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INTEGRATED ARRIVAL AND DEPARTURE MANAGEMENT FOR JEJU INTERNATIONAL AIRPORT

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Abstract

This paper deals with operational concept and core technologies of Management on Integrated operations of Departure, Arrival, and Surface (MIDAS), which has been being researched and developed considering the air traffic environment around Jeju International Airport in Korea. In addition, it introduces the configuration and interface of the prototypes of the decision supporting systems designed based on the concept of operations.

1 Introduction

As air traffic continues to increase, congestion and delays on airport surfaces and in airspace around the airport are becoming more severe. Therefore, interest in efficient air traffic management techniques is increasing. Various types of arrival and departure management techniques and controller decision support systems have been studied to secure flight safety, minimize delay, and increase efficiency [1-3]. This study suggests concept of operations for the integrated arrival and departure management for Jeju International Airport (CJU) in Korea after introducing the operational characteristics of CJU regarding air traffic management (ATM). The paper also explains the system prototype which has been being developed based on the operational concept.

This paper is organized as follows: The current ATM operations of CJU including the overview and ATM issues of CJU are presented in section 2. In section 3, the concepts of the controller decision support systems for arrival management and departure management are shown. The architecture of proposed systems is presented in section 4, and concluding remarks are given in section 5.

2 Current Operations

2.1 General Information of CJU

Fig. 1 shows the geographical location of CJU and Jeju Terminal Maneuvering Area (TMA). Jeju TMA has a size of 75 and 90 nautical miles on the latitudinal and longitudinal direction, respectively, and CJU is situated slightly biased to the southwest in the TMA. The number of flights operated in the airport is more than 160,000 in 2017, and cancellation rates and delay rates over the last 5 years are shown in Fig. 2. In this figure, “delay” means a delay of more than 60 minutes for international flights and more than 30 minutes for domestic flights. The delay rate of CJU has exceeded 13% since 2015 and has risen sharply to 22% in 2016.

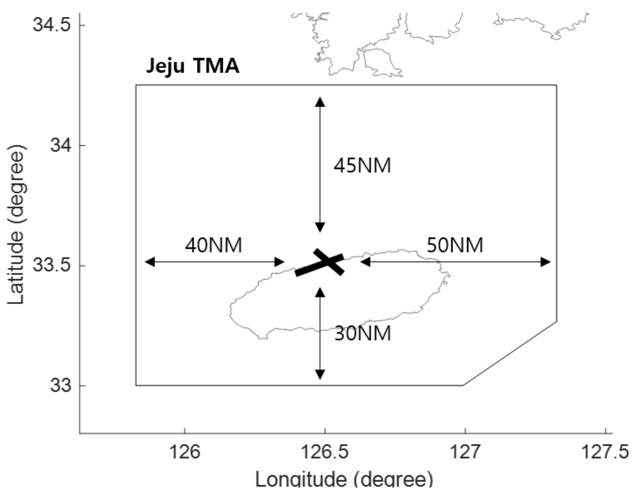

Fig. 1 CJU and Jeju TMA

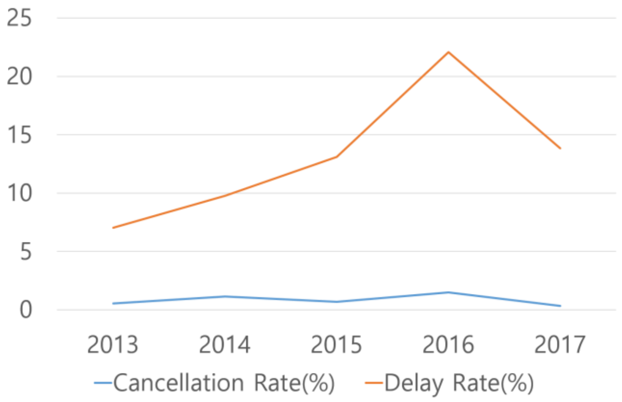

Fig. 2 Cancellation and Delay Rate of CJU [4]

