ON THE SEARCH FOR NOVEL SIMULATION APPLICATIONS TO SUPPORT AIRPORT OPERATIONS MANAGEMENT

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ABSTRACT
Airports are complex socio-technical systems with many different stakeholders which often have very different needs. Operations Research modelling tools and techniques are used successfully to support the management of such systems by helping to better understand and improve their operations. A review of the literature shows that there are many existing modelling studies related to airport operations management but it also unveils some territories that are still untapped. This might be due to the fact that the right tools or techniques for these jobs have not been identified yet. In this paper we identify some of these untapped areas and discuss how simulation modelling could be used as a decision support tool for gaining insight into systems operation in these areas. We take a closer look at one of the identified areas (airport facilities maintenance scheduling) and conduct a hypothetical proof-of-principle simulation study to demonstrate the feasibility and applicability of using simulation in this area. Our conclusion is that simulation studies are a very useful aid for this kind of investigation.

Keywords: airport, operations management, agent-based modelling, simulation, maintenance scheduling.

1. INTRODUCTION
An airport is a complex, large-scale socio-technical system comprising multiple stakeholders, multiple jurisdictions and complex interaction between many actors (Wu and Mengersen 2013). The large growth of air travel in the last two decades has forced many airports to increase their capacity and optimise their processes (Ma et al. 2011). There are many operation divisions in an airport which have the roles of ensuring that all operation facilities (such as aircrafts and other airport facilities) are serviceable at all times while also managing crises such as emergency situations efficiently. Increasing the performance and efficiency of existing airport facilities requires, a thorough understanding of different stakeholders needs. These stakeholders within their jurisdictions have different views and needs that have to be considered when finding solutions to various airport problems. And like in many other systems, we cannot afford to find the right solutions by experimenting with real objects since building; destroying and making changes may be too expensive, dangerous or even practically impossible (XJ Technologies 2012). As such, simulation modelling has become one of the ways of solving problems that appear in the real world when other forms of modelling prove to be impossible to use in Operations Research (OR).

The goal of this paper is to identify and find new simulation modelling applications for airport operations and investigate the feasibility of these applications in airport operations by building hypothetical proof-of-principle models using different worldviews with appropriate simulation paradigms.

The remainder of the paper is structured as follows: Section 2 provides a literature review on existing airport operation management models and identifies areas with potential for further development. We then choose one of these areas (airport facilities maintenance scheduling) and provide a proof-of principle study, described in the following sections. Section 3 focuses on the design and the implementation of our simulation model. Section 4 covers testing through experiments. The results of the experiments are then discussed in Section 5. Finally, in Section 6 we provide our conclusions and propose further developments.

2. LITERATURE REVIEW

2.1. Simulation Methods
Besides analytical methods that are often used in airport operations management, several simulation modelling methods exists that can be used for this purpose. The main ones are System Dynamics (SD), Discrete Event (DE), and Agent-Based (AB) simulation modelling.

SD models help us to understand the behaviour of complex systems over time (Wakeland et al. 2004). They use a very high abstraction level, are deterministic, and represent a system in terms of aggregates and flows (Kirkwood 1998). In DE models, movement of passive entities (components) that make up a system can only be described based on state change and the time at which the change occurs (Albrecht 2010). In AB models, the components can be viewed as individual objects with autonomy and interactivity (Ma et al. 2011) where detailed individual object emergent behaviours can be studied when large populations of objects interact with each other. However, AB modelling is a mindset more than a technology. This mindset consists of describing a system from the perspective of its constituent units (Bonabeau 2002) and therefore allows system components to execute various behaviours appropriate for the system they represent. This allows unanticipated behaviour to emerge, make it a good modeling method for heterogeneous, autonomous and proactive actors such as human centered systems.

2.2. Airport Modelling Studies

Quite a large number of airport modelling studies have been found in the literature. These focus on various areas of airport operations. Below we provide an overview of these studies subdivided into various areas of airport operations.

Passenger Terminal Models

Existing studies in this area include the work of Tang et al. (2012); Hebert and Dietz (1997); Suryani, Chou and Chen (2010); Schultz and Fricke (2011); and Hanta and Pozivil (2010). These studies used either analytical, SD, or DE modelling technique which has limited capability in representing passengers' behaviour. Furthermore, discretionary activities such as duty free shopping and the use of bathrooms are not considered. More detailed consideration of human behaviour in these models would provide more realistic predictions of overall system performance.

