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SIMULATION AND VISUALIZATION OF AIR-SIDE OPERATIONS AT DETROIT METROPOLITAN AIRPORT

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ABSTRACT

This paper presents the simulation model and 3D animation of the airside operations at Detroit Metro Airport, Romulus, Michigan. The paper illustrates how simulation modeling and visualization can be of substantial help in studying airside airport operations, and by consequence can greatly contribute in planning and designing construction operations at airports in a way that has the least impact on airside operations. Given that construction processes modeling was studied effectively in previous research efforts, the presented example investigates only airport operations. The focus of the presented work is on evaluating the capabilities of state-of-the-art construction simulation and visualization tools in being able to accurately model and animate airside airport operations. The solution to the problem is described in detail using a simulation model developed in STROBOSCOPE and a 3D animation created using VITASCOPE.

1 INTRODUCTION

Construction activities within the operations areas of an airport can considerably affect normal operational safety of aircraft and other airport traffic. Cautious planning and implementation of alleviating actions are required to diminish the effect construction activities may have on normal airport operations. For this reason, studying airside operations and analyzing how they may interact with planned construction operations are vital in planning airport construction.

This paper proves that airside airport operations can be modeled and animated very effectively using general-purpose simulation modeling and visualization tools that are used and were successfully implemented in construction operations planning and design (Kamat and Martinez 2001, 2001a, 2001b, 2002, 2003; Ioannou and Martinez 1996). Having said that, modeling both domains simultaneously can be effectively accomplished. However, for simplicity purposes, the example investigates airport operations and illustrates different scenarios depending on the meteorological weather conditions. The solution to the problem is described in detail using a simulation model developed in STROBOSCOPE (Martinez 1996) and a 3D animation created using VITASCOPE (Kamat 2003).

2 PREVIOUS WORK

Previous research efforts have focused on studying aircraft runway and taxiway operations at airports. Macroscopic models such as the Airport Capacity Model (ACM) and Runway Delay Simulation (RDSIM) can be used to make policy decisions regarding the best runway operational practices (Odoni et al 2001). Microscopic models such as the Total Airport and Airspace Model (TAAM) and the FAA airport and airspace simulation model (SIMMOD) can handle detailed runway and taxiway operations but at an added detailed user cost (Odoni et al 2001).

Simulation models were also developed to analyze the daily taxi and takeoff operation of aircraft at the UPS Louisville Park. The model assists planners in developing aircraft departure schedules that minimize taxi and ramp delay times (Ford et al 1999). The taxi simulation model was developed and validated using Arena.

However, existing airport models have some limitations. They can not model the interaction of operations in different domains, for example construction and air transportation simultaneously. They are designed to exclusively model landside and airside aircraft performance and behavior. In such situations, general purpose simulation and visualization tools such as STROBOSCOPE and VITASCOPE can be of significant help in modeling and studying how, for example, planned construction operations can interact with airside airport traffic.

3 DETROIT METROPOLITAN WAYNE COUNTY AIRPORT

3.1 Airport Layout

Detroit Metropolitan Wayne County Airport (DTW) is an airport in Romulus, Michigan, located 20 miles southwest of downtown Detroit, Michigan. In 2002, the nation's 10th busiest airport, DTW, completed a $1.2 billion expansion project, which includes the 97-gate McNamara Terminal (Fricker 2002).

Figure 1 shows the general airport layout for DTW. The airport has six runways; four main parallel runways (4R-22L, 4L-22R, 3L-21R, 3R-21L) oriented on a northeast-southwest heading and two crosswind runways (9L-27R and 9R-27L) oriented on an east-west heading. DTW airport's new configuration (four parallel runways) increased the airport's potential capacity. The two crosswind runways are rarely used, and therefore were not taken into consideration in the model.

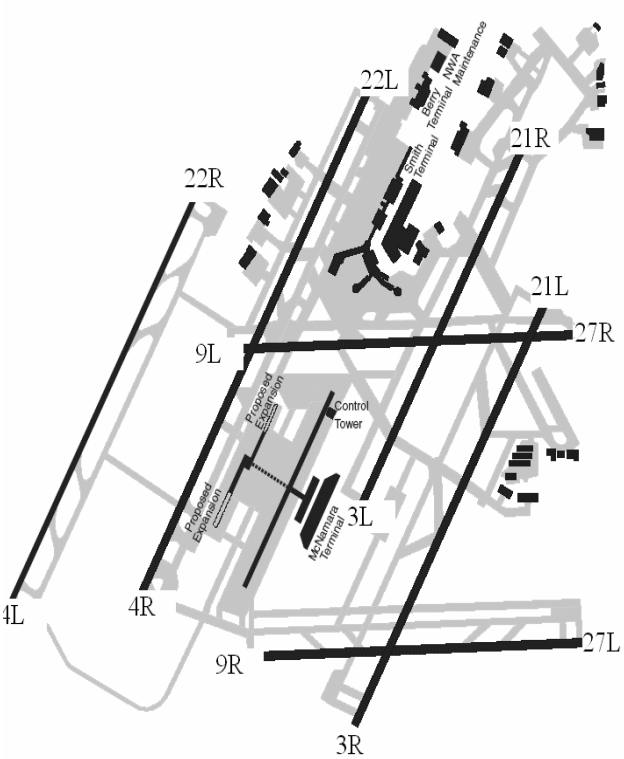

Figure 1: DTW airport layout
[Source:http://www.answers.com/topic/detroitmetropolitan-wayne-county-airport.]

