INTEGRATING BIRD STRIKE RISK INFORMATION INTO THE AIRPORT MANAGEMENT SYSTEM

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Abstract

Birds pose a remarkable threat to aviation safety. Since 1960, bird strikes – collisions between birds and aircraft – have caused at least 30 hull losses of commercial aircraft, 19 of them resulting in a total of 194 fatalities. Due to increasing population sizes, especially of large birds and a rise in global air traffic, the danger of bird strike is expected to rise in the future. The risk is largest below 3000 ft and as such in airport environments.

Within the airport system, air traffic control has a major role in guiding the air side movements. Therefore, air traffic control is an important partner in the so called airport collaborative decision making process. In negotiations with airlines, airport operations and ground handlers, air traffic control has a significant influence on decisions about handling of congested traffic situations or disruptive events. Supporting air traffic control with a bird strike advisory system might not only improve the traffic guidance, but also planning activities of airport management if air traffic control provides the additional information to the other stakeholders.

A current DLR project considers the integration of information about short- and long-term predictions for bird activity at and around an airfield to the airport management system. The project's scope lies on evaluating how the additional information is taken into account for the decision-making of the airport stakeholders. For this purpose, workshops in a serious gaming environment and a Human-in-the-Loop simulation environment were performed. This paper describes the chosen approach as well as the obtained results.

1 Introduction

Collisions between aircraft and birds are a serious concern for aviation safety. Since 1960, bird strikes have caused at least 30 hull loss accidents, where 19 of them resulted in a total of 194 fatalities [1]. The majority of bird strikes occurs in low altitudes: Studies from the United States of America (USA) and Europe reveal, that between 88% and 95% of all bird strikes happen below 3000ft [2], [3], [4]. Hence, aircraft are most endangered during departure and landing. The danger for serious aircraft damage increases with the biomass and the number of involved birds [2]. Therefore, major concerns are bird strikes involving flocks of large birds. The research for avoiding collisions between birds and aircraft has mainly been driven by the military forces. As such, air forces of different countries such as the USA and the Netherlands have developed Bird Avoidance Model (BAM) focusing on detecting and modelling bird migration movements [4]. The resulting information can be used for flight planning in order to avoid areas with high densities of (predicted) bird movements. In civil aviation, bird movement information is usually not taken into account in flight planning [4].

In the beginning of the 21th century, the European Organization for the Safety of Air Navigation (EUROCONTROL) introduced a distinct way to perform airport management. The so called Airport Collaborative Decision Making (A-CDM) allows airport stakeholders to share information and negotiate on available resources. Using A-CDM procedures, events delaying air traffic can be handled more efficiently [5].

This study evaluated the possibilities of integrating bird strike risk information into A-CDM procedures. The main focus of the study lied on the question, how well A-CDM stakeholders can develop strategies for minimizing bird strike risk and up to what extent prediction tools can support this process. For this purpose, two workshops with experts in the field of flight guidance were conducted in simulated A-CDM environments with capabilities to integrate bird strike risk information.

This paper is structured as follows: First, we give an overview on the simulation environments we focused. This is followed by a description of the applied method and the gained results. Finally we discuss the results and give suggestions for future work.

2 Method

The DLR Institute of Flight Guidance provides different experimental set-ups for testing A-CDM processes. This study focuses on the Serious Game *Decisions based on Collaborative Interactions in Teams (D-CITE)* and the Human-in-the-Loop simulation environment *Airport Control Center Simulator (ACCES)*. To test, how airport stakeholders take into account information about bird strike risk, workshops with experts were conducted. In the first workshop, the participants played an adapted version D-CITE. In the second workshop, other participants performed the tasks of the A-CDM stakeholders in the ACCES. In both workshops, the participants were asked to evaluate their own performance with questionnaires. The results were used to answer the three main research questions which we had formulated for this study:

1. How well can bird strike risk events be generated in A-CDM simulation environments?
2. How well can the A-CDM stakeholders develop strategies to minimize the bird strike risk?
3. How much do prediction tools improve the performance of the A-CDM stakeholders in minimizing bird strike risk?

