

Support of Traffic Management Coordinators in an Airport Air Traffic Control Tower Using the Surface Management System

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Abstract

This paper describes a subset of the findings of a simulation study conducted to explore the usefulness and usability of a prototype of the Surface Management System (SMS), designed to assist in expediting the movements of aircraft on the surface of a large airport. In particular, this paper focuses on the use of SMS by Traffic Management Coordinators (TMCs) in airport Air Traffic Control Towers. The overall study included three airport tower air traffic controllers supported by a traffic management coordinator working in a full mission simulation of air and surface traffic environment at the Dallas-Ft. Worth International Airport (DFW). During each of nine one-hour runs of the simulation, the controllers at the four positions were responsible for approximately 120 airline aircraft preparing for departure or arriving at the airport. The findings include results of behavioral protocols, questionnaires completed by the subjects immediately after each run, and knowledge elicitation interviews with the controllers who served as the TMC or TMC Assistant during the simulation.

Introduction

This report focuses on the uses of the Surface Management System (SMS) [1] as a decision support tool to assist airport professionals in expediting the movements of aircraft departing from or arriving at a large metropolitan airport (DFW). Among the human operators who might benefit from the availability of such a system are Federal Aviation Administration (FAA) airport Tower Controllers, Traffic Management Coordinators, (TMCs), airline personnel Airline Operations Center (AOC) and Ramp Control staff.

Within the simulation study, the management of surface operations at DFW involved four different controller positions in the tower that were responsible for the direct coordination of aircraft surface movements. These positions were:

- Arrival Ground Controller
- Departure Ground Controller
- Local Controller
- Traffic Management Coordinator (TMC).

This paper focuses on the roles of the TMC, and on the potential for SMS to enhance the performance of this individual.

The goals of the study were threefold:

- To identify the tasks performed by the TMC during the simulation, and to gain insights into how these tasks were completed.
- To understand when and how SMS and other tools were used by the TMC to help complete these tasks.
- To suggest ways in which the design of SMS (and associated changes in roles or procedures) could be refined or extended to improve the performance of the TMC.

Methods

Because this was an exploratory study rather than a formal evaluation of the use of SMS by the TMC, a variety of data were collected:

- Behavioral protocols based on observations during the simulation.
- Think-aloud verbal protocols collected as the TMC performed various tasks during the simulation.
- Responses to questions during structured knowledge elicitation interviews.
- Questionnaire responses focusing on the use and usability of SMS displays/tools.

These data were collected in a simulation study in the Future Flight Central facility at the NASA-Ames Research Center. The facility emulates an FAA Control Tower and the airport environment visible from that Tower, including runways, taxiways and other aircraft movement areas on the airport. Aircraft on the ground and in the air in the immediate vicinity of the airport are controlled by pseudo-pilots in response to directions from controllers in the Tower cab.



Figure 1: Surface Management System displays: Map of airport showing aircraft locations. Coded data blocks (not shown) display aircraft identification, type and other data. Load graph shows machine-predicted delays at future times; both arrival and departure delays are calculated.

Each of three different traffic scenarios was conducted once under each of 3 conditions (for a total of nine experimental runs). In Condition 1, runs were conducted without SMS assistance (except that the TMC had a map display and one load graph to assist in assigning one of the four runways for takeoffs or landings). In Condition 2, SMS showed a map display, load graphs, timelines and advisories. In Condition 3, an even more capable SMS was simulated; it added an advisory tool to assist in switching runways from departures to landings. During each run, a human factors professional shadowed the controller acting as TMC and made notes on the observed behaviors. The TMC was also asked to think out loud while performing tasks, as long as this did not interfere with the completion of these tasks.

Immediately after each run, the TMC and TMC Assistant filled out structured questionnaires concerning their uses of the data available to them.

