

## **Singapore Changi Airport People Mover System – An Update**

### **ABSTRACT**

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The Singapore Changi Airport People Mover System (PMS) has been discussed at the previous two ASCE APM conferences. Those papers focused on the planning and general design and purpose of the system. This paper updates the previous ones and provides a discussion of several topics important to the procurement and design of the system.

A summary description of the existing and new systems will be given early in the paper, along with alignment drawings and photos.

The PMS system equipment is being procured using a design-build-operate-maintain approach. The facilities (guideway, stations, and maintenance facilities) are being designed to meet the selected system requirements while being integrated into the overall design of the airport and Terminals 1, 2, and 3. For the System, a request for proposals, contract documents, and performance specifications were developed and published. Three supplier teams responded: ADtranz (now Bombardier)/Keppel, Mitsubishi, and Niigata/SMRT. Tender offers were received and evaluated. Additional value engineering was then undertaken and a second round of tenders was implemented. Proposals came in significantly lower and were again evaluated. Mitsubishi was selected. They have started work, and the facility design work is underway based on this technology. Details of the process will be provided in the paper.

CAAS has the goal of keeping Changi Airport as the best in the world. Important to this goal is a high level of service to all passengers. The system has both airside and landside routes. Many passengers will have carry-on, or even all their baggage. CAAS decided that to keep service levels high, baggage trolleys would be permitted on the system. The stations and vehicles are being designed with this in mind. The implications and design responses for baggage trolleys will be discussed in this paper. A major complicating issue for this project is the phasing in of the new PMS while operating the existing one as long as possible. Several lines on the new system will replace the existing Sky Train system. The approach of the phasing plan will be to minimize the downtime of the Terminal 1 to Terminal 2 service. This approach will also be discussed in this paper.

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### **I. Summary of the New and Existing Systems**

#### **A. The New System**

The Changi Airport People Mover System (PMS) is part of the new Terminal 3 expansion project that is being built in order to accommodate an anticipated substantial growth in air passenger traffic at the Changi Airport in the coming decades. The PMS Project is scheduled for passenger service in June 2006, in time for the opening of the new Terminal 3. The PMS represents a firm commitment by CAAS to assure that the Singapore Changi Airport continues to top the list of the world's best airports. Furthermore, CAAS is committed to providing a high level of service to patrons of the airport as well as to all passengers on the new PMS.

The PMS will carry passengers between all three terminals (T1, T2 and T3) on a total of seven airside, landside and mixed airside/landside routes. The routes will have single lane, double lane and by-pass shuttle configurations. There will be a total of 6.4 lane kilometers of guideway connecting seven stations that are integral with the terminal buildings.

*INSERT System Overview Figures Here.*

The new PMS will actually consist of two separate and physically isolated systems. There will be a North system, connecting the north side of Terminal 3 to Terminals 1 and 2, and there will be a South system that will run the length of the south finger of Terminal 3. The South system will also connect the south side of Terminal 3 with Terminal 2.

There will be three Maintenance and Storage Facilities (M&SFs) for the PMS, two on the North system and one on the South system. The M&SF near Station A-South will be the main maintenance facility for the entire PMS, and will include one lane for heavy maintenance and one for light maintenance. It will include storage for parts and equipment, offices, personnel facilities, shops, and other common areas. Next, there will be a smaller M&SF near Station C that will function as a satellite facility. It too will have one heavy and one light maintenance lane, but it will not include much of the other equipment and facilities provided at M&SF-A-South. Finally, there will be a light maintenance area in-situ at Station E on the D-E Airside line.

There will be two separate control facilities from each of which, both the north and south systems can be supervised and controlled. The Satellite Control Facility (SCF) for the PMS will be located in the Terminal 3 Airport Operations Center (AOC). The SCF will actually be the primary operations center used to control the PMS during normal operations. If this facility is inoperable for any reason, then the PMS will be controlled

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from the Central Control Facility (CCF) located in the Maintenance and Storage Facility near the A-South Station.

Mitsubishi Consortium (MC) is furnishing the newest version of their Crystal Mover vehicles. These are similar to those being provided for the Sengkang/Punggol systems in Singapore and the Miami Airport North Terminal APM system in Miami, Florida, USA.

As part of its commitment to a high level of passenger service, CAAS has decided that baggage trolleys will be permitted on the system. The stations and vehicles are being designed with this in mind. The implications and design responses for baggage trolleys will be discussed in this paper.