2.2 Surface Operations

Fig. 3 depicts the airport surface configuration of CJU. The CJU has two crossing runways and 40 stands. The runway 07/25 with a total length of 3,180m is usually used for both departures and arrivals, whereas runway 13/31 with 1,900m length is rarely used. In ramp area, there are two parallel groups of stands as shown in Fig. 4. Since the pushback routes for group A and B overlay each other, aircraft on the stands of group A start taxiing immediately without pushback procedure after controller's instructions. One of key characteristics of CJU is the bottleneck around the ramp area. With limited taxiways and narrow ramp area, if a taxiway is occupied by a pushback or taxiing aircraft, the other aircraft should stay in their designated stands. For this reason, the departure sequence is almost identical to the ramp exit sequence, which cannot reflect the priority of aircraft with sufficient time before the scheduled time of departure. One of the issues with CJU in terms of departure is Traffic Management Initiative (TMI). TMI is a departure restriction frequently issued due to the neighboring regions such as China, Southeast Asia, and Japan.

The air traffic services for CJU are provided by three controllers of Jeju Tower: clearance delivery, ground, and local controllers. The position for ramp controller does not exist because the ground controller is also responsible for ramp control. The sequence for pushback clearance is based on First-Come First-Served (FCFS) operations. The handoff process in the tower is accomplished by handing over the paper strips manually to another controller seated next to the controller.

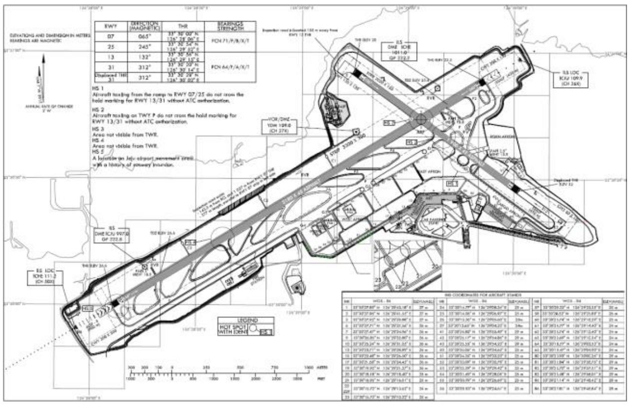

Fig. 3 Plan View of CJU [5]

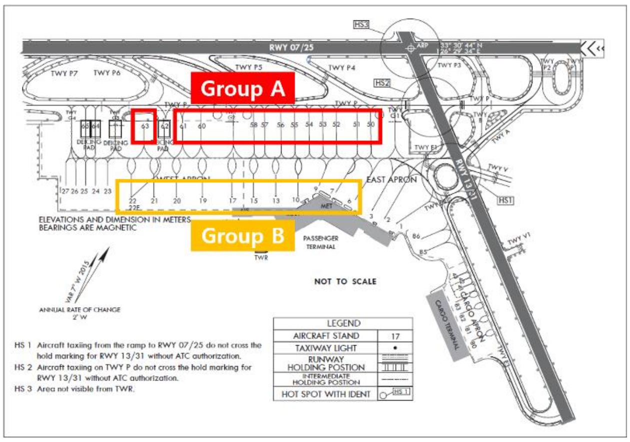

Fig. 4 Ramp Area of CJU [5]

2.3 Airspace Operations

Jeju terminal airspace, which is a corridor from the airport to air route, is managed by Jeju approach center. Fig. 5 and 6 show the standard instrument departure procedure and standard terminal arrival procedure, respectively. They also show the trajectories of departures/arrivals using actual flight data for the month of July in 2017. There are five departure fixes and six arrival fixes on the boundaries of the terminal airspace. The arriving aircraft leaves the air route and enters TMA through one of arrival fixes depicted in Fig. 6. Then, the air traffic control services such as altitude or heading instructions are provided to the aircraft. In this situation, the approach controller should consider other arrival aircraft approaching from various directions, and ensure that the aircraft land on the runway in order maintaining proper spacing. If the traffic volume is not high, the aircraft can fly along the pre-defined arrival procedure. However, in many cases with heavy traffic, the controllers often give aircraft instructions, called radar vectoring, to maintain spacing with other aircraft as shown in Fig. 6.