Maintenance Scheduling Models

Many modelling studies on maintenance scheduling have focused on the development of optimisation methods. These studies include Suryani, Chou and Chen (2010); Hecht et al. (1998), and Duffuaa and Al-Sultan (1997). It is observed that all of these studies used methods with high abstraction levels such as integer programming, queuing theory or SD. Also at a high abstraction level, Miller and Clarke (2007) used Monte Carlo simulation to evaluate the strategic value of air transportation infrastructure. These high abstraction levels have limitations when it comes to modelling some maintenance scheduling problems where high levels of agents' interactions and message passing between objects of the systems are relevant to study system operations. Furthermore, there is limited information about modelling maintenance of other airports' infrastructure that provide conveniences to customers.

Human Behaviours Models

Studies on human behaviours in airport operations are looked into in two ways:

1. **Human behaviour in a normal situation:** Schultz and Fricke (2011) modelled human behaviour as flow using a mathematical model while Ma et al. (2011) and Cimler et al. (2013) used AB models to study advanced passenger traits movement in the departure hall.
2. **Human behaviour in an extreme situation:** Galea and Galparsoro (1994) and Galea, Owen and Lawrence (1996), developed a prototype egress model to simulate the evacuation of large numbers of individuals from an enclosure such as an aircraft. Matthew et al. (2011) used AB modelling to model the evacuation of individuals with disabilities in a densely populated airport. Chow and Fong (2011) modelled emergency evacuation in the arrival hall of a crowded airport terminal using EXODUS and SIMULEX. However, the paradigms used in these studies can be considered appropriate because of their capability to support adequate representation of the systems' components and interactions, but it is observed that studies on terrorist attacks are limited.

Airport Marketing Models

Kuhn et al. (2010) present an AB model to assist market share analysis and help the investment analyst to develop earnings forecasts for the year ahead. It is clear that there are limited existing models in this area, and the available one used AB modelling to model a macro level factor, which could best be studied using an aggregate viewing tool for better prediction of model behaviour.

2.3. Classification of Existing Airport Models

Based on the findings from the literature review and with the help of several experts in the field, a graphical representation that classifies the existing airport operation models has been developed which is shown in Figure 1. This classification tells us, at a glance, some of the essentials of the model structure. The horizontal axis distinguishes the levels of abstraction (macro, meso, and micro), while the vertical axis represents the queue constraints (from low to high). The approaches listed on the horizontal axis are: mathematical models (at the extreme level of abstraction) where system problems are represented as mathematical equations using various analytical methods. Continuous modelling follows which may be in the form of SD models, and then discrete modelling follows in form of DE models which focus on processes, and AB models which focus on individual entities and their interactions. These have the lowest level of abstraction.

Figure 1 shows that modelling airport terminal operations such as passenger movement in the departure area, human behaviour, baggage handling and security check-in were mostly carried out using either analytical, SD or DE techniques. It also shows that in airport infrastructure maintenance scheduling, studies were limited to using analytical techniques which have limited capabilities to represent objects' interactions and message passing - one of the key factors in maintenance scheduling. Modelling maintenance scheduling for airport facilities such as escalators, lifts, air conditioners, television sets, power supply points, hot spots, and so on are not considered. Furthermore, studies in emergency evacuation show that not much has been done on discretionary activities and terrorist attacks in particular. On airline and airport marketing, limited works were found, and the available ones did not focus on airport or airline performance improvement.

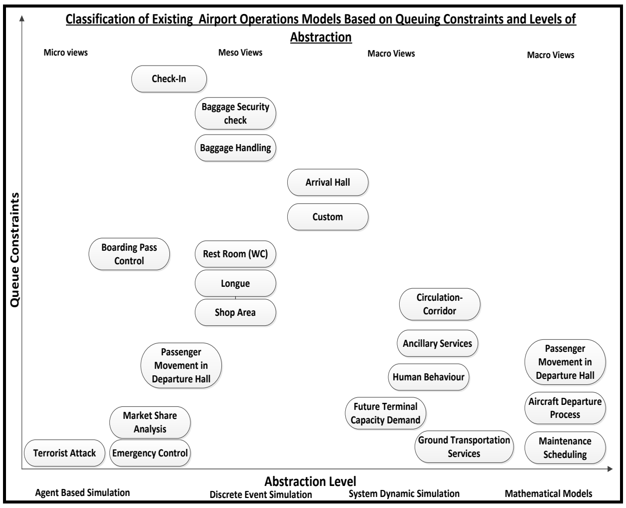

Figure 1: Classification of Existing Airport Operations Models

To support finding the gaps we have re-categorised the airport models presented in Figure 1 while considering the system operation areas and the adequacy of system component representation in the models.

