

# Exploring Scenario Forms and Ways of Use to Discover Requirements on Airports that Minimize Environmental Impact

Neil Maiden<sup>1</sup>

Cornelius Ncube<sup>1</sup>

Simin Kamali<sup>1</sup>

Norbert Seyff<sup>2</sup>

Paul Grünbacher<sup>2</sup>

*City University London<sup>1</sup>  
Centre for HCI Design  
London EC1V 0HB, UK  
n.a.m.maiden@city.ac.uk*

*Johannes Kepler University<sup>2</sup>  
Systems Engineering & Automation  
4040 Linz, Austria  
nseyff@sea.uni-linz.ac.at*

## Abstract

*This scientific evaluation paper investigates the effectiveness of different scenario forms and uses on requirements discovery. It reports results from the application of scenario tools during the specification of requirements on socio-technical systems to improve the environmental impact of aircraft operations at a regional UK airport. Stakeholders walked through scenarios in both text and visual simulation form, and discovered requirements during workshops and whilst observing actors in their workplace. Results revealed both qualitative and quantitative differences in discovered requirements that have potential implications for models of scenario-based requirements discovery and the design of scenario tools.*

## 1. Different Scenario Forms and Uses

Scenarios are one of the more effective techniques for discovering stakeholder requirements. They come in different forms, from simple narrative stories to complex simulations of different system behaviour. Scenarios can also be used in different ways, from reading through simple stories to surface new requirements [4] to investigating system simulations to discover emergent system properties [6]. However, despite these successes, we still lack data with which to determine effective uses and forms of scenarios for discovering requirements. This paper reports results from a scenario-driven process to discover requirements for an air traffic management system called VANTAGE (*Validation of Network-Centric, Technology Rich ATM System Guided by the Need for Environmental Governance*). We use this process to explore the effectiveness of different forms and ways of using scenarios.

To explore different scenario forms we walked through two types of scenario – structured text and visual simulation. Our ART-SCENE scenario technique presents scenarios to walkthrough as text that is structured into a normal course event sequence and sets of possible alternative course events linked to each normal courses event [7]. Although it has been used successfully in previous projects to discover requirements for air traffic management systems [11], the large number of events in each scenario and the types of requirements discovered raised concerns

about its wider effectiveness. Recent extensions to ART-SCENE to include rich media scenarios [14] suggested that other scenario forms can improve requirements discovery. In VANTAGE we developed a visual simulation of agents in the domain that we presented to stakeholders alongside text scenarios in ART-SCENE. Both were walked through to provide empirical data about their effectiveness when discovering requirements.

Scenarios can also be used in different ways to discover requirements. Traditionally with ART-SCENE we run scenario workshops for same-time same-place discovery of requirements using the desktop version of ART-SCENE [7]. A trained facilitator drives the walkthrough process whilst a scribe documents requirements and scenario changes in ART-SCENE. Similar practices with scenarios are reported in [5,13]. However bringing stakeholders together can be difficult and time-consuming, whilst removing them from their context of work can miss important contextual triggers for requirements. One alternative is to walk through scenarios in the work context using mobile technologies. Previously we developed a version of ART-SCENE called the Mobile Scenario Presenter (MSP) to run on a PDA. Evaluations of the MSP [9,10] revealed that it could be used to discover requirements in the workplace, however analysts found it difficult to document requirements using the stylus when moving and/or communicating with the observed stakeholders. Therefore, in VANTAGE, we also walked through ART-SCENE scenarios in the work context to provide empirical data about their effectiveness.

We used data from scenario walkthroughs in VANTAGE to answer three research questions:

- Q1 Can a visual simulation of a scenario trigger requirements that might not be discovered with an ART-SCENE scenario walkthrough?
- Q2 Can a scenario walkthrough in the work context trigger requirements that might not be discovered with a scenario workshop?
- Q3 Can a scenario walkthrough in the work context trigger a larger number of requirements than an equivalent scenario workshop?

We distinguished between Q2 and Q3 to investigate whether scenario walkthroughs in the work context gen-

erated different subsets of requirements.

Sections 2 and 3 report the different forms and ways of using scenarios that were applied in VANTAGE. Section 4 reports a model of scenario-based design that informs the 3 research questions. Sections 5 and 6 report results from the VANTAGE scenario walkthroughs to answer the research questions. Section 7 discusses future work.

## 2. Scenarios and Visual Simulations

The VANTAGE scenarios were developed using two technologies – ART-SCENE and AgentSheets.

### 2.1 ART-SCENE Scenarios

ART-SCENE is a scenario technique for discovering and documenting stakeholder requirements [7]. It supports analysts and stakeholders when they walk through scenarios that are automatically generated from use case specifications. The big idea that underpins these walkthroughs is very simple – that people are better at identifying errors of commission rather than omission [3]. From this general trend in human cognition for recall to be weaker than recognition, ART-SCENE scenario walkthroughs offer stakeholders recognition cues in the form of automatically generated alternative courses. If the alternative course is relevant to the system being specified but not yet handled in the specification, then a potential omission has been identified, and ART-SCENE guides the analysts to specify and document the relevant requirements. ART-SCENE provides scenarios to stakeholders to recognize events and discover requirements in two ways – in formal workshops and in the work context of stakeholders. Each is described in turn.