2.1 Participants

In this study, eight experts in the field of flight guidance participated. Four of them played the serious game D-CITE, the other four took part in the simulation within ACCES. We had one female participant and seven male participants. The average age was 37.63 years (standard deviation = 12.05, Range = 20 - 56 years). In the D-CITE workshop, they were assigned to the roles of two airline agents, one airport agent and one ground handler agent. In the ACCES-workshop, the participants were assigned to the roles of two airline agents, one airport agent and one Air Traffic Control (ATC) agent.

2.2 Experimental Setup

The experimental set-up consisted of two workshops. In the first workshop, an adapted version of D-CITE, which took into account uncertain events in the form of bird strikes, was used. In the second workshop, A-CDM scenarios including the risk of bird strikes were performed in ACCES. Both workshops took approximately three hours. In the following chapters, a brief overview of the two experimental set-ups is given.

2.2.1 Serious Game – D-CITE

In general, serious games are used for training or education purposes [6]. In contrast to kinds of simulations, the use of serious games offers a number of advantages. It is possible to represent complex human processes (e.g., decision-making) in an abstracted way [7]. Serious games are easier to understand as well as more intuitive than complex simulations [8].

The DLR initially developed the serious game D-CITE as a research instrument to analyse complex decision-making processes in airport management [9]. It also has successfully been used as a training instrument [10]. D-CITE is a round-based multi-player game and playable for four to five players. The provided roles consist of two to three airline agents, one airport agent and one ground-handler agent [11]. The function of an air traffic controller is considered as an automated game player. A game master moderates and coordinates the game. All players have the goal of optimizing the business of a generic airport, which has one runway and three stands. Therefore, they have to maximize their individual score as well as a team score. For this purpose, all players have to pay attention to their financial in- and outcomes during playing each round of D-CITE. The players get a general financial income for take-off of each aircraft and a bonus for a punctual dispatch/ handling time. Furthermore, there are some role-specific in- and outcomes. The team score serves as a performance and collaboration indicator of the team and the individual money score as a base for individual economic success. D-CITE's game-mechanism includes monetary penalties for delayed or cancelled operations as well as for decisions which lead to passenger dissatisfaction. These penalties decrease the financial income. Furthermore, they represent a reduction of the airport's reputation which can lead to financial losses in the future, as passengers might decide to fly from another airport.

D-CITE consists of two phases for each round: planning phase and simulation phase. During the planning phase, the players have the task of collaboratively tuning an Airport Operation Plan (AOP), consisting of seven time steps and a limited number of flights (cf. Figure 1).

Each column within Figure 1 represents one time step. The rows indicate possible positions respective phases of the aircraft: approach routes from A to D, landing phase, stand position for aircraft on ground or departure slot. Markers for each aircraft indicate the current position or state – these can be placed and shifted during the planning phase. The more the players share useful information during the planning phase, the better the game works and the team can achieve a higher team score. After finishing the planning phase of one round, the simulation phase starts with the simulation of each time step of this round (cf. Figure 2).

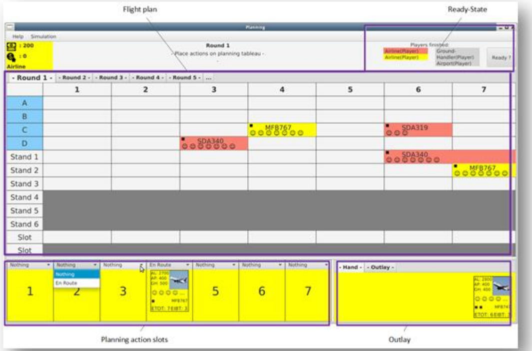

Figure 1: D-CITE overview for the planning phase [11]

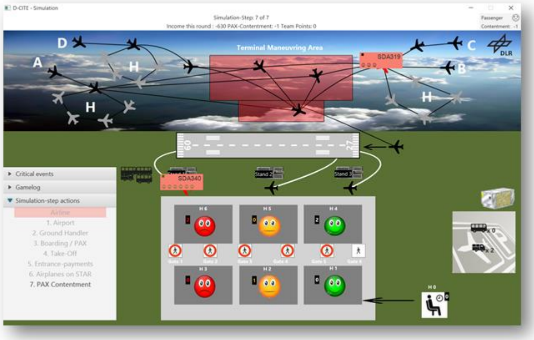

Figure 2: D-CITE overview for the simulation phase [11]

In a prior version of D-CITE, critical events – problems, which also happen in reality – were defined. Examples for critical events are a runway closure for one time step, required maintenance of equipment or a thunderstorm. All these critical events result in limitations (e.g., within one time step it is not possible to land or to take-off), which have to be considered by the players. The critical events are used to incorporate an unpredictable moment in the game setting. This is not only an important game element, but also leads to new challenges in rescheduling the initial AOP of all players.