### **B. The Existing System**

Of the many challenging aspects of this project, probably the most significant is the requirement to replace the existing SkyTrain system while, at the same time and to the maximum extent possible, maintaining passenger service on the existing guideway lanes.

The existing SkyTrain system is essentially a two-lane shuttle system (one lane for airside passengers, the other for landside passengers).

*INSERT Existing System Overview Figure Here.*

CAAS wishes to keep as much of the existing system facilities infrastructure as possible. The existing guideway, which is built for a center guidance system, will be taken down to the slab level and then be re-built to accommodate the new side guidance system by MC. It is recognized that the replacement of the existing train control system and the requisite refurbishment of the guideways and stations will pose a significant coordination and interface challenge. This is discussed in further detail in Section 4 below.

## **II. Brief of the Procurement Process**

Lea+Elliott provided their professional consultancy services and their assistance in the preliminary engineering design of the system and in the development of the required PMS Contract Documents. These documents consisted primarily of the Technical Provisions, the Special Provisions and the O&M provisions of the Contract, although input was provided for the development of all of the other Contract documents as well. Lea+Elliott performed assessments of various candidate suppliers and their technologies and evaluated the tender offers of the three suppliers that submitted tender proposals.

As a result of the tender clarification process, and in an effort to limit their costs, it became desirable for CAAS to modify the alignment and consider other changes to the System that turned out to be significant with regard to the PMS System scope of work. This led CAAS to initiate a 2<sup>nd</sup> stage of the Tender Process. All of the original tenderers were advised of the intended changes, as indicated in revised Contract documents, and they were given an opportunity to re-submit their proposals accordingly. All of them did so.

CAAS considered all 2<sup>nd</sup> stage tender offers and ultimately selected the Mitsubishi Consortium to be the system supplier.

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### **III. Challenges Posed by the Implementation of the New PMS**

#### **A. Construction On or Near the Existing Infrastructure**

Several aspects of this project will be built on or near existing infrastructure. These include the modification of the existing stations and guideways, as well as construction of guideways that will traverse the Airport Boulevard in order to connect Terminals 2 and 3.

The existing guideways that link Terminals 1 and 2 will have to be modified for use by the new system. Presently, there are two guideways between Terminals 1 and 2 – one on the airside and one on the landside. The new system will comprise three guideways – one each that links the airside and landside between Terminals 1 and 2 and one that connects the shared airside and landside service between the northern ends of Terminals 2 and 3.

Much coordination has to be done in order to facilitate these modifications. The existing guideways are adjacent to a row of staff car parking lots. They are also very close to two ramps, one that leads up from the basement level of Terminal 1 and the other that leads into the basement level of Terminal 2. Public buses and goods vehicles are very frequent users of both ramps. There is also a network of underground services where the new guideways will be situated. Construction processes will have to be carefully worked out and coordinated so that there will be minimal closure or disruption of these infrastructure.

There will be a total of seven stations in the new PMS. Two of these seven stations exist on the current system. Additions and Alterations (A&A) works will have to be carried out on these two stations so that they can accommodate the new system. Some of the works include: alteration to the length of stations to suit the new trains, modification to the existing station façade to fit the new platform screen doors as well as other system specific equipment and upgrading of the stations' interiors to accommodate new services etc.

Similarly, works on the guideways that traverse the Airport Boulevard will have to be planned properly and closely coordinated. The Airport Boulevard is the main carriageway for motor vehicles travelling to and from the Changi Airport. At present, there are a total of four lanes on each carriageway. Construction of the guideway across the boulevard will require strategic planning so as to allow traffic to flow across the carriageways with minimal interference.

Incremental launching methods will be used to launch the guideway beams across the Airport Boulevard. This will enable construction to be carried out without the need to close any lane on the carriageway. At the same time, there will need to be sufficient overhead clearance so that commercial vehicles such as buses and goods vehicles can still reach the airport via the boulevard. Although this phase of the works will take about 10 months, daily airport operations must still be carried out with minimal interruption or interference.

Construction of the stations and maintenance facilities will also affect daily operations of various facilities including the Business Aviation Centre, a childcare centre, a vehicular access point that connects the air and landside of the airport, the Fire Command Centre, coach stands at T1, the transit hotel and part of the departure transit hall at T2. Fast track

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construction will ensure that works at critical areas will be carried out in the shortest amount of time possible so as to allow these facilities to be operated as normally as possible.