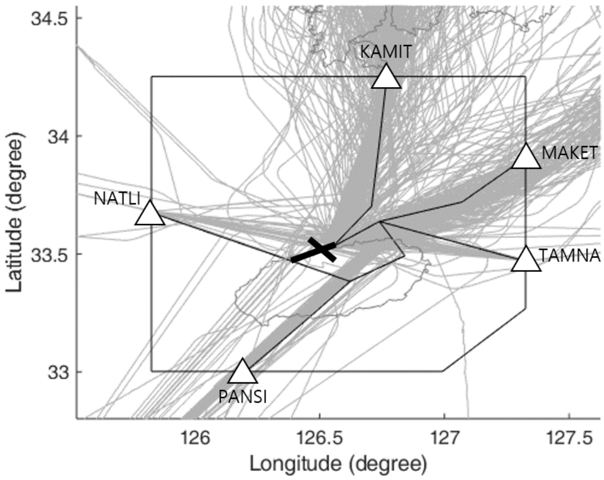

Fig. 5 Standard Instrument Departure Procedure of CJU

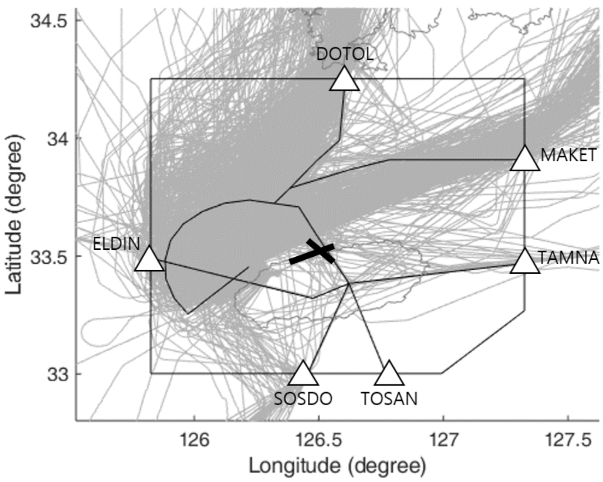

Fig. 6 Standard Terminal Arrival Procedure of CJU

3 Concept of Proposed System

In the traditional air traffic control, the flow of the departing and arriving aircraft was managed by controller manually using ground delay of the departing aircraft and air delay of the arriving aircraft depending on the capability of the controller. In this tactical traffic flow management approach, the arriving aircraft are typically controlled by the radar vectoring, which results in high controller and pilot workloads. For departing aircraft, the delay and the fuel consumption increase and efficiency is reduced due to waiting on the taxiway or runway queue after pushback from the gate.

In the previous studies for the arrival manager (AMAN) as a decision support tool for controllers, it was important to schedule the arrival sequence and time of aircraft entering the terminal maneuvering area (TMA) in consideration of the separation interval at a specific scheduling point, and to provide relevant advisory information to the controller [6-7]. In the case of departure management, research and development on basic departure manager (DMAN) of the concept of pre-departure sequencing proposed in conjunction with Airport – Collaborative Decision Making (A-CDM) in EUROCONTROL have been being carried out variously [8-9].

In this study, we aim at Management on Integrated operations of Departure, Arrival, and Surface (MIDAS) in Jeju TMA. The characteristics of this study are summarized as follows in comparison with previous studies. 1) In the case of arrival management, it aims at management of aircraft "in" the TMA, unlike the existing method of handling sequencing of aircraft arriving "into" the TMA. To do this, we propose a method to provide route advisory using point merge procedure [10]. 2) In the case of departure management, in addition to implementing several types of TMIs, scheduling horizon is extended to the metering fix at airway so that the enroute traffic situation can be considered as a constraint during the runway scheduling process. Taxiway scheduling is also incorporated considering real-time surface traffic congestion, runway crossing, and so on. 3) Considering mixed mode operation using one runway at CJU, both departure and arrival management are linked together.

The followings are the assumptions for MIDAS system.