For this study, we performed some changes concerning the critical events happening during D-CITE. These are described in the following chapter.

2.2.2 Serious Game – Workshop

All participants of the serious game-workshop have already played prior versions of D-CITE. Hence, no special training was necessary. After a short briefing, D-CITE was started. The game exists in a digital as well as in a paper-based version. Both versions have identical game-mechanisms. For this workshop, we decided to use the paper-based version of D-CITE, as it is more flexible in adding new critical events and rescheduling the AOP. The set-up of the paper-based version can be found in Figure 3.

Figure 3: Set-up of the paper-based version of D-CITE

During the workshop's initial briefing, the participants were informed about the risk of bird strikes and the consequences of such an occurrence. Furthermore, they were provided with a pre-planned AOP. The participants had the task to reschedule the contained flight plan by considering critical events. Moreover, they had the opportunity to plan a limited number of additional flights per round. Three rounds of D-CITE were played. The participants were not informed about the total number of rounds. In each round, a critical event in form of high bird activity with a certain level of uncertainty was presented. The players received the information about this critical event on a so called game card (cf. Figure 4) at the beginning of the planning phase of each round.

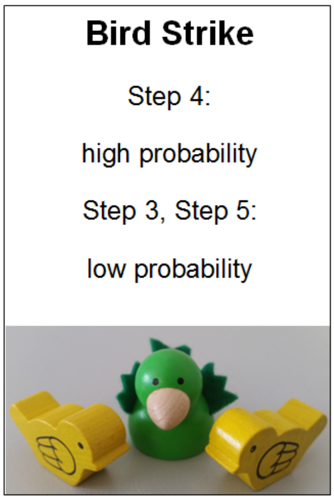

Figure 4: Critical event card

As the movements of birds are only predictable up to a certain extent, the critical event would always affect three time-steps – one step had a high probability for a bird strike occurrence, while the adjacent time-steps had a low probability for a bird strike occurrence. All other steps did not have any probability for a bird strike. It was predefined, whether a bird strike actually would occur and if yes, in which of the time-steps. Table 1 visualizes the critical events presented to the players during the planning phase of each round as well as the realization of the critical events during the simulation phase.

Table 1: Critical events in form of bird strikes and their realization during the D-CITE workshop

round	*critical event (planning phase)*	*realization of critical event (simulation phase)*
round 1	step 4: high probability, step 3 and 5: low probability	step 3: bird strike
round 2	step 6: high probability, step 5 and 7: low probability	step 6: bird strike
round 3	step 3: high probability, step 2 and 4. low probability	no bird strike

The affected time-steps were chosen in a way that the participants had to adjust their initial planning if they wanted to avoid the bird strike. If a bird strike occurs, the consequences depend on the aircraft's flight phase. Table 2 summarizes the consequences for bird strike occurrences in the different flight phases.

Depending on the individual assessment for the risk of bird strike, the players had to develop strategies for risk mitigation. Because of the increasing number of aircraft per round, the complexity of the game rose.

After finishing the planning phase of one round, the simulation phase for this round starts. In this phase, the planning for every step is simulated in a particular order. Therefore, in a first step the plans of the airlines are put into action; secondly, the plans of the airport; thirdly, the plans of the ground handler. This is followed by simulating the boarding/ passenger movements, the take-offs, payments and aircraft movements on final approach. Furthermore, the participants receive the information, whether any bird strike has happened. The occurrence of a bird strike can have effects on the AOP, for example when an aircraft needs to return as an emergency to the airport and therefore requires the runway for the next time-step. In this case, a rescheduling for planned flights might be required.

