Surface Management System - Simulation 2: Findings Regarding the TMC Position

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February 20, 2002

This paper summarizes the results of an exploratory study of the performance of the Traffic Management Coordinator (TMC) using different features of SMS during Simulation 2. The goals were threefold:

1. To identify the tasks performed by the TMC during the simulation, and to gain insights into how these tasks were completed.
2. To understand when and how SMS and other tools were used by the TMC to help complete these tasks.
3. 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.

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:

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

Background

Currently, the management of surface operations at DFW involves four different controller positions in the tower that are responsible for the direct coordination of aircraft surface movements. These positions are:

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

There are multiple data sources in the tower that these controllers use in coordinating their operations, including CTAS, DBRITE, ASDE, aircraft flight strips and direct vision.

The controllers use flight strips to coordinate the operations of the individual aircraft that are located within their surface “jurisdiction” and to pass off aircraft responsibility/control when aircraft leave their jurisdiction. The flight strip data include:

- aircraft ID
- aircraft type

- spot location – an assigned position within the terminal area where an aircraft waits to receive instructions on its taxi route and runway assignment from the Departure Ground Controller (or in some cases at DFW, the Arrival Ground Controller)
- departure runway
- assigned taxi route (this information is added by the Departure Ground Controller)
- flight route – including departure fix.

Roles of the TMC

Once an aircraft has reached its spot (the controller currently determines this by looking out the window), it is the responsibility of the Departure Ground Controller to assign and direct aircraft onto a specific taxi route in order to arrive at a queue for the assigned departure runway. At some point, as the aircraft approaches Zulu – the point at which aircraft control passes to the Local Controller – the Departure Ground Controller will tell the aircraft to switch over to the Local Controller's frequency.

To maintain situation awareness about the intended sequencing of flights for departure, the Departure Ground Controller makes use of the flight strips. The Departure Ground Controller initially has these flight strips grouped by airline and sorted in numerical order (call sign). This ordering allows the controller to quickly locate a particular flight.

When the Departure Ground Controller wants to assign a specific taxi route to arrive at a queue for the assigned departure runway, he/she marks the taxi route and/or assigned departure runway on that flight strip if necessary. (This may not be necessary if, for example, there is only one departure runway in use). These flight strips are passed to the Local Controller sorted by the departure sequence that the Departure Ground Controller thinks is appropriate. The Local Controller is then responsible for the flight from Zulu to the runway threshold (clearing it across Runway 17R if necessary), and clears the flight for take-off at the appropriate time.