3.2 Runway Configuration Usage

This section reflects the different runway configurations at Detroit Airport based on two weather conditions, Visual Flight Rule (VFR) and Instrument Flight Rule (IFR) conditions. Under VFR conditions, pilots can see so far and are permitted to approach, land, or take off without relying on their instruments to fly safely, as is the case under IFR, but by visual reference. Table 1 represents the existent runway configurations for both arrivals and departures based on the weather conditions and Figure 2 is an illustration of the two different runway configurations aforementioned.

Under IFR conditions, runways 22R and 22L can process simultaneous arrivals-departures since the centerline distance is approximately 3000 ft (> required distance=2500 ft). The same applies to runways 22L and 21R that process simultaneous departures because the distance is 3600 ft. But, this does not apply to runways 21R and 21L because the centerline distance is 2000 ft.

Under VFR conditions, simultaneous arrivals-departures can be conducted on runways (22R-22L) and (21R-21L). But in the case of runway 22L, priority is accorded to arrivals over departures and simultaneous arrivals on runways 22L-22R can be carried out.

Table 1: Runway configuration usage according to weather conditions

Weather Conditions	**Runway Configuration**
IFR	Arrivals on Runways 21L, 22R Departures on 21R, 22L
VFR	Arrivals on Runways 21L,22L,22R Departures on 21R, 22L

[Source: http://www.answers.com/topic/detroit-metropolitan-wayne-county-airport.]

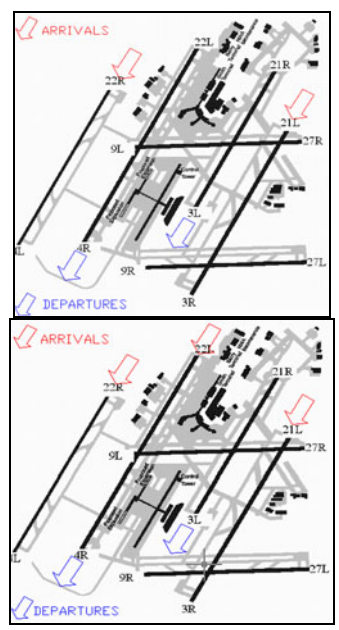

Figure 2: Arrivals and departures under IFR (left) and VFR conditions (right).

The following sections discuss two different scenarios picturing the possible modes of operations at Detroit Metro Airport under the aforementioned meteorological conditions (IFR and VFR conditions) and depending on the type of aircraft. Throughout the paper, aircraft are classified according to the wake vortex criteria: light, medium and heavy. This classification is based on aircraft maximum gross mass. Light aircraft have a maximum takeoff mass of less than 18,635 kg. Medium size aircraft weigh up to 116,000 kg and heavy aircraft are those with a maximum takeoff mass above 116,000 kg. Runways assigned for departures are the same under both flight conditions.

3.3 Airport Operations Scenario I - IFR Conditions

The first scenario operates under IFR conditions where two runways 21L and 22R process arrivals. Heavy, medium and light airplanes can land on any of these two runways. For departures, Runway 21R processes medium and light aircraft whereas 22L processes heavy ones.

3.4 Airport Operations Scenario II - VFR Conditions

In this case, three runways (Runways 21L, 22L and 22R) are used for arrivals and this applies to any aircraft type. Departures procedures meet the same requirements as under IFR conditions (scenario I).

4 STROBSCOPE SIMULATION MODEL

Parameters and assumptions were used to create the desired model for the DTW airport. The parameters used are the same as described in (Martinez et al 2001). The common approach path was assumed to be 15 km in length. The minimum separation distances between successive aircraft, which air traffic controllers comply with to account for wake turbulence, depend on the types of the aircraft. They also include a "buffer" distance of 2100 meters that acts as a safety factor. But since it is subject to measurement errors on the part of the air traffic controller, the actual buffer is assumed to be normally distributed with a mean of 2100 meters and a standard deviation of 1260 meters. When the trailing airplane is slower than the leading airplane, the minimum separation occurs when the airplane that follows enters the common approach path. When the trailing airplane is faster than the leading airplane, the minimum separation occurs when the leading airplane crosses the runway threshold. Table 2 shows the necessary separation between aircraft when the trailing airplane enters the common approach path.