Table 2: Consequences of bird strike occurrences

flight phase	*process-oriented consequences*	*financial consequences*
landing	the hit aircraft is removed out of the game as it has to be repaired. The subsequent take-off of this aircraft is cancelled	due to the cancelled take-off, the players receive no money for this aircraft
take-off prior to rotation (time steps with low risk probability)	delayed take-off for the hit aircraft, as it has to roll back to the stand to be checked for damage	monetary penalty for delayed take-off for the airline of the affected aircraft
take-off after rotation (time steps with high risk probability)	aircraft has to return to the airport due to serious engine damage in the following time-step. In case a flight was scheduled to take off or land in this time-step, it has to be delayed to give priority to the emergency landing	monetary penalty for delayed take-off for the airline of the affected aircraft as well as any airline which has to delay a take-off in order to give priority to the emergency landing

The bird strike events as well as emerging consequences result in most of the cases in financial losses for all players. Hence, it is important that the participants develop a common strategy for the risk mitigation.

After each round of D-CITE, the participants were asked to fill out a questionnaire. After the game, a debriefing took place. The impact of the critical events on the planning activities of all participants will be presented in the result section and discussed later.

2.3 Human-in-the-Loop Simulation

The DLR operates the ACCES, which is viszalized in Figure 5. This Human-In-The-Loop simulator is used to design and validate new procedures and systems for the airport management [12]. On one hand, the ACCES offers most flexible working positions to generate different airport control centre layouts. On the other hand, it provides an elaborate software system to simulate the A-CDM process [13]. The software consists of different user interfaces. These enable the airport stakeholders to interact with the simulation and plan their flights [14]. The simulation core itself includes flight dynamics representing each flight as a sequence of processes (e.g. cruise, initial approach, final approach, turnaround). Due to parameters such as aircraft type, available stands or runway time, the process duration for landing, taxi or take-off can change (cf. [15]). If, for instance, an aircraft's designated gate is blocked by another aircraft, the taxi process of the first aircraft takes until the gate is available. The simulation core is also able to simulate certain events that can influence the process duration. Among others, weather events such as a thunderstorm can be introduced. This is modelled as a delay in the turnaround process within the simulation (the ground handling staff is not allowed to work during this period) or a delay in the final approach (increased separation minima).

The airport management simulation software is capable of simulating any realistic or virtual airport as well as real or fictional traffic schedules. As the bird strike workshop was not dedicated to the effects on a special airport, a virtual airport with two runways, 15 gates and 10 remote positions was selected. Figure 6 visualizes the layout of the chosen airport design which was already successfully used in former DLR simulations [16]. The traffic schedule was taken from those simulations and relies on realistic data with changes to the virtual airport. Thereby, traffic volume and flight data meet current traffic conditions without including special effects and dependencies of any real airports.

Figure 5: ACCES

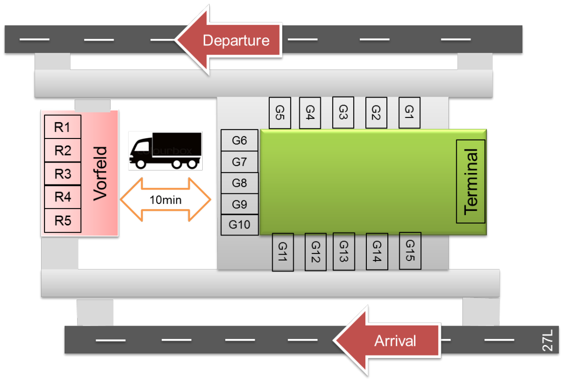

Figure 6: The layout of the virtual airport ZZZZ

The bird strike itself was designed as an uncertain event. Therefore, the simulation software was configured to randomly choose a five minute interval with high bird activity within a total time span of 30 minutes. The total simulation time lasted 45 minutes per scenario, of which the bird strike could occur in the last 30 minutes. The participants were not informed about the total simulation time. In the case that flights would arrive or depart within this five-minute interval with high bird activity, the first aircraft to use the runway would experience a bird strike. The impact of this bird strike is a five hour delay for this flight. This is justified by the time which is required to check the aircraft for damage and to perform small repairs. If a bird strike occurs, the runway is closed for 20 minutes in order to inspect the runway. This affects all aircraft which intend to depart or to land after the bird strike. In the beginning of each round, the stakeholders were provided with a pre-planned flight plan. In contrast to the D-CITE workshop, adjustments of the initial planning took place during the simulation, i.e. while the scenario was already running. As soon as the five-minute interval with high bird activity was reached, the participants were informed and it was checked, whether any aircraft had been hit by a bird. In case that a bird strike had taken place, the participants were provided with the opportunity to adjust their planning for subsequent flights before the simulation was ended. In case that no bird strike had taken place, the simulation was ended at that point.

