main order.

The other two suppliers (Thales and Skyweb Express) did not address this option.

Based on the RFIF responses SDI's response appears to be the most promising as it extends the service life of the system by 15 years but most importantly could provide a solution that minimizes disruption to the existing Skyway operations. It is however not certain that this option is feasible since the detailed project constraints have not been shared with SDI, nor have the propulsion issues. It is recommended to pursue this option in order to ascertain its feasibility. To that effect, it is suggested that detailed meetings be held with SDI to clarify the issues (project specific constraints) and to gain confidence and a higher level of comfort that SDI is capable of performing the overhaul considering all the risks involved.

RFIF Option 2 – Replace Vehicle "in-kind"

The vehicle replacement "in-kind" also offers significant challenges. The first challenge is that in order for a vehicle to be designed, built, tested and made reliable, it takes time; it may take years. It appears likely that the major car manufacturers will not be interested in this option. Let us consider three suppliers as a case study: a) Siemens, 2) Mitsubishi Heavy Industries and 3) Bombardier.

Siemens (Matra, at the time) technology, VAL for Vehicle Automatique Leger, was the technology in use on the Jacksonville Skyway starter line, between the Convention Center and Central stations. As mentioned in section 3.0, Siemens has recently developed the NeoVal vehicle and has made numerous attempts in the last few years to market the product. Siemens has been recently awarded a contract in Rennes (France) where it will deploy the NeoVal (CityVal) in 2018. It seems therefore unlikely that Siemens would be interested in Option 2.

Bombardier is also deploying the new Innovia APM 300 on several sites, but this product is not in passenger service yet. It is therefore unlikely that Bombardier would be interested in Option 2.

The Mitsubishi Crystal Mover, deployed by Mitsubishi Heavy Industries on several sites around the world is a careful evolution of the Japanese APMs, and the Hong Kong Airport APM, both smaller versions of the Crystal Mover. Given the Japanese regulatory requirements for the manufacture and deployment of a new vehicle, it seems unlikely that MHI would be interested in Option 2.

For Option 2 none of the four respondents provided a positive response. SDI stated that it would extend the service life of the Skyway by 30 years but also cited that this does not come without challenges specifically related to replacement of the propulsion motor and controller. Bombardier also did not recommend Option 2 stating that it would be difficult and costly to locate suppliers and vendors willing to “recreate” the very specialized components contained within the drive train and bogies of the UMIII VAL vehicles.

The other two suppliers (Thales and Skyweb Express) did not address this option completely or at all.

Based on the RFIF responses, it is noted that although replacing the system and vehicles in-kind could provide for an extended service life of 30 years and beyond the JTA must consider that a specialized vehicle to replace the Skyway vehicles would be a one-of-a-kind vehicle and would present potential issues in the future to obtain support and spare parts, etc. and would have some major impacts on existing Skyway operations. Based on industry response, it does not appear that this option warrants further analysis.

RFIF Option 3 – Replacement of Existing Skyway Vehicle with a New Vehicle with No Net Increase on the Guideway Infrastructure

This option limits competition as it appears doubtful that major APM suppliers would not be interested in building a new vehicle to fit within the existing infrastructure constraints knowing that it takes years to do so and a few more years to achieve a reliable product. Further most APM suppliers are deploying new vehicles and would, probably, not be interested in building a new vehicle given that the Jacksonville Skyway System fleet size is small as compared to other urban systems and the market for such small monorails may not be attractive.

Option 3 was the only option that all four respondents offered proposed solutions for. However, each of them comes with its own risk that must be considered by the JTA when evaluating the proposed options. Each of these proposed solutions would also have major impact to existing Skyway operations and would likely need to shut down the system for an extended duration to implement.

Bombardier suggests that the monorail beam be removed and that they propose to use a vehicle technology that would closely match the original Skyway system technology, the Matra VAL 256. Bombardier states that they have experience in replacement of the Matra VAL 256 with their Innovia APM 256 vehicle technology in Taipei and are currently under contract to replace it again at Chicago O'Hare International Airport. Bombardier's experience with previously performing this work and utilizing a standard Bombardier APM vehicle should be noted as a benefit.

A potential concern with this proposed solution is that Bombardier would need to verify and confirm that the entire Skyway guideway (original/starter line and all extensions & MSF) is designed and constructed for the heavier Innovia APM 256 technology. If not, there may be extensive infrastructure re-design and reinforcement requirements that must be considered. The JTA would need to do a complete cost benefit analysis on this proposed solution.

SDI recommends Option 3 and state that they could adapt their technology, vehicle and system and that will have minimal impact on the existing infrastructure and provide for a 30 year service life. It is suggested that detailed meetings be held with SDI to gain confidence and a higher level of comfort that SDI is capable of performing the replacement and to understand the extent of the required changes to the Infrastructure and to the Operating System. Also the JTA could consider sharing the technical contractual requirements of the Jacksonville Skyway monorail with SDI. Some of the project constraints are somewhat challenging (such as 8% grade, Y-junction) and it would be advisable that the JTA makes sure that SDI fully understands the project requirement and is capable of delivering a reliable system.

Thales proposed to replace the ATC and communications system but offers no solution for the vehicle replacement. This is understandable given that Thales is a train control supplier. Skyweb Express proposes a Personal Rapid Transit (PRT) System to replace the current trains with lighter, more private single vehicles. Skyweb Express strongly believes that the JTA's short-term and long-term solution (extending into historic neighborhoods) lie with a solution such as PRT. Skyweb Express discusses comparative cost per mile benefits that should be verified. Skyweb indicates that the Conversion of the current system would require alteration only at Rosa Park, King Street and Prime Osborn stations by allowing a balloon track to move cars from one side to the other on a two-way track.

Skyweb express discussion of System capacity appears optimistic as the advertised headways may not have been proven in passenger service (see Lea+Elliott note on PRT headway included in Lea+Elliott Technology Assessment Report dated November 2014). It is recommended that detailed discussions be held with Skyweb Express to determine the extent of the proposed changes, their impact on the infrastructure and the operations of the proposed system. Furthermore, the decision to implement a PRT requires a complete separate study by the JTA to determine alignment, station locations, fleet size, ridership, business case etc.

2.6 Retained Options and Comparisons

The options retained by the JTA to conclude this study are **slightly different** from the options presented in the RFIF. These options are listed below (refer to *Skyway Technical Assessment* Report dated August 2015 for complete details regarding the Options and the discussions and analysis).

- Option 1: Mid-Life Overhaul Operating System and Infrastructure,
- Option 2: Replacement in-kind with a similar vehicle and Overhaul of the Infrastructure
- Option 3: Streetcar as a possible "one-for-one" replacement of the Skyway

Note: RFIF Options 1 and 2 are identical to the JTA retained options 1 and 2; RFIF Option 3 is different from JTA Option 3. Option 3 refers to "Streetcar as a possible "one-for-one" replacement of the Skyway", while RFIF Option 3, refers to "System Replacement with Minimal Infrastructure Modifications".

2.7 Retained Options Comparison

This section includes a "Pros-Cons" comparison between the retained options. Option 3 has been split into three distinct options as described below.

Table 2-4: Retained Options Comparison

JTA Retained Options	1. Overhaul vehicle and run for 10 to 15 years and develop replacement system in meantime	2. Replace vehicle "in-kind" Extensions using elevated structure	2b. Replace vehicle "in-kind" using existing infrastructure Extension with alternative mode – Streetcar or BRT	3A. Replace existing System with street-car "dedicated-lanes", at-grade; River Crossing uses existing Skyway alignment	3B. Replace existing System with street-car "dedicated-lanes", at-grade; River Crossing uses outside travel lane	3C. Replace existing System with street-car "dedicated-lanes", at-grade; River Crossing uses expansion of bridge, new structure for streetcar
Pros	» Second Lowest relative Cost of the options » Allows use of existing infrastructure (Guideway/Stations/ Infrastructure) » No Learning curve » No FTA obligation/payback » Improved System Availability » Allows significant time for development of future transportation plan	» 25 years vehicle life » Improved System Availability » Possibility of Extensions using similar technology » Potential increased attractiveness of the Skyway using transit-oriented development » Extension could provide service to traffic generators	» 25-30 years vehicle life » Improved System Availability » Integrates Skyway with planned BRT transportation modes » Greater flexibility integrating with future transportation plan	» 30 -year-service life » Downtown renewal » Easier expandability (to stadium) » Better insertion into the urban fabric. » Greater flexibility integrating with future transportation plan » Increased opportunities to enhance ridership	» 30 -year-service life » Downtown renewal » Easier expandability (to stadium) » Better insertion into the urban fabric. » Greater flexibility integrating with future transportation plan » Increased opportunities to enhance ridership » Uses existing space of Skyway on Acosta Bridge for Streetcar	» 30 -year-service life » Downtown renewal » Easier expandability (to stadium) » Better insertion into the urban fabric. » Greater flexibility integrating with future transportation plan » Increased opportunities to enhance ridership » Limited impact to existing traffic flow along Acosta Bridge
Cons	» Propulsion Replacement uncertainty » Infrastructure at midpoint of useful design life » Requires infrastructure capital investment » Existing vehicle is unique vehicle (obsolescence issue) » Limited fleet -> Limited capacity of extension » Minor Passenger Service Interruption	» Higher Relative Cost (than other options) » Unique, custom made, vehicle/long term support » Staff Learning Curve o Maintenance o Inventory, parts » Limited procurement competition (sole source), hence higher cost- may not be feasible » Infrastructure at midpoint of useful design life » Requires infrastructure capital investment » System Operation to be considered (Y-junction) » FTA obligation/payback for vehicles?	» BRT costs already considered » Unique, custom made, vehicle/long term support » Staff Learning Curve o Maintenance o Inventory, parts » Limited procurement competition (sole source), hence higher cost- may not be feasible » Infrastructure at midpoint of useful design life » Requires infrastructure capital investment » FTA obligation/payback for vehicles » Major Passenger Service Interruption	» Aesthetics (catenary option) » Underground impacts » (underground power option) » High operating costs (drivers) » Adverse impact to road traffic and capacity » FTA payback (highest) » Capital Cost (highest of 3 options) » Duplication with BRT Southeast First Coast Flyer » Need for additional real estate (yard, substations, equipment rooms, central) » Disposition of existing guideway infrastructure, stations and right of way	» Aesthetics (catenary option) » Underground impacts » (underground power option) » High operating costs (drivers) » Adverse impact to road traffic and capacity » FTA payback (highest) » Capital Cost (highest of 3 options) » Duplication with BRT Southeast First Coast Flyer » Need for additional real estate (yard, substations, equipment rooms, central) » Disposition of existing guideway infrastructure, stations and right of way	» Aesthetics (catenary option) » Underground impacts » (underground power option) » High operating costs (drivers) » Adverse impact to road traffic and capacity » FTA payback (highest) » Capital Cost (highest, includes bridge expansion) » Higher impact to adjoining properties at each bridge approach and to adjacent railroad bridge » Duplication with BRT Southeast First Coast Flyer » Need for additional real estate (yard, substations, equipment rooms, central)