The arrival-departure distance is assumed to be 3200 meters so that a departing airplane terminates its runway occupation before the arriving aircraft touches the runway. Since departing aircraft create wake turbulence that affects other aircraft departing on the same runway, minimum times between successive departures have to be set to account for differences in takeoff speed (i.e., to prevent a fast plane overtaking a slow plane) and for wake turbulence effects. These times are shown in Table 3.

The speed of landing aircraft while in the common approach path depends on the type of aircraft. The time of runway occupation is normally distributed and depends on the type of aircraft and on whether the aircraft is landing or taking off. Table 4 shows the various approach speeds and occupation times.

Table 2: Minimum distance between aircraft entering the final approach corridor

Following Airplane Type	Leading Airplane Type	Minimum Distance (meters)
Heavy	Heavy	6000
Heavy	Medium	6840
Heavy	Light	8760
Medium	Heavy	9000
Medium	Medium	6000
Medium	Light	8120
Light	Heavy	12000
Light	Medium	9000
Light	Light	6000

Table 3: Minimum time between successive departures

Trailing Plane Type	Leading Plane Type	Minimum Time Between Successive Departures (seconds)
Heavy	Heavy	60
Heavy	Medium	90
Heavy	Light	120
Medium	Heavy	60
Medium	Medium	60
Medium	Light	90
Light	Heavy	60
Light	Medium	60
Light	Light	60

Table 4: Approach speed and runway occupation times (ROT)

Plane Type	Aprch Speed m/sec	Land ROT Mean (secs)	Land ROT s. dev (secs)	Take off ROT Mean (secs)	Take off ROT s. dev (secs)
Heavy	75	55	6	38	4
Medium	68	50	10	43	6
Light	52	45	10	50	6

The aircraft mix for this simulation model is 33% heavy, 33% medium size and 33% light, but can be easily modified in the model to reflect any other aircraft mix. The DTW arrival and departure schedule shown in Table 5 was obtained from the BTS database by looking up the "DETAILED STATISTICS" for arrivals and departures according to each airline and then computing the daily averages for the busy month of December 2004.

The purpose of this simulation is to determine the expected average and maximum daily waiting times for arriving and departing airplanes for any runway configuration. This information is used to determine if the airport is capable of supporting the demands shown in Table 5 with acceptable delays.

Other assumptions were taken into consideration. The model does not include holding delays at the gate in calculating the total outbound delay. L.C Smith Terminal was the only terminal considered in the model and in particular concourse C with its different gates. Aircraft will taxi out and in from this concourse. Figure 3 shows Smith terminal and highlights the concourse in question.

The model thus assumes oversimplified taxi and gate operations, i.e. all arriving planes taxi to the same concourse C before they are destroyed. Similarly, departing planes all start from the same concourse C and taxi to the appropriate designated departure runway. The taxi times assumed for all the operations are calculated based on a speed of 11m/s.

If waiting times are excessive, minimizing airport traffic or improving runway utilization is a necessary action to be taken. One way to improve the use of the runway is with the employment of better surveillance technology that helps reducing the safety buffer added to the minimum prescribed separation between aircraft by air traffic controllers (Martinez, Trani and Ioannou 2001).

4.1 Airport Operations Scenario I

In the case of arrivals, two runways process arrivals, 21L and 22R. Heavy, medium and light airplanes can land on any of these two runways. The model network that reflects the activities of this case is shown in Figure 4. This network illustrates three major portions: the first one introduces airplanes to the system through arrival scheduler resource, the second models approach and landing of airplanes through resource *Plane* and the third one models the minimum separations between airplanes in the common approach path through *Sequencer* resource.

The first portion of the network comprised of the *PArrival* Combi activity; the *ArvlSchdlrs* Queue; and the *AS1*, *AS2*, and *AP1* links models the airplanes arrival to the system. Each of the twenty four resources of type *ArvSchd*, which are initially in *ArvlSchdlrs* queue, represents the information in the first two columns of the corresponding row in Table 5 defined earlier, and enables the creation of a separate instance of *PArrival*. The duration of *PArrival* is set such that each instance ends at the time at which an airplane of the corresponding time period arrives. This duration is defined in the model with the following expression:

Table 5: Arrival and departure rates as a function of time of day

Time of day (hr)	Arrivals per Hour VFR	Arrivals per Hour IFR	Departures per Hour VFR	Departures per Hour IFR
12 PM - 1 AM	3.94	3.28	0	0.00
1 AM - 2AM	0	0.00	0	0.00
2 AM - 3 AM	0	0.00	0	0.00
3 AM - 4 AM	0	0.00	0	0.00
4 AM - 5 AM	0	0.00	0	0.00
5 AM - 6 AM	6.55	5.46	2	1.67
6 AM - 7 AM	0	0.00	11.68	9.73
7 AM - 8 AM	10.51	8.76	20.68	17.23
8 AM - 9 AM	18.26	15.22	18.84	15.70
9 AM - 10 AM	24.6	20.50	30.13	25.11
10 AM - 11 AM	22.4	18.67	30.97	25.81
11 AM - 12 AM	32.84	27.37	8.06	6.72
12 AM - 1 PM	30.54	25.45	38.26	31.88
1 PM - 2 PM	6.51	5.43	35.65	29.71
2 PM - 3 PM	36.19	30.16	9.71	8.09
3 PM - 4 PM	26.29	21.91	38.74	32.28
4 PM - 5 PM	30.35	25.29	10.29	8.58
5 PM - 6 PM	21	17.50	43.19	35.99
6 PM - 7 PM	29.22	24.35	8.58	7.15
7 PM - 8 PM	23	19.17	42.84	35.70
8 PM - 9 PM	32.32	26.93	5.16	4.30
9 PM - 10 PM	17.16	14.30	24.97	20.81
10 PM - 11 PM	8.5	7.08	7.94	6.62
11 PM - 12 PM	6.06	5.05	0	0.00