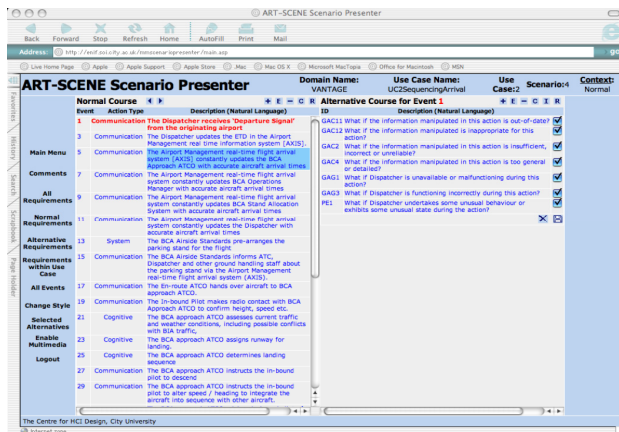


Figure 1. One VANTAGE scenario in the desktop version of ART-SCENE used during a workshop

### 2.2 Scenario Walkthroughs in Workshops

The Scenario Presenter is an ASP.NET web application connected to server-side ART-SCENE scenario and requirements databases that allows stakeholders using a desktop browser to walk through a scenario. Figure 1 de-

picts one scenario generated for VANTAGE and presented using the Scenario Presenter. Stakeholders usually walk through scenarios in this form in half-day scenario workshops [7]. A facilitator guides the stakeholders to recognise which scenario normal and alternative course events the new system must handle. The facilitator then uses simple heuristics to discover one or more requirements that, if satisfied, will enable the system to avoid, respond to or mitigate the effects of the event. The scribe documents all requirements in ART-SCENE and links them to the scenario events that triggered them.

One limitation of workshops is that stakeholders need to take time out of their work environments to participate in formal requirements sessions. As well as restricting access to stakeholders who might not have the time to participate, these sessions take place out of the work context, thus potentially diminishing the effectiveness in the requirements discovery process [14].

### 2.3 Scenario Walkthroughs in Work Contexts

The MSP [9] is a PDA-based ASP.NET web application that uses a mobile browser and wireless access to server-side ART-SCENE scenario and requirements databases. The tool is optimized for Microsoft's Pocket Internet Explorer included with Microsoft's Pocket PC OS. The MSP allows its user to discover and document requirements systematically in the workplace using structured scenarios generated by ART-SCENE. The MSP user walks through scenarios of future system behaviour and observes current system behaviour at the same time. What-if capabilities – generated candidate alternative courses for each event – enable the user to follow up and ask questions about abnormal and unusual behaviour in different work contexts, thus leading to more complete requirements discovery. Figure 2 shows some normal and alternative course events of a second VANTAGE scenario that we walked through using the MSP.



Figure 2. One VANTAGE scenario in the MSP version of ART-SCENE used in the work context

One important enhancement to the MSP used in

VANTAGE was audio recording of requirements. Earlier versions captured new requirements in typed form using the PDA stylus [9]. However this was less successful than expected due to the effort needed to type requirements. Therefore the scenario walkthrough in the work context took place with audio recording of spoken requirements. To deliver this capability the MSP implemented a new plug-in solution on top of the full-screen browser application. The solution was integrated into the menu of the full-screen browser. The capability could be started using one touch with the stylus once the plug-in solution was enacted. Audio files of generated requirements were stored using common file formats so that analysts could continue their work on the desktop ART-SCENE after synchronization. All created multimedia files were linked to the underlying MSP database using special IDs included in the filename.

Another change in VANTAGE was the process of using the MSP during walkthroughs. In previous applications we replaced facilitated workshops with a two-stage process – one-on-one observations and fact gathering by a single analyst in the workplace followed by project-wide interpretation sessions using the desktop Scenario Presenter. However this procedure was problematic. A single analyst was not able to observe the work context, navigate the scenario, communicate with stakeholders and document requirements using a stylus because earlier audio-recording features were too cumbersome to use [9]. Therefore, in VANTAGE, we introduced the two roles of facilitator and scribe. Whilst the scribe used the MSP to navigate between scenario events and to document requirements and comments, the facilitator observed the work context, asked questions about it, and filtered the raw data to generate first-cut requirement statements, based on recognition cues provided by the MSP.

## 2.4 Visual Simulations of Scenarios

AgentSheets is an agent-based simulation-authoring tool for developing interactive simulations that integrates agent, spreadsheet and Java technologies in a single medium [1]. In the simulations, any number of agents can be created using a simple interface. The agents are end-user programmable objects that represent all the objects in a simulation. Agents are programmed to react to various pre-programmed or interactive events including mouse clicks and keyboard input. Any number of agents can be created and programmed to interact with each other in a spreadsheet-like grid. The end result is referred to as an AgentSheets simulation. End-users such as VANTAGE stakeholders can interact with this simulation to explore how agents in the VANTAGE domain, such as aircraft, behave both when interacting with each other and in response to events input by the end-users. This behaviour is presented to the end-user as a visualization of the physical behaviour of the agents.

Figure 3 depicts one screenshot of the visual simula-

tion of aircraft ground movements at Belfast City Airport (BCA), the focus of the VANTAGE project. It presents the topographic layout of the runway, taxiways and stands at BCA. Aircraft – pre-programmed agents specified for the types of aircraft that use BCA – move along the runway and taxiways and park at stands. Figure 3 shows one aircraft landing on the runway from right to left. Aircraft agents were also pre-programmed to interact with each other. For example, one aircraft taxiing towards the runway will stop on the taxiway if a second aircraft landing or taking off already occupied the runway. The resulting visual simulation was also interactive. Users could control the speed of the simulation, change how aircraft agents behave, and introduce new aircraft instances.