JTA Retained Options	1. Overhaul vehicle and run for 10 to 15 years and develop replacement system in meantime	2. Replace vehicle "in-kind" Extensions using elevated structure	2b. Replace vehicle "in-kind" using existing infrastructure Extension with alternative mode – Streetcar or BRT	3A. Replace existing System with street-car "dedicated-lanes", at-grade; River Crossing uses existing Skyway alignment	3B. Replace existing System with street-car "dedicated-lanes", at-grade; River Crossing uses outside travel lane	3C. Replace existing System with street-car "dedicated-lanes", at-grade; River Crossing uses expansion of bridge, new structure for streetcar
		» Major Passenger Service Interruption » Limited flexibility with integration with future transportation plan » Limited ability to increase system capacity	» Requires transfer from Skyway to alternate mode for extension. » Operation/ Maintenance of two different systems » Potential adverse impacts to roadway traffic and capacity for the extension	» Requires construction of flyover ramp to access center of the Acosta Bridge » Complete training of the workforce » Maintenance learning curve (rail system) » Lowest level of service (8-12 mph commercial speed) » Extensive planning and coordination with stakeholders including FTA, COJ, FDOT, TPO etc.	» Reduces number of travel lanes on the bridge crossing » Modification to Acosta Bridge deck for embedded rail/platform » Modification to bridge approach/new access ramps to Acosta Bridge » Complete training of the workforce » Maintenance learning curve (rail system) » Lowest level of service (8-12 mph commercial speed) » Extensive planning and coordination with stakeholders including FTA, COJ, FDOT, TPO etc.	» Disposition of existing guideway infrastructure, stations and right of way » Complete training of the workforce » Maintenance learning curve (rail system) » Lowest level of service (8-12 mph commercial speed) » Extensive planning and coordination with stakeholders including FTA, COJ, FDOT, TPO etc.
Recommendation	» Pursue the process initiated with the Request for Industry Feedback to ascertain with greater certainty the feasibility of the option. » Engage in detailed discussions with SDI to. Consider not proceeding without having firm assurance and guarantee that a replacement propulsion system has been identified, or that the propulsion system can be overhauled. Based on Bombardier's response to the RFIF, investigate whether bogie parts could be manufactured, if required.	» Given the lack of interest noted as part of the RFIF, this options does not appear viable and it is recommended that it be dropped from further consideration.	» Given the lack of interest noted as part of the RFIF, this options does not appear viable and it is recommended that it be dropped from further consideration.	» A business case needs to be elaborated to justify the migration from the Skyway to this technology. » The existing guideway structure is unlikely to support a heavier streetcar system. » The option is viable for further investigation » Any modification to the Acosta Bridge including the existing skyway support must be coordinated with FDOT and City of Jacksonville due to both operational and structural impacts.	» A business case needs to be elaborated to justify the migration from the Skyway to this technology. » The option is viable for further investigation » Any modification to the Acosta Bridge including the existing skyway support must be coordinated with FDOT and City of Jacksonville due to both operational and structural impacts.	» A business case needs to be elaborated to justify the migration from the Skyway to this technology. » The option is viable for further investigation » Any modification to the Acosta Bridge including the existing skyway support must be coordinated with FDOT and City of Jacksonville due to both operational and structural impacts.

2.8 Life Cycle Cost Analysis

Once the technology options were refined, it was important to then provide a cost evaluation and analysis to further refine the potential options and understand the overall cost impacts. A Life Cycle Cost Analysis (LCCA) was completed (and previously presented for discussion). The LCCA provides a common comparator for all the options under consideration and identifies the overall cost of ownership for the various alternatives. The factors considered include:

» Initial Capital Costs
» Recurring Capital Costs
» Operation and Maintenance Costs
» Replacement / Decommissioning Costs

It is important to note that the LCCA does not take into account socio-economic factors or include the potential for revenue generation. The estimates performed were conceptual and more detailed estimates will be required once the preferred options enter the more detailed study/design phase. The following options were evaluated using the LCCA process:

» Overhaul Vehicles
» New Vehicles
» Decommission: Streetcar, BRT, or Bus Circulator
» Repurpose: Streetcar, BRT, or Bus Circulator

All of the above options were evaluated with the same assumptions including: operation of existing system for 5 years, each option will provide the same service as the existing Skyway; the Skyway length is 2.5 miles; the replacement options double the length to 5 miles; and it is assumed that there is no FTA payback for Overhaul, Replacement or Street Car Options. The following table shows the results in Net Present Value (NPV) for the above scenarios.

Table 2-5: LCCA Results – Net Present Value

Scenario Name	Scenario Details	40-Year NPV*	20-Year NPV*
Decommission+Trolley	O&M Expenditures	$131 M	$73 M
	Capital Expenditures	$100 M	$80 M
Decommission+BRT	O&M Expenditures	$131 M	$73 M
	Capital Expenditures	$140 M	$123 M
Overhaul+Decommission+Trolley	O&M Expenditures	$183 M	$126 M
	Capital Expenditures	$137 M	$118 M
Repurpose+Trolley	O&M Expenditures	$199 M	$102 M
	Capital Expenditures	$142 M	$78 M
Overhaul+Decommission+BRT	O&M Expenditures	$183 M	$126 M
	Capital Expenditures	$167 M	$153 M
Repurpose+BRT	O&M Expenditures	$199 M	$102 M
	Capital Expenditures	$171 M	$110 M
Overhaul+Repurpose+Trolley	O&M Expenditures	$224 M	$127 M
	Capital Expenditures	$181 M	$118 M
Overhaul+Repurpose+BRT	O&M Expenditures	$224 M	$127 M
	Capital Expenditures	$211 M	$153 M
New Vehicle	O&M Expenditures	$247 M	$123 M
	Capital Expenditures	$227 M	$185 M
Overhaul+Decommission+Streetcar	O&M Expenditures	$267 M	$130 M
	Capital Expenditures	$407 M	$344 M
Decommission+Streetcar	O&M Expenditures	$270 M	$132 M
	Capital Expenditures	$399 M	$318 M
Overhaul+Repurpose+Streetcar	O&M Expenditures	$308 M	$131 M
	Capital Expenditures	$451 M	$345 M
Repurpose+Streetcar	O&M Expenditures	$337 M	$161 M
	Capital Expenditures	$430 M	$305 M

Beyond the costs shown above, it is import to consider additional factors which are not shown in the above table. These include: Level of Service; effects on the ridership; economic benefits, community input; expandability; compatibility with future networks; and potential for revenue and funding. Taking all factors and the cost into consideration; the list of possible options were further refined and presented to the Skyway Advisory Group and development of the Skyway Modernization Program.

3.0 Skyway Modernization Program

Following completion of the Skyway Technology Assessment, the JTA subsequently launched the planning for the Skyway Modernization Program in the spring 2016. Per the JTA guidelines, the planning process is not being constrained by the existing system and infrastructure and all potential innovative alternates for the modernization and extension of the system are to being considered including new vehicles, autonomous technology and elevated and at grade options for extensions.

This Section 3 of this report reviews the technology options that have been discussed at these project team workshops including the vehicle and system characteristics and the pros and cons of each technology option.

3.1 Initial Options

Option #1 Rehabilitation of Existing Vehicle/System

Option 1 continues to remain the same option from the initial stages of project development and as previously defined. This option involved rehabilitating the existing vehicles and operating systems. Since the existing vehicle have a service life of 25 years, or 1,250,000 miles (and the highest mileage vehicle has only 500,000 miles) there is room to explore this possibility. The biggest challenge remains that this vehicle is a custom design, which is no longer supported by OEM.

This option provides an approximate additional service life of 10-15 years and the lowest possible cost of all the alternatives. This could allow for JTA to provide a short-term solution, while a more permanent, long-term solution (including possible system extensions) is developed. Option 1 would not require infrastructure modifications and would only come with minor operational impacts.

Option #2 Replace with Same Type of Vehicle on Guidebeam

Option 2 considers the possibility of replacing the current vehicles with similar monorail type vehicles that will fit onto the existing guideway with minimal infrastructure modifications (other than rehabilitation costs where applicable). New vehicles will provide a service life up to 30 years, and assumes an upgrade to the existing operating system. This option is in the mid-cost range and will provide minimal disruption to the Operations. One of the major concerns with this option will remain the extended commitment (+30 years) to the current technology and there is a reduced flexibility with the possibility of system expansions (significant infrastructure costs for any extensions).

Option #3 Replace with Vehicle without Guidebeam (Self-Propelled APM)

Option 3 considers the possibility of replacing the current vehicles with new vehicles that do not operate on a guidebeam. Because of this, there will be extensive modifications required to the existing guideway structure and the stations. But, the new vehicles will provide a service life up to 30 years, and a new operating system will be installed. This is the most expensive option and will provide the biggest impact to the existing Operations while the system is under construction. As there are many suppliers in the marketplace, this option allows the JTA greater confidence that the system can be maintained for a longer period of time (parts are less likely to become obsolete). Another added value for Option #3 is these vehicles have higher capacities, and can travel at higher speeds, which allows for greater flexibility and options for future growth and expansion.

Option #4 New Technology – Autonomous Vehicle

This is a rapidly emerging technology that has a lot of unknowns and is relatively unproven in the current marketplace. Depending on the system selected, it will most likely require significant modifications at the stations and the guideway. The service life for the vehicles is unknown, though it may be similar to that of a bus. The operating systems will be completely different from the existing ones. These technologies however, have the potential to be very affordable and cost effective and provide a great deal of flexibility for future growth and extensions. Refer to Appendix 1-A: Automated Driverless/Autonomous Vehicle Technology Options for additional details on current technologies in the marketplace.

The pros and cons for all of these options are further described within Table 3-1 below. A Vehicle Comparison Matrix is also provided within Table 3-2.

Table 3-1: Technology Options Pros and Cons

#	Option	Pros	Cons
1	**Rehab existing vehicle/system**	» Lowest cost » No modifications to existing infrastructure required. » Minor disruption to existing operations during installation » Adds time and flexibility for JTA to develop a long-term plan for system modernization and extensions. » Adds time for new technologies to develop and potentially become more viable options.	» Modest service life extension of up to 10 -15 years. » Some risk that rehabilitation may have a shorter service life than anticipated. » Is not a long-term solution. » Does not advance system expansion and may limit flexibility in future.
2	**Replace with same type of vehicle**	» Service Life up to 30 years » Medium Cost » No modifications to existing infrastructure other than rehab costs. » Minor disruption to existing operations during installation. » Operating features are anticipated to be equivalent to the existing system.	» Reduces flexibility for future development with a long-term commitment to a replacement technology. » Would be a special purpose vehicle with potential for reduced maintenance and spare parts support overtime by the system supplier.
3	**Replace with vehicle without Guide-beam (Self-propelled APM)**	» Service Life up to 30 years » With new vehicle, added flexibility to accommodate system extensions. » Service proven and reliable technology with long-term supplier support anticipated. » Vehicles have larger capacity and can operate a greater speeds and frequencies than the existing system.	» Highest Cost » Vehicles are larger and heavier than existing equipment and thus extensive modifications and/or replacement of existing guideway and stations are anticipated. » Infrastructure modifications/replacement will cause significant disruption to existing operations.
4	**New Technology – Autonomous Vehicle**	» Potential to offer flexibility for future extensions. » Unproven technology with near term risk but long term potential » Allows for utilization of the latest technology.	» Undetermined service life - may be similar to buses » Significant modifications to guideway and stations are likely. » Change to Operating system/infrastructure would disrupt operations during installation.