To examine how advanced bird strike information is taken into account by the airport stakeholders, three scenarios were simulated in ACCES. The first scenario served for training and familiarization with the simulation. As all participants had worked with this simulation environment before, this brief introduction was sufficient. This first scenario included the closure of four gates and a runway and the stakeholders could practice how to reschedule flights and find negotiation mechanisms for the following scenarios. In the second scenario, the stakeholders got informed about increased bird activity from minute 15 to minute 45 of the scenario. Thereby, the participants could negotiate on delaying flights to avoid the phase of bird activity or take the risk of a bird strike. In the third scenario, the stakeholders got information about the migrating pattern of the flock of birds which was initially predicted to cross the runway between minute 15 and minute 45. This information was provided in form of a map giving time-stamped information about the bird's current and past positions (cf. Figure 7).

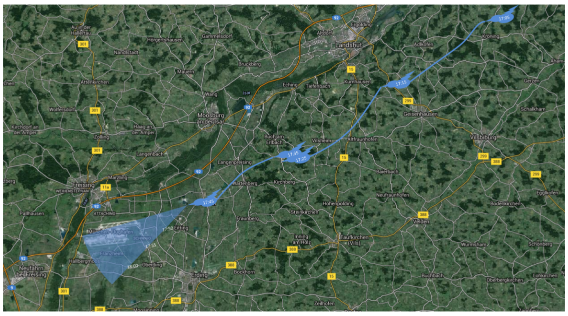

Figure 7: Information about the migration pattern of birds

2.4 Research Instrument

The main research instrument was a self-developed questionnaire, which the participants of both workshops had to fill in during and after the respective workshops. All questions were designed as closed questions. The answering scale included values from one to four. Thereby, the participants could agree up to a chosen extent within the four levels. This design was used to get a distinct rather than an open feedback from the participants. Moreover by not providing neutral element (neither satisfied nor dissatisfied) was used to force the participants to make a distinct decision on the aspect in focus. The participants were asked to fill out the questionnaire after each round in D-CITE respective after each scenario in the ACCES simulation.

The questionnaire covered three areas. Firstly, the participants were asked about the comprehensibility of the bird strike risk within the current scenario. This question was rated on the above mentioned scale form one to four. The comprehensibility was defined as acceptable in case that the average rating to that question is equals or above 3.0 (slight to full affirmation) and additionally no individual rating is below 2.0 (total rejection).

The second part was specifically designed for the D-CITE workshop. The target of this workshop was to observe, whether the participants considered the bird strike risk as relevant and if yes, how they develop different strategies on mitigating bird strike risk. Therefore, the participants were asked whether they took any bird strike risk into account in their decisions. We assume that at least one stakeholder takes bird strike risk into account in case that the bird strike risk is assessed as relevant. Moreover, the participants were asked, whether they would use the strategy applied in the current round / strategy again. If airport management is able to minimize the bird strike risk by their decisions it is anticipated that the participants adapt to the risk throughout the rounds. Thereby we assume rising acceptance of the strategies with increasing round number.

The third part of the questionnaire focused on the ACCES workshop. In this part, it was analysed, how well tools for predicting bird strike risk over time supported the decision-making process. In the third scenario of the second workshop, the participants were provided with additional information about bird strike risk in form of a map with historic time-stamped bird trajectories. In the questionnaire, they were asked whether they felt that this additional information improved the predictability of the bird strike risk.

For this purpose, the participants were asked whether additional information on bird strike risk, which the participants were provided with in the third round, was perceived as helpful. We assume that the predictability in the scenario with the map is rated higher than in the situations without the map.

2.5 Base for Statistical Analysis

Because of the fact, that only eight participants (four per workshop) were tested, the data will be presented only descriptive (mean score as well as frequency analysis). To do more complex statistical analysis, it is necessary to test more participants.

