What to say when: Guidelines for Decision Making
An evaluation of a concept for cooperation in an APOC

Anne Papenfuss, Nils Carstengerdes, Sebastian Schier, Yves Günther
Institute of Flight Guidance
German Aerospace Center
Braunschweig, Germany
{firstname.lastname}@dlr.de

Abstract—Because airports are currently a bottleneck in the ATM system research and development effort is spent in creating high performing airport operations. In order to actively influence airport performance, joint decisions made in an Airport Operations Control Center (APOC) are proposed. This idea raises several research questions; one is in how far guidelines for a structured communication process mitigate factors like conflicts and personality which might prevent an effective and efficient decision making in the APOC. This paper explores the impact of a concept for cooperation for airport stakeholders in a planning task. Four teams with four airport experts took part in a high-fidelity study. The guidelines significantly improved experienced team effectiveness. Results show that guidelines lead to a more pro-active, information driven decision making and mitigate some effects of individual interaction behavior.

CDM; Collaborative Decision Making; Cooperation; Airport Operations; Human Factors

I. INTRODUCTION

A. Reasons for Implementing an Airport Operation Center

In the current ATM system, airports and their capacity are a bottleneck, significantly influencing performance of air traffic. Furthermore, airports are operated and thus influenced by a variety of stakeholders, which are airspace users, airport authorities, air navigation service providers, ground handling and security.

The concept of an airport operations center (APOC) is based on the assumption that airport performance can be improved through an optimized use of airport resources. In particular, efficiency of airport operations should be increased through communication and coordination between all stakeholders at an airport.

Analyses of the current situation at airports with regards to coordination between stakeholders revealed that

- stakeholders at airports have different goals for their specific operations, resulting in a variety of (latent) conflicts
- thus, cooperation between stakeholders is affected
- the better coordination between airport stakeholders, the better is airport performance.

It is assumed that because operational processes of stakeholders are not sufficiently coordinated, not the whole potential of airport capacities is utilized.

Especially when planned processes are disturbed by weather, incidents or accidents or technical failures, coordination between stakeholders and adjustment of plans is necessary in order to recover the airport and its performance as fast as possible. The adjustment of plans within an operations center between stakeholders with different goals was focus of the project “Collaboration within Control Centers (COCO)”, financed and executed by the German Aerospace Center DLR. Schulze-Kissing et al. [1] defined control centers as a socio-technical system, where operators act in different roles. They spatially and temporarily coordinate resources required for their operations (staff, technology) and by doing this they either follow a schedule, or react upon an unforeseen event. A control center consists of both human operators and technology, assisting the human operator. The human factor therefore is crucial for defining and installing an APOC.

B. Existing Concepts and Ideas for Airport Operation Centers

Airport operations have a large potential for optimization. Airports are complex systems with multiple interconnections between numerous processes owned by a multitude of stakeholders ([2]). Each stakeholder at an airport plans their processes and actions according to individual goals and standards and corporate business plans. But most stakeholders miss information about intentions, goals and actions of other (cooperating or competing) parties at the same airport. Relevant information is not available, available, but incorrect or available but too late (cf. [3]).

Hence, harmonizing plans between different stakeholders at an airport is rather time consuming and difficult, especially regarding partly conflicting goals of airport stakeholders and their unwillingness to share all information about their plans. Assessing the impact of other parties actions on one’s own plan is therefore difficult and an integrated view of total airport operations is missing, cf. [4]. To foster a proactive behavior, Airport collaborative decision making (A-CDM) was developed [5], where at least some information is shared (like the Target Off-Block Time, TOBT). This concept was further developed to a solution called Total Airport Management (TAM) [6]. TAM enhances the airside-focused A-CDM concept by integrating landside processes and developing ideas for highly collaborative decision making in APOCs (cf. [7]).
recent years, the TAM idea was complemented by concepts like Performance-based airport management (PBAM, [8]) and detailed description of APOC processes and use cases in APOCs in the context of the Single European Sky ATM Research Programme SESAR (cf. [9][10][11]).