Table 3-2: JTA Skyway Technology Comparisons

JTA Skyway Technology Comparisons

Characteristics	Existing System - Characteristics on per <u>Train Basis</u>		Alternative Technologies - Characteristics on <u>Per Car Basis</u>						
	Bombardier	**Bombardier**	**Schwager Davis**	**Bombardier**	**Hitachi**	**Bombardier**	**MHI**	**Siemens**	**Bombardier**
	UMIII VAL 2-Car Train [1]	UMIII VAL 3-Car Train [1]	UniTrak [2]	Innovia Monorail 300 [2]	Standard Monorail	APM Innovia 200/300 [2]	APM Crystal Mover [2]	APM CityVal [2]	APM Innovia 256 [3]
Train Length (ft)	48	68	22	38.7 - 44	48.2	41.8	37.6	36.7	45
Train Width (ft)	7.0	7.0	7.9	10.3	9.8	9.4	8.9	9.2	8.33
Train Height (ft)	9.0	9.0	9.8	13.5	16.7	11.1	12.1	11.8	11.76
Unloaded Weight	26,100	33,100	15,000	29,983	52,600 - 55,000	34,950	34,200	35,275	43,150
Crush Weight	39,540	53,260				63,700	62,300	62,000	67,775
Guidance System	Concrete Guidebeam	Concrete Guidebeam	Can be modified for Concrete Guidebeam	Concrete or Steel Guidebeam	Concrete or Steel Guidebeam	Center Guidebeam	Side Guiderails	Center Guidebeam	Center Guidebeam
Passenger Capacity (Normal Load)	56	84	27	86 - 95	82	100 - 103	105	103	83
Maximum Speed (mph)	35	35	28	50	37	50	50	50	50
Minimum Curve Radius (ft)	100	100	100	150.9	229.7	100	98.4	98.4	100

Prepared by Lea+Elliott

Data Sources:

1.) JTA Request for Industry Feedback, April 2015

2.) JTA Skyway Technology Overview, Lea+Elliott, November 2014

3.) Skyway Monorail Operating System RFIF, Bombardier, May 2015

Car Passenger Capacity	28	28	27	86 - 95	82	100 - 103	105	103	83
3-Car Length Train Equivalency	2	3	3.1	1.5	1.4	1.6	1.8	1.9	1.5

Note: Shaded areas are to highlight differences from existing technology

3.2 Industry Input

The JTA recently issued a letter to the industry (see attached list in Table 3-3) as an outreach to gauge the interest in participation the skyway modernization program. The letter included the following list of questions (Letter is attached in Appendix A-2):

Would your company be interested in responding to:

1. Request for Proposals (RFP) for rehabilitation of current vehicles and aging subsystems (i.e. Automatic Train Control, Central Control, Communications, etc.)?
2. RFP for replacement of current vehicle and aging subsystems, with new vehicle built to same specifications to operate on guidebeam?
3. RFP for replacement of current vehicle and aging subsystems, with different vehicle built to different specifications to operate on infrastructure without guidebeam including any guideway structure modifications required to accommodate new technology vehicle?
4. RFP for Design, Build, Operate and Maintain (DBOM)?
5. RFP for Design, Build, Finance, Operate and Maintain (DBFOM)?
6. RFP for implementation as Public-Private-Partnership (P3) concession?
7. RFP for all of the above that would include extensions of the system?

3.3 Summary of Vendor Visits/Presentations

Bombardier:

- Bombardier suggests that the monorail beam be removed and that they propose to use a vehicle technology that would closely match the original Skyway system technology, the Matra VAL 256. Bombardier states that they have experience in replacement of the Matra VAL 256 with their Innovia APM 256 vehicle technology in Taipei and are currently under contract to replace it again at Chicago O'Hare International Airport.
- Bombardier recommends "Bombardier CITYFLO 650 automatic train control" (ATC), the train control system that was also applied in Taipei (and in many other applications around the world).
- **Previous experience**: INNOVIA APM 256 currently in operation in Taipei and will soon be in operation at the Chicago O'Hare International Airport.
- **A follow-up action with this proposed solution is that Bombardier would need to verify and confirm that the entire Skyway guideway (original/starter line and all extensions & MSF) is compatible with the Innovia APM 256 technology.**

Schwager Davis (SDI):

- SDI state that they could adapt their existing technology deployed in Indianapolis (Clarian Health System), vehicle and system and that will have minimal impact on the existing infrastructure and provide for a 30 year service life. It is suggested that detailed meetings be held with SDI to gain confidence and a higher level of comfort that SDI is capable of performing the replacement and to understand the extent of the required changes to the Infrastructure and to the Operating System. Also the JTA could consider sharing the technical contractual requirements of the Jacksonville Skyway monorail with SDI. Some of the project constraints are somewhat challenging (such as 8% grade, Y-junction) and it would be advisable that the JTA makes sure that SDI fully understands the project requirement and is capable of delivering a reliable system. It was noted at the meeting that SDI was not aware, for example, that the Skyway System included an 8% grade.
- SDI also discussed the possibility of performing an overhaul of the vehicles and operating system. SDI would be interested in performing an overhaul but would recommend replacement with their Unitrack technology modified to fit the skyway parameters.
- **Previous experience**: Hilton Waikoloa I-Tramway (Hawaii), Primadonna Shuttle System (Nevada), Bellagio Monte Carlo Tram (Vegas), Bronx Zoo Monorail (New York).
- **SDI to evaluate and determine the fit of their proposed technology with the existing Skyway (Operating System and Infrastructure) and potential extensions.**

Skyweb Express (Taxi 2000):

- Skyweb Express proposes a Personal Rapid Transit (PRT) System to replace the current trains with lighter, more private single vehicles. Skyweb Express strongly believes that the JTA's short-term and long-term solution (extending into historic neighborhoods) lie with a solution such as PRT.
- **If Skyweb Express/Taxi 200 is considered to be a viable option the next steps would be:**
    - **Engage detailed discussions with Skyweb Express to determine the extent of the proposed changes, their impact on the infrastructure and the operations of the proposed system.**
    - **The decision to implement a PRT requires a complete separate study by the JTA to determine alignment, station locations, fleet size, ridership, business case etc.**
    - **Qualifications of the proposed technology should be studied further**

2getther:

- PRT and GRT Manufacturer.
- Proposes a third generation GRT based on previous experience at business park Rivium (Netherlands) and the PRT at Masdar City. A car would hold between 18 and 24 passengers, depending on the number of seats. It is powered by two Lithium-Ion nano NMC (Lithium Nickel Manganese Cobalt). The batteries are charged automatically when a vehicle arrives at a station. Also, a vehicle is sent automatically to a charging station when the battery charge reaches a given threshold level. Batteries are charged from a wall station located at specific stations, parking locations, or the maintenance and storage facility.
- **If 2getthere is considered to be a viable option the next steps would be:**
  - **Engage discussions with 2get there to determine the extent of the proposed changes, their impact on the infrastructure and the operations of the proposed system.**
  - **Qualifications of the proposed technology should be studied further**

Leitner Poma:

- **Leitner-Poma of America, Inc.** is a North American subsidiary of **Pomagalski S.A.**, a corporation with headquarters in Voreppe, France and Leitner Technologies, a corporation with headquarters in Sterzing, Italy. Leitner – Poma of America engineers, manufactures, installs and services all types of ropeway systems for the ski industry, amusement parks, and urban transport.
- Presented its MiniMetro cable-propelled and air levitated technologies. Applications include: Perugia, Cairo, Minneapolis and Miami International Airport satellite E.
- **Action: Leitner Poma to evaluate and determine the fit of its proposed technology with the existing Skyway (Operating System and Infrastructure) and potential extensions.**

Mitsubishi Heavy Industries – Sumitomo:

- Presented its Crystal Mover technology. Indicated that it would propose the same vehicle as proposed for the Tokyo, Yurikamome system.
- The proposed vehicles incorporate MHI's all-aluminum-alloy shell. Overall dimensions are shorter and narrower than the Crystal Mover Technology deployed at Miami International Airport, Atlanta Conrac, Dulles International Airport and more recently at Orlando International Airport and Tampa Airport.
- The Yurikamome Line is a public transport system inaugurated in November 1995. Spanning a total distance of 14.7 kilometers, the line consists of 16 stations linking central Tokyo with the city's waterfront area. Situated along the line are the Shiodome business district, the Odaiba and Ariake waterfront zones, and a raft of sightseeing spots,

convention halls and other facilities that attract large numbers of visitors. As a result, the Yurikamome Line averages some 124,000 users per day (data for 2015).

- **Action: MHIA to evaluate and determine the fit of its proposed technology with the existing Skyway (Operating System and Infrastructure).**

Woojin Woojin IS America Inc.:

- Woojin is a Korean supplier.
- Woojin discussed its flagship project: The Busan subway. The system is 12.74 km, with 14 stations. The vehicle is based on the Japanese APM technology, utilizes rubber tires and operates in a 6-car trainset. The total fleet is 102 cars.
- Woojin also discussed a new monorail concept, apparently based on the Hitachi heavy Monorail deployed by Hitachi in Japan.
- Woojin also discussed the possibility of a vehicle and operating system overhaul. They stated that they have performed overhaul on vehicles in South Korea.
- **Action: Woojin to provide qualifications of its proposed vehicle technology and determine its fit with the existing Skyway (Operating System and Infrastructure).**
- **Qualifications of the proposed technology should be studied further.**

3.3 Summary Technology Options Matrix

A matrix that summarizes the finding/results of the above identified vendor meetings is attached in Appendix A-3. Note that subsequent to the above listed vendor meetings further discussion were held with two other potential vendors which are included in the attached matrix as well.

3.4 Buy America

Another important thing to be considered as part of this project would be the funding options. For example, if federal funding is utilized the associated Buy America requirements could present challenges and limit competition as many of the candidate vendors/suppliers identified are non-US Based companies. Of course there are ways to manage this depending on the project structuring which could be explored further. One option might be to procure the fixed facility infrastructure separately from the operating system and vehicles and federal funding could be applied to the infrastructure portion. Also, some vendors have set up vehicle manufacturing plants in the US to assemble the production cars as way to comply with buy America requirements.