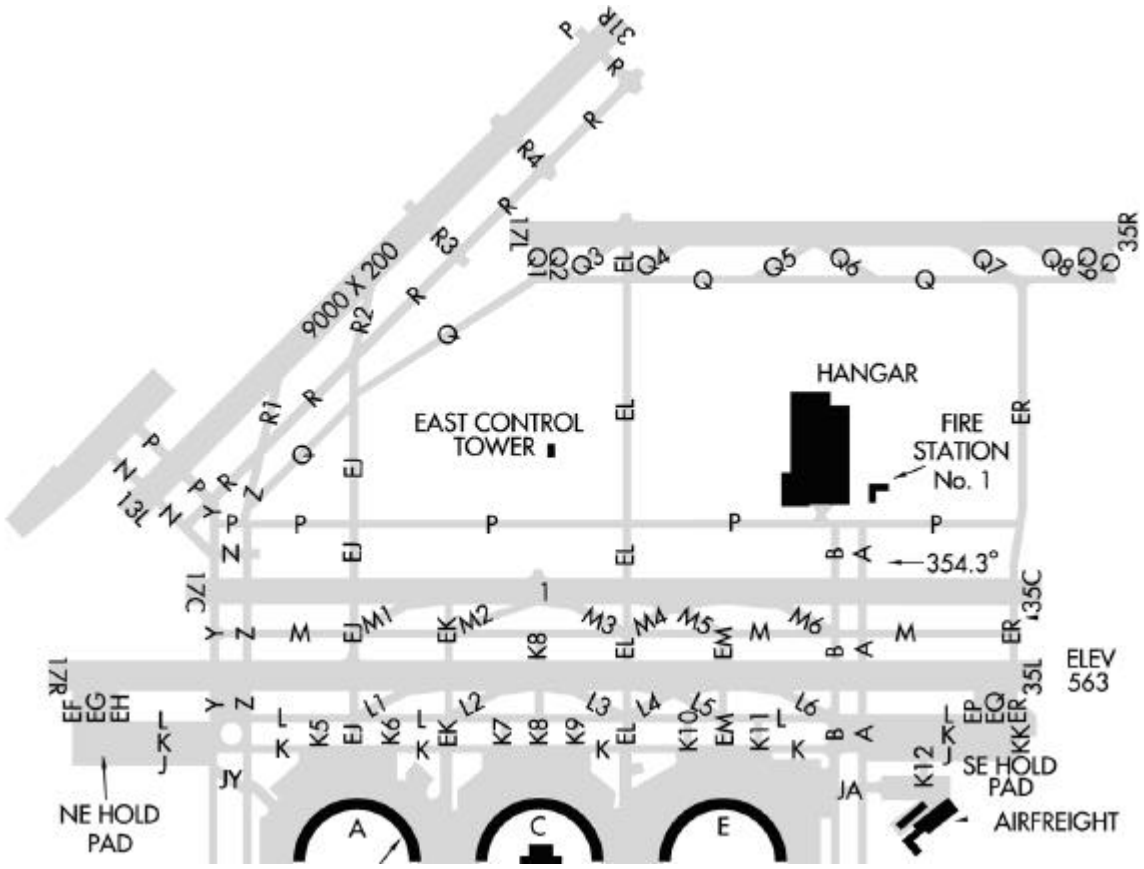

Figure 1. Airport layout as used in Simulation 2 (DFW East).

Below, several tasks are described in which the TMC performed different decision making activities during the Simulation.

TMC: Task 1. Runway Utilization

As part of Simulation 2, the TMC had the option of changing Runway 17C from an arrival runway to a departure runway at some discrete point in time. 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 compare 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 Point: 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 delay 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 3	2,2	1	2,3

This 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 a little 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."

Recommendation 1. 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).

The TMC (with agreement from a dispatcher and ramp controller who were also present during this interview) also suggested that average delay information is not sufficient. She recommended providing a display that indicated peaks for individual flights as well:

Interviewer: "Is it better to have an average delay of 6 minutes with some flights that have delays of up at 18 minutes, or is it better to have an average delay of 7 minutes, where everybody is 12 minutes or lower?"

TMC: "We try to eliminate as many of the peaks as possible, because those are the ones that are going to stick out and they're going to scream. … If you can … spread out the wealth over everybody, and keep them all about the same, I think it works better."

Recommendation 2. Add a display showing predicted delays for individual flights in addition to the average impact.

A third area for potential refinement of SMS concerned the use of the Configuration Change Time Advisory Tool to make runway utilization decisions. This issue dealt with the accuracy of the predictions. The TMC indicated that she thought this specific tool was potentially useful:

Interviewer: "Did adding the SMS recommendation [Configuration Change Time Advisory Tool] provide assistance?"

TMC: "That helped us a couple of times, you know, seeing the optimal time to do that [change 17C to arrivals]."

However, the TMC also questioned its accuracy in some cases:

“I thought it was pretty close. [For one run] I felt that maybe keeping departures on the center [17C] for probably about another 5 minutes [would have been a better recommendation] because I don’t think that that would have impacted the arrivals that much.”

“The arrival delays were running like about 9 minutes, 9 something, and the departures were like less than 6 minutes. … Once you start to use the center runway, then the … departure delays increase dramatically. … I think it was like one time I saw about 18 minutes. I think that you probably could have gotten – if we would have stayed off the Center for about another 5 minutes, you probably could have gotten what kicked those guys up past 15 – you could have avoided that.”

“[SMS wasn’t] taking into account the time that it takes to cross lanes. It was between what, 40 seconds or maybe more, just to get across these lanes. … If you get them down that quick and you’re having to stop the departures because they have to cross all the arrivals, then you’re not actually moving the departures. … If you start feeding airplanes into the airport and nothing’s getting off, you’re just progressing yourself towards gridlock on the airways. … You’re cutting off your taxi routes, so you’re not accomplishing anything by getting all those airplanes on the ground.”