- Target Off Block Time (TOBT) which is the earliest possible push-back time, will be provided by aircraft operators or ground handlers through airport operational system such as A-CDM system. TOBT will be used as an important initial value to estimate Variable Taxi Time (VTT) and to calculate time advisories for pushback and takeoff.

- The gate and runway for each aircraft will be assigned and given before the departure sequencing. These data will be transmitted by either Air Traffic Control (ATC) system or A-CDM system. Any tactical management information (e.g., runway blocking) will be provided via manual entry by the tower controllers.
- Flights regulated by TMIs such as release time or Calculated Take Off Time (CTOT) will be identified for the MIDAS system by A-CDM system or controllers' manual inputs.
- Aircraft surface and in-flight track data will be available via Aircraft Surface Detection Equipment (ASDE) and terminal ATC system.
- Flight plans will be provided by ATC system.
- Target Landing Time (TLDT) of arrival flights will be generated by MIDAS system and used for sequencing of departure flights.

The concept of operation of MIDAS, which is also shown in Fig. 7, can be summarized sequentially as follows.

- The MIDAS System uses the flight plans and the in-flight tracks to perform sequencing of the arriving aircraft, and generates the route advisories using the point merge procedures. It also generates the TLDT of each aircraft.
- For a departing aircraft, Initial Take Off Time (ITOT) is computed by adding VTT to TOBT. Then, TTOT is generated considering ITOT of departure aircraft, TLDT of arrival aircraft, TMIs, runway separation rules, and overflights merging into the merging fixes and so on.
- The Target Start-up Approval Time (TSAT), which is the pushback advisory for ramp controllers, is derived from TTOT and VTT.