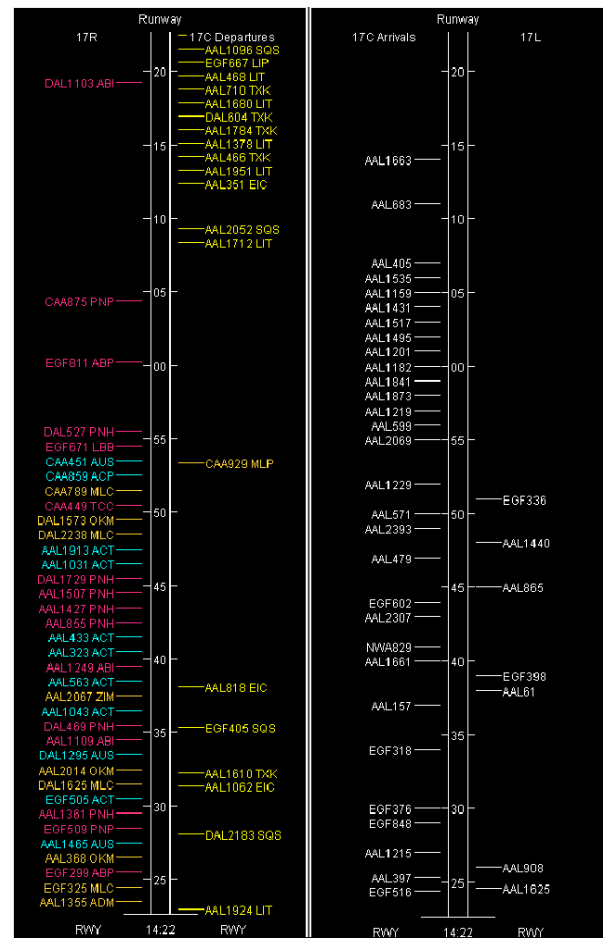


Figure 2: Timelines show aircraft sequences and the times at which they are expected to arrive at a departure runway, or expected arrival times. These figures do not show the configuration change advisory tool, which places a color-coded vertical line on a load graph.

The subjects were five experienced air traffic controllers who work as active controllers and/or TMCs at Dallas-Fort Worth International Airport (DFW), the facility emulated in the simulation. In each simulated scenario, the following positions were occupied by one or more controllers: departure ground control, local control, arrival ground control, and a traffic management coordinator who assisted the other controllers and supervised coordination among them. The same controller played the role of the TMC for all simulation runs, as she was the only controller with actual experience at this position at DFW. On each run, the controller who was not serving in one of the four positions served as the TMC Assistant, providing suggestions to the TMC as she performed her tasks.

Three scenarios were programmed. Each scenario lasted approximately one hour and involved the movement of approximately 120 aircraft: approximately 60 departing from their gates, taxiing to an assigned runway, taking off and departing the local area, and a roughly equal number ar-

iving in the local area, conducting an approach to and landing on an assigned runway, then taxiing as directed to designated spots within their airline arrival ramps.

Results and Discussion

The results are organized below in terms of the tasks performed by the TMC.

TMC: Task 1. Runway Utilization

As part of Simulation 2, the TMC had the option of changing Runway 17C at DFW from a departure runway to an arrival runway at some discrete point in time. Each of the traffic scenarios used during the simulation began as a departure push and transitioned to an arrival rush. In order to make this decision about runway utilization, the TMC considered several factors, including future arrival demands as well as the departure demands for different departure fixes and destinations. As the TMC noted:

I'm looking at basically when the departures are going to start and come out, when they'll be at the runways, and then looking to see how many departures, either counting them on strips or counting them on the timeline, looking to see how many departures we have. I'm also looking to see what it's composed of. If it's a heavy east, heavy west, what routes are in there?

To make this decision, the TMC used several decision support tools provided by SMS (in those runs where they were available). First, the TMC used the timeline display located at the TMC console to look at departure and arrival demands, departure gates (color-coded), first departure fix, aircraft weight classes and suggested runway assignments. This timeline display assisted the TMC in visualizing arrival and departure demands as a function of time.

The arrival/departure average delay load graph further assisted the TMC in assessing the impact of the current runway utilization on departure and arrival delays. Finally, by entering proposed times for changing 17C from a departure to an arrival runway, the TMC used the resultant predictions on the timeline display and the average load graph to help assess the impact of alternative change times, sometimes trying more than one alternative in order to compare the predicted impacts using the timeline display and the average load graph.