Note: During one interview, both the TMC and a dispatcher commented that, even at the same airport, the flight crews on aircraft for different airlines can behave quite differently in terms of the timeliness of their response to ATC taxi instructions and in terms of taxi speeds. This could be an additional factor that could affect the accuracy of SMS predictions in an operational setting.

Recommendation 3. Improve the predictive accuracy of SMS by modeling lane crossing times.

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?”

“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.”

Recommendation 4. Enhance SMS to consider actual out times to help make decisions about when to decide when to change the runway utilization.

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.

1. 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.
2. 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.
3. 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.
4. 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 departures 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 bounds 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.

Recommendation 1. One approach to supporting this task is to 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.

Recommendation 2. 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.

Recommendation 3. 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.

Recommendation 4. 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 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.

TMC: Task 3 – 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 determining aircraft surface movement.

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. This re-sequencing occurs as the flight strips are passed to the Local Controller – the TMC will stand between the Departure Ground Controller and the Local Controller and simply reach out and directly change the order of the flight strips. Alternatively, the TMC may suggest a particular sequencing to the Departure Ground Controller and let him/her actually place the strips in the stack to reflect that departure sequence. Such sequencing decisions are based on consideration of route restrictions (MIT), departure fixes, aircraft type, departure queue lengths, etc.

Without the availability of the flight strips, SMS does not support this task very effectively. The SMS timeline for departures did not take into consideration the factors that the controllers considered in determining the final departure queue, and hence could not be used to determine

which flight should be launched next. In an environment using flight strips, this task could be performed as presently done. However, this would mean that SMS would not know the intended departure lineup. One implication of this is that the timeline would not display the correct lineup. It would also mean that SMS would not be contributing useful suggestions regarding the final lineup.

Recommendations. If the SMS timeline were somehow incorporated into the process for establishing and displaying the final lineup, a number of design concepts and constraints would need to be considered. These include:

1. Should SMS establish an initial proposed lineup, and let the TMC, Departure Ground Controller and Local Controller modify this lineup, or should SMS behave like the TMC at present (as a critic)?
2. If the SMS timeline was somehow incorporated into the process for establishing and displaying the final lineup, a number of design concepts and constraints would need to be evaluated. These include:
    A. Regardless of the role of SMS, all 3 of the controller positions would need to be able to change the lineup as displayed on the timeline.
    B. Significant issues arise in terms of situation awareness and the location of the display and associated controls to support making changes in the final lineup by all 3 controller positions.

If either of these roles for SMS are considered, it might be useful to develop a modified SMS timeline display that that portrays the sequences at the queues feeding particular runways (shown as timelines), and that shows the intended departure sequence on a timeline showing the departure lineup. Thus, if there were three feeder queues for one runway and two for a second runway, the modified SMS display would show six timelines, one for each queue and one for the departure lineup. SMS could also highlight the next flight for departure in its respective queue timeline to help the Local Controller identify its location. (Note that a critical issue for this proposal is the availability of enough screen space to present such a display. An alternative might be to incorporate some of this functionality by linking the map display with the timeline showing the departure lineup.)

Other TMC Tasks

This simulation did not explore TMC tasks (and SMS design considerations) during irregular operations (especially SWAP). These need more exploration as the SMEs representing the TMC, ramp control and AOC perspectives all agreed that SMS could be especially useful during those situations.

The simulation also did not explore the communication tasks that arise when the TMC needs to coordinate with other traffic managers at the ATCSCC, ARTCCs, and 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.

Conclusions

Above, details have been provided on what was learned about the tasks performed by TMCs, about the use of SMS by the TMC in this simulation, and about potential enhancements of SMS to support this position. In general terms, the data indicate that the TMC found SMS to provide some very useful tools, especially use of the timeline display (as a very useful visual representation of critical data to support runway utilization decisions) and use of the arrival/departure average delay load graph to support runway utilization decisions. The results also generated a number of recommendations for refining the design of SMS and adding additional functionality. The details of these recommendations were provided earlier in this report in the context of the specific tasks performed by the TMC.

Finally, as the interviews with the TMC indicated, there is a wide range of scenarios that could not be explored within this simulation and that could show significant benefits from the incorporation of SMS. Some of these scenarios deal with the use of SMS during irregular operations, such as during severe weather. Others are concerned with communication and coordination among different FAA and airline facilities.