### **B. Phasing-In of Interim Service**

In order to maintain a high level of service at Changi Airport, it is not desirable to shut down the existing system for any more time than is absolutely necessary in order to accommodate the construction, installation and testing of the new system. This necessitates a considerable amount of planning for, and coordination of, the implementation of the new system while at the same time allowing the current system to continue to serve passenger needs to the maximum extent possible. Two factors are of utmost importance – safety of passengers and efficiency of system operations.

First, the existing East guideway will be shut down for modification works. At the same time, passenger traffic will be served by utilising the existing West guideway. Both airside and landside passenger services will share the same West guideway on a shared dual-car shuttle mode. Mitigation works will have to be performed on the existing guideway as well as on the existing Skytrain PMS operating system software in order to allow for this interim downgrade of service. During this interim phase, the system Contractor will have to set up a Satellite Operation Control Centre (OCC) next to the one used by the existing Skytrain Contractor. MC will use the Satellite OCC to perform Testing and Commissioning of the system on the East Guideway while the Skytrain Contractor will continue operating the shared airside and landside service from its existing premises.

During this phase of interim operations, construction will be taking place on both sides of the operational guideway. Because the new guideways will be very close to the operational guideway, extra care has to be taken to ensure passenger safety at all times.

It is inevitable that the level of service will be reduced slightly to cater for this works. During this phase, there will not be a redundant guideway to act as a back-up in case of system failure on the other. Furthermore, there will only be two cars left in service, which is the minimum number of cars to provide for both airside and landside service. Steps will therefore have to be taken during the maintenance periods to ensure the high degree of reliability of the system during this interim phase.

Some of the existing stations will have to be closed in phases in order to allow for the required A&A works. Temporary platforms will then have to be built in place of the closed stations. Despite these stations being temporary ones and the need for them to be fully functional in the midst of a construction environment, measures will have to be taken to ensure full efficiency of the system and passenger comfort.

Once the East Guideway has been fully modified and ready for operations, the West Guideway will be shut down for modification works. The new system by MC will then run on a dual-car shuttle mode serving both landside and airside operations on the East Guideway. Because the East Guideway has been designed for a single-car shuttle mode, the safety buffers at the two ends of the guideway would be able to take the impact of one

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car only. To accommodate interim dual-car operations on a system designed for single-car service, MC will have to modify their software to ensure that safety is not compromised.

### **C. Interfacing by the T3 Main Building Contractor and the Guideway Contractor**

The construction of the PMS guideway that is adjacent to the T3 Main Building is under the scope of the T3 Main Building Contractor whereas the construction of the rest of the PMS guideway is under the scope of the Guideway Contractor. (Refer to Appendix YYY. Drawing to show guideway and location of contract boundaries.).

The interfacing between these two Contractors and their respective works will be critical. Not only would a misaligned guideway reduce the efficiency of the system, it would also affect passenger ride quality and comfort. A misalignment of the guideway may also lead to difficulties should there be a need to upgrade the system in the future. Measures will be put in place to ensure that the guideway for the entire system will be properly aligned.

From the early stages of planning, both Contractors will use a common coordinate system. Careful coordination will be ensured between the two contractors through a series of regular working sessions. There is also an overlap in the contract boundaries so that both the contractors will share responsibilities in the design and construction of the guideway at the interfacing sections. In addition to checks done by the contractors constructing the guideway, the PMS contractor will be responsible for checking the design and work by the T3 Main Contractor and the Guideway Contractor, from the design stage to the construction process, to fully ensure that alignment of the guideway will be proper and that the guideway that is built will be fully compatible for use by their system.

### **D. Conformation to Tight Construction Schedule**

Construction of Terminal 3 is scheduled to be complete by mid 2006. The construction schedule of the guideway, being one of the key components of this project, will have to be closely tied to the schedule of the Main Terminal 3 Contract. Any delay in the handing or taking over of works areas by the different contractors will have a domino effect on the overall construction programme. Therefore, there is a critical need to closely monitor and coordinate the schedules and progress of the building, guideway and system contractors so that delays, if any, will be strictly kept to a minimum. Regular meetings will be held between the different contractors and CAAS to update one another on the different stages of progress so that any problems that surface can be acted upon right from the onset.