**Figure 3. An interactive visual simulation of aircraft landing at BCA developed in AgentSheets**

## 3. Walking Through Scenarios in VANTAGE

We walked through scenarios to discover requirements for VANTAGE Phase-1, a system to reduce the environmental impact of aircraft movements near airports. The two-year project, funded by the UK's Department of Trade and Industry, integrated new technologies into the operations of regional airports in the United Kingdom to reduce their environmental impact, measured as noise and gas emissions. Partners who include Thales and Qinetiq are introducing new technologies at BCA.

We walked stakeholders through scenarios as part of RESCUE (*Requirements Engineering with Scenarios in a User-Centred Environment*), a scenario-driven requirements process [8]. Prior to the walkthroughs the requirements team had discovered requirements on the new VANTAGE system using brainstorming sessions and a creativity workshop, and generated requirements automatically from *i\** models. A use case model specified 20 core use cases that specified how the future VANTAGE-enhanced airport operations at BCA should behave during landing, taxiing, on-stand operations and take-off, as well as to support airport management such as producing daily flight schedules. Requirements on the VANTAGE system were associated with behaviour specified in the use cases. However, we still needed VANTAGE stakeholders, who

included the BCA environmental manager, environmental experts, technology specialists, and airline pilots and operational staff, to discover complete requirements on VANTAGE using projections of future operations at BCA. This is where scenario walkthroughs came in.

The visual simulation and text scenario walkthroughs took place with real-world project constraints such as time and availability of stakeholders that could not be controlled in the walkthroughs without disrupting the project or invalidating its results. Therefore we adopted an action research approach, generating and analyzing data in context, taking care to draw conclusions from the results.

### 3.1 The Scenario Walkthrough Schedule

We generated a scenario walkthrough schedule from the VANTAGE use case model. VANTAGE stakeholders prioritized the use cases for the potential of the specified behaviour to minimize environmental impact. Not surprisingly, given aircraft movements are the main source of noise and gas emissions, the priority use cases specified VANTAGE requirements on the arrival, turnaround and departure of an aircraft from the airport.

Time and resource constraints meant that 5 use cases could be investigated. We set up the walkthrough schedule in Table 1 and used the ART-SCENE scenario generation algorithm to generate one scenario per use case.

| Date     | Scenario                               | Scenario Form                 | Way of Use   |
|----------|----------------------------------------|-------------------------------|--------------|
| 11/09/06 | Sc2: Approach/arrival sequence control | ART-SCENE                     | Workshop     |
| 11/09/06 | Sc3: Ground movement control arrivals  | ART-SCENE & visual simulation | Workshop     |
| 17/10/06 | Sc1: Ground movement control departure | ART-SCENE                     | Workshop     |
| 17/10/06 | Sc11: Coordinate flight departures     | ART-SCENE                     | Workshop     |
| 29/11/06 | Sc4: On-stand operations               | ART-SCENE                     | Work context |

**Table 1. Scenario walkthrough schedule**

We chose to run workshops to walk through scenarios that describe aircraft movement, such as *Sc2 Approach and arrival sequence control* and *Sc11 Coordinate flight departures*. Not only were walkthroughs of such scenarios in the work context difficult (not to say dangerous!), but scenario workshops were tractable because representatives of stakeholders such as airlines (pilots and dispatchers), air traffic controllers and managers, the airport environment manager, and solution experts from VANTAGE technical partners were all available to attend them.

Figure 1 shows part of the ART-SCENE scenario for *Sc2 Approach and arrival sequence control*. Typical events included *dispatcher communicates with ramp staff* and *BCA approach controller makes decisions about landing approach*. Each workshop took place in a meeting room with one facilitator and one scribe. Each was designed to run for 2-4 hours, depending on the number of events in the scenario.

Scenarios that described aircraft movement at BCA

were also amenable to simulation. Therefore we developed one visual simulation of aircraft movement events specified in *Sc3 Ground movement control arrivals*. Figure 3 shows one screenshot of the simulation of the generated scenario with one aircraft landing.

The one scenario in which aircraft do not move was more amenable to walk through in the work context. The *Sc4 On-stand operations scenario* specifies all behaviour related to the turnaround of an aircraft from when it parks to its pushback. Typical events included *refuel the aircraft* and *disembark passengers*. The walk through of this scenario took place over 4 hours on a weekday. The analyst who facilitated the scenario workshops also facilitated the walkthrough. A different scribe operated the MSP. The facilitator observed on-stand operations on different aircraft turned around by airlines and the local service operator. He asked questions to airport and airline staff being observed. All spoken requirements and comments were recorded in the MSP.

Figure 4 shows the facilitator and scribe walking through the scenario in the work context. The left-hand side depicts the scribe in the cockpit of an A321 aircraft whilst the facilitator asked questions about ground system-aircraft uploads, whilst the right-hand side shows the facilitator asking questions of the operator during aircraft refueling. Note the bad weather!