Table 3-3: Industry Outreach Contact List

Company	Contact	Phone	E-mail	Address
APM				
Bombardier	Jason Aguire	(412) 655-5534	Jason.aguirre@rail.bombardier.com	1501 Lebanon Church Road Pittsburgh, PA 15236
DCC Doppelmayr Cable Car GmbH & CO KG	Mr. Nenad Zdravkovic Head of Sales and Business Development	T +43 5574 604 1260 F +43 5574 604 1231 M +43 664 850 3283	Nenad.Zdravkovic@doppelmayr.com	Holzreidstrasse 29 A-6922 Wolfurt, Austria
Leitner- POMA of America Inc.	Attn: Rick Spear, President	T: US–970-241-4442 F: US- 970-241-3023	rws@leitner-poma.com	2746 Seeber Drive, Bldg A. Grand Junction, CO 81506; USA
Schwager Davis, Inc.	Lee Larsen Project Manager - Transit Division	ph: 408.281.9300 x104 Cell: 702.400.5415 fx: 408.281.9301	llarsen@schwagerdavis.com	198 Hillsdale Avenue San Jose, CA 95136
Mitsubishi Heavy Industries America, Inc.	Mr. Darin Friedmann VP and General Manager, Transportation Systems Division	Business: (212) 969-9000 X. 144 Business 2: (212) 397-6144	darin_friedmann@mhiahq.com	420 Lexington Avenue Suite 1644 New York, NY 10170
OTIS Elevator Service Company, Inc.	Mr. Frank Bares	Ph: 860-286-1617 Fax: 860-998-3284	frank.bares@otis.com	47 Water Street Torrington, CT 06790
Siemens Industry Inc. Mobility Division Rolling Stock	Mr. Richard Trail, Directo	Office:+1 412-257-2111 Ext: 607 Cell: +1 412-980-2042	richard.trail@siemens.com	600 Bursca Drive Suite 606 Bridgeville,PA 15017, USA
Taxi 2000 (T2) Corporation (Skyweb Express)	Mike Lester CEO	763-717-4310	info@taxi2000.com mlester@taxi2000.com	8050 University Avenue N. Fridley, MN 55432 USA
Woojin is America, Inc.	Mr. Frank Guzzo Marketing/Sales Agent	Tel: (916) 987-7888 Mobile: (916) 990-7420	frank.guzzo1@gmail.com	5124 Long Canyon Drive Fair Oaks, CA 95628
	Mr. Joseph Sang-Hyun Kim Vice President & COO	Tel: (626) 386-0101 Mobile: (626) 429-7252 Fax: (626) 386-0102	jsk@wjisamerica.com	5108 Azusa Canyon Rd Irwindale, CA 91706
Automated/Autonomous Vehicle				
Vectus (now operating under POSCO)	Mr. Jörgen Gustafsson Vectus Intelligent Transport (adress email to Jörgen and copy others)		jorgen@arogus.se kyusang.choi@poscoict.com posmap@posco.com janelee@posco.com kennyshin@posco.com	
Vectus Limited (Registered office in UK)				7th Floor, 52/54 Gracechurch Street London EC3V 0EH, UK
Vectus Ltd. Korea Office		Tel: +82 31 723 3740		4th Floor, POSCO ICT Building, 622 Sampyeong-dong, Bundang-gu, Seongnam City, Gyeonggi Province, 463-400 Korea
Navya	Andy Rogers VP Business Development & Sales - North America	mobile: 508-530-1474	andy.rogers@navya.tech	
2getthere Sustainable Mobility Solutions	Robbert Lohmann, Commercial Director	T: +31 (0)30 238-7203	robbert@2getthere.eu	Proostwetering 26a 3543 AP Utrecht the Netherlands
EasyMile	Xavier Salort Senior Sales Manager	+33 (0)6 74 71 17 20	xavier.salort@easymile.com	Toulouse, France
Yutong		+86-371-66718999	sales@yutong.com	Zhengzhou,Henan province,China

4.0 Refined Options Matrix

After vendor visits/presentations, the results of the meetings and the refined options were further evaluated and the following evaluation ranking matrix was developed together with the JTA to define important factors that would then be weighted as to the level of importance to the JTA when determining what the best option would be for the Skyway rehabilitation/replacement and future extensions. Below is what has been developed for this purpose.

4.1 Criteria Overview

1. At-Grade Capability (10)

   Explanation: Evaluates ability to function at street level. Given the desire for the system to reach nearby residential areas, this criteria is weighted at 10.
   APM-Beam – Cannot operate at ground level without significant safety issues and impacts on auto, bike and pedestrian circulation.
   APM-Rail – Cannot operate at ground level without significant safety issues and impacts on auto, bike and pedestrian circulation.
   Autonomous Vehicles – Can function at grade with dedicated lanes and transit signal priority. As technology advances, has potential to function in mixed traffic.
   Personal Rapid Transit – Cannot operate at ground level without significant safety issues and impacts on auto, bike and pedestrian circulation.

2. Elevated Capability (5)

   Explanation: Ability of system to function above grade is important to sustain reliable frequency and cross critical ground level constraints such as the FEC rail line. In the proper location, the elevated system is the best operational solution.
   APM-Beam – Would function exclusively as an elevated system.
   APM-Rail – Would function exclusively as an elevated system.
   Autonomous Vehicles – Can operate as an elevated system.
   Personal Rapid Transit – Would function exclusively as an elevated system.
   Note that the APM-Beam, APM-Rail and PRT could also operate at grade but would require dedicated and protected right of way.

3. Operational Flexibility (10)

   Explanation: This criteria evaluates the ability of the system to respond to changing demands. Examples of flexibility included being able to have vehicles operate individual our couple up as a train set, or have point to point service capacity. Criteria weighted at 10 as emerging technology and shared mobility trends place higher emphasis on flexibility and demand responsive transit.
   APM-Beam – Vehicles function as two-car trains. There is flexibility to increase to three or 4 car trains but requires physical coupling.

APM-Rail – Vehicles function as 1, 2, 3 or 4 car trains depending on platform lengths to accommodate larger train consists. There is flexibility to increase to three or four car trains but requires physical coupling.
Autonomous Vehicles – Can operate as individual trains or function as train set by coupling virtually using connected vehicle technology. Also has the ability to provide direct, point to point service with due consideration of infrastructure modifications at stations to allow for vehicles/trains to bypass.
Personal Rapid Transit – Functions as individual vehicles with extremely high frequency. Provides point-to-point service. Ability to adjust to heavy loads limited by practicality of efficient loading at stations.

4. Cost – Vehicle (5)

Explanation: Evaluates the cost of vehicle and associated operating system. Higher cost results in lower score. Cost criteria is split between 4 areas. Each is weighted at 5 points but total 20 points for the 4 criteria.
APM-Beam – Vehicles are highest cost and comparable to APM-Rail. Cost per vehicle expected to be in $4-5 million range for two car train.
APM-Rail – Vehicles are comparable to APM-Beam but since they are more common in industry, there may be lower cost per vehicle and opportunity for joint procurement.
Autonomous Vehicles – The vehicles are lowest cost. Smaller vehicles will require more vehicles to maintain system capacity but still less costly. Vehicles expected to have shorter useful life and would require replacement instead of mid-life overhaul.
Personal Rapid Transit – system requires many vehicles and complex operating system. While less costly on a per vehicle basis, the actual vehicle cost and total number of vehicles needed is uncertain.

5. Cost – Infrastructure (existing) (5)

Explanation: Evaluates comparative cost of modifying infrastructure to accommodate new vehicle. Higher cost results in lower score.
APM-Beam – Would require the least (if any) modification of elevated guideway)
APM-Rail – Would require removal of beam and installation of steel I-Beam and running surfaces, power rails and wayside train control and communications. Ability to install steel I-Beam could be fatal flaw.
Autonomous Vehicles – Would require removal of beam. Parapet walls need to be evaluated for capacity to provide sufficient safety rail for autonomous vehicle and may require modification. Guideway at stations would need to be modified to enable vehicles to load and unload at current platforms.
Personal Rapid Transit – Guideway could be manufactured such that the guidebeam would not need to be removed resulting in lower cost. High number of vehicles would likely require additional O&M center and vehicle storage facility. This would also require infrastructure modifications to allow station bypass for point to point service.

6. Cost – Infrastructure (new)(5)

   Explanation: Considers comparative cost of system expansion.
   APM-Beam – High cost associated with elevated structure needed to support larger heavy vehicles.
   APM-Rail – High cost associated with elevated structure needed to support larger heavy vehicles.
   Autonomous Vehicles – lighter vehicles would lower cost of elevated extensions. At-grade extensions require dedicated lanes and cost would vary depending on availability of right of way. Station areas would be significantly less costly than elevated system.
   Personal Rapid Transit – Lightest vehicles would require least costly structure for elevated guideway. Would require high cost elevated stations and bypass capability.

7. Cost – O&M (5)

   APM-Beam – Vehicle would remain proprietary and limit options for maintenance. Existing system has high cost per hour or service compared to peer systems.
   APM-Rail – Could have lower lost to operate and maintain vehicle due to existence of similar vehicles.
   Autonomous Vehicles – smaller and lighter vehicles expected to have lower maintenance costs. At grade extensions likely to include operator initially. Savings partially offset of additional vehicles needed to address system capacity.
   Personal Rapid Transit – high number of vehicles with lower capacity expected to have higher regular maintenance costs. Station area infrastructure would require more maintenance.

8. Vehicle Capacity (5)

   Explanation: measures the capacity of the vehicle to heavy loads associated with peak hour services and crush loads during events
   APM-Beam – Replacement vehicle would be slightly smaller than current vehicle but has ability to create three and potentially four car train
   APM-Rail – Replacement vehicle would likely be larger than current vehicle with significantly greater system capacity.
   Autonomous Vehicles – Smaller vehicle with capacity up to 24 passengers but could be linked in train set of two, three or four vehicles.
   Personal Rapid Transit – Individual pods would carry up to 3 passengers. It is expected that during crush loads, individuals could choose to ride a pod as a single passenger. Also, loading individual vehicles would limit the ability to move large numbers of people quickly.

9. Proven Technology (10)

   Explanation: evaluates the degree to which vehicles have been deployed in service or are more conceptual.
   APM-Beam – Technology has been deployed in Jacksonville for two decades. However, technology has not been utilized widely as anticipated. A new vehicle would be proprietary and not necessarily be a proven technology.

APM-Rail – Most widely utilized people mover technology and very common in airports throughout the world.
Autonomous Vehicles – rapidly developing technology. An autonomous shuttle has been in service since 1999 in the Netherlands. Several companies are actively developing this technology.
Personal Rapid Transit – An at-grade PRT system has been in operations in Masdar City since 2010. However, the Taxi 2000 version considered for this project is largely conceptual and unproven in transit operations.

10. Frequency (15)

Explanation: frequency of service improves the customer experience and can reduce overall trip times.
APM-Beam – Current service is 6 to 7 minute headway. However, with additional vehicles in service, headways could be reduced to 3 to 4 minutes. With additional extensions such as riverside/Brooklyn, the switch could limit the ability to operate with higher frequency.
APM-Rail – similar to APM-Beam
Autonomous Vehicles – Has flexibility to operate with more, smaller vehicles with higher frequency than current system. System would not require physical switch so shorter headways can be achieved even with additional extensions.
Personal Rapid Transit – PRT would have shortest headways with many more small pods operating with ultra-high frequency.

11. Vehicle Speed (5)

Explanation: Evaluates actual speed of vehicle.
APM-Beam – up to 30 mph. speed limited by track configuration (curves) and passenger comfort (acceleration and deceleration)
APM-Rail – Similar to APM Beam
Autonomous Vehicles – Can reach similar speeds as APM but likely slower acceleration and speed on incline.
Personal Rapid Transit – Can operate at higher speeds.

12. Maintainability (5)

Explanation: Vehicles in common use have a greater maintainability over the long-term.
APM-Beam – Would be proprietary system and could have challenges with long-term maintenance of vehicles
APM-Rail – Vehicles or more commonly available and in use.
Autonomous Vehicles – Newer technology is less common. However, high level of investment in autonomous vehicle technology this is likely to be less of an issue in the future.
Personal Rapid Transit – The PRT system is a concept that has not been deployed elsewhere in the form considered. It would be a one-of-a-kind vehicle with limited options for maintaining the vehicles and operating system.

13. Reliability (5)

Explanation: Evaluates the ability to maintain a high level of service reliability
APM-Beam – Can expect 99% reliability
APM-Rail – Can expect 99% reliability
Autonomous Vehicles – reliability likely to be impacted with street level extensions. Would require dedicated lanes and pre-empting transit signal priority to maintain operational reliability.
Personal Rapid Transit – Concerns about system functioning in reality. Concept looks good on paper but has not been demonstrated in full deployment. Additional concerns about the switch mechanism. Failure of system and algorithm could result in complete system shut down.