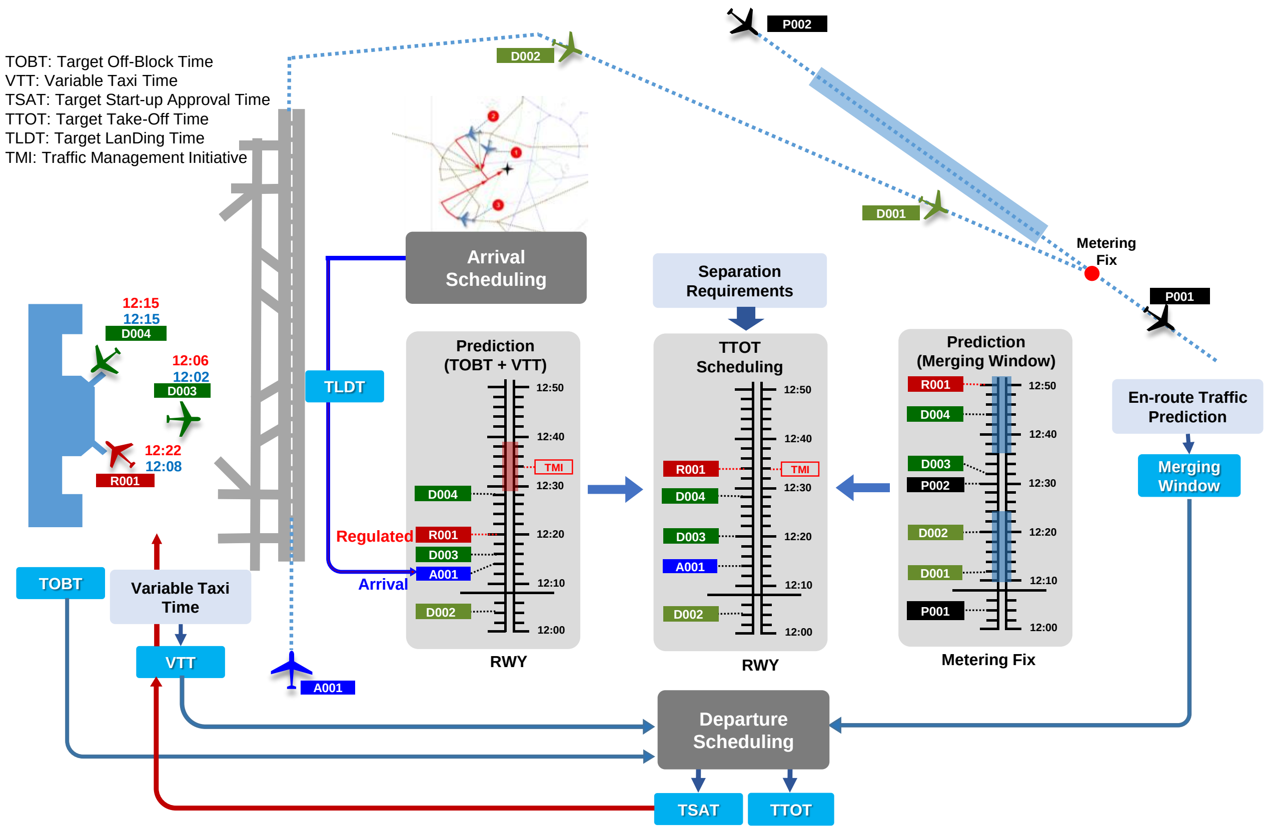

Fig. 7 Operation Concept of MIDAS

The detailed concepts of arrival/departure management based on the above assumptions and concepts are described in the next sub-sections.

3.1 Arrival Management

In this study, the arrival management aims at alleviating unnecessary delay of aircraft and increasing control efficiency in the terminal area. An arrival management technique based on point merge procedure is proposed since Jeju TMA has established that procedure as a standard arrival procedure.

Fig. 8 shows the arrival procedure for the case of using the runway 07 of CJU [5]. The CJU has two sequencing legs starting from CHANY, as shown in the figure. The two sequencing legs have altitudes of 7,000ft and 9,000ft, respectively, vertically separated by 2,000ft. There are six routes to the CJU, which start from DOTOL, MAKET, TAMNA, TOSAN, SOSDO and TOLIS. While the aircraft entering through DOTOL are supposed to use a sequencing leg with 7,000ft, the aircraft accessed through the other five fixes use the other sequencing leg with 9,000 ft. It should be noted that these aircraft metering with 9,000ft should be pre-separated before entering the sequencing leg since they will join at CHANY with the same altitude. Based on the concept of point merge system, when the appropriate spacing is reached with preceding aircraft in the sequence, a "direct-to" instruction to the merge point (YUMIN in Fig. 8) can be issued [10].

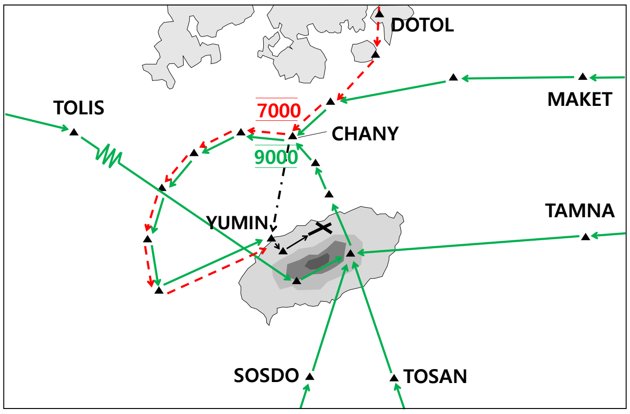

Fig. 8 Point merge based arrival procedure at CJU

In order to schedule the arrival flights for CJU, radar tracks and flight plans are used as input data, and Wake Turbulence Category (WTC) - based separation is also applied as a constraint for scheduling. As a result of the scheduling, the sequence of the arriving aircraft, the TLDT of each aircraft, and the route advisories are expected to be generated. Here, the route advisory represents a point in the leg, where the aircraft is expected to turn to merge point, YUMIN. It can be provided in the form of the name of a certain fix in the point merge legs and appropriate distance to go from that fix (e.g. PC602+2NM). In addition to route advisories, Time-To-Lose (TTL) or Time-To-Gain (TTG) may also be needed for the flights entering the fixes other than DOTOL since they should be pre-separated before the leg entry fix, CHANY. The inputs, constraints, and outputs for arrival management can be summarized as Table 1.