3 Results

In both workshops, the participants were asked after each round, how comprehensible the bird strike risk was. The possible answers were

1= not comprehensible
2= partially comprehensible
3= principally comprehensible
4=fully comprehensible

Over the three rounds of D-CITE, the participants had a mean comprehension value of 3.25, what lies between principally and fully comprehensible. The average comprehensibility in the Human-in-the-Loop simulation amounted to 3.58. Both values are above the defined threshold of 3.0 and an individual rating below 2.0 could not be found. The individual values per round and agent are visualised Figure 8.

Within the D-CITE workshop, the participants were asked if they did take the bird strike risk into account. The replies varied strongly between the stakeholders. At least one stakeholder per round did consider the bird strike risk in his plan (cf. Table 3)

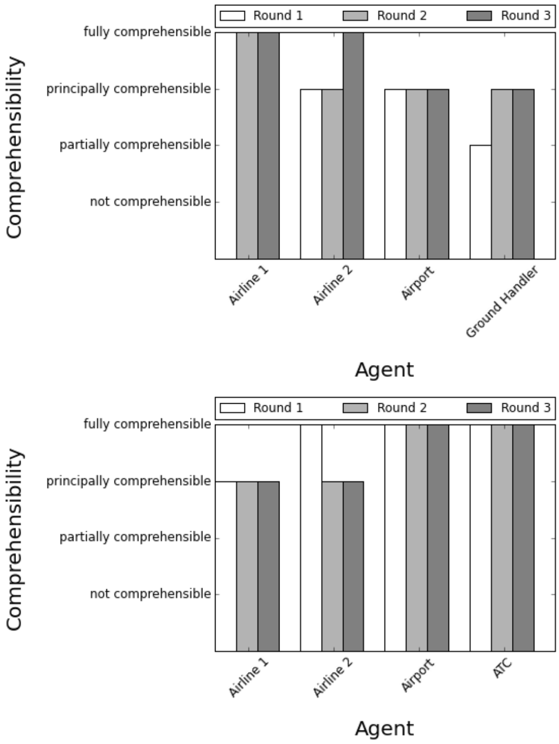

Figure 8: Comprehensibility of the bird strike risk information for D-CITE (top) and the ACCES simulation (bottom)

Table 3: Strategy Adaption within D-CITE (yes = I will plan flights in a way that they do not take place in any slot with bird strike risk / no = I will still plan flights in slots with bird strike risk)

agent	*round 1*	*round 2*	*round 3*
airline 1	No	No	No
airline 2	No	Yes	Yes
airport	Yes	Yes	Yes
ground handler	No	Yes	No

The agents were furthermore questioned, whether they would pursue the same strategy in future rounds. Their answers per round can be found in Figure 9. In average the strategy of round one was rated with 2.5 (fundamental to slight adaptations) while round two and three were rated with 3.5 (slight adaptations to no adaptations).

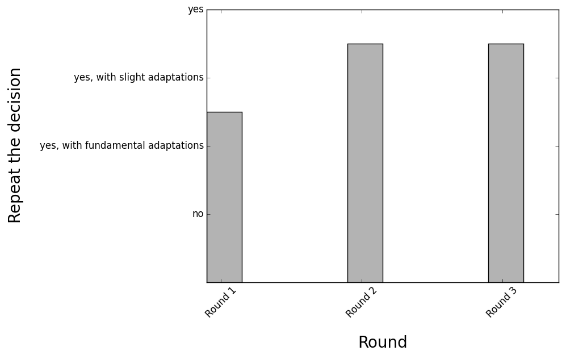

Figure 9: Willingness of the stakeholders to repeat their decisions how to take bird strike risk into account

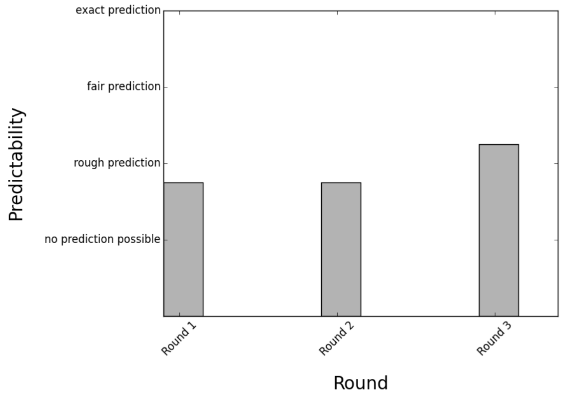

Figure 10: Predictability of the bird strike risk (round 1 and 2 without, round 3 with tool)