14. Transition Impacts (5)

Explanation: considers the degree to which existing service would be disrupted during transition to the new vehicle.
APM-Beam – Minimal impact since the vehicle can operate on existing infrastructure and operating system.
APM-Rail – Significant impact to remove beam and replace with steel I-Beam, running surface, power rail, wayside train control and communications.
Autonomous Vehicles – significant impact with removal of beam but retrofit should otherwise be less impactful than APM-Rail.
Personal Rapid Transit – Transition impacts /can be minimized by installing guideway around existing beam. Work needed to install operating system and make station modifications to install fare collection and manage system access.

Table 4-1: Options Evaluation Matrix

Criteria	Weight	APM-Beam	APM-Rail	AV	PRT
At-Grade	10	1	1	5	1
Elevated	5	5	5	5	5
Operational Flexibility	10	2	2	5	4
Cost -Vehicle	5	1	2	5	3
Cost- Infrastructure (exist)	5	5	1	2	3
Cost- Infrastructure (new)	5	1	1	3	3
Cost O&M	5	1	1	4	1
Vehicle Capacity	5	4	5	3	1
Proven Technology	10	4	5	2	1
Frequency	15	3	3	4	5
Vehicle Speed	5	4	4	2	5
Maintainability	5	1	4	3	1
Reliability	5	5	5	4	4
Transition Impacts	10	5	1	1	2
Total	**100**	**3**	**2.75**	**3.45**	**2.85**

The values in the table above are based on a combination of a score per item calculated against and overall weight for each item. Each item was given a value between 1 and 5 (1 being the lowest and 5 the most desirable) and the value was then adjusted against the pre-determined weight for that item. After all the values were assigned (based on the prior discussion) they were weighted and summed creating the final rankings (shown in the total line). Using the values assigned and the resulting calculations the following ranks the results from the Options Evaluation Matrix:

1. AV (score of 3.45)
2. APM-Beam (score of 3.0)
3. PRT (score of 2.85)
4. APM-Rail (score of 2.75)

4.2 Recommendations/Preferred Technology

In summation, based on the completion of the various industry reviews, cost analysis, rankings, etc. it has been determined that the preferred technology is the Autonomous Vehicle. Table 4-2 below provides a summary of technology options evaluation.

Table 4-2: Technology Options Summary Table

Project Phase	Technology Options	Analysis/Actions
Skyway Technology Assessment	**Preliminary Options:** » Do Nothing » Overhaul » Replace System Using Existing Infrastructure (similar vehicle) » Replace System Using Existing Infrastructure (different vehicle) » Replace System Abandon Existing Infrastructure **Refined Options:** » Overhaul » Replace Existing Vehicle with Same (new) Vehicle » Replace Existing Vehicle with Alternate APM Technology » Replace the Skyway with a Light Rail Transit (LRT) System **Other Options Considered:** » Run Skyway until it stops and replace with Streetcar or BRT » Overhaul vehicle and run for 10 to 15 years and develop replacement system in the meantime. » Replace vehicle with one that can run on the existing infrastructure. Extensions using elevated structure. » Replace vehicle with one that can run on existing infrastructure. Extensions with alternative mode – Streetcar or BRT **Retained Options:** » Overhaul vehicle and run for 10 to 15 years and develop replacement system in meantime » Replace vehicle "in-kind" Extensions using elevated structure. » Replace vehicle "in-kind" using existing infrastructure. Extension with alternative mode – Streetcar or BRT. » Replace vehicle with one that can run on existing infrastructure. Extensions with alternative mode – Streetcar or BRT **Streetcar Options:** » Replace existing System with street-car "dedicated-lanes", at-grade; River Crossing uses existing Skyway alignment » Replace existing System with street-car "dedicated-lanes", at-grade; River Crossing uses outside travel lane	Structural Assessment Operating System Assessment Vehicle Assessment Request for Industry Feedback

Project Phase	Technology Options	Analysis/Actions
	» Replace existing System with street-car "dedicated-lanes", at-grade; River Crossing uses expansion of bridge, new structure for streetcar.	
Skyway Advisory Group/ Subcommittee	**LCCA Options:** » Overhaul Vehicles » New Vehicles » Decommission Skyway o Replace with Streetcar or BRT, or Bus Circulator » Repurpose Skyway (Pedestrian/Bicycle Path) o Streetcar, BRT, or Bus Circulator	Life Cycle Cost Analysis Stakeholder Input Public Input Decommission & Repurpose options were removed from further consideration.
Keep, Modernize and Expand (Board Action)		
Skyway Modernization Program	**Initial Options:** » Rehabilitation of Existing Vehicle/System » Replace with same type of vehicle on guidebeam o Monorail » Replace with new vehicle without guidebeam o Self-propelled APM, Group Rapid Transit, Personal Rapid Transit (PRT) » New Technology o Autonomous Vehicle (AV) **Refined Options:** » APM X – Vehicle same as Existing with Beam » APM N – New Vehicle similar to Bombardier Innovia 256 Rail w/o Beam » Autonomous Vehicles (AV) **Preferred Option for further analysis:** » AV	Peer System Assessment System Plan Industry Input Stakeholder Input Public Input
Enter Development Phase (Board Approval)		

5.0 Appendices

Appendix A-1: Automated Driverless/Autonomous Vehicle Technology Options

Automated Driverless/Autonomous Vehicle Technology Options

SEPTEMBER 2016

LEA ELLIOTT

Table of Contents

Table of Figures

1. INTRODUCTION

The industry of driverless technology is changing day to day. One of the rapidly developing areas is that of automated shuttles. This typically involves a smaller, minibus style vehicle (capacities range from 6-15 passengers), which has some form of a driverless operating system. For some systems, this is fully automated (Level 5) and others are a hybrid approach, Levels 3 or 4. The following discusses the various technologies in operation today, including the vehicles, the locations, capacities, constraints, etc.

1.1. Automated Vehicle Classifications:

Prior to discussing the actual technologies, it is important to understand the actual classifications for driverless technologies. These classifications are based on the amount of intervention and attentiveness that is required from the driver. The following is defined by the Society of Automotive Engineers (SAE).

- Level 0: Automated system has no vehicle control, but may issue warnings.
- Level 1: Driver must be ready to take control at any time. Automated system may include features such as Adaptive Cruise Control (ACC), Parking Assistance with automated steering, and Lane Keeping Assistance (LKA) Type II in any combination.
- Level 2: The driver is obliged to detect objects and events and respond if the automated system fails to respond properly. The automated system executes accelerating, braking, and steering. The automated system can deactivate immediately upon takeover by the driver.
- Level 3: Within known, limited environments (such as freeways), the driver can safely turn their attention away from driving tasks.
- Level 4: The automated system can control the vehicle in all but a few environments such as severe weather. The driver must enable the automated system only when it is safe to do so. When enabled, driver attention is not required.
- Level 5: Other than setting the destination and starting the system, no human intervention is required. The automatic system can drive to any location where it is legal to drive.

1.2. Basic Automated Vehicle Technologies

Driverless technologies operate, generally, in a similar fashion. Currently the technology is being applied to a variety of vehicles, these can range from personal (2-6 passenger cars, vans, SUVs) to small shuttle systems (10-20 passengers) and then onto larger freight, transport, and buses. All of these vehicles are typically outfitted with a series of cameras, lenses, and sensors located around the vehicle to see the surrounding environment and sense the location of the vehicle in proximity to obstacles. The cameras/sensors are then tied together with a mapping system (Lidar) and/or GPS to provide the programming and routing for the vehicle to navigate. This information is managed through proprietary operating systems that are controlling the vehicle speed, steering, direction, braking, etc.

There are several potential limitations to the technology. First, as this is very new, many of the countries, states, etc. have restricting rules in place that prohibit the technology from operating on roadways without a driver. This limits the testing and trials that are necessary for continued refinement and development of the systems. Second, because these systems are highly dependent on satellite data, there are some potential issues as they relate to signal transmission; heavy rain, snow, fog, dust, high-rise buildings can interfere with the transmission of signals. Third, how will these systems respond and handle unknown changes that cannot be found on a map. Are there issues with road closures for construction or accidents? And finally, there is an over societal limitation. Will people leave their cars (which they love to drive and serve as a status symbol) and trust in the safety of driverless technologies?

The following sections will discuss the available technologies under the bigger classifications of Autonomous Vehicles including Automated Cars, Automated Shuttles, and Automated Buses.

2. AUTOMATED CARS

Around the globe today there is a rush to capture the market of the self-driving car. Many of the car manufactures are working in close coordination with technology and mapping companies working to become the first in the market to capture a true Level 5 classification. The following by no means represents the complete depth of the auto industry attempts to get into the market, but instead reflects those that are actively operating pilot programs for their systems.

2.1. Google

Google Self Driving Car Project Started in 2009 and is currently in 4 cities: Mountain View, CA, Austin, TX, Kirkland, WA and Metro Phoenix, AZ. To date the self-driven vehicles have covered more that 1.5 million miles. The vehicles have been from a Toyota Prius, to a modified Lexus SUV to the new Google prototype, which was released in 2014 and is in limited test markets.

The system operates with a series of cameras, sensors, mapping, and software. The software is analysing the data and determining the solution for the vehicle (steering, braking, etc.). Throughout the test markets, the operating systems have continued to refine themselves; eventually leading to a fully automated, integrated electric vehicle that could meet Level 4 or Level 5 classifications.

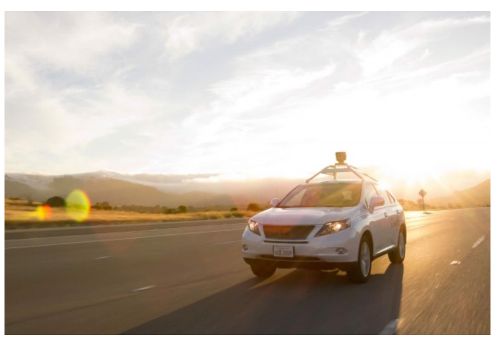


Figure 1 –Google Technology Using the Lexus RX450h

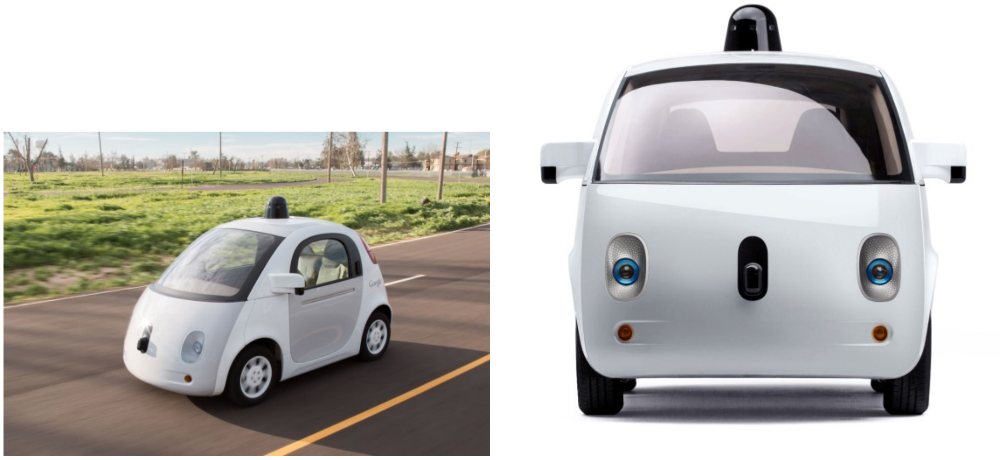


Figure 2 – Google Prototype Self-Driving Car

2.2. nuTonomy

nuTomony has established the first pilot for a self-driving taxi service. The pilot project will operate within a 2 square km business park in Singapore. The initial pilot program will include 6 vehicles, operating on a 6 km route within the park. The patrons will be selected ahead of time and will hail the taxi through a smart phone app. Once nuTonomy has achieved a series of milestones, the pilot project will be rolled out to other areas of the city for testing.