**Figure 4. Two uses of the MSP when walking through the *Sc4 On-stand operations scenario* in context**

### 3.2 Generating the Scenarios and Simulation

In VANTAGE we generated one scenario for each of the 5 prioritized use cases. Each scenario normal course event sequence specified the expected event ordering during aircraft approach, landing, taxiing, turnaround and takeoff. For each normal course event in the 5 scenarios the algorithm generated one or more candidate alternative courses for each normal course event. Alternative courses were generated using the domain-independent version of the ART-SCENE algorithm [7] not tailored to air traffic control. VANTAGE scenario alternative courses expressed abnormal behaviours and states that were domain-independent, such as *what if the dispatcher lacks the necessary knowledge?* and *what if the aircraft exhibits some abnormal behaviour?*, rather than *what if the aircraft uses the wrong taxiway when arriving at the terminal?* A generated scenario specified on average 20 normal course events and 8 alternative course events per normal course

event. The shortest scenario was *Sc11 Coordinate flight schedules* with 8 normal course and 41 alternative course events. The longest was *Sc4 On-stand operations* with 35 normal course and 271 alternative course events.

The visual simulation of the *Sc3 Ground movement control arrivals* scenario was developed in four steps over a two-month period. In the first the simulation was restricted to model aircraft movement at BCA during a typical one-hour period during the morning rush hour based on the landing and take-off schedule. In the second we used geographical data about BCA to model the static features of the airport – runway, taxiways and aircraft stands. The modeled runway, taxiways and aircraft stands were overlaid on the photograph of BCA shown in Figure 3. In the third the behaviour of simulation agents – different classes of aircraft and their instances – were specified. Data about aircraft speeds and taxi routes were gathered during a one-day observation of aircraft performance at BCA. Finally the simulation was made consistent with the *Sc3 scenario* events generated in ART-SCENE.

#### 4. A Model of Scenario-Based Requirements Discovery

We investigated the scenario-driven requirements process in VANTAGE to answer the 3 research questions reported in section 1 about the effectiveness of different scenario forms and uses on requirements discovery. The questions were grounded in a logical task model that describes essential cognitive tasks that stakeholders undertake during a scenario walkthrough to specify a future system using tools such as the Scenario Presenter.

The model describes scenario-based requirements discovery as an iteration of tasks. Stakeholders read scenario event descriptions and recognize one or more as possible and to be handled by the system. Recognizing whether an event is *relevant* is an essential pre-requisite to discovering requirements from a scenario walkthrough. Because stakeholders are better at recognizing incorrect events rather than recalling missing ones, the model predicts that stakeholders will discover more requirements using scenario events that are presented to them to recognize as relevant than they will from unaided recall of such events. For each event recognized as possible, stakeholders generate one or more requirements.

We developed and validated the model for workshop scenario walkthroughs with tools such as the Scenario Presenter. New forms of scenario, such as visual simulations, and ways of using them, such as in the work context, challenge assumptions behind the model. For example, visual simulations might display more scenario events – recognition cues – that can arise and need to be handled by the future system. On the other hand, the absence of discrete event descriptions might make event recognition more difficult. Therefore we explored the effect of recognition cues from visual simulations to answer Q1 using data from VANTAGE scenario walkthroughs.

Likewise, walking through scenarios in the work context might expose analysts and stakeholders to more event recognition cues. However the timing of these events cannot be controlled, thus making it more difficult for analysts to capture and specify new requirements. We also explored the effect of combined recognition cues from scenarios and the work context and audio requirements recording techniques to answer Q2 and Q3 with data from the scenario walkthroughs.

Data that was used to answer the research questions included data about the requirements generated (number, description, type, triggering scenario and event) and observations of the walkthrough processes (duration, number of stakeholders, style of interaction), drawn directly from ART-SCENE's scenario and requirements databases and observational notes recorded by the facilitator and scribe during walkthroughs. We did not investigate stakeholder perceptions of the walkthroughs and scenarios due to difficulties capturing such data in VANTAGE. Stakeholders such as pilots were simply not available to be debriefed at the end of sessions, and the availability of other stakeholders was restricted during the project.

#### 5. Scenario Walkthrough Results

All scenario walkthroughs took place as planned. Each workshop lasted between 2 and 4 hours. The walkthrough in the work context lasted 4 hours. Between 6 and 10 stakeholders attended each workshop depending on availability – commercial airline pilots and air traffic controllers were often unable to commit time to scenario workshops, hence the workshop schedule was a compromise between stakeholder availability and deadlines. Nonetheless all four included at least one representative from BCA (e.g. *an air traffic controller*), an airline (e.g. *a BMI dispatcher and pilot*), a solution technology provider (e.g. *Thales and Raytheon*), and an environmental researcher from an academic partner in VANTAGE. Many stakeholders participated in more than one workshop.

Results from the scenario walkthroughs are reported in Table 2. The five walkthroughs generated 147 requirements. All requirements were documented in ART-SCENE using four attributes – the requirement description, rationale, type and source [12]. During workshops the scribe entered these fields using a desktop computer keyboard, whilst during the work context walkthrough the scribe selected the requirement type from a pull-down menu, then the facilitator recorded the spoken requirement description, rationale and source in the MSP. After the walkthrough the facilitator and scribe transcribed all spoken requirements, comments and scenario changes, then the documented requirements were validated with source stakeholders. In the workshops the stakeholders were able to validate requirements as the scribe entered them into the displayed ART-SCENE requirements form.