In the Human-in-the-Loop simulation, two rounds were being performed without any prediction tool. In the third round, the stakeholders were supported by information about the birds. This should help them to estimate more precisely, when the danger of bird strike was largest. Figure 10 shows the subjective impression of the predictability per simulation round. In both rounds without support, they assessed the predictability with 1.75 on average, in the last round, where additional support was provided, the predictability increased to 2.25 on average.

4 Discussion

This paper posed the following research questions on considering bird strike risk within A-CDM processes:

1. How well can bird strike risk events be generated in A-CDM simulation environments?

2. How well can the A-CDM stakeholders develop strategies to minimize the bird strike risk?

3. How much do prediction tools improve the performance of the A-CDM stakeholders in

minimizing bird strike risk?

To answer the first research question, we evaluated how well the information about the bird strike risk and occurrence was understood by the participants in both workshops. The results section showed that the criteria (slight to full comprehension in average and no individual total rejection) were fulfilled. Hence, it can be stated that the distinct way of modelling the bird strike event is a successful approach for the examined participants. Due to the small number of different events (two workshops) and participants (eight) the results must be limited to this case study. A general answer for all airport experts and all ways of modelling the bird strike cannot be given based on those results.

To answer the second research question, it was analysed whether and if yes, in which way the participants took bird strike risk into account when making strategic decisions. The results showed that in each round of the D-CITE workshop at least one participant considered the risk. Moreover, the strategy of round one was rated with more need for adaptation than the strategies of the later rounds. Confirming these predefined criteria, it can be stated that the examined stakeholders considered the bird strike risk and agreed on a strategy. Regarding this finding, it must be stated again that the number of participants is too small to generally conclude that bird strike risk can be minimized by airport management. Moreover, a so called expectation effect might have influenced the results. Simulations as well as gaming are often expected to challenge the participants as these approaches are very broadly known for their advantage in training risky or uncommon situations [17]. The participants were briefed about the general problem of bird strike previous to both workshops. Hence, they might have the expectation that they would be challenged by a bird strike occurrence. For this reason, they might have reacted more cautiously than operational staff.

The second workshop – the Human-in-the-Loop simulation in the ACCES – focussed on the potential of supporting the airport stakeholders with additional information and tools in order to answer the third research question. Therefore, the participants conducted two rounds without any supporting information about bird strike risk. In the third round, they were provided with a bird activity map as an additional information source. We assumed that the participants would rate their prediction abilities higher when being supported by the map. This assumption was confirmed by the obtained results. Nevertheless, the differences between the condition with and without the map need to be analysed carefully. On one hand only one run with the map was conducted. On the other hand, the measured differences are rather small (0.5 on the 4 point scale).

We conclude that it is possible to generate bird strike risk events in airport management validation environments in an understandable way for the participants. The obtained results from the D-CITE workshop indicate that there is a learning effect in developing strategies to minimize the risk of bird strike. Moreover we analysed that certain additional information does support the stakeholders in choosing an appropriated strategy. Nevertheless, the small size of the study only allows observing local effects that need to be proved with a greater approach. In the end we can summarize that there is potential to conduct future research activities in airport management to reduce the bird strike risk.

5 Outlook and Future Work

For future studies on the subject of integrating bird strike risk information into the A-CDM process, we suggest to include a larger number of participants to gain a broader statistical base. For the D-CITE workshop, we propose to generate bird strike risks randomly in order to generate even more uncertainty for the participants. Another study could focus on differences in strategies if an aircraft is hit or no aircraft is hit in the first round. Considering the ACCES workshop prediction tools with different qualities could be implemented in order to test the trust of the airport stakeholder in this kind of technical support. In this study, we focused on the strategies of the individual stakeholders. A follow-up study could include metrics for gaining information about the team strategy of the A-CDM stakeholders and involve operational staff.

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