Figure 3 - nuTonomy

2.3. Uber

Recently, Uber publicly opened up a self-driving rideshare program in Pittsburgh. The fleet includes 14 Ford Fusion vehicles equipped with radar, cameras, and other mapping software to publicly test the vehicles in actual conditions. Passengers will still sit in the back with a safety driver in the front. At this time, the system may still require driver intervention at times and for safety reasons, all tests will still include a driver. Uber has also released self-driving vehicles in San Francisco, CA but these are not public use vehicles they are undergoing testing in various environmental conditions to refine the safety and security of the vehicle operations.

Figure 4 – Uber Technology on the Ford Fusion, Pittsburgh, PA

3. AUTOMATED SHUTTLES

Automated shuttles are typically comprised of small, minibus type vehicles with a capacity ranging from 10-20 passengers. This solution is generally used to address the "last mile" of transport; the area where a larger transit solution (rail, train, etc.) leaves a passenger and that person still has a small, localized distance to cover. The system creates a smaller feeder network that provides additional solutions for travelers.

Most automated systems require little additional infrastructure to operate. In most instances, the route the vehicle follows is pre-programmed through mapping software and can be adjusted as necessary. For some of the technologies, they do require small magnets installed in the driving surface (asphalt) that assist in the vehicle guidance and safety. This system is thus limited in for route adjustment.

This area is a rapidly evolving transit solution. As governments are starting to recognize the need for improved transit solutions that are environmentally friendly, cost effective, and safe; several companies are responding and providing solutions that are being implemented for trials around the world. One of the restricting factors to testing and implementation are the exiting transit regulations; many of which restrict driverless vehicles from operating on the same roadways as other vehicular traffic. Because of this, it is difficult to classify as a true Level 5 automated vehicle; in most cases, the vehicle is segregated from the rest of the traffic and is operating on a dedicated lane, with limited involvement from the rest of the traffic patterns. In many instances, the vehicles are operating within business parks, pedestrian avenues, and parks. The following details some of the systems found in the marketplace today.

3.1. EasyMile

3.1.1. Description

The EZ10 is a driverless, shuttle (capacity up to 14 passengers) that can operate either forward or backwards (there is no need for the vehicle to turn around). The shuttle can operate on a point-to-point route (with stops along the way), in a single lane and then reverse course and return to the origin. The shuttle can operate in a continuous loop mode (i.e. within a business park); or the shuttle can be operated "on-demand" through a mobile application, much like a taxi.

The vehicle is an electric car and operates on lithium ion batteries, which will last up to 10-14 hours (depending on use) and require charging (230V 16A). The operating speed is 25 km/h and can get up to 40 km/h.

There are minimal additional infrastructure requirements identified. The system is able to operate on actual road conditions, though testing of these conditions has been limited due to regulations. In some instances additional signage, road markings, etc. may be required to ensure that the other traffic is aware that there are driverless vehicles in operation. This vehicle does meet the classification of a Level 4 vehicle, however the implementation and testing of this has been limited.

3.1.2. Case Studies

Gardens by the Bay, Singapore:

Figure 5 – EZ10 Shuttle, Gardens by the Bay

In December 2015, EasyMile began EZ10 driverless shuttle trial at Gardens of the Bay in Singapore. This successful trial has now been transitioned into full-time service and operations. As this is a private park, there are limited traffic navigation issues, but there are significant pedestrian hazards that the vehicles must navigate. The operational system is comprised of 10 passenger vehicles. The vehicles can operate at a maximum speed of 40 km/h; however they travel at a typical speed of 8-12 km/h within the Garden. Because of the weather conditions here (heavy rain at times) the technology is continuing to make modifications to the sensing system and get better positioned to handle weather constraints.

Mohammed bin Rashid Boulevard, Dubai, UAE:

Figure 6 – EZ10 Shuttle Road Test Dubai, UAE

Beginning September 1, 2016, EasyMile (EZ10 vehicle) in conjunction with the Roads and Transportation Authority (RTA) in Dubai started trial runs for a 10 seat, passenger shuttle covering a 700 meter route along Mohammed bin Rashid Boulevard. This is a significant trial as the vehicles will be subjected to harsher temperatures and environmental conditions than previous trials throughout Europe.

SOHJA Project, Finland:

Figure 7 – EZ10 Shuttle SOHJA Helsinki, Finland

Figure 8 – EZ10 Suttle in Operation in Finland

As part of a pilot program, in August 2016, EasyMile began operating the EZ10 vehicles on the public roadways of Helsinki. They will be operating under real traffic conditions and will operate in three different locations within Finland (Helsinki, Espoo, and Tampere). The trial will last 1 year, but will stop during the winter months and resume in the spring. There are two vehicles operating for the trial with a capacity of 9 passengers.

3.2. 2getthere

3.2.1. Description

2getthere has been operating in the automated transit market with their Personal Rapid Transit (PRT) and Group Rapid Transit (GRT) systems. 2getthere's GRT system operates on a defined right of way. The system utilizes automated minibuses (ParkShuttles) which have a capacity of up to 25 passengers. The system utilizes a passive guidance system with magnets installed in the asphalt, just below the road surface, at maximum intervals of 6 meters. The ParkShuttle systems are ideally suited as feeder systems to both public transit nodes and parking facilities. They can also be used as local transit systems, connecting facilities within a certain location (e.g. within a business district).

One of the limitations to this technology is the system can only operate on the installed magnet system, and there is little flexibility with regard to route adjustments; constrained to predetermine routes. If at grade intersection flows are too high, grade separations may be required for the vehicle to operate safely and effectively.

3.2.2. Case Studies

Rivium Business Park, The Netherlands:

Figure 9 – Rivium Business Park, 2gethere GRT Operational Shuttle

Initially opened in 1999 as a 1300 meter track with 3 vehicles, it was realized that initial capacity was exceeded and in 2001 the system was expanded to an 1800 meter, dual lane track with 5 stations and 6, 20 passenger vehicles. During peak periods when all 6 vehicles are operational, the system operates on a schedule with 2 ½ minute intervals (averages 2,500 passengers per day). When the system is off-peak it is transitioned into an on-demand system. This system operates at grade and with at-grade intersections for both cars and pedestrians. System availability is >99%.

Masdar City, Abu Dhabi:

Figure 10 – Masdar City, 2getthere PRT Shuttle in Operation

Personal Rapid Transit; network is 1.5 km long, includes 5 stations and 10 vehicles (2-4 passengers) and 2 stations (each end of the route); and in 2014 the system carried its 1 millionth passenger. System availability is >99.4%

3.3. Navya Arma

3.3.1. Description

The Navya Arma is a 100% electric, automated transport vehicle. Current systems have the capacity to carry 15 passengers per vehicle and can travel safely at speeds up to 45km/h. This specific vehicle operates at a Level 4 automated vehicle classification.

The Arma vehicle has a vehicle capacity of 15 passengers (maximum of 11 seated positions); the system uses an induction charging system, with a 33 kWh battery and its batteries can be recharged by induction and can last from 5 to 13 hours according to the configuration and the traffic conditions. The vehicle can reach a maximum speed of 45 km/h but the operating speed is 25 km/h.

The driverless system operates on an interconnected technology comprised of GPS/GPSRTK, Lidar data, stereovision cameras, and an inertial central system (vehicle orientation, rotation, odometer, and 3D positioning).

The NAVYA engineers will map the area and program the route into the application site. The information is then sent over to the NAVYA shuttles and they repeat the programmed track with an accuracy of 2 cm detection for environmental issues (pedestrians, obstacles, etc.). Because the system is constantly updating through the GPS and Lidar mapping, the engineers can adjust and program routes as necessary. There are no additional infrastructure requirements identified. The system is able to operate on actual road conditions.

3.3.2. Case Studies

Confluence District of Lyon, France:

Figure 11 – NAVYA ARMA, Confluence District Lyon, France

This recently announced project will operate on a 1300 meter route, with 5 stops, 2 at the ends, and 3 in the middle, thus allowing the system to stop for the various buildings within the business district. The vehicle will operate at a maximum speed of 15km/h and will take 13 minutes and 30 seconds to complete a rotation. The route does not include any traffic signals, crosswalks or intersections. This is still under development.

Sion, Switzerland:

Figure 12 – ANVYA ARMA Driverless Shuttle in Sion, Switzerland

The NAVYA ARMA driverless shuttles have begun open road testing in Sion, Switzerland. They are operating 2 shuttles, with a passenger capacity of 11 passengers per vehicle. The shuttles operate at speeds of 25 km/h and can reach speeds up to 40 km/h. These shuttles successfully completed closed-road testing and on June 23, 2016 began passenger operations.

3.4. Local Motors: OLLI

3.4.1. Description

Figure 13 – Local Motors, OLLI, Preparing for Demonstations

Local Motors is an automaker that has created a 3D printed, partially recyclable electric shuttle called Olli. Olli can carry 12 passengers and operates autonomously using overlapping sensors (radar, Lidar and cameras) and transmits the information to the operating system. The vehicle is an electric vehicle and operates on batteries. Local Motors designed Olli to be accessible from a hand-held application. The user will call Olli on the app and then direct the vehicle where they would like to go. Local Motors sees this as a transit solution for a variety of users from large municipalities to private corporations.

3.4.2. Case Studies

There are no case studies out at this time, however the vehicle was showcased and provided rides at the International Manufacturing Technology Show in Chicago, IL this past month. Local Motors has also set up a technology test track at National Harbor, MD and was providing rides throughout the summer of 2016.

4. AUTOMATED BUSES

4.1. Daimler (Mercedes-Benz Future Bus) with CityPilot

4.1.1. Description

Mercedes-Benz, with CityPilot have released the automated driving Future Bus. This vehicle operates on a similar platform to that of the Highway Pilot (Mercedes-Benz Actros truck) but has been further refined and has added functions. The CityPilot is able to recognize traffic lights and safely navigate them, recognizes obstacles, and implements automated braking. When operating on a fixed bus route, the bus is able to approach the designated bus stops, automatically open and close the doors, and then safely return into the lane of traffic. The vehicles are now also able navigate through tunnels (which previous iterations of the tech had issues). The Future Bus has a top speed of 70 km/h on open road. To date, the vehicle is still under testing with a driver, however the driver does not need to accelerate or brake. Per safety regulations, the driver is required to take the wheel when there is oncoming traffic and they can intervene at any time and take immediate control.

Figure 14 – Mereceds Benz, Future Bus, Amsterdam

4.1.2. Case Studies

In July of 2016, the Future Bus drove a little more than 12 miles from Amsterdam's Schiphol airport to Haarlem, a city just outside Amsterdam without issue.

4.2. Yutong

4.2.1. Description

Yutong, a Chinese company, has successfully road-tested a driverless bus on the streets. The bus was able to navigate the 32 km route from one city to the next, change lanes, pass vehicles, and traverse 26 traffic controlled intersections. This however is only the first phase of the driverless bus and the system will undergo three additional development phases.