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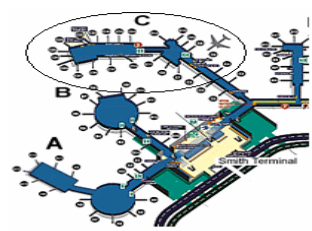

Figure 3: Smith terminal at DTW
[Source:http://www.gofox.com/flights/airportmaps.php?code=DTW]

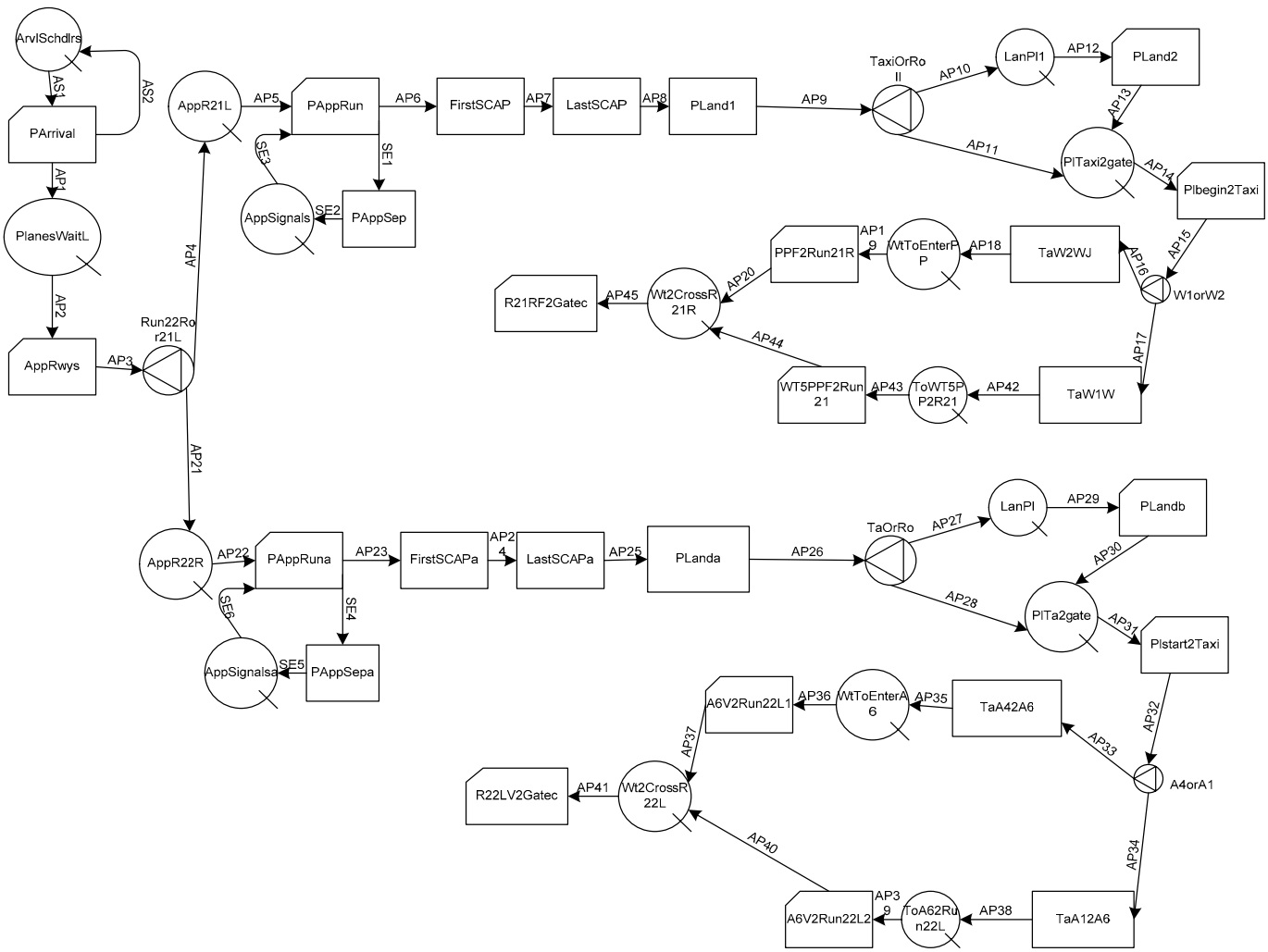

Figure 4: Stroboscope network for arrivals, scenario IDURATION PArrival

```
'PArrival.ArvSchdlr.i==0?PArrival.ArvSchdlr.Samp
ledIAT: PArrival.ArvSchdlr.NextArv';
```