In addition, for some runs, SMS also provided a Configuration Change Time Advisory Tool that the TMC could use to get advice, allowing the TMC to compare her thoughts about the best runway configuration change time decision with the recommendation of SMS. For example, upon reviewing the data provided in the timeline and load graph, the TMC might think that 1815 would be the optimal time to switch runways. By using the Configuration Change Time Advisory Tool, the TMC could input 1815 and see the tool's prediction of arrival and departure delay given the 1815 runway switch time. She could also com-

pare her selected change time with a recommendation that SMS would display. (SMS, for instance, might recommend an earlier switch such as 1810.)

Task 1: Findings. The behavioral and verbal protocols, as well as the questionnaire responses and the structured interviews provided a number of insights. When asked how she made the decision about when to switch 17C from departures to arrivals, the TMC responded:

The difference between the timeline and relying on the strips is that ... SMS has the ability to do some predictive modeling and to adjust to the reality. So if SMS knows that some of these guys were late coming out of the gate, then its going to adjust these times, whereas with the strips you'd have mentally look out there and realize he's late. ... In that sense, the timelines were very helpful.

I'm looking to see, in respect to the arrivals, when they're starting to arrive at the airport, and using one of the other graphs [the arrival/departure average delay load graph] to see what kind of delays they were getting. Basically, what I do is to try to get the departures off both runways, you know, without trying to heavily impact the arrivals.

In filling out the questionnaire, the TMC and TMC-Assistant further indicated the potential value of the timelines, the arrival/departure average delay load graphs and the Configuration Change Time Advisory Tool, as indicated in the tables below. (Note that when there are two numbers, this indicates that both the TMC and TMC-Assistant responded.)

How useful was the information provided by the timelines?

End Points: 1, Very Useful; 7, Not At All Useful

	1st Run	2nd Run	3rd Run
Condition 2	1,1	1	4,3
Condition 3	2,1	1	1,3

How useful was the graph of arrival and departure demand on the Arrival/Departure load graph?

End Point: 1, Very Useful – 7, Not At All Useful

	1st Run	2nd Run	3rd Run
Condition 2	1,1	1	2,3
Condition 3	2,1	2	6,3

How easy was it to determine the arrival and departure delay from the Arrival/Departure load graph?

End Point: 1, Very Easy – 7, Very Difficult

	1st Run	2nd Run	3rd Run
Condition 2	2,2	2	2,4
Condition 3	2,2	2	5,3

The questionnaire results also indicated that the information on the timelines and the arrival/departure average de-

lay load graphs was perceived to be fairly accurate (although the lower ratings for Condition 3 merit further investigation).

How accurate were the predicted times on the timelines?

End Point: 1, Very Accurate – 7, Not at all Accurate

	1st Run	2nd Run	3rd Run
Condition 2	1,1	1	4,3
Condition 3	2,1	2	2,4

How accurate was the delay information on the Arrival/Departure load graph?

End Point: 1, Very Accurate – 7, Not At All Accurate

	1st Run	2nd Run	3rd Run
Condition 2	2,2	2	2,4
Condition 3	3,1	2	5,4

How accurate did you think the configuration change advisory tool prediction of arrival and departure delay information was?

End Point: 1, Very Accurate – 7, Not at all Accurate

	1st Run	2nd Run	3rd Run
Condition 2	2,2	1	2,3

The perceived value of the timelines and the arrival/departure average delay load graphs is further supported by the following responses for Conditions 2 and 3, although there was less agreement between the TMC and TMC-Assistant in Condition 3.

Please rank the relative usefulness of each of the following information sources for ranking the decision about the time to switch departure scenarios from most useful (1) to least useful (6).

Condition 2

	Run 3	Run 6	Run 8
Map Display	4,3	3	3,4
D-BRITE	5,5	4	4,5
Out the window	3,2	5	5,3
Timelines	1,2	1	1,1
Load Graphs	2,1	2	2,2

Condition 3

	Run 4	Run 5	Run 9
Map Display	4,1	4	6,4
D-BRITE	5,6	5	5,6
Out the window	3,2	6	4,5
Timelines	1,3	1	1,1
Load Graphs	2,5	2	3,2
Advisory Tool	4,4	3	2,3

Task 1: Recommendations. More detailed discussions suggested some ways to refine or extend SMS to support runway utilization decisions. One such suggestion focused

on making it easier to explore alternative runway change times:

Interviewer: “I noticed you playing a what-if game. You’d try 1815 and see what the effect was on the delay graph, and then try 1810 and see what happened. Was that kind of capability useful to you?”