Unfortunately, up to now most research focused on the technical part of the socio-technical system (e.g. [4]). Different solutions for APOCs were evaluated, but less research was performed to optimize social characteristics. Ideas to foster pro-active, collaborative behavior mainly focused on the competitive roles of several airlines and involved the development of negotiation protocols and bonus-malus-systems [12][13].

Cooperation and relevant Mechanisms

Cooperation is facilitated by a set of mechanisms. First, following the argumentation above, the definition of a shared and valued goal for all stakeholders is basis for cooperation. Second, coordination of resources, tasks and decisions especially regarding their timing enables cooperation [16][19].

Third, collaboration, namely participation and contribution of two or more stakeholders to a shared task or process, fosters cooperation [19]. The guidelines for cooperation make use of collaboration and coordination by defining a collaborative decision making process which structure coordinates the contribution of decision and information from airport stakeholders.

Decision Making in the APOC

The result of decision making in an APOC is an Airport Operations Plan that adapts the schedule according to events that influence airport operations. Than the schedule is implemented by tactical operators, e.g. tower controllers or airline dispatcher. At an airport, operations and decisions of stakeholders are dependent on operations and decisions of other stakeholders. Accordingly, plans of one stakeholder also influence plans of other stakeholders.

Thus, decisions made in the APOC need to have sufficient quality, take into account interdependencies between stakeholders and should be made in an efficient manner. At the same time, airport stakeholders that should cooperate within an APOC have conflicts regarding their individual goals, use of limited resources (e.g. runway) as well as conflicts of power and information (cf. [20]). As one example, during winter operations airlines might have the goal to accommodate all flights as punctual as possible whilst air traffic control might have the goal to feed air traffic in a constant flow into the airspace.

Conflicts have an impact on decision making processes. Negotiations are discussions aimed at resolving incompatible goals [20]. Decision making via negotiation has been studied mainly in the business domain. Strategies within a negotiation can be classified as integrative and distributive [21]. One successful integrative strategy to negotiate decisions affected by conflicting goals, is information sharing [21] thus demonstrating openness and creating transparency. Especially, information about goals and priorities lead to successful negotiations and high quality results. When used with a reasonable amount, distributive strategies like requests improve negotiation outcome.

Olekalns et al. [22] found out that a negotiation structure is helpful if in a first phase information is gathered, in a second phase facts and goals are discussed followed by a third phase, where options are developed. For the third phase, flexibility and creativity are important.

C. Teamwork and the Importance of Interaction

A team is defined as a set of two or more operators with specific roles or functions who share a common goal and interact dynamically, interdependently, and adaptively to reach this goal [23]. Whilst in today’s airport operations, stakeholders would not meet the definition of a team, by implementing the PBAM concept with mutually agreed performance targets for airport operations, stakeholders within the APOC can be described as a team pursuing a common goal.
Teams are a cognitive entity, with cognitive processes to an individual’s cognition, cf. [24]. Thus, successful performance requires the team to have shared mental models and to develop shared situation awareness as a prerequisite for decision making.

Whilst executing their specific task (e.g. adapting the AOP according to an unforeseen event), teams conduct two strands – taskwork (e.g. planning stand and gates) and teamwork. According to this scheme, taskwork is rather product-related. Teamwork refers to the process itself; i.e. how work of the team is done. It is believed that besides the differences of teams regarding the task they fulfill, there are universal processes of teamwork (e.g. [25]).

Interaction within the team is a meta-function of teamwork, including verbal and non-verbal communication as well as input into technical systems. Interaction is the mechanism to operationalize collaboration and coordination, as well as cognitive processes of a team. According to this understanding, manipulating the teams’ interactions by a guideline for cooperation, team cognition and thus team decision making can be influenced.

D. Standardization

The guidelines for cooperation structure the decision making process of APOC stakeholder teams. Guidelines standardize interaction with regards to nature and timing of information and decision that is provided. Standardization of communication is an established method in air traffic management to minimize uncertainty [26]. A prominent example is the standardized communication between air traffic control and pilots. Operators in the ATM environment are used to work according to rules, guidelines and checklists. Accordingly, providing guidelines for decision making processes in the APOC does not only ensure the flow of most relevant information but is also expected to increase acceptance of the operational concept.