SampledIAT is the interarrival time between airplanes and is based on the rates from Table 5. *StartHr* and *EndHr* define one hour range timing for each arrival scheduler resource and they are giving in Table 5. The variable *CurHour* and the property *NextArv,* which is referenced in the above expression, are calculated as follows:

```
VARIABLE CurHour
Mod[SimTime/3600+SimBeginHour,24];
VARPROP ArvSchdlr NextArv
'SampledIAT+CurHour*3600<EndHr*3600 ?
SampledIAT: SampledIAT+(24-(EndHr-
StartHr))*3600';
```

When *PArrival* terminates, the arrival scheduler is released to *ArvlSchdlrs*, creating by this another instance of *PArrival*. Arrival schedulers are thus constantly circulating in this part of the network and constantly introducing arriving airplanes to the system. Each time an instance of *PArrival* terminates, an airplane of the appropriate type (*Light*, *Medium*, or *Heavy*) is generated and placed in the *PlanesWaitL* queue. The type of the airplane is determined such that there is an equal probability of the plane being light, medium, or heavy.

The second portion of the network represents the system logic that controls airplanes approaching the runway and landing on either 21L or 22R. This is achieved in the model by first defining the property *LandRun* for the characterized resource *Plane* and assigning it to any of the runways based on a probabilistic selection. The next step is to use the fork *Run22Ror21L* and set the conditions on links *AP4* and *AP21*. *AppRwys* is a zero-duration dummy activity that marks the entry of airplanes into the common approach path either for runway 21L or 22R.

From this point, all tasks performed on each runway are almost the same. In other words, the system logic behind the operations on both runways is the same, and

thus only operations carried out on runway 21L are considered in this paper. Before proceeding with this portion of the network, it is important to first introduce the third one.

The third portion of the network comprised of *AppSignals*, *PAppSep* and the *SE1, SE2* and *SE3* links controls the separation distances between airplanes in the common approach path. *PAppSep* takes place immediately after *PAppRun* concludes and its duration is set to the minimum lead-time of the corresponding plane. *MinLeadTime* is a property of *Plane,* which specifies the minimum separation time between the arriving plane and the next plane to arrive. This value is determined by looking up in Table 2 (which is represented by a matrix in STROBOSCOPE), adding a stochastic buffer, and dividing by the approach speed. This is defined in the model with the following expression:

```
ONRELEASE AP1 ASSIGN MinLeadTime
'Min [ComAppL, (MatrixIJ[NextArvType==Heavy
?0:NextArvType==Medium?1:2, Type]
+Max[MinBufferd,Min[sNormal[BufferDist,BuffDists
d,2],MaxBufferd]])]/AppSpeed;
```

It is after this time has passed that a resource is released to *AppSignals*, thus preventing other airplanes that may be in *AppR21L* to begin approaching during that time. *PAppRun,* a zero-duration dummy that marks the entry of an airplane into the common approach path toward runway 21L, can then start whenever *both AppSignals* and *AppR21L* queues contain at least one resource each (first available resource in each is removed, FIFO). The common approach path is broken into two parts, *FirstSCAP* and *LastSCAP*. *FirstSCAP*, which takes place immediately after *PAppRun* concludes, represents an airplane traversing the first 11,800 m of the common approach path. *LastSCAP* starts immediately after *FirstSCAP* and represents an airplane traversing the last 3200 m of the common approach path. The arriving airplane then lands on the runway and starts to roll on the landing run. Each airplane has properties determined from its type that correspond to those specified in Table 4. However, depending on the type of the plane and the sampled duration of the ROT, the arriving plane can either use the nearest possible exit and clears the runway or roll beyond the first possible exit and takes the next exit. The first case applies to light and medium airplanes whereas the second case applies to heavy ones. This is achieved in the model by defining the fork *TaxiOrRoll* and setting the conditions on links *AP10 (heavy)* and *AP11 (medium and light)* as follows:

```
STRENGTH AP10 '(PLand1.Plane.Type==0) ? 1: 0' ;/
type 0 refer to heavy
STRENGTH AP11 '((PLand1.Plane.Type!=0)) ? 1: 0'
; /in this case its either type 1 or 2 (medium
or light)
```