TMC: “Oh, yes, very much so. ... I was looking to see how I could get the most departures out while still keeping the arrival delays, you know, pretty close to what the departures were getting.”

Interviewer: “Would it be useful to be able to see the effects of both of those what-ifs displayed at the same time?”

TMC: “Yeah, if you could ... pop up two windows. ... Yeah, that’s good stuff.”

These inputs lead to a recommendation to allow TMC to display - simultaneously on the screen - the predicted impacts of several alternative runway switching times (making it easier to compare the impacts of different decisions).

Other recommendations (based on data not presented here but available in (2) were:

- Provide a display that indicated peaks for individual flights.
- Add a display showing predicted delays for individual flights in addition to the average impact.
- Improve the predictive accuracy of SMS by modeling lane crossing times.
- Enhance SMS to consider actual out times to help make decisions about when to change the runway utilization.

Finally, the TMC suggested that an important consideration not incorporated into SMS is the decision about when to make the decision about changing runway utilization:

Interviewer: “When would you normally like to make the decision about when to change 17C from departures to arrivals?”

TMC: “I don’t shut them off [the departures] until I see if the departures are late getting off the gate. You kind of watch that, and then see how the arrivals are going to affect the departures. We’ll ask [to change the runway utilization] at that time, only 8 to 10 minutes ahead sometimes.”

“You have to give it just a little time. You have to see how everybody’s going. How are the arrivals coming to the airport? Are they landing heavy on the east side? Are they landing heavy on the west side? ...Were they early? Are they late? ...You wait until you can tell, and then you ask for whatever you need.”

TMC: Task 2 – Critiquing Runway and Runway Departure Queue Assignments

After using the tools provided at the TMC console to make the decision of when to switch 17C from a departure to an arrival runway, the TMC generally moved to stand in between the Departure Ground Controller and the Local Controller. This was done in order to make suggestions about runway and runway departure queue assignments and about the ordering of the final departure queue. This section discusses the role of the TMC in making suggestions about departure runway and runway departure queue assignments.

Task 2: Findings. Below are examples of the different potential scenarios involved in assigning to an aircraft its taxi route, departure runway and runway departure queue. In some of these scenarios the TMC is not involved, while in others he/she plays an important role in determining the final assignment of departure runway to a specific aircraft.

- The Departure Ground Controller decides the taxi route, runway assignment and runway departure queue assignment for a specific aircraft and informs the flight crew. As an example, the Departure Ground Controller might instruct the flight crew to taxi to Runway 17C via Yankee.
- The Departure Ground Controller decides the taxi route, runway assignment and runway departure queue assignment for a specific aircraft, but the Local Controller changes the runway and/or runway departure queue assignment and redirects the flight crew based on this change.
- The TMC intervenes before the flight has been handed off to the Local Controller (at Zulu) and suggests that the Departure Ground Controller redirect the aircraft to a particular departure runway and/or runway departure queue.
- The TMC intervenes after the flight has been handed off to the Local Controller (at Zulu) and suggests that the Local Controller redirect the aircraft to a particular departure runway and/or runway departure queue.

In short, in terms of Task 2, the Departure Ground Controller has primary responsibility for directing aircraft toward specific queues for departure from specific runways, and informing the Local Controller of this plan. The TMC plays the role of a “critic,” suggesting modifications to these decisions when he/she sees a potential for improving performance, and communicating these modifications by either talking to the Departure Ground Controller before the flights reach Zulu or by talking to the Local Controller after the flight has changed to the Local Controller’s frequency.

This role of critic was viewed as very valuable by both the Departure Ground Controller and the Local Controller. As one of them noted:

(The TMC) is an extra set of hands and eyes...I’ll take any help that I can get.