2.4. Identifying the Gaps

The new classification has been achieved by adopting Greasley's worldview framework (Greasley 2013). It provides us with suggested techniques based on the level of detail required to represent the components of a system under study in sufficient detail, and looking into the kind of insight each of the available simulation methods used in these areas give. Using this framework we were able to identify some gaps in the existing classification as presented in red ovals in Figure 2.

By adopting Greasley's worldview framework we can see that many operations are shifted towards the AB modelling paradigm. This is a result of the system operations being non-static, considering the behaviour of the components of the systems involved.

The red ovals in Figure 2 represent areas of airport operations where gaps have been found. These areas are Airport Facilities Maintenance Scheduling and the Airline Marketing Strategy. The two areas could be of significant importance to the growth of an airport in terms of revenue generation. Airport revenues are increasingly dependent on the numbers of customers that use the airport. Moreover, customers' satisfaction and some marketing strategies will play a huge role in wining and retaining customers over time. Customers' satisfaction depends on, among other things, availability of needed facilities in the terminals and lounge where customers spend most of their time, while winning more customers requires strategic planning. However, to achieve success in these areas, airport management needs a good decision support system to aid its decision and policy making.

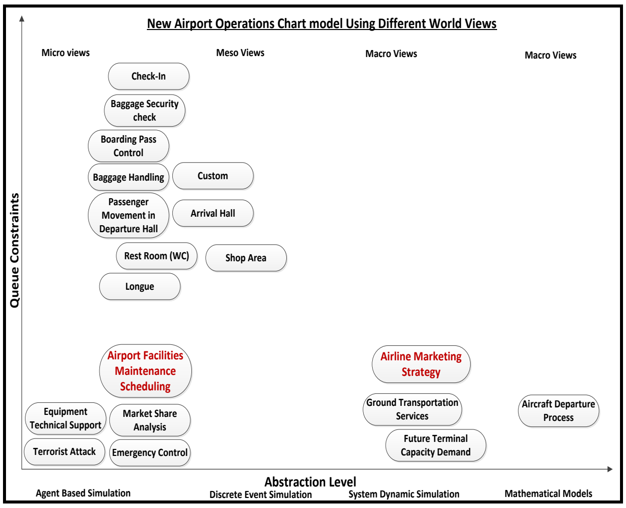

Figure 2: Classification of Airport Models Including New Areas

3. HYPOTHETICAL CASE STUDY

In this section we take a closer look at one of the new simulation modelling opportunities identified earlier (Airport Facilities Maintenance Scheduling) through a hypothetical proof-of-principle simulation study.

We acknowledge that (due to space constraints) some of the diagrams in this section are difficult to read. You can download larger versions of these from our website (Siebers 2014).

3.1. Problem Description

Here is a description of our hypothetical problem: A group of airport facilities are distributed geographically within the airport mostly in the terminal area where passengers and well-wishers spend most of their time. Facilities such as escalators, lifts, air conditioners, television sets, power supply points, hot spots, and so on are provided for customers' convenience while at the lounges and terminals. Also there is an airport hangar that houses a fleet of aircrafts that need routine maintenance and various levels of service. These airport facilities and aircrafts contribute to the growth of the airport in form of revenue and customer satisfaction while working, so they need to be up and running for optimum daily operations. However, they sometimes break down and need to be maintained, repaired or replaced.

To service these facilities, there are facilities maintenance crews (facilities-technicians) and aircraft maintenance experts (aircraft-technicians) in the airport estates office who service the facilities and aircrafts based on certain management policies (replacement and maintenance policies). But the airport management has limited capability to employ a maximum of five technicians each for the aircraft and other airport facilities.

3.2. Conceptual Model

For defining our conceptual model we have employed Robinson's conceptual modelling framework (Robinson 2004).

The specific objectives of this case study are "to determine the number of technicians required to ensure that 90% of the airport facilities and 95% of the aircrafts are in good working condition", and "to ensure that 80% of airport facilities and 95% aircrafts are available all of the time", and "to determine the replacement policy that will give the optimum result at minimum cost". Our constraints are that at most five technicians can be employed for both, airport facilities and aircrafts.

Assumptions are that: airport facilities problem identification takes zero time; technicians never fail and always have all necessary spare parts and tools on board; technicians do not optimise their routes; and technicians are equipped with a radio and can take a new assignment while in motion.

Simplifications are that: distance travelled by the technicians before getting to the site of work is not modelled; all technicians work 24 hours a day; the airport facilities parameters are the same; the aircraft maintenance check types (A, C, or D) are also not modelled; and the parameters are the same.

We decided to use an AB approach for modelling this system as we are dealing with individual entities that are communicating with each other.

The Sequence Diagram in Figure 3 shows the event ordering and message exchange between the Airport Facility Object (airport facilities) and the Technician Object (maintenance crew). It is a result of discussions with several airport operations managers and has been validated by them.