| Scenario                                   | Total number requirements documented | Number of requirements on use case and normal course event behaviour | Number of requirements on alternative case behaviour | Average number of requirements per normal course event |
|--------------------------------------------|--------------------------------------|----------------------------------------------------------------------|------------------------------------------------------|--------------------------------------------------------|
| Sc2: Approach and arrival sequence control | 32                                   | 30                                                                   | 2                                                    | 1.19                                                   |
| Sc3: Ground movement control arrivals      | 28                                   | 27                                                                   | 1                                                    | 2.44                                                   |
| Sc1: Ground movement control departure     | 16                                   | 15                                                                   | 1                                                    | 0.70                                                   |
| Sc11: Coordinate flight departures         | 12                                   | 12                                                                   | 0                                                    | 1.5                                                    |
| Sc4: On-stand operations                   | 59                                   | 59                                                                   | 0                                                    | 1.55                                                   |
| <b>Total</b>                               | <b>147</b>                           | <b>143</b>                                                           | <b>4</b>                                             |                                                        |

**Table 2. The total number of requirements documented during each scenario, types of event for which requirements were documented, and average number of requirements generated per scenario normal course event**

Results reveal that walking through *Sc4 On-stand operations* in the work context generated 59 requirements, whilst the most requirements generated during any one workshop was 32, for *Sc2 Approach and arrival sequence control*. Each workshop generated on average 22 requirements per scenario. The average number of requirements generated per scenario normal course event is also reported in Table 2, but there was no discernible association between scenario length and the number of requirements generated. Walking through *Sc3 Ground movement control arrivals* using ART-SCENE and the visual simulation did not result in more requirements than in the other workshops.

Alternative course events appeared to have little effect on requirements discovery – only 4 requirements were associated with alternative course events in the 5 scenarios. The main reason for this was probably the number of normal course events in each scenario. A walkthrough permitted stakeholders to walk through all normal course events but not most alternative course ones. Previous studies revealed that requirements documented with MSP and stylus were shorter than requirements documented via keyboard [9]. In VANTAGE, requirements transcribed from the recordings of the spoken requirements in the MSP were similar in length to requirements typed by the scribe in the 4 workshops.

Table 3 reports the totals of requirement generated by type. Walking through the scenario in the work context led to generation of more availability- and usability-type requirements than during the workshops. Walking through the visual simulation did not generate types of requirement that were not generated in other workshops.

Occasionally the walkthroughs resulted in changes to the scenarios themselves in response to stakeholder comments and facilitator observations. The walkthrough in the work context of *Sc4 On-stand operations* resulted in 11 changes, including addition of 2 observed new normal

course events (e.g. *the engineer enters the aircraft*) and 9 observed alternative course events, for example *what if the stand is occupied?* In contrast the four workshops resulted in just one change – an event is undertaken by an *air traffic support assistant* rather than a *controller*.

| Type | AR | FR | LFR | IR | PR | RR | SR | TR | UR |
|------|----|----|-----|----|----|----|----|----|----|
| Sc2  | 0  | 17 | 0   | 0  | 8  | 0  | 1  | 0  | 2  |
| Sc3  | 0  | 10 | 0   | 0  | 6  | 0  | 0  | 0  | 0  |
| Sc1  | 1  | 26 | 0   | 0  | 2  | 2  | 0  | 0  | 1  |
| Sc11 | 0  | 10 | 0   | 0  | 1  | 0  | 0  | 0  | 1  |
| Sc4  | 9  | 28 | 0   | 1  | 6  | 1  | 0  | 1  | 13 |

**Table 3. The total number of requirements documented during each scenario by type. AR=availability; FR=functional; LFR=look-and-feel; IR=inter-operability; PR=performance; RR=reliability; SR=safety; TR=training; UR=usability**

## 5.1 Qualitative Requirements Analysis

We investigated all 147 requirements to detect qualitative differences between requirements associated with the different scenario forms and ways of use.

### 5.1.1 Requirements Subjects

The first characteristic was the subject of each requirement. ART-SCENE mandated that all requirements were expressed using *shall* statements with a common structure [2] that leads to specification of properties of one or more actors. These actors were the subjects of the requirements. Results are reported in Table 4. Most requirements generated with scenario *Sc3*, using desktop ART-SCENE and the visual simulation, were requirements on the VANTAGE software system. Similar results were obtained with the other workshops. In contrast the *Sc4 On-stand operations* scenario generated 20 requirements on the *dispatcher* and 12 on the *dispatch coordinator*, both actors in on-stand activities observed by the facilitator and scribe. And yet the four workshops only generated a total of 6 requirements on the dispatcher, in spite of the presence of dispatchers in each. This indicates that use of the scenario, rather than dispatcher availability, influenced the generation of these 20 requirements.

| Requirement subject       | Sc2 | Sc3 | Sc1 | Sc11 | Sc4 |
|---------------------------|-----|-----|-----|------|-----|
| ATCO                      | 3   | 1   | 7   | 2    |     |
| BCA                       |     |     |     |      | 3   |
| VANTAGE system            | 14  | 8   | 16  | 4    | 19  |
| Dispatcher                | 1   | 2   | 2   | 1    | 20  |
| Ramp staff                | 2   | 1   | 2   | 1    | 1   |
| Support services staff    | 2   |     |     |      |     |
| Customer services agent   | 1   |     |     |      | 1   |
| Dispatch coordinator      |     |     |     |      | 12  |
| Pilot / Aircraft          | 2   |     | 1   |      | 1   |
| Airline                   |     |     | 3   |      |     |
| Airport operations staff  | 1   | 3   | 1   | 3    |     |
| Passengers/general public | 1   |     |     |      | 2   |
| Stand guidance system     |     | 1   |     |      |     |
| Other                     | 1   |     |     |      |     |