Upon exiting the runway, the aircraft uses the best feasible taxiways to travel from the exit to the designated parking gate. Heavy airplanes travel on a different taxiway *(WT5PPF2Run21R)* than medium and light airplanes *(PPF2Run21R)*. A taxiing airplane is always aware of the operations that take place on the airport. For example, an airplane will obviously not cross a runway when there are arrivals or departures being processed on that runway. In our case, airplanes taxiing from R21L to concourse C in Smith Terminal can not cross runway 21R when there are departures conducted on it. This is achieved in the model by using a semaphore for the activity *R21RF2Gatec* as in the expression below. After crossing runway 21R, airplanes travel to gate in concourse C, which is represented by *R21RF2Gatec* in the model.

```
SEMAPHORE R21RF2Gatec '!RollingR21R.CurInst &
!TakeOffR21R.CurInst& !R21RF2Gatec.CurInst' ;
```

The model network that describes the logic of airplanes departing is defined in figure 5. This network illustrates two major portions: the first one introduces departing airplanes to the system through arrival scheduler resource and the second models departures of airplanes through resource *Plane.* Airplanes departing are generated independently of arrivals according to the rates specified in Table 5 and are placed in the *PlanesWaitD* queue.

Departures are modeled by the portion of the network comprised of the *PDeparture* Combi activity, the *DptSchdlrs* Queue, and the *DS1*, *DS2*, and *DP1 links* in much the same way as the arrivals to the system are modeled.

A generated departing plane is assigned a particular runway for departure at the time of its creation. In this case, two runways process departures, 22L and 21R. The assigned runway depends on the current runways designated for processing departures and the type of the departing airplane. Heavy airplanes depart on 22L and light and medium on 21R. This is achieved in the model by creating the fork *WestorEast* and setting the probabilistic conditions on links *DP4* and *DP5* as follows:

```
STRENGTH DP4 '(TaxiOut2Run.Plane.Type==0)?1:0';
/ type 0 refer to heavy
STRENGTH DP5  ' ((TaxiOut2Run.Plane.Type!=0))
?1: 0' ; /in this case its either type 1 or 2
(medium or light).
```

An airplane ready to depart uses the optimum taxiway path to travel from the parking gate to the assigned runway. Thus, heavy planes travel heading west and medium and light heading east. An airplane departing from any of the runways is cleared for departure when there is no other traffic on the assigned departure runway. This is achieved in the model by setting semaphores for both activities *ONRun22L*(see below) and *ONRun21R* as well as *RollingR22L*(see below) and *RollingR21R*.

```
SEMAPHORE ONRun22L
'!ONRun22L.CurInst&!RollingR22L.CurInst&!Rdy2Rol
lR22L.CurCount' ;/ heavy
PRIORITY RollingR22L 10;
SEMAPHORE RollingR22L
'!R22LV2Gatec.CurInst&!TakeOffR22L.CurInst' ;
```

Rolling activities, in both cases, are given priority over runway crossings (*R22LV2Gatec* and *R21RF2Gatec*). In addition, they can not start if there is a plane taking off. For rolling activity *RollingR21R,* additional conditions are set because under IFR conditions, runways 21R and 21L can not process simultaneous arrivals-departures since the centerline distance is approximately 2000 ft (< required distance=2500 ft). Thus, a plane ready to depart from runway 21R, must be cleared for rolling when there are no arrivals to be conducted on runway 21L (arrivals are first allowed to be conducted).

A departing plane, after being cleared for departure, then occupies the runway for the sampled ROT duration before taking off. Since departing aircraft create wake turbulence that affects other aircraft departing on the same runway, minimum times between successive departures (shown in Table 3 and represented by a matrix in STROBOSCOPE) have to be set to account for differences in takeoff speed and thus prevent a fast plane overtaking a slow plane and avoid wake turbulence effects. Therefore, the duration for takeoff is equivalent to the difference between minimum times between successive departures and ROT before taking off

4.2 Airport Operations Scenario II

In this case, three runways process arrivals, 21L, 22R and 22L and heavy, medium and light airplanes can land on any of these three runways. The simulation network that corresponds to this scenario is the same as in Figure 4 but with an additional portion (middle branch) accounting for runway 22L.

```
STRENGTH AP46 'AppRwys.Plane.LandRun==R22L' ;
```

The property *LandRun* for the characterized resource *Plane* is assigned a third new variable representing runway 22L based on a probabilistic selection. Moreover, a new condition on link AP46 is set.

The simulation network that models departures under this scenario is the same as in Figure 5. But in this case, new conditions are added to the semaphores related to departures activities performed on runway 22L since this runway is processing arrivals and departures. This is defined in the STROBOSCOPE code as follows:

```
SEMAPHORE ONRun22L '!ONRun22L.CurInst &
!RollingR22L.CurInst&
!Rdy2RollR22L.CurCount
&!R22LV2Gatec.CurInst&!LastSCAPI.CurInst
&!PLandI.CurInst&
!PLandII.CurInst
&!TakeOffR22L.CurInst' ;
```

The simulation network that models departures under this scenario is the same as in Figure 5 except that conditions are removed from semaphores for departure activities performed on runway 21R since operations are conducted under VFR conditions. In this case, there are no constraints concerning the arrival activities performed on the parallel runway 21L as opposed to the other scenario.