3.3. Model Implementation

To implement the conceptual model we used AnyLogic, a Java based multi-paradigm simulation modelling IDE (AnyLogic 2014).

In our implementation the active object classes are the AirportFacilities (aircraft and other facilities) and the MaintenanceCrew (facilities technician and aircraft technician). The AirportFacilities agent types are the same considering states and transitions but have different parameter values. They are autonomous and can respond to changes in their internal state such as failed, repaired, and maintained. The same is true for the MaintenanceCrew agent types.

3.3.1. AirportFacilities Agents

The state chart representing all AirportFacilities agent types is presented in Figure 4.

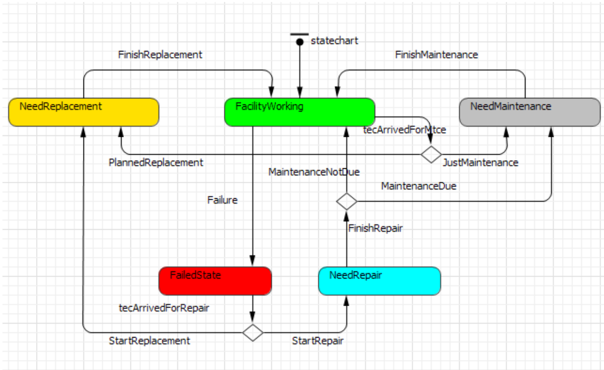

Figure 4: AirportFacilities Agent State Chart

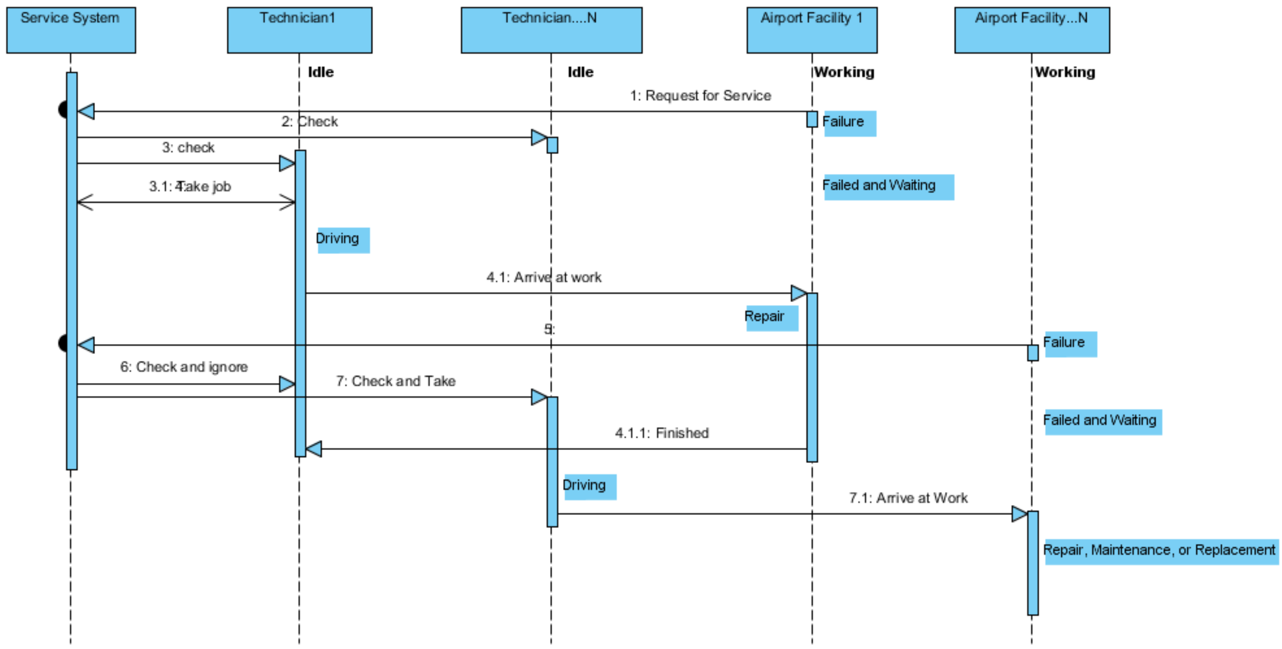

Figure 3: Airport Facilities Maintenance Scheduling Sequence Diagram

All airport facilities and aircrafts are assumed to be working initially i.e. in "FacilityWorking" state.