**Table 4. Totals of requirements with subject actor, generated per scenario walkthrough**

The 12 requirements on the *dispatch coordinator* were important in VANTAGE. In spite of earlier modeling of

airport operations with  $i^*$ , the focus on dispatchers working for airlines such as BMI rather than the airport services operator led the project to overlook the dispatch coordinator. As a result the scenario workshops did not include representatives of the air services operator, and no requirements on the *dispatch coordinator* were generated during them. In contrast, the walkthrough of one aircraft turnaround scenario took the facilitator and scribe in front of the dispatch coordination office. After asking about the office the facilitator negotiated access to it and asked questions to the *dispatch coordinator* about their work, problems, resources and needs. Some of the 12 requirements generated on the dispatch coordinator specified the need to support effective local working practices, for example *the dispatch coordinator using VANTAGE shall maintain important information about aircraft in a stats sheet*. Other requirements revealed basic problems with airport operations that had consequences, not known beforehand to the requirements process, on environmental impact. One such problem was a lack of functioning radios that meant that dispatchers could not communicate effectively during aircraft turnarounds. The inference was that working radios would improve the efficiency of aircraft turnaround and, as a result, aircraft movements that would reduce noise and gas emissions. The facilitator generated requirements such as *AR108 dispatchers, the dispatch coordinator the boarding staff shall have sufficient communication resources to enable two-way communication between these actors at all times*.

### 5.1.2 Requirements Themes

A second characteristic was the theme of each requirement. Walking through the scenario in the workplace led to generation of requirements with themes that were not generated during the workshops. Fourteen requirements specified how VANTAGE should respond to bad weather conditions. The walkthrough took place in bad weather conditions depicted in Figure 4. During a follow-up interview the conditions prompted the facilitator to ask how they affected aircraft turnaround. One dispatcher provided paper documentation that specified bad weather restrictions on turnaround equipment use, from which the facilitator generated requirements such as *AR112 the VANTAGE system shall support airport operations in all possible adverse weather conditions that can arise at BCA* and *FR250 the VANTAGE system shall recognize the maximum operable wind speed of 50 knots for stand parking of the A320/1 aircraft*.

The scenario walkthrough in the work context revealed another theme – that dispatch work was highly mobile – which led the facilitator to ask about requirements about mobile working. One dispatcher reported previous experiences with mobile tools at the nearby Belfast International Airport that revealed an opportunity for mobile computing for dispatchers at BCA. An example availability requirement was *AR111 the VANTAGE system shall con-*

*nect with different mobile computing platforms at all airside locations*. Again, dispatchers in the workshops did not generate requirements on this theme.

### 5.1.3 Geographical Features in Requirements

A third characteristic was description of geographical features of the airport in each requirement. We might expect the walkthroughs of the visual simulation (which explicitly depicts the airport’s geographical layout) and in the work context (in which the analyst moves about the airport) to include more references to geographical features than requirements generated during the workshops. Table 5 reports the totals of requirements that described geographic features by scenario. Not surprisingly scenarios *Sc3*, which modeled the geographical layout of the airport in the visual simulation, and *Sc4*, which was walked through in the work context, generated the largest number of such requirements. Some requirements make reference to the complexities of taxiing and parking that emerges from the topological layout of the airport, for example *FR363 The VANTAGE system shall include rules which incorporate the specification of stands* and *FR369 The BCA tower ATCO shall have access to information about the optimum taxi route to allocated stand based on aircraft type and loading*. The walkthrough of *Sc4* in the work context generated all of the requirements that described air bridges, dispatch offices and departure gates, for example *AR106 BCA shall have sufficient airside staff on duty at any one time to stand behind an aircraft and stop road traffic during its pushback*. Other workshop walkthroughs did not describe details of the airport geography in the same level of detail.

| Requirement geographic reference | Sc2 | Sc3 | Sc1 | Sc11 | Sc4 |
|----------------------------------|-----|-----|-----|------|-----|
| Stand                            | 8   | 11  | 3   | 1    | 7   |
| Air bridge                       |     |     |     |      | 2   |
| Air side                         |     |     |     | 1    | 8   |
| Dispatch office                  |     |     |     |      | 2   |
| Departure gate                   |     |     |     |      | 4   |
| Road way                         |     |     |     |      | 1   |

**Table 5. Totals of requirements that reference geographic features, generated per scenario walkthrough**

## 5.2 Walkthrough with the Visual Simulation

Qualitative analyses revealed little effect of the visual simulation on requirements discovery, so we reviewed the walkthrough process. The visual simulation was demonstrated to stakeholders at the start of the *Sc3* workshop. However, its limited implementation – it simulated just one aircraft movement at a time – restricted useful interactions with it. During the subsequent walkthrough, stakeholders viewed the ART-SCENE scenario and visual simulation side-by-side, and the facilitator directed stakeholders to the simulation to demonstrate events in terms of the visualization of the airport layout. However, the visual simulation only played a minor role in the remainder of the workshop, providing an image of the air-

port on which to discuss possible aircraft movements that could not be simulated.

### 5.3 Walkthrough in the Work Context

The facilitator and scribe adapted the *Sc4* walkthrough to work contexts. It was difficult to observe one aircraft turnaround from start to end because more than one aircraft turned around at the same time. Furthermore event timings and action durations were unpredictable. Some scenario events related to a single aircraft were simultaneous and described concurrent actions that were difficult to observe, for example *ramp staff insert chokes*, *passenger steps* and *plug-in the aircraft to ground power* at the same time. Others actions lasted a long time but revealed little to observe, for example *the crew clean the aircraft*. Therefore the facilitator and scribe walked through selected scenario events with one aircraft before jumping to other scenario events with another aircraft.