### **E. Maintaining High Levels of Service**

As noted earlier, there will be a total of seven stations and lines in the new system. Comparatively, there are only two stations and lines in the present one. Careful thought has to be given when designing the interior layout of the new stations to ensure smooth passenger flow. Signs will also have to be cleverly placed in order to prevent confusing commuters while abiding by T3's design philosophy of clarity with minimal signage at the same time.

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The guideway of the present PMS is flat and does not include any grades. However, due to the layout of the new system, there is a need to design and construct the guideway with grades as much as 4.2% (Refer to Appendix ZZZ). Passenger safety and comfort will be the key considerations when designing the guideways.

The use of baggage trolleys on the PMS is a factor that sets it apart from other systems in Singapore and around the world. The main concern is the unintended motion of baggage trolleys when the trains travel up or down grades on the guideways. Baggage trolleys in use on the landside of Changi Airport are equipped with trolley brakes, which must be manually released in order to set the trolleys in motion. However, trolleys in use on the airside are not equipped with such brakes. The grades and curves as well as acceleration and deceleration while traveling along the guideway will pose a problem to passengers who use trolleys especially on the airside lanes. Ideas to keep the trolleys in place during the motion of the trains are currently being explored so as to accord the highest level of service, safety and comfort to all passengers.

Two of the seven lines will operate on synchronised by-pass mode (Refer to Appendix AAA). Due to the lack of redundancy along the single-track sections of these guideways, a breakdown on these sections, especially at the switch areas, will result in longer downtime than a breakdown on a dedicated guideway. There will therefore be a need to maintain the highest standards of operation both on the system as well as on the guideway to ensure minimum downtime should there be a breakdown on the single-track sections of the lines that will operate on synchronised by-pass mode. Recovery procedures for breakdown along these sections will also have to be thoughtfully worked out.

### **IV. Phasing in of the System**

One of the biggest challenges faced in this project is the phasing in of the new system while allowing the current system to function as normally as possible. Detailed planning and considerations have to be put in place to ensure that the safety and comfort of passengers and efficiency of the system are not compromised.

There are two guideways in the present system that link Terminals 1 and 2 - the East and West Guideway. The East Guideway is a dedicated guideway used by the airside train only whilst the West Guideway can be shared by both the landside and airside trains.

The following A&A works are to be carried out on the current system:

1. Modification to the existing stations.
2. Modification to the existing guideways which link Terminals 1 and 2, as well as the addition of a new guideway to link Terminals 2 and 3.

A safety canopy made of steel will be utilised in order to ensure the safety of passengers in the trains when they are travelling along sections of the guideway where modification works are being carried out on the adjacent area (Refer to Appendix BBB). This canopy will effectively create a tunnel effect at these sections and will act as a barrier to segregate the functional area from the work area.

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Modification works will be carried out in coordinated phases to ensure that the system can function normally when A&A works is carried out on the existing system.

### Phase I

The East Guideway (which is a dedicated guideway for the airside train) will be shut down completely for modification works. At the same time, a new platform for Station E will be constructed. The existing system will continue to ferry passengers to and fro Terminals 1 and 2. Both the landside and airside trains will share the West Guideway operating on a single-car shuttle mode (Refer to Appendix CCC-1). The system will have to function without any redundancy. A breakdown in any of the trains or the guideway will cripple the entire system.

Once the structural modification works in Phase I is completed, MC will proceed with the installation of their Crystal Mover system. They will operate the system from a temporary control facility which will be housed adjacent to the existing one. This first phase will be concluded with the Testing and Commissioning of the Crystal Mover system on the East Guideway.

### Phase II

Once Phase I is completed, the existing system will be de-commissioned and works on the West Guideway will commence. Two new cars by MC will be coupled to run on a dual-car shuttle mode on the East Guideway. (Refer to Appendix CCC-2. Phase 2 drawing.). Because the East Guideway is a dedicated guideway to serve the airside stations only, temporary measures will have to be taken to allow the airside stations to serve landside passengers as well. Hoarding and station platforms will be put up to create temporary public areas at the airside stations. One of the cars in the two-car train will be designated for landside passengers while the other will be used by airside ones.

Similar to the sequence of works in Phase I, Phase II of will end off with a Testing and Commissioning of the new system along the West Guideway.