- Transition to "FailedState" state is triggered by a stochastic event failure rate. Request for service is made, and broadcast notification is sent to all technicians.
- One of the technicians takes the job and drives to the failed facility while the others return back to their "Idle" state.
- The transition from "NeedReplacement" state to "FacilityWorking" state is triggered by a timeout (triangular distribution).
- The transition from "NeedRepair" state to "FacilityWorking" is deterministic having two branches "MaintenanceNotDue" and "MaintenanceDue".
- The transition from "NeedMaintenance" state to "FacilityWorking" state is triggered by a timeout (triangular distribution).
- A working facility may request for scheduled maintenance or being on a planned replacement after a given number of maintenance periods, therefore, the transition from "FacilityWorking" has two branches which depend on whether the "ReplaceOldFacility" policy is active or not.

3.3.2. MaintenanceCrew Agents

The state chart representing all MaintenanceCrew agent types is presented in Figure 5.

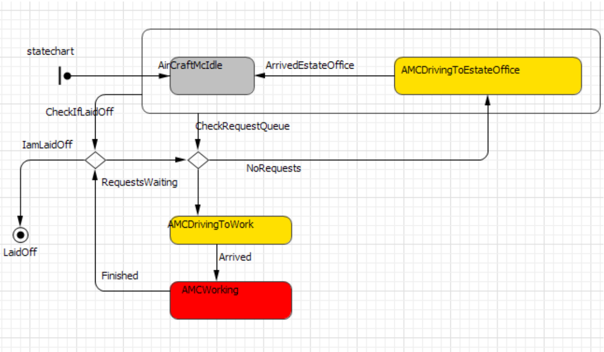

Figure 5: MaintenanceCrew Agent State Chart

All technicians are at the "Idle" state in the estates office at the initial stage. The agent implementation is based on the following transitions among states:

- The transition "CheckRequestQueue" sent by service system (dispatcher) to all technicians has two branches: "RequestsWaiting" and "NoRequests".
- The transition "Arrived" always indicates that a technician has arrived at the failed facility for work.
- The transition "Finished" sent by the facility to the technician indicates "FacilityWorking" and then releases the facility.

However, a technician can be employed or laid-off. Therefore, each technician in the collection has an index that is used to check its employability status. After completing a job, the technician checks if the index is still within the "Service Capacity". If the technician is idle or driving to the estate office, a special message "CHECK IF LAID OFF" is sent to the technician to check the same condition.

3.4. Model Verification and Validation

When developing simulation models it is crucial to gain credibility through verification and validation. This is particularly important for real world case studies related to airport operations management.

The model discussed in this paper, however, is purely academic and is based on a hypothetical situation due to non-availability of real world data. It has been thoroughly verified (e.g. code debugging) and model design and implementation have been validated by domain experts (face validation). This ensures that the model design is a reasonable imitation of the real world system and that our model implementation produces reasonable outputs.

4. TESTING THROUGH EXPERIMENTATION

In the experimentation presented here we are interested in the number of technicians and replacement policy that give optimum results for both, airport facility and aircraft availabilities, at low cost. Therefore, our focus is on technician utilisation, facility and aircraft availabilities, and a combination of the number of technicians and replacement policies that give optimum results in terms of profit. The replacement policy is the amount of maintenance that a facility or an aircraft must have before it can be replaced, whether it is still working or not.

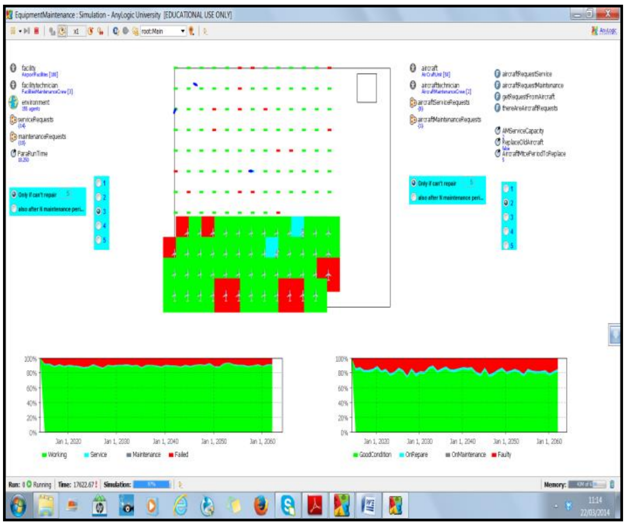

Figure 6: Screenshot for Simulation Model run

Three different scenarios were simulated and the output from each of the scenario is presented as a screenshot to gain a quick overview.

A: Base Scenario

The base scenario uses all of the default values as shown in the Table 1. The output from the base scenario simulated model for airport facilities and aircrafts is presented in Figure 7 and the results of the simulation run are shown in Table 2.