The results shown in Figure 6 were collected by running the simulation models for the two scenarios for a period of 1 day (86400 seconds). These results indicate that the average daily waiting time for arriving and departing airplanes over the 10 days simulated under scenario I was about 2.28 minutes and about 0.71 minutes respectively. Under scenario II (VFR conditions), the numbers are 0.9 minutes and 0.24 minutes respectively, which shows clearly that under better weather conditions waiting times diminish.

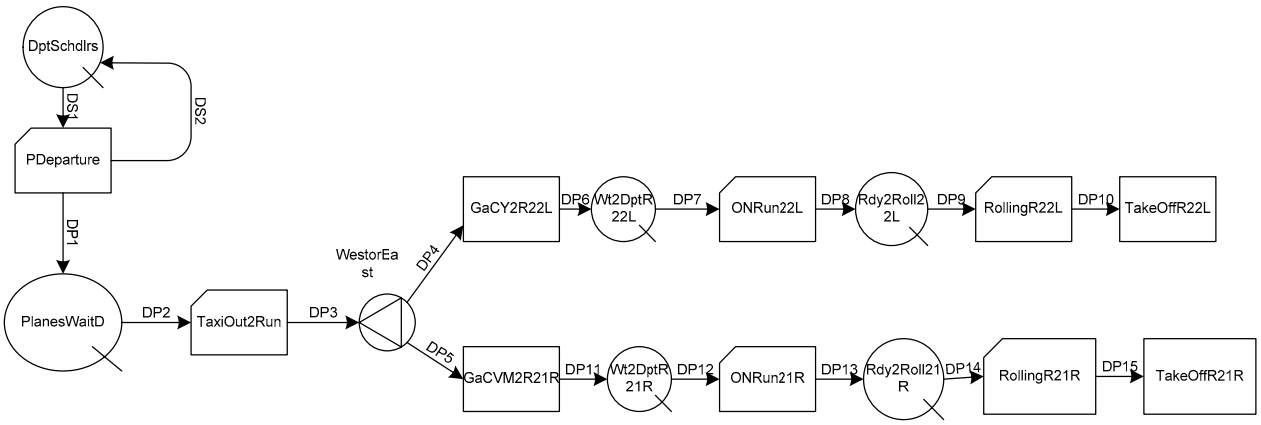

Figure 5: Stroboscope network for departures, scenario I

Scenario I

	Daily Arrival Values			Daily Departure Values		
	Av Arvs/hr	Max Wait	Ave Wait	Av Depts/hr	Max Wait	Ave Wait
	9.79	11.19	2.11	8.46	5.19	0.55
	10.58	15.68	2.36	8.00	5.89	0.73
	10.42	20.24	3.99	8.83	6.20	0.83
	10.29	14.16	2.62	8.46	5.85	0.81
	9.96	14.04	2.28	9.63	10.96	0.85
	9.38	14.49	2.19	8.88	8.52	0.61
	10.21	10.09	2.08	7.04	3.92	0.68
	9.88	7.53	1.24	9.04	8.32	0.73
	9.71	10.52	1.75	7.88	4.59	0.62
	9.33	12.11	2.24	8.58	8.33	0.73
Mean	9.95	13.01	2.28	8.48	6.78	0.71
SD	0.42	3.54	0.71	0.71	2.18	0.10

Scenario II

	Daily Arrival Values			Daily Departure Values		
	Av Arvs/hr	Max Wait	Ave Wait	Av Depts/hr	Max Wait	Ave Wait
	9.79	6.20	1.04	8.46	1.81	0.17
	10.58	9.62	1.04	8.00	1.79	0.29
	10.42	8.76	1.14	8.83	1.80	0.25
	10.29	7.65	0.96	8.46	1.78	0.25
	9.96	7.68	0.86	9.63	1.80	0.30
	9.38	7.10	0.92	8.88	1.80	0.27
	10.21	5.87	0.78	7.04	1.82	0.22
	9.88	6.52	0.68	9.04	1.81	0.27
	9.71	7.56	0.73	7.88	1.81	0.22
	9.33	8.36	0.89	8.58	1.78	0.19
Mean	9.95	7.53	0.90	8.48	1.80	0.24
SD	0.42	1.17	0.15	0.71	0.01	0.04

Figure 6: STROBOSCOPE simulation results for scenarios I (left) and II (right)

5 VITASCOPE 3D ANIMATION

One of the primary disadvantages in the use of discrete-event simulation models is that there are often no means to check the credibility of the models and the authenticity of the results (Kamat and Martinez 2003). Visualization and animation of simulated operations can be of paramount importance in the verification, validation and accreditation (VV&A) of models. By consequence, 3D animation objectives are: 1) to verify that code is free of errors; 2) to validate simulation models; and 3) to ensure the credibility of models once verified and validated. The STROBOSCOPE models presented earlier are validated in this study using VITASCOPE (Kamat 2003).This section describes how VITASCOPE can be used as a tool to visualize the operations at DTW airport.