Table 1 Inputs/Constraints/Outputs for Arrival Management

Inputs	Tracks
	Flight Plans
Constraints	Point Merge Procedures
	WTC-based Separation
Outputs	Sequence of Arrivals
	TLDT
	TTL / TTG
	Route Advisory (Point for turning to merge point)

In order to implement the requirements described above, two-step scheduling approach was adopted to implement the concepts and requirements defined above. As shown in Fig. 9, pre-scheduling is performed for the aircraft metering into the leg entry fix, CHANY, in the first step. In the second step, the scheduling is conducted for pre-scheduled flights. In this study, FCFS scheduling was used in the first step and Multi-Objective Dynamic Programming (MODP) with two objectives which consists of minimizing makespan and minimizing total delay was used in the second step [11].

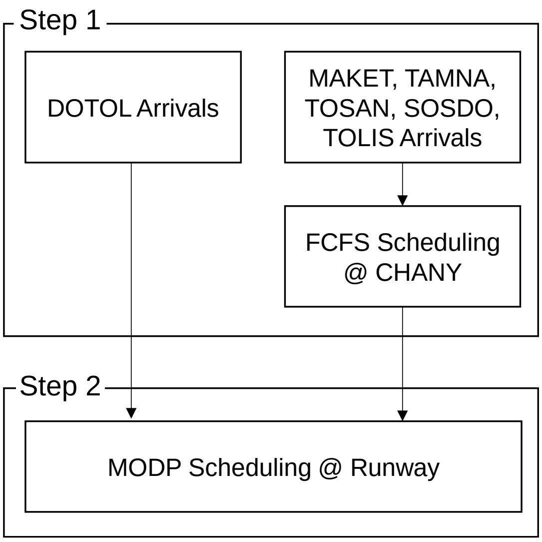

Fig. 9 Two-Step Scheduling for Arrival Management

3.2 Departure Management

The departure management aims at predicting the traffic situation and scheduling the flights based on this prediction, thereby consequently preventing unnecessary ground and/or airborne delays.

For runway scheduling, several constraints are considered. In addition to the basic matters such as TOBT, which is the earliest possible push-back time, WTC-based runway separations, and Miles-In-Trail / Minimum Departure Interval (MIT / MDI), several other constraints including release time from area control center and Calculated Take Off Time (CTOT) provided by air traffic flow management center are also incorporated into the scheduling process. Furthermore, for the integrated arrival and departure management, TLDTs of arrival flights, which are generated by the arrival management implemented in MIDAS system, are also utilized as given constraints to schedule the departure flights. This study also introduces the concept of multiple available time slots at enroute because it is necessary to reflect the available merging window at merging fixes for overflight aircraft. Here, the slot represents a period in which the departure aircraft is not disturbed by the overflight aircraft flow at the merging fix. This can be applied in the form of multiple take-off time windows, considering the transit time from runway to metering fix. In case of CJU, there is a gate conflict problem described in section 2. Therefore, the maximum gate holding time limit is also set as a limiting condition because there may be a problem of excessive gate occupancy due to the departure scheduling. Based on the above, the inputs, constraints, and outputs for the departure management are summarized as follows.

Table 2 Inputs/Constraints/Outputs for Departure Management

Inputs	Tracks
	Flight Plans
	Airport Operational Database
Constraints	TOBT
	WTC-based Runway Separation
	MIT / MDI
	Release Time
	CTOT
	TLDT of Arrival Flight
	Estimated Time of Arrival of Overflight at Merging Fix
	Maximum Gate Holding Time Limit
Outputs	Sequence of Departures
	TTOT
	TSAT
	Target Times at Pre-defined Ground Fixes
	VTT

In this study, the departure management for CJU is based on the 3-step approach which has also been applied to Incheon International Airport [12]. This approach as shown in Fig. 10 consists of Step 1) unimpeded taxi-out time estimation; Step 2) runway scheduling for departures; and Step 3) taxiway scheduling.