Table 1: Base Scenario: Experimental Factors

	Airport Facilities	Aircrafts
Number of technicians	3	2
Replacement policy	Replace only failed facility that cannot be repaired	Replace only failed aircraft that cannot be repaired

This scenario runs on default technicians' values of 3 for airport facilities and 2 for aircraft. It gives 89% and 80% availability, 11% and 20% unavailability for airport facilities and aircrafts, respectively. And 96% and 95% technician utilisation with idle levels of 4% and 5%, respectively. The costs of operating the system are £7,500 for airport facilities and £8,000 for aircrafts, while the respective profits are put at £18,500 and £25,000.

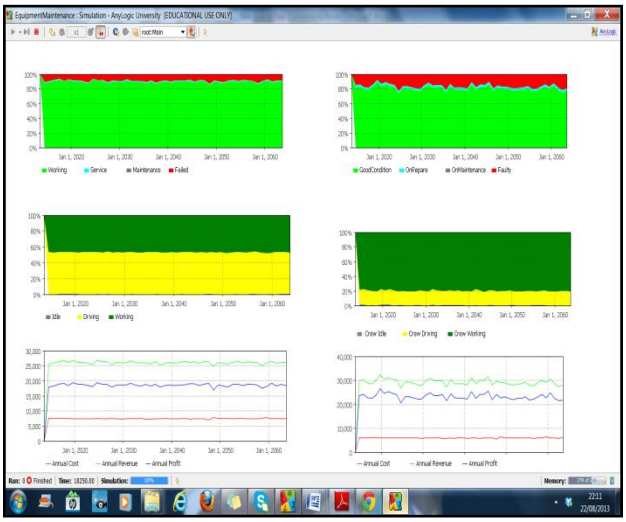

Figure 7: Base Scenario Output View

Table 2: Base Scenario Results

	Airport Facilities	Aircrafts
Number of technicians	3	2
Facilities		
Availability (%)	89	80
Unavailability (%)	11	20
Technicians		
Utilised (%)	96	95
Idle (%)	4	5
Cost/Benefit		
Profit (in 1000s)	18.5	25
Cost (in 1000s)	7.5	8

B: Scenario 1

Scenario 1 was observed based on varying the number of technicians working on the facilities while the replacement policy remained at default value as shown in Table 3 below.

Table 3: Scenario 1 Experimental Factors

	Airport Facilities	Aircrafts
Number of technicians	Options A,B,C 3,4,2	Options A,B,C 2,3,1
Replacement policy	Replace only failed facility that cannot be repaired (default)	Replace only failed aircraft that cannot be repaired (default)

In this scenario, there are three options A, B, C representing changes made to the number of technicians at default replacement policy. The output from this run is shown in Figure 8 and the results in Table 4.

Option A: The simulation starts with default technicians' values for the two cases as in the base scenario. This gives the same result as the base scenario shown in Table 2.

Option B: The number of staff is increased from 3 to 4 for airport facilities and 2 to 3 for aircrafts. The result is 97% and 96% facility and aircraft availabilities, 3% and 4% non-availability, respectively; technician utilisation of 92% and 90% and idleness of 8% and 10% for facilities and aircrafts, respectively, and the costs of operations are £7,600 and £8,000, while the respective profits are put at £20,000 and £28,000 for facilities and aircrafts.

Lastly, in option C the number of technicians is reduced from 4 to 2 for airport facilities and from 3 to 1 for aircrafts. This gives 22% and 39% availability with non-availability of 78% and 61%, respectively; however, technician utilisation of 100% and idleness of 0% are recorded for both airport facilities and aircrafts, respectively. The costs of this option are £4,000 and £3,000 while the profits are £4,000 and £12,000, respectively, for airport facilities and aircrafts.