The core of the driverless system is the intelligence master controller, the intelligence sensing system, and the intelligence control system. These systems are comprised of a complex, interconnectivity between laser, radar and cameras on all four sides of the vehicle. The controller will use the radar and cameras to send directions to the vehicle thus controlling the braking and steering of the vehicle.

The additional development stages will include basic movement control, driving on average roadway conditions, and driving on highways.

Detailed technical specifications were not available for discussion. It is unknown if vehicle is electric or gas.

It appears that there are no infrastructure requirements at this time. Since limited data was available for review, it was assumed that because the trial was conducted on intercity roadways, throughout the cities, the driverless buses require no additional infrastructure to operate safely. However, since this is only the analysis of the trial performed and the technology is undergoing further stages of development, it is possible that additional requirements may develop.

At this time, since the product is undergoing further development the limitations are constrained to the additional testing and development required and the subsequent release into the marketplace for public/private use.

Additionally, since the vehicle is in the early stages of development and the technical details were not readily available, it appears that Yutong is implementing the driverless technology into one of their existing bus fleet. These are not electric vehicles, they are gas powered. This does not provide any benefit in terms of environmental awareness and reduction of carbon footprint.

4.2.2. Case Studies

In September 2015, Yutong successfully completed a trial of an automated, driverless bus system that traveled over 32 km and reached speeds of 68 km/h. This trial was conducted on an operating intercity roadway that includes lane changes, passing, and traffic lights (26 in total). The trail was conducted with an operator behind the wheel for safety purposes, however this operator did not engage during the course of the trial.

Figure 15 – Yutong, Self-Driving Technology Demonstration on Bus.

5. OVERALL LIMITATIONS / CONCERNS

With any automated transit solution there are limitations and areas of concerns. Until the Federal, State, and Local regulations are ready to accept driverless vehicles on open roadways, it will be difficult to test and implement driverless solutions with proven track records. The Federal Government recently (September 2016) began addressing this exact issue and is working towards a solution that will unify the guidelines throughout the country.

As most of these systems are dependent upon sensors, cameras, Lidar, GPS, etc., any environmental condition that inhibits transmission of clear signals will be a concern. This can be anything from high-rise office buildings, to tunnels, heavy rainfall, fog, etc. This issue may be able to be addressed by installing additional infrastructure throughout the driving route to insure strong signals and reduce impacts, but again, until the technologies are able to be tested and proven under all the conditions, they continue to include potential risks with driverless automated operations.

In addition to the above potential risks, it is important to note that there has been little or no discussion regarding the potential Liability and Insurance regulations and requirements that municipalities may have to take on in order to implement a driverless solution. Since the industry is still proving itself, this concern may be unknown for several years.

Most of the systems previously discussed are operating with electric vehicles, the result of campaigning to reduce the carbon footprint and reduce the number of vehicles on the roadway. This impact becomes two-fold. First, most of the vehicles in testing today have a limited range and operating speed. This is in part driven by the battery power of the vehicles. If the area where the driverless vehicles are to operate is highly urban, then these lower speeds will not have a significant impact. However, if the desired routes involve highways, then different solutions may need to be explored.

6. SUMMARY

The driverless automated transit solution is evolving at such a rapid pace; one can expect that within a short amount of time, it will be able to accommodate most urban transit needs and solutions. The most important piece is ultimately understanding what the goal of the solution is. Do you want the technology to solve the “first and last mile” dilemma, or is it to operate more and perhaps like an on-demand taxi service. What are the passenger capacities required, the peak demands, the routes? Additional explorations will be necessary to determine the ultimate needs of the system; but given the amount of technology emerging on the market and the demand to identify and find proven solutions, it is certain to say that this technology will only be improving in the future.

Appendix A-2: Industry Feedback Letter

JACKSONVILLE TRANSPORTATION AUTHORITY
2016 APTA Award Winner

2016 OUTSTANDING PUBLIC TRANSPORTATION SYSTEM ACHIEVEMENT AWARD

October 19, 2016

Schwager Davis, Inc.
ATTN: Lee Larsen
Project Manager – Transit Division
198 Hillsdale Avenue
San Jose, CA 95136

llarsen@schwagerdavis.com

RE Jacksonville Transportation Authority
Skyway Modernization Program
Industry Feedback

Dear Mr. Larsen,

The Jacksonville Transportation Authority (JTA) in Jacksonville Florida is seeking feedback from industry to assist with development of our Skyway Modernization Program. Pursuant to a JTA Board adopted resolution to keep, modernize and expand the Skyway system; we are currently developing plans for modernizing our automated people mover system and evaluating potential extensions that will be part of a major capital investment program. We are open to considering all innovative ideas and are not constrained by the present system vehicles, technology and infrastructure.

Attached are a system map, system information and key questions regarding implementation of the modernization program. Additional information is available upon request, including as built plans for the current system.

We would like to invite representatives of your company to attend a one-hour meeting with JTA representatives on November 9th or 10th, 2016 at a time scheduled between 9:00AM and 4:00PM. If interested, please let me know your preferred day and time by contacting me at (904) 598-8765 or e-mail bgthoburn@jtafla.com by COB on October 28th, 2016. We will follow up with schedule confirmation.

At our meeting, we request that you be prepared to ask questions that will assist with your understanding of our modernization plan, and also discuss the attached questions. Please let us know if we can provide additional information in advance that will help you prepare for the meeting.

We look forward to meeting with you as we develop our program and we value any and all input that you may have that will help make our Skyway Modernization Program a success.

Sincerely,

Brad Thoburn
Vice President, Planning, Development and Innovation

Skyway Modernization Program Overview

Skyway System Overview

- Skyway serves as a downtown circulator with the intention to relieve downtown congestion, improve air quality and provide peripheral parking to support downtown development.
- The 2.5 mile system includes eight stations and ten 2-car rubber tired trains.
- The Skyway is fully automated using an Automatic Train Control System.
- The trains, designed by Bombardier Transportation, use UMIII monorail technology and run along a 34-inch wide beam, 28 inches deep, fixed on an 11-foot wide guideway with parapet walls.
- Three substations provide 480 volt AC traction power for the trains.
- Each Skyway train has three motors, six load tires and 18 guide tires.
- A two-car Skyway train can carry 56 passengers.
- The system has two routes running south from Rosa Parks Station, splitting at Central Station with one route running west to the Convention Center Station and the other runs to the Southbank.
- Skyway stations and trains are monitored by closed-circuit television.
- Each station has electronic message boards that provide real-time passenger information.
- Daily ridership has increased to 5000 customers per day.

Skyway History and Background

- 1971 – Jacksonville Planning Board approves federal planning grant for downtown people mover (one of five urban areas selected, others are Detroit, Irving, Miami, and Morgantown).
- 1985 – Jacksonville receives $23 million in federal funds to build Automated Skyway Express.
- 1987 – Construction begins on starter line.
- 1989 – Starter line begins operations at 7/10th of a mile, Convention Center to Central Station.
- 1995 – JTA issues new Request for Proposal, Bombardier wins new contract.
- 1997 – Conversion to current system, a proprietary monorail system.
- 2000 – Skyway system complete – service from Rosa Parks Station to Hemming Plaza across Acosta Bridge to Kings Ave Garage.
- 2012 – Skyway becomes fare free (Feb. 2012).
- 2014 – Skyway celebrates 25th Anniversary.
- 2015 – JTA Board approves a resolution to keep, modernize and expand the Skyway.

Funding and Financial Background

- Initial $185 million total investment federal (56.7%), state (20.45%), city (9.91%) and JTA (12.95%) funds.
- Generally, trains have 25-year service life and structures have 50-year service life.
- Annual operating costs and maintenance costs are approximately $6.3 million.
- State of Good Repair needs for operating systems estimated at $15-19 million.
- State of Good Repair needs for infrastructure (guideway and stations) estimated at $24 million.

Skyway Modernization Program Overview

Skyway Current Conditions

- Vehicles are past the mid-life and due for overhaul.
- Six of the ten trains are in service.
- Obsolescence of vehicle replacement parts is affecting operational reliability and maintenance costs.
- Infrastructure, guideway and stations are structurally sound, but annual preventive maintenance is required.

System Planning Issues

- JTA Board and community support modernization and expansion of the Skyway.
- Skyway Modernization Program launched in spring 2016 to upgrade vehicles, technology and infrastructure and evaluate extensions
- How does Skyway as the downtown circulator fit into plans for larger transit system plans, specifically connectivity to bus rapid transit (First Coast Flyer) and future commuter rail)?
- How does the future of the Skyway impact Downtown Development?
- How will the preferred option be funded?
- JTA is not constrained by existing system and infrastructure and is open to evaluation of all potential innovative alternates for modernization and extensions including new vehicles, autonomous technology, elevated and at grade options for extensions.
- JTA is planning modernization and extensions as part of a multi-year capital plan.

Key Questions to Industry

- Would your company be interested in responding to:
    1. Request for Proposals (RFP) for rehabilitation of current vehicles and aging subsystems (i.e. Automatic Train Control, Central Control, Communications, etc.)?
    2. RFP for replacement of current vehicle and aging subsystems, with new vehicle built to same specifications to operate on guidebeam?
    3. RFP for replacement of current vehicle and aging subsystems, with different vehicle built to different specifications to operate on infrastructure without guidebeam including any guideway structure modifications required to accommodate new technology vehicle?
    4. RFP for Design, Build, Operate and Maintain (DBOM)?
    5. RFP for Design, Build, Finance, Operate and Maintain (DBFOM)?
    6. RFP for implementation as Public-Private-Partnership (P3) concession?
    7. RFP for all of the above that would include extensions of the system?


UF Health and VA
8th and Main
8th St.
Kings Rd.
Myrtle Ave.
95
Main St.
N Jefferson St.
Broad St.
2nd and Main
W. Beaver St.
1st St.
W Union St.
A Philip Randolph Blvd.
Rosa Parks
E. State St.
Operations Center
JRTC (Coming Soon)
Convention Center
Hogan St.
Hemming Park
Matthews Expy.
Jefferson
Central
W Forsyth St.
W Bay St.
Skyway O&M
Brooklyn
Old City Hall
Shipyards
Amphitheater/ Practice Fields
Park St.
Acosta Br.
Main St.
Gator Bowl Blvd.
Shipyards
Riverside
Sports Complex
10
San Marco
Riverplace
San Marco Riverwalk
Riverside Arts Market
St. Johns River
Five Points
Kings Avenue
The District
The District
St. Johns River
95
San Marco Blvd.
Riverside Ave.
MD Anderson
San Marco and LaSalle
Kings Ave.
LaSalle St.
Commuter Rail Connection
Atlantic Blvd.
Beach Blvd.
San Marco Square
95
Hendricks Ave.
Jackson Square
Philips Hwy.
St. Johns River
JTA Skyway Modernization Program
Legend
Existing Skyway Route
Potential Skyway Route
First Coast Flyer BRT Corridors
JTA Local Bus Routes
Existing Skyway Station
Potential Skyway Station
Candidate Commuter Rail Corridor with Stops
Potential Skyway Extensions Quarter Mile Buffer
N

Appendix A-3: Vendor Technology Options Matrix

Skyway Modernization Program
Vendor Technology Options Matrix
Phase 1 - Modernize Existing

	Bombardier APM	SDI APM	MHIA APM	Woojin APM	Siemens APM	Leitner-Poma (Cable)	2getthere A/V	Easy Mile A/V	Skyweb Express Taxi 2000 PRT
Rehabilitate Vehicle		X		X					
Partial Rehabilitation of Subsystems			X						
APM - with Guidebeam		X		X					
APM - Remove Guidebeam - Add Guide Rail	X	X	X	X	?	X			
A/V - Remove Guidebeam							X	X	
PRT - with Guidebeam - Add PRT Rail									X

Note:

1. MHIA may be interested in mini overhaul of some subsystems only but not the entire vehicle and Operating System.
2. SDI would try to adapt their Unitrack technology to match the existing guideway infrastructure.
3. Woojin would try to adapt their smart monorail to match the existing guideway infrastructure.
4. For the 3 vendors that expressed some potential interest in rehabilitation, it is recommended that they are provided time to inspect the vehicles and subsystems that require upgrade/rehabilitation to familiarize themselves with the issues and determine what they can offer.
5. Siemens will confirm availability of APM.
6. PRT Option could retain guidebeam but will require added rail and modifications at stations and termini.