#### 5.3.1 What Triggered Requirements Generation

During most walkthroughs the facilitator recognized more event triggers to generate new requirements from the work context than from scenario events presented on the MSP. For example requirement FR235 *The dispatcher shall be able to see and hear refueling activities on the aircraft for which the dispatcher is responsible* was generated in response to observations of a dispatcher's reaction to the (loud) sound of the refueling truck stopping when refueling stopped. We identified three possible reasons for this dominance of work context triggers. One was the richness of the triggers in a complex and dynamic context such as an airport. The facilitator was an experienced analyst who drew on his experience to ask requirements discovery questions in response to observed events that he knew the VANTAGE system needed to respond to. A second reason was the small screen size of the MSP. It was difficult for the facilitator and scribe to read the MSP scenario at the same time. Therefore, during the walkthrough, the facilitator and scribe developed a workaround. The scribe would read out recognized events – typically alternative course events – then the facilitator to investigate these events as he was able. However, this workaround meant that the more experienced facilitator could not browse and recognize scenario events directly. A third possible reason was the mismatch between the large number of alternative course events generated in the scenario and browsed in the MSP, and the relatively small number of real-world events that might conceivably happen in the airport environment. The effort needed by the scribe to scroll and read alternative course events in the MSP was greater than that needed to observe the work context. Hence the facilitator took the simpler option during the walkthrough.

#### 5.3.2 How Requirements Were Documented

The procedure with which the facilitator specified re-

quirements also varied. In response to some events the facilitator was able to document a requirement at the time of the scenario event using information gathered from short interactions with observed stakeholders. For example the requirement *AR105 BCA shall have sufficient air-side staff on duty at any one time not to delay the off-block time of departing aircraft* was generated in response to asking a dispatcher why she had to stand next to aircraft during pushback, and what would happen if she did not do it – an interaction of no more than 20 seconds.

Other requirements could not be specified during the scenario event because the event was too short, dangerous or difficult, so the scribe marked the events to follow up when relevant stakeholders were available. Between observations of scenario events, the facilitator conducted structured interviews, sometimes lasting as long as 10 minutes, with stakeholders to discuss observed events and document stakeholder requirements. All were audio-recorded in full using the MSP. For example, an interview with an experienced dispatcher led to requirement *TR76 All dispatchers who dispatch aircraft that load passengers using the air bridge shall be trained to use aircraft cockpit instructions to inform themselves of refueling status...* based on observations of a busy dispatcher entering the aircraft cockpit whilst embarking passengers. In one case – when exploring requirements for dispatcher mobile working – the facilitator prompted a mini-brainstorm, using the PDA on which the MSP was running, to demonstrate possible uses.

### 5.4 Scenario Walkthrough Productivity

The scenario walkthroughs consumed airport and airline resources including pilots and air traffic controllers. Therefore we computed the estimates of stakeholder time needed to generate a requirement in a workshop and the work context. On average each of the four workshops involved 8 stakeholders, lasted 2.5 hours and generated 22 requirements. From this data we compute that 1.1 requirements were generated per hour of stakeholder participation. Stakeholder involvement in the work context was more difficult to estimate. The walkthrough timetable was reviewed to reveal that the work context walkthrough consumed approximately 7.2 person-hours, including 5 hours of time from the BCA environmental manager who acted as a chaperone for the walkthrough. The walkthrough generated 59 requirements. From this data we compute that 8.2 requirements were generated per hour of stakeholder involvement. The estimates, although crude, do suggest that scenarios in the work context are more productive in terms of stakeholder time.

## 6. Research Questions Revisited

In VANTAGE the scenario walkthroughs were a success. They led to generation of 147 new requirements. The use of ART-SCENE was also a success. We applied a research prototype to a challenging requirements problem.

Whilst the use of the desktop Scenario Presenter in facilitated workshops is not new [11], the use of the MSP in VANTAGE is one of the first reported effective uses of mobile requirements tools on large projects [10]. Simple-to-use audio recording of spoken requirements overcame the usability problems reported in [9], whilst giving the MSP to an experienced analyst realized its potential. That said, problems remained, such as difficulties encountered by two people browsing scenario events. We reviewed VANTAGE results to answer the three research questions.

### 6.1 An effect from the Visual Simulation?

The answer to question Q1 – does the visual simulation lead to generation of different types of requirement on VANTAGE – was no. The types of requirements generated in the four workshops were, overall, the same.

The obvious explanation for this was the limited capabilities of the visual simulation. We conjecture that the programmed agent behaviour was too simple to trigger stakeholders to recognize the complex and problematic aircraft movement events that VANTAGE needed to respond to. Instead the limited simulation only depicted the event-by-event movement of a single aircraft – the same discrete events described in the ART-SCENE scenario. However stakeholders seemed to find the text representation of these events was more effective for discovering requirements. Furthermore, given the cost of generating such simulations, analysts need to consider carefully when to use them.

### 6.2 Different Requirements from Scenario Walkthroughs in the Work Context?

The answer to question Q2 – does walking through ART-SCENE scenarios in the work context lead to generation of different requirements to workshops – is a tentative yes. The walkthrough generated requirements on VANTAGE actors that the workshops did not generate requirements on. It acquired requirements from new stakeholders not identified during earlier analyses. It acquired requirements from stakeholders who had attended the workshops but not specified these requirements during them. And it generated requirements of different types on important themes not identified during the workshops.