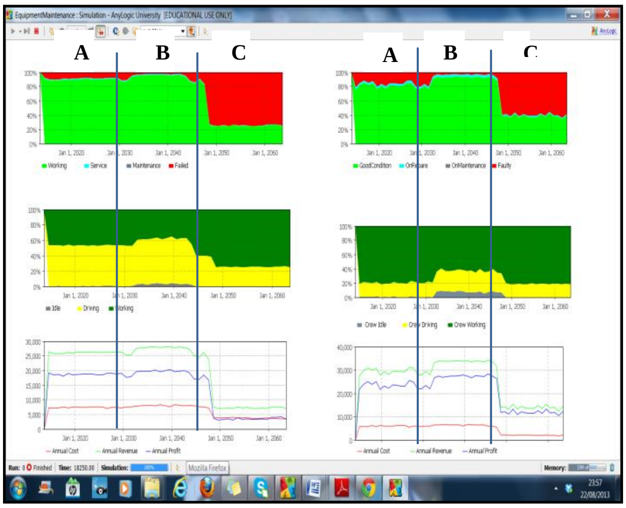

Figure 8: Scenario 1 Output View

Table 4: Scenario 1 Results

	Airport Facilities			Aircrafts		
Option	A	B	C	A	B	C
Number of technicians	3	4	2	2	3	1
Facilities						
Availability (%)	89	97	22	80	96	39
Unavailability (%)	11	3	77	20	4	61
Technicians						
Utilised (%)	96	92	100	95	90	100
Idle (%)	4	8	0	5	10	0
Cost/Benefit						
Profit (in 1000s)	18.5	20	4	25	28	12
Cost (in 1000s)	7.5	7.6	4	8	8	3

C: Scenario 2

Scenario 2 was observed based on varying the number of technicians working on the facilities while varying the replacement policy as shown in Table 5. The output for all possible combinations of experimental factors (number of technicians and replacement policy) for Scenario 2 are shown in Figure 9 as options A–E and the results from this run are shown in in Table 6.

Table 5: Scenario 2 Experimental Factors

	Airport Facilities	Aircraft
Number of technicians	A,B,C,D,E 3, 3, 4, 4,2	A,B,C,D,E 2, 2, 3,3,1
Replacement policy	Replace after (default,3,3,2,2) maintenance	Replace after (default,4,4,3,3) maintenance

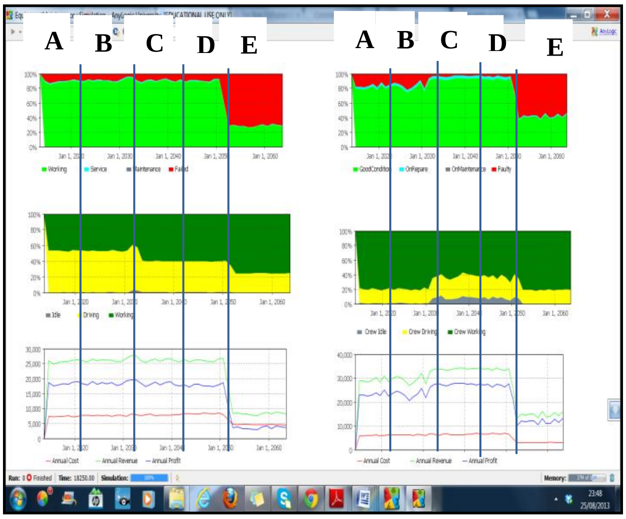

Figure 9: Scenario 2 Output View

Options are defined as follows:

Option A: This presents the default settings, and gives the same results as the base scenario, see Table 2.

In Option B the replacement policy is changed from "replace only failed facility" to "replaced airport facility after 3 maintenance periods" and "replace aircraft after 4 maintenance periods". This option gives facility and aircraft availabilities of 91% and 82; and non-availability 9% and 18% for both facilities and aircrafts, respectively; with technician utilisation of 96% and 97% and idleness of 4% and 3% for facilities and aircrafts, respectively. The costs are £7,500 and £6,200; while the profit is £27,000 and £24,000, respectively, for facilities and aircrafts.

Option C: there is an increase in the number of technicians from 3 to 4 for airport facilities and from 2 to 3 for aircrafts, while replacement policy settings remain unchanged from the previous run in both cases. This gives availability 93% and 97% for facilities and aircrafts, respectively; and non-availability of 7% and 3%, respectively; the technician utilisation shows 93% and 89% for facilities and aircrafts with idleness of 7% and 11%, respectively. Also, the costs of running this option gave £7,600 and £6,200 for facilities and aircrafts, respectively, with profit of £28,000 in both cases.

Option D: There is a change in the replacement policy years settings from 3 maintenance periods for airport facilities to 2 maintenance periods and also from 4 maintenance periods for aircraft to 3 maintenance periods while the numbers of technician remain the same as in previous run. This option gives facilities availability of 94% and 96% for aircraft, and non-availability of 6% and 4%, respectively, technician utilisation of 93% and 90% respectively and idleness of 7% and 10% respectively. While the costs remain the same as in the previous option for the two cases, the profit is at £27,000 for both cases. In Option E, there is further reduction in the number of technicians to 2 for facilities and 1 for aircrafts, while the replacement policy is the same as the last run. This option produces facilities availability of 25% and 40% aircrafts availability, and non-availability of 75% and 60%, respectively, and gives technician utilisation of 100% in both cases. The costs of this option are £5,000 and £4,000 for facilities and aircrafts with profit of £4,000 and £12,000, respectively.