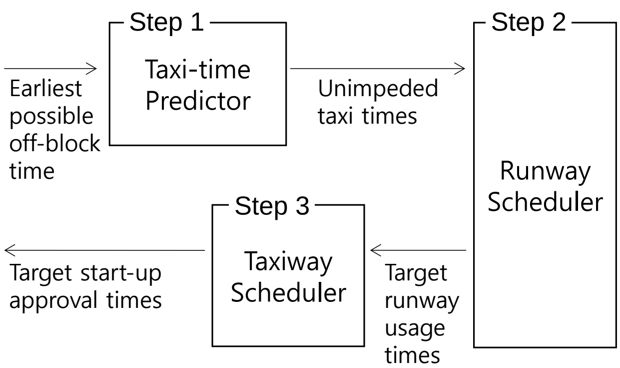

Fig. 10 Three-Step Scheduling for Departure Management

4 Proposed System Architecture

Based on the operational concept described above, we have developed a prototype of MIDAS system which integrates DMAN and Terminal - AMAN (T-AMAN) dedicated to In-TMA, as shown in Fig. 11. DMAN consists of External Interface System (EIF), DMAN Main Processor (DMP), Ground Situation Display (GSD), and Electronic Flight Strip (EFS) considering that CJU has a necessity to replace paper strips with electronic ones. EIF receives external inputs such as Airport Operational Database (AODB), TMIs, Flight Plans (FPLs), and tracks for the inputs and constraints for scheduling. One of the main components of DMAN, DMP, consists of taxi time predictor, runway scheduler, and taxiway scheduler as shown in Fig.10. DMP provides the advisories including TTOT, TSAT, and VTT to GSD and EFS. Similar to DMAN, T-AMAN is composed of EIF, T-AMAN Main Processor (TAMP), and Air Situation Display (ASD). TAMP generates the TLDT, TTL/TTG, and route advisories to ASD.

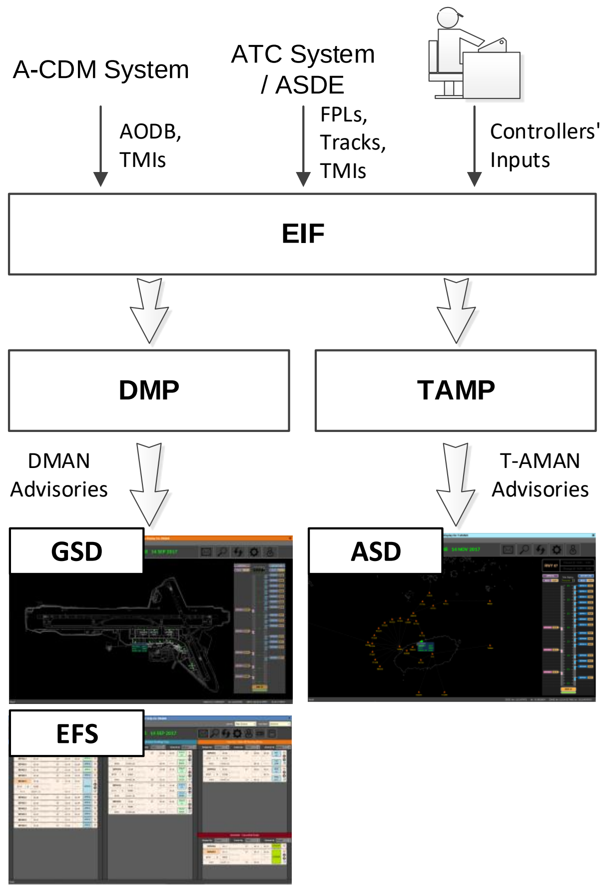

Fig. 11 Proposed System Architecture for MIDAS

5 Conclusions

This paper describes the concept of operations for the integrated departure and arrival management for CJU. It also presents the system inputs/constraints/outputs and system architecture defined on the basis of the concept. Arrival management technique is developed to provide the route advisories considering the point merge procedures adopted at CJU. In addition, departure management technology was developed and linked with arrival management considering various types of TMIs, air traffics at enroute merging fixes, the TLDTs of arrival aircraft, and etc. The developed technology has been implemented into a prototype system, and will be validated through the fast-time simulation and human-in-the-loop simulation followed by the field operation at CJU.

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