There are several possible reasons for this. The first is the use of scenario walkthroughs in the work context to do a stakeholder analysis – discovering then involving all of the important actors in VANTAGE. This was true for the dispatch coordinator role. A second possible reason was that observing the work context enabled the facilitator to act as an apprentice and learn about actor's work, as supported in contextual inquiry [15]. Indeed, some periods of the walkthrough in the work context were indeed a form of ethnographic observation, albeit structured using the scenario in the MSP. This learning then enabled the facilitator to ask more informed questions during observations and structured interviews, as well as to infer more

correct and complete VANTAGE requirements. In contrast the facilitator and scribe in the workshops often lacked domain knowledge to complete the specification of requirements because the work context knowledge was not available to them.

A third possible reason – an important one – is that the work context provided different event recognition cues to discover requirements on different themes. Indeed, rather than trigger event recognition, the facilitator used the MSP scenario primarily to capture requirements and requirements-related data in the context of the observed normal course event. This had two important advantages. The first is that related requirements and material could be reviewed during and between walkthroughs, thus enabling the facilitator to ask more informed structured interview questions. The second is that, during post-walkthrough analyses, analysts could review the requirements and related material in context, thus providing cues to recall the observed event and more information with which to infer new requirements.

### 6.3 More Requirements from Scenario Walkthroughs in the Work Context?

The answer to question Q3 – does walking through ART-SCENE scenarios in the work context lead to generation of more requirements than in workshops – is also a tentative yes. The one walkthrough in the work context generated a larger number of requirements than any single workshop. It was more productive in terms of stakeholder time. That said, we cannot rule out the effect of the scenario length. Scenario *Sc4 On-stand operations* had the largest number of normal and alternative course events that, according to our model, should have offered the largest number of requirements recognition cues.

There are two other possible reasons for the greater productivity of scenario walkthroughs in the work context. The first is the role of the facilitator who, in the work context, directly inferred and documented more requirements than in the workshops because of the limited communication that was possible with stakeholders engaged in other tasks. The outcome was that the facilitator was able to infer more requirements than he was able to acquire from stakeholders in the workshops. This has implications for redesigning the workshops to enable the facilitator to infer and propose new requirements.

Conversely, a second reason is that the walkthrough in the work context increased the requirements communication bandwidth. Whereas stakeholders did not bring written material to the workshops, the facilitator in the work context was able to collect documents such as the bad weather operation document, as well as observe workplace artifacts such the dispatch coordinator's stats sheet and take photographs. This material added to the spoken requirements recorded in the MSP and provided a richer data corpus which the analyst used to infer larger numbers of requirements than in the workshops. Again this raises

the need to design workshops to encourage inference of requirements from different information sources.

#### 6.4 Threats to Validity

We report walkthroughs that pragmatically combined scenario forms and ways of use to solve the VANTAGE requirements problem. Our decision not to balance independent variables and control dependent ones across a low number of walkthroughs means that all results need to be interpreted with care. For example, the effectiveness of the scenario walkthrough in the work context can also be explained the design of the walkthroughs, stakeholder participation in them, and the reporting of the results. The walkthrough was the last in the schedule, hence facilitator behaviour might be been informed by domain knowledge obtained in the earlier workshops. The scenario focus – on-stand operations – was more amenable to observation of work than the others, hence it can be argued that the result was built into the original schedule. Implicit biases might also have risen from the desire of the facilitator and scribe to see the MSP scenario walkthrough succeed, especially in light of problems reported in earlier uses [9].

That said, our role in VANTAGE was to discover and document requirements on system to minimize the environmental impact of aircraft at BCA. Running the scenario process was a challenge and all staff, including the facilitator and scribes, were fully focused on requirements tasks during walkthroughs. This single focus, we argue, reduced the possible implicit biases in our analyses.

#### 7. Future Research

Future research is in four directions. The first will extend the model of scenario-based requirements discovery with new physical tasks such as *perceive recognition cues in the work context* and cognitive tasks such as *infer new requirement*, which will relate to models of creativity in requirements engineering. We will then apply the model in our second direction, to redesign the scenario workshops to support analysts to infer candidate requirements and propose them to stakeholders. ART-SCENE will be extended with pattern-based requirements generation that can recommend outline requirements automatically.

Whilst MSP audio recording of spoken requirements overcame earlier usability problems, its use here revealed new challenges to solve. One is the provision of scenario event cues to both the facilitator and scribe. Screen size is dictated by available PDA devices, so one solution is to synchronize scenario walkthroughs on two devices. Whilst the scribe navigates the scenario on one device running the current MSP, a selected subset of scenario events, for example one normal course event and alternative course events associated with it, are displayed on the second device to provide the facilitator with manageable, context-specific event recognition cues. Analysts could also use this feature to select between generated alternative course events to present to the facilitator, to reduce

information overload. One possible further refinement is to use context-aware devices to filter scenario events dynamically according to proximity to a location or actor.

Finally we still believe that scenarios in visual simulation form can support requirements discovery. Simulation development problems notwithstanding, workshops might not be the most effective medium for exploring interactive simulations. In future projects we will use AgentSheet features to invoke agent behaviour in a simulation from corresponding scenario events in ART-SCENE, then publish the simulation as a web application with the ART-SCENE scenario to encourage interactive exploration of both prior to more formal requirements events.

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