Table 6: Scenario 2 Results

	Airport Facilities					Aircrafts				
Option	A	B	C	D	E	A	B	C	D	E
Number of technicians	3	3	4	4	2	2	2	3	3	1
Replacement policy	5	3	3	2	2	5	4	4	3	3
Facilities										
Availability (%)	89	91	93	94	25	80	82	97	96	40
Unavailability (%)	11	9	7	6	75	20	18	3	4	60
Technicians										
Utilised (%)	96	96	93	93	100	98	97	89	90	100
Idle (%)	4	4	7	7	0	2	3	11	10	0
Cost/Benefit										
Profit (in 1000s)	26	27	28	27	4	23	24	28	27	12
Cost (in 1000s)	7.5	7.5	7.6	7.6	5	6	6.2	6.2	6.2	4

5. DISCUSSION

Comparing with the base scenario (see Table 2), Scenario 1 (see Table 4) showed that an increase in the number of technicians by 1 for both, facilities and aircrafts, has a significant impact on the availability of working facilities (9%) and aircraft (20%) with a corresponding increase in profit of 8% and 12%, respectively, during this period; while the costs of operating the system slightly increased by 1.3%. This setting actually provides a solution that complies with the objective of this study - to increase the level of facility and aircraft availabilities to 90% and 95%, respectively. However, the increase in the cost is expected because additional technicians would increase the running cost. There is also an increase in the technicians' idle time by 100% (i.e. from 4% to 8%) as shown in Table 4. This shows that engaged technicians are more than what is expected to give an optimum results. Furthermore, reduction in the number of technicians by 1 from the default value returns very low level facility and aircraft availabilities despite 100% technicians' utilisation. This in turn results in a significant reduction in profit.

It can be seen from Table 6 option B that reduction in the replacement policy from 5 (default) to 3 maintenance periods increases the availability of facilities and aircrafts slightly; while the technicians utilisation remain the same hence, costs remain the same, there is also a slight increase in the profit. Table 6 options C and D show that the same number of technicians with different replacement periods gives different facility and aircraft availabilities, almost the same technician utilisation and different profit.

Furthermore, it is good to note as shown in Option E that choosing low replacement policy with fewer technicians (very low) will not improve availability but rather increase facilities failure. This is expected because few technicians regardless of replacement policy will not be adequate to give optimum service even with a low replacement period. But choosing appropriate replacement policy allows fewer technicians to be engaged for the same number of facilities and hence, reduced cost of maintaining technicians.

The results also show that the cost of facility and aircraft replacements always increase the overall cost of running the system, but the benefits accrued from this option always out-weight the costs in terms of facility and aircraft availabilities, reliability and increase in profit. This is evident in the simulated model results (see Table 2, 4 and 6) that the effectiveness of replacement policy depends largely on the number of technicians engaged. Therefore, appropriate number of technicians should be combined with a certain replacement policy in order to get optimum results.

However, there are some issues that need further investigation. The effect of replacement policy is observed to be less significant even with an adequate number of technicians as shown in Table 6 options C and D, this is against our expectation. Though the cause of this is not clear, it is believed to be as a result of non-availability of real life data.

6. CONCLUSIONS

Proffering solutions to problems involving complex socio-technical systems such as airports cannot be found by experimenting with the real object. Simulation modelling provides an alternative means for an easier and better prediction of a systems performance to aid decision making. We think that it provides a transparent model development process that can be used even by non-experts in simulation modelling, and that it requires less intellectual effort to interpret the results and communicate the model internally to others than alternative (e.g. mathematical) modelling approach.

In this paper we have identified some new application areas for simulation modelling in an airport operations management context and selected one of them for further investigation. We have demonstrated with a proof-of-principle simulation study how one could build a simulation model for "Airport Facilities Maintenance Scheduling" and what kind of outputs one can expect from such a simulation model. The simulation study helped us to come up with a solution that fulfilled all of the criteria listed in the simulation study objectives while minimizing the operational costs.

To support effective decision making through our simulation study we decided to use an AB approach, as we are dealing with a human centric system. Such an approach allows us to take an object oriented worldview in order to address the problems of individuality, autonomy and interactivity among the entities within this complex, non-linear system. It also supports the study of individual entities' emergent and unanticipated behaviours.

In the end we have achieved our objectives by finding new opportunities for simulation modelling and by demonstrating the feasibility for one of the identified areas. The next steps will involve looking more closely at the other areas we have identified, and providing proof-of-principle models for those areas. Also, we are interested in looking at some of the existing traditional simulation applications within an airport context which currently employ SD or DE simulation to see if AB simulation can provide any advantages or additional insight in these cases. We believe there are many more opportunities of applying this method – which have yet to be seized.

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