Beside these advantages of standardization, there are potential drawbacks with regard to APOC decision making. A great advantage of human operators is their flexibility and creativity in finding solutions for new situations. They can adapt to changed environmental situations. It might be that a formal and standardized process reduces flexibility. The guidelines are designed so that stakeholders are still able to act creative and flexible. Nevertheless, it is of interest to assess with regards to team effectiveness if it is beneficial to structure information exchange or to leave the process of distributing information open.

III. RESEARCH QUESTION

Guidelines for cooperation are proposed as a means to enable stakeholders to make decisions within an airports operations center whilst also following individual and competing goals. The guidelines structure the way which information and decision is provided at which time to whom. Thereby, relevant information will be available at the right time, creating a standardized decision making process.

First, it is of interest to understand, how satisfied teams are when applying the guidelines. It is assumed that effectiveness of the team decision making process should be rated better when information is available at the right time.

Secondly, it is of interest in how far teams apply the rules or whether they rather ignore them and/or develop “individual” ways of sharing their information. This research question is explorative. It is assumed that application of rules depends on teams’ characteristics. Nevertheless, the success of the guidelines depends on whether they can be applied in a variety of APOCs and team constellations.

Subsequently, as a third research question, this paper investigates in how far guidelines affect individual team members’ interaction behavior. This behavior is also influenced by factors like personality of team members. Do guidelines for cooperation influence the individual interaction style and specific features of behavior, thus leading to a more standardized process than without guidelines?

IV. METHOD

A. Simulation Setup and Scenario

The experiment was based on DLR’s airport management simulation. This human-in-the-loop simulation was developed to validate new concepts and systems for airport management stakeholders (cf. [27]). Moreover training sessions for airport management procedures can be conducted based on this platform (cf. [28]). The airport database is the core of this simulation platform. This database is able to store all data required by EUROCONTROL’s A-CDM process, cf. [5], including scenario and airport data. All users of the airport management simulation were able to access flight and airport data in the database. Thereby the information sharing concept of A-CDM is implemented.

Access to the database is provided by different graphical user interfaces. All interfaces were designed to gain both a high comparability to real airport management tools (cf. [29] e.g. stand and gate planner, airline dispatching tools) and a generic layout that allows stakeholders from different airports to quickly familiarize with the interface.

![Figure 3. Scheme of the airport model and the resources](image-url)
For this study a generic airport with two independent runways was designed. A schematic view of the airport model is shown in Fig. 1. Each runway was configured to handle a maximum of 30 arrivals or departures an hour. A mixed mode was not allowed. The airport was equipped with 15 stands with direct access to the terminal and five remote stands. Due to passenger and equipment transport, turn arounds at remote stands took ten minutes longer than at terminal stands. Standard times for taxi and turn around process were used to calculate A-CDM milestones based on SOBT or TOBT respectively (based on availability). To reduce complexity, turn around was a single process which time was dependent on type of stand and aircraft type. A sequence at the departure runway was calculated automatically based on S/TOBTs and runway capacity.

The scenario consisted of 45 arrival flights and their connected departure flights scheduled for takeoff in a period of two hours, with an average demand of four flights per 15 minutes (max = 7 flights). Within a 30 minute interval, capacity at the airport was reduced due to an external event, e.g. in one scenario a heavy thunderstorm. Departure demand thus was shifted to later time intervals. Because the shifted demand added to scheduled demand, the overall demand was shifted to later time intervals. Because the shifted demand was too high for capacities available, delays occurred. The stakeholders had to decide on an adapted departure sequence which minimized delay and takes into account their individual goals.

Within this experiment a subset of the user roles and respective individual goals were provided:

- Two airline dispatcher: Both dispatchers were responsible of defining target off block times (TOBT) of their flights and the rotation schedule. The two airlines had similar goals and where competing about slots in the departure sequence and about ground handling staff in order to have their priority flights punctual and minimize their delay.