To critique the runway and runway departure queue assignments, the TMC had to reason about the impacts of departure fixes, aircraft types, destinations, etc. in order to determine what runway and runway departure queue assignments to suggest. She also considered the lengths of the different departure queues and the best way to ensure efficient lane crossings. As one example, the TMC noted:

If it were heavy west bounders over there, then we’d load up 17 Right a lot more. ... If it’s a heavy east push, we load up Center initially, because then that’ll be the bulk of it, try to get as many east-bounders off as we can, and then go back to using 17 Right.

It was also noted in Run 1 (Condition 1) that the TMC would go back to the TMC station to see when the arrivals were going to hit, suggesting that such data is useful to this task as well as to Task 1.

Task 2: Recommendations. Below, several suggestions are made in order to integrate SMS in support of this task performed by the TMC:

- Allow the TMC to perform Task 2 as is currently done, standing between the Departure Ground Controller and the Local Controller and talking directly to them. If this procedure is supported, which has a number of merits in terms of group dynamics and situation awareness (due to looking out the window and overhearing conversations), SMS should provide easy access to the relevant information for the TMC to complete these critiques.
- SMS currently provides the Departure Ground Controller with recommendations regarding the departure runway. This role could be enhanced to also consider the runway departure queue to which a flight should be assigned. As part of this enhancement, the algorithm for generating suggested departure runways and departure runway queues should be refined.
- Since this role for SMS is similar to the role of the TMC (generating suggestions for changes in the departure runway and runway departure queue), it might be desirable to allow the TMC to take over reviewing such SMS suggestions when the Departure Ground Controller is busy. This would require careful thought regarding how to provide access to control over this function if the TMC is standing near the Departure Ground Controller.
- A complementary design solution would be to allow the TMC to provide critiques while standing near the Departure Ground and Local Controllers when that seems appropriate, but to also develop a more powerful suite of tools that could be used at the TMC station. While there would be a potential loss of shared situation awareness (that would have to be overcome in the design of this suite of tools), such tools could allow the TMC greater look-ahead in making recommendations for runway and runway departure queue

assignments. The integration of such a suite of tools at the TMC station might also allow the TMC to respond in a more timely and effective manner during Severe Weather Avoidance Plan (SWAP) events when runway and runway departure queue assignments need to be revised more dynamically.

If this approach is considered, it will be very important to consider how to make sure the Departure Ground Controller is informed regarding TMC decisions, and to make sure that this communication process doesn't increase workload for the Departure Ground Controller.

Other TMC Tasks. In addition to tasks 1 and 2 as described above, several other TMC tasks were explored either within the simulation itself, or as part of the follow-up knowledge elicitations. These are briefly described below. Additional information is available on these tasks in (Spencer et al 2002).

Critiquing the Final Departure Sequence. As described above, in the process of passing the flight strips to the Local Controller, the Departure Ground Controller will arrange the strips to reflect the intended departure sequence, including flights from both runways in this sequencing of the flight strips (bottom strip - first to depart; top strip - last to depart). Like Task 2, this is another point in this distributed work setting where the TMC sometimes becomes directly involved in affecting aircraft surface movement, and therefore needs to be considered in the design of SMS.

TMC involvement arises because the Departure Ground Controller may miss preferable sequencing opportunities due to the workload associated with his/her other tasks. Because of this demand on his/her attention, it can often fall to the TMC to look at the "big picture", to critique the sequencing initially set up by the Departure Ground

Controller and, as needed, to re-sequence the aircraft for departure.

Irregular Operations and Weather. The simulation did not explore TMC tasks (and SMS design considerations) during irregular operations (especially SWAP). However, the TMC indicated that SMS could be especially useful during those situations, and indicated relevant scenarios where the design of SMS could be adapted or extended.

Communication Tasks. The simulation also did not explore the communication tasks that arise when the TMC needs to coordinate with other traffic managers at the Air Traffic Control System Command Center (ATCSCC), Air Route Traffic Control Centers (ARTCCs), Terminal Radar Approach Controls (TRACONS) and with airline staff at AOCs and Ramp Control facilities. SMS further offers opportunities to improve shared situation awareness and more efficient coordination among these individuals.

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