Appendix A-4: Summary of Technology Options

Personal Rapid Transit

Personal Rapid Transit (PRT) is a transit technology characterized by small (4-6 passengers) vehicles, operating over a dispersed network, and designed to provide nonstop, origin-to-destination service to individuals or small groups of passengers. Currently there are three PRT suppliers world-wide that have systems in passenger service or on test tracks: ULTra (U.K.), 2GetThere (Netherlands), and Vectus (Korea). ULTra has a three-station operating system between a parking lot and Terminal 5 at the London Heathrow International Airport (LHR). 2GetThere has a two station system operating at Masdar City in Abu Dhabi. Vectus has a test track in Sweden and is building a two-station system at an amusement park in Suncheon Bay, South Korea. All of these are "starter" systems and do not represent a dispersed network application with on-demand origin/destination and direct routing i.e., the representative project application for a PRT.

Key factors to consider with PRT include:

- Small, limited operating systems with limited capacities
- Small cars with limited interior capacity (maximum of 4 to 6 passengers) and low headroom
- Low operating speed (less than 40 km/h)
- Three small starter systems with very limited complexity and capacity, though this technology has been promoted/developed for over 30 years.
- Operating headway and resulting system capacity remains controversial. PRT suppliers claim that the operating headways can be as close as 0.5 seconds to get higher capacities. However, this has not been service proven (even on a test track) with a representative operating fleet and guideway configuration. To accommodate such a high vehicle volume, the infrastructure at the stations and bypass lanes would be substantially larger than the larger vehicle APM systems described subsequently.

Monorails

Small Monorails

Monorails that have been applied in airport environments are typically in the small/medium category. These are characterized by trains with connected vehicles, usually operating at speeds of 30 to 50 km/h, designed to carry a moderate number of passengers within a geographically compact area. Examples of small monorails in the US are the Bombardier UM III Series Monorail at a parking garage at Tampa International Airport (TPA), JTA's existing system, and the Bombardier Type III Monorail at Newark International Airport (EWR). Hitachi also provides small monorails; the only fairly recent (last ten years) example of which is on Sentosa Island in Singapore. Intiman has built several small manually operated monorails in Europe Asia. Siemens built a suspended monorail at the Dusseldorf International Airport in Germany. Suspended monorails do not meet NFPA 130 requirements for emergency evacuation. Only the EWR system serves passengers going between airport landside facilities. The TPA monorail operates within the TPA parking garage.

Key factors to consider with small monorails include:

- Small vehicles/cabins with single doors
- Longer, narrower vehicles for same number of passengers
- Fixed vehicle length
- Limited flexibility to extend train length by coupling due to front and tail car nose
- Relatively small guideway but large guideway replacement switches

Large Monorails

There are two types of large monorail systems: straddle-beam (guidebeam below the vehicle) and suspended (guidebeam above the vehicle. Large straddle-beam monorail systems have been built overseas by: 1) Hitachi in Japan and Dubai (Palm monorail) in urban applications and one airport access (Tokyo Haneda) application; and 2) a Malaysian company in an urban application in Kuala Lumpur. In the United States, there are manually driven large monorails in downtown Seattle, in Disneyland and in Disney World. Bombardier has fully automated monorails: an operating system in an urban application in Las Vegas and urban applications in Riyadh, Saudi Arabia, and Sao Paulo, Brazil. Suspended monorails cannot meet NFPA 130 for emergency evacuation.

Key factors to consider with large monorails include:

- Larger cabins with one or two bi-parting door sets
- Fixed vehicle length
- Limited flexibility to extend train length by coupling due to front and tail car nose
- Inefficient vehicle floor use due to bogies – longer vehicle per number of passengers
- Relatively small guideway but massive guideway replacement switches

Cable-Propelled APMs

This type of technology consists of medium capacity vehicles that use cable propulsion and various types of suspension systems (rubber tire, air levitated or steel-wheel/steel-rail). Trains can be up to five cars long. Suppliers' claim that longer trains are possible but these have not been implemented – primarily impacts are to the drive cable and drive machinery which must now "pull" the higher weights associated with the longer train. The number of cars per train is fixed; a train has permanently coupled individual cars and grips to the cable at fixed points.

Typically, cable systems are operated in a shuttle mode. Typical configurations are single and dual-lane shuttles and bypass shuttles: one or two trains shuttling back and forth between end-of-line stations. Single lane shuttles have only one train and guideway. Dual lane shuttles are in effect two single lane shuttles, controlled to operate synchronously: one train starts from each end station, station; they pass in the middle, and end at the other station. Otis Transit Systems (subsequently Poma-Otis, and now Leitner-Poma) installed air levitated, cable systems at Cincinnati, Narita (Tokyo), Minneapolis/St Paul, Detroit, and Zurich International Airports. Leitner-Poma selected to replace the MIA Concourse E APM. The Tampa Harbour Island APM was an Otis air-levitated system. Doppelmayr Cable Company (DCC) has cable-propelled systems installed at Mexico City and Birmingham (UK) International Airports and systems under implementation within the terminal building at the new Hamad International Airport (Doha, Qatar) and a 5 km airport access system connecting the Oakland International Airport and the BART rail system.

Key factors to consider with cable-propelled APMs include:

- Cabin sizes: small cabins with one door set or medium cabins with two bi-parting door sets
- Fixed train lengths – cannot change train length without long term train being out of service
- Fixed grip for shuttle mode or releasable grips for pinched loop mode
- Limited cable length: up to 2.5 km
- Station spacing and multiple trains on a single segment between stations for "synchronized" headway operations.
- End of line or on-line M&SF required without releasable grips
- Majority of systems operate in a shuttle mode with only a couple operating in pinched loop.

Self-Propelled Rubber-Tired APMs

Large vehicle rubber-tired APM systems are in widespread use at airports around the world and in some urban areas. These systems feature one-car to six-car trains operating in a shuttle or pinched loop configuration. Train speeds of up to 80.5 km/h can be achieved and are limited by the guideway length and configuration. Passenger capacity for landside applications typically is about 50 to 55 passengers per car due to baggage and often bag carts. Airside system car capacity is about 65 passengers per car since passengers travel with only their carry-on baggage. Currently available self-propelled vehicle rubber-tire APM systems include Bombardier: Innovia 100 (previously CX-100) and Innovia 200/300, Mitsubishi Heavy Industries (MHI): Crystal Mover and "Japanese Standard", IHI/Niigata: I-Max and "Japanese Standard", Siemens-Matra VAL258 and AirVAL.

Key factors to consider with self-propelled rubber-tired APMs include:

- Approximately 12 m. cars with two bi-parting door sets per side

- Flexible train length: normally 1 to 4 cars (6-car trains are being implemented at HKG)
- Shuttle, loop, and pinched loop operating modes
- Speeds up to 80 km
- Generally the APMs provided at airports.

Automated Light Rail Transit System (ALRT)

Large steel-wheel APM systems operate in numerous urban settings and two landside airport applications: New York Kennedy (JFK) and the new Beijing (PEK) International Airports. Urban applications of this technology include Vancouver, Toronto, Detroit, Dubai, Riyadh, Copenhagen, Breccia, Kuala Lumpur, and Honolulu (under construction). Train length ranges from two to six vehicles. Train speeds range between 80 and 95 km/h. Suppliers of this type of technology include Alstom, Ansaldo-Breda, Bombardier, MHI, and Rotan.

Most light rail systems are manually driven. However, some have been fitted with automatic controls to allow fully automated operation. Three examples of automated light rail transit (ALRT) systems are:

- The Mark II system manufactured by the Bombardier and installed at New York JFK (Air Train), Beijing Airport (Airport Express of the Beijing Subway) and Vancouver (SkyTrain)
- Breda Metro driverless light rail system for Copenhagen, Denmark
- The Kinki Sharyo/ Mitsubishi system for the Dubai Metro.

The greater capacity and speed of this technology makes it more suitable for relatively straight alignment on dedicated transportation right of way for the system. A vast majority of the ALRTs are steel wheel–steel rail "ALRT (SW-SR)", however, some ALRTs systems are run on rubber tired wheels "ALRT (RT)". Typically, ALRT (SW-SR) and ALRT (RT) systems have longer car lengths than APMs. However ALRT (RT) vehicle lengths are shorter than ALRT (SW-SR). Apart from the length of the car, the rubber tired ALRT characteristics are very similar to the APM.

Key factors to consider with self-propelled large steel wheel-rail APMs include:

- Vehicles typically longer than rubber tired vehicles (typically 15 to 20 meters)
- Flexible train length: 1 to 6 cars
- Shuttle, loop, and pinched loop operating modes
- Higher operating speeds – typically 80 to 95 km/h
- Generally applied to urban/metro systems that are longer and have more stations
- Steel wheel-rail noise, particularly in curves

Light Rail Transit (LRT)/Tram/Streetcar-Technology Overview

For the purpose of this study, a wide definition of streetcars is used. Vehicle products that could be used in the City of Jacksonville, along with their technical characteristics, are described in the following sections.

Alstom Citadis [402]

Alstom, headquartered in France, has implemented its self-propelled, steel-wheeled Citadis tram in over 40 cities around the world of varying models. These systems are guided by steel rails, utilize on board rotary electric motors and can operate as trains of 3- to 7-cars. Power is supplied via overhead catenary, a power rail embedded in the guideway (called APS) or by on board batteries (for recovery only). They are typically manually operated.

Bombardier Flexity [2]

Bombardier has implemented its self-propelled, steel-wheeled Flexity tram in over 40 cities around the world. These systems are guided by steel rails, utilize on board rotary electric motors and can operate as trains of 3- to 7-cars. Power is supplied via overhead catenary wire or by contactless, wireless charging using inductive energy transfer between underground components and receiving equipment beneath the vehicle (called Primove). They are typically manually operated.

Brookville Liberty Modern Streetcar

Brookville Equipment Corporation, headquartered in the United States, introduced its self-propelled, steel-wheeled Liberty Modern Streetcar in 2011. This system is guided by steel rails, utilizes on board rotary electric motors and operates as trains of 3-cars. Power is supplied via overhead catenary or by on board batteries. They are manually operated.

United Modern Streetcar

United Streetcar, headquartered in the United States, is a division of Oregon Iron Works, Inc. It introduced its self-propelled, steel-wheeled modern streetcar in 2009. This system is guided by steel rails, utilizes on board rotary electric motors and operates as trains of 3-cars. Power is supplied via overhead catenary or by on board batteries. They are manually operated. It has been reported that United Streetcar was dissolved in February 2015.