- Air operation: Responsible for stand and gate allocation. The airport’s goal was to solve any stand and gate conflict and to serve as many aircraft as possible at a gate position.

- Ground handling staff manager: Responsible for allocation of ground handling teams. By varying the team size the staff manager was able to influence turn around duration. The goal of the ground handling position was to satisfy airlines as customers and to minimize staff cost.

- Supervisor: Taking over the role of the tower supervisor, responsible for departure planning (using a pre departure planner). The supervisor did not had an individual goal.

All participants were instructed to reach their individual goals whilst following the overall goal of improving departure punctuality. By this, two types of conflicts leading to competition were induced in all scenarios:

- competition due to conflicting goals (e.g. ground handling staff costs vs. airline punctuality)

- competition due to limited resources between the two airlines (e.g. competition about runway slots, gate positions and about ground handling resources)

In all experimental runs, the team’s goal was pre-defined and thus decision making focused on accomplishing the overall goal rather than on defining it.

Upon initialization, the scenario was loaded into the airport management simulation. The supervisor informed participants about the occurring problem (e.g. thunderstorm – no ground handling). Concerned resources were then marked as blocked and all stakeholders started replanning and negotiating on best suitable actions and decisions to overcome the problem. At the latest, after 45 minutes participants were asked to enter their final solution.

The experiment focused on airport management as a planning task without dynamic aspects like movements of aircraft. So, the departure sequence and flight rotation were only updated in case a stakeholder sent a changed TOBT to the database. Nevertheless, the airport management simulation is also capable to provide a traffic simulation (cf. [30]) generating actual times for A-CDM milestones. This could have been used if further events were meant to occur or if the implementation of the plan into actual operations would have been of interest.

B. Data Gathering and Preparation

For this study, interaction data and subjective data via questionnaires was gathered. During the 45 minutes of the decision making process, four trained observers captured interactions of each stakeholder. An observation sheet was used that combined elements of the IKD-approach [31] with additional data fields relevant for the study and research question. To ensure a high inter-rater reliability, the observers were briefed and trained weeks before the experimental runs started. In this study, reliability of the coding scheme was not assessed. In general, literature reports good interrater-reliability for comparable coding schemes in terms of interaction events, sender and receiver [32]. The IKD also achieved good reliabilities for the main categories of knowledge combination [31].

Each observer coded all interactions sent and received by the stakeholder under his/her observation. For each single unit of meaning the time of occurrence was noted, sender and receiver, a short note about content, function within the decision making process, as well as the phase of the guidelines for cooperation this interaction belonged to. As functions within the decision making process, three different categories were distinguished: socio-emotional function, knowledge combination and control function (cf. [31]). The category knowledge combination was further subdivided into question, information, decision and coordination. Coordination in this coding scheme referred to high-frequency interaction between two stakeholders with the goal to clarify data (e.g. in case the callsign of a flight was not correctly understood). One part of the observation sheet is shown in Fig. 2.

After the experiments, the observation sheets of all four stakeholders were combined into one single data table record of stakeholders’ interaction. Time stamps were calculated as relative times. Only interaction originating from the sending
stakeholder was used, in order to avoid double counting. Double coded interaction can be used to calculate the inter-rater-reliability of the coding scheme.

The combined data table was used to calculate quantitative metrics describing interaction and communication behavior.

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Observer</th>
<th>Operator</th>
<th>Category</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airline</td>
<td>Ground handler</td>
<td>refined</td>
<td>1 2 3 4 5 6</td>
<td>4</td>
</tr>
<tr>
<td>Ground handler</td>
<td>Airline</td>
<td>refined</td>
<td>1 2 3 4 5 6</td>
<td>4</td>
</tr>
</tbody>
</table>

Figure 2. Part of the observation sheet used for capturing interaction data

C. Experimental design

A single-factor within-subject design was used, where participants collaboratively worked on challenging problem scenarios at a generic airport. In the first two scenarios, participants had to solve the problem by their professional experience and without a structured communication guideline. In the third scenario, participants should use the structured communication guideline, which was explained and trained beforehand. The sequence of scenarios was counterbalanced between the teams to control for order effects. As dependent variables, personality, performance and team interaction measures were gathered. The independent and dependent variables will be explained in detail in the next section.