VITASCOPE is a general-purpose, user-extensible 3D animation system designed for visualizing simulated processes in smooth, continuous, 3D virtual worlds. VITASCOPE is capable of visualizing modeled operations in 3D by connecting ASCII animation trace and 3D CAD models of the involved resources (Kamat and Martinez 2003). VITASCOPE characteristics are: 1) maintaining an independent simulation clock; 2) allowing the user to navigate in 3D space; 3) allowing the user to jump to any desired time; and 4) permitting the viewer to start and pause the animation at any simulation time to check the trace files (Kamat and Martinez 2001). A VITASCOPE trace file consists of sequential animation command statements such as TIME, CLASS, CREATE, MOVE and DESTROY. The trace file also contains statements such as PATH and NONDIRECPATH that define resource movement trajectories for the animated simulation entities.

Simulation models need to be instrumented to generate VITASCOPE animation commands during a simulation run. 3D CAD models need to be imported to visualize the simulated operations. AC3D (Colebourne 2000) is one of the 3D modelers that can be used to create the 3D models required to visualize any simulated operation.

Once all the models are instrumented, trace files are generated. After the statements are processed, the result is a pictorial representation of the actual operations being conducted in a 3D virtual environment. All VITASCOPE characteristics can be of great use here. The animation can be replayed at varying speeds but in our case the animation is set to a speed of 40 (*VIEWRATIO 40)*. The user can jump to any desired time and check what is happening and can also navigate easily in the 3D virtual space. Figure 7 presents VITASCOPE animation snapshots of the operations on the airport.

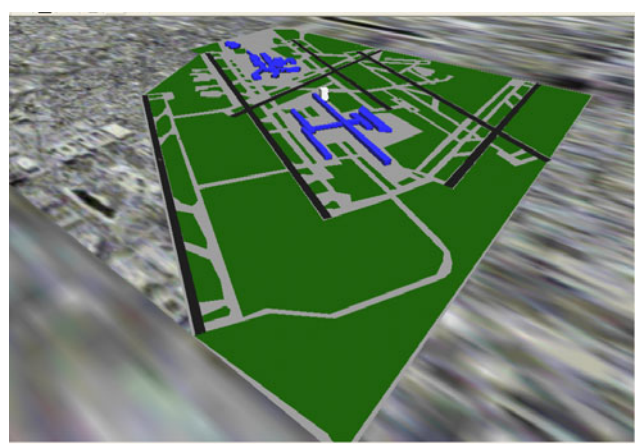

Figure 7. VITAscope animation snapshots

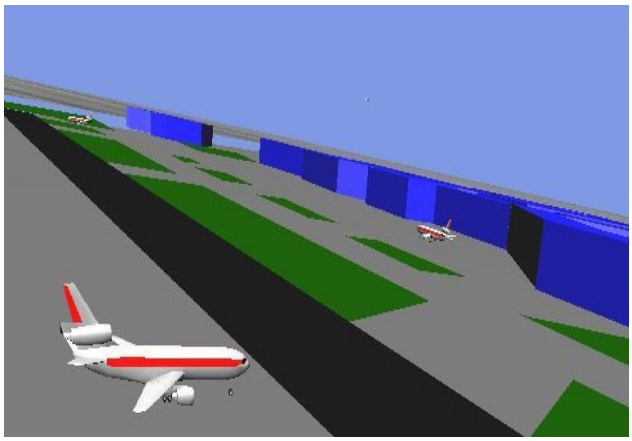

Figure 7 ctd.: VITASCOPE animation snapshots

6 CONCLUSION

This study modeled airside airport operations using a general purpose simulation tool typically used in construction in order to determine the simulation tool's ability to simultaneously model operations in the construction and airport operations domains. Previous work on airports simulation and animation was examined, followed by the description of airport operations at Detroit Metropolitan Airport modeled and animated using general purpose tools typically used in construction simulation and visualization. Two scenarios based on different meteorological conditions were examined. By consequence, respective STROBOSCOPE models, in which all required parameters were included, were presented. Then VITASCOPE was used as 3D animation tool to ensure the credibility and validation of the models. At the end, results were generated from STROBOSCOPE models. Only airport operations were modeled using general-purpose tools. Future work will include mixed construction-airport operations.

The STROBOSCOPE language is described in (Martinez 1996). Example applications can be found in (Ioannou and Martinez 1996a, 1996b, 1996c) and (Martinez and Ioannou1994, 1999). The VITASCOPE visualization system is described in (Kamat 2003). Example applications and add-ons can be found in (Kamat and Martinez 2001a, 2001b, 2001c, 2002a, 2002b, 2003a, 2003b, 2003c, 2004a, 2004b, 2004c, 2005). STROBOSCOPE, its documentation, and several solved examples are available at <http://strobos.ce.vt.edu>. VITASCOPE, its documentation, and several solved examples are also available from <http://pathfinder.engin.umich.edu>.

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