D. Independent Variable – Guideline to facilitate Cooperation

The guidelines are a workflow within which it is captured, which tasks and decisions in which order should be solved by whom. Within the study, two tasks were used that were identified to be relevant for a couple of different scenarios and which can influence punctuality at an airport. These two tasks are 1) prioritization / sequencing of departure flights and 2) replanning of stands and gates. For these two tasks, airlines, airport and ground handler are required to feed their information and decisions about priorities, resources and intentions into the decision making process. It is assumed that today each stakeholder plans their resources independently but without knowing exactly the effects onto the plans of other stakeholders. The impact of the replanning is only visible to all stakeholders if individual changes to plans are published by the stakeholder and thereby fed back into the airport database. It is expected that with guidelines, the consequences and interdependencies of the individual planning become apparent due to the consecutive order of replanning. Thus, the collaborative planning should be more effective in terms of overall satisfaction with the final decision.

The guidelines are structured into six generic phases of decision making: 1) getting awareness of a potential conflict event 2) analyzing the impact of that event, 3) generating solutions that take into account downsized capacity 4) detect secondary conflicts 5) refine the solutions of step 3, and 6) decision about the final solution.

For each stakeholder, his/her required actions and information is defined for each phase for the two tasks “priorities departures” and “stand and gate planning”. In phase 4, the two tasks can trigger the other tasks. For instance, in order to prioritize a departure in the sequence it might be necessary to move it to a remote stand, thus the two tasks are not independent. A notation of the guidelines, indicating the phases, is shown in Fig. 3.

As another example, if the ground handler is not able to accommodate a turn around within the planned time slot the stand is occupied longer than planned. In that case, stand and gate planning needs to be adjusted. Each stakeholder has a view onto the problem showing his/her resources and conflicts within resources. All stakeholders share a common view of the published time stamps for each flight event. For each task, the six phases are described in more detail:

a) Prioritize Departures:

Due to a predicted external event (e.g. a thunderstorm with lightning over the airport) all turn around activities need to be cancelled during this time (phase 1). For that reason, the ground handler needs to determine new ground handling start times after operations will have been reestablished again (phase 2). In that example conflicts arise for departures because there are not enough ground handling resources to accommodate the new departure demand. The ground handler creates a first handling sequence and distributes his proposal (TOBTs) to the airport and the airlines for verification of possible impacts on their own resources and planning (phase 3). If any secondary conflicts arise, the stakeholder announce their wishes (e.g. for the sequence of handling, demand for fast turn around and other stand), or/and communicate their conflicts (phase 4). In phase 5 all wishes and changes will be discussed and a mutual plan for the sequence of TOBTs is agreed upon. Finally the ground handler fixates the joint plan (phase 6, operational staff becomes aware of the sequence and all relevant information to perform the handling as expected).

b) Stand and Gate Planning:

A dysfunction (e.g. taxiway not usable due to an incident) leads to the situation that a certain number of stands at the terminal are unavailable (phase 1). With this information, the airport as stakeholder responsible for stands, checks if any conflicts in stand and gate allocation arise (phase 2). In case there are conflicts, s/he reallocates flights to available outer stands and distributes the new stand and gate plan to airlines and ground handler (phase 3).

Due to the influence of stand location on ground handling resources (e.g. more busses needed) and therefore longer ground handling times, a possible handling sequence and airline priorities will be communicated back to the airport (phase 4). In a structured discussion phase, all stakeholders jointly decide about the final stand and gate allocation plan (phase 5) by following the pattern “airport communicates to ground handler communicates to airlines”. Finally the new plan will be fixed and distributed (phase 6).
2) Dependent Variables

a) Team Effectiveness

The survey to assess subjective evaluation of teamwork was derived from the “Team Effectiveness Survey” scale [32]. The questionnaire consisted of 12 suitable items out of the original 16 items. Each item consisted of two diametric statements, e.g. “There is a lack of procedures to guide team functioning” versus “There are effective procedures to guide team functioning”. Each item was rated on a 5-point Likert scale with three as neutral position. Values smaller than three indicate a favor for the negative attribute, values larger than three a favor for positive team behavior attributes.

b) Quantity of Interaction

This metric counts how often teams and individual team members initiate an interaction. This metric captures the quantity of interaction without differentiating for interaction function or content.

c) Conformity of Process with Guideline

This metric captures the structure of interaction in terms of communication patterns between the team members. The guidelines for cooperation control the flow of information between stakeholders. Especially, who should provide information to whom, which can be defined as a normative behavior. The metric counts the percentage of normative transitions in all transitions. The metric has a theoretical range of 0 to 100 percent. Therefore, on basis of the interaction data table a transition matrix is created.

In the fifth phase of the guidelines for cooperation options for the solution are developed by all stakeholders. An optimized communication pattern was developed proposed, where 1) the airport should propose a change first, followed 2) by the ground handler, and finally 3) by the two airspace users. The guidelines propose a three-turn-sequence, consisting of two two-step-sequences that are captured by the transition matrix. The sum of all interactions following this normative sequence was used for this metric.

d) Style and Manner of Knowledge Combination

In teamwork research a pro-active communication style should be beneficial for team performance, also described as anticipatory behavior [33] as it describes the fact that team members are aware of the information needs of their team partners. The metric is the quotient of the number of all information and decisions and the number of questions. The range is from zero to infinity. If more questions were raised than information and decisions were given, the value drops below one. Questions might be unanswered. A value larger than one describes a manner where more information and decisions is given than asked for.

e) Passive vs. Active Communication Style

This metric describes the ratio between the number of sent interaction and the number of received interactions in order to differentiate between passive and active interaction style. A value of one means a balanced ratio of sending and receiving. A value smaller than one resembles a passive interaction style; where the individual receives more interaction than s/he sends. A value larger than one means an active interaction style, where the team member is sending more than s/he is receiving.

E. Procedure

The study started with a briefing, introducing the research topic and also explaining the goals of the PBAM concept as the operational basis for the study. As can be seen in Tab. 1, after the briefing participants had 80 minutes to familiarize with the simulation and the graphical user interfaces, under supervision of trained observers. This step also included a training scenario where participants could test all functions.

Afterwards there were two simulation runs; each lasted 45 minutes followed by the team effectiveness questionnaire. During the simulation runs the stakeholders’ interaction was observed. After a short break, participants were briefed on the guidelines for cooperation and also conducted a training run. Afterwards, the third simulation run took place, followed by
the questionnaires. The experiment was then accomplished by the final debriefing.

<table>
<thead>
<tr>
<th>TABLE I. PROCEDURE OF STUDY FOR EACH TEAM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Duration</strong></td>
</tr>
<tr>
<td>60 min</td>
</tr>
<tr>
<td>80 min</td>
</tr>
<tr>
<td>45 min</td>
</tr>
<tr>
<td>45 min</td>
</tr>
<tr>
<td>25 min</td>
</tr>
<tr>
<td>45 min</td>
</tr>
<tr>
<td>30 min</td>
</tr>
</tbody>
</table>

F. Sample

16 experts from German speaking airports participated in the study, 14 where male. The average age was 42 years (sd = 7, min = 29, max = 52) and the average professional experience was 8 years (sd = 8, Min = 0, Max = 25). The minimum number of zero years is due to the fact that in two teams, three experts from the DLR not involved in the project but familiar with the topic, participated to fill up the teams in case the required number of experts were not sufficient experts available at that date. All were familiar with the A-CDM concept and were recruited to act in the study according to their professional role. If requested, the experts received 280 € (including time for an additional, independent study) and travel cost reimbursement for their participation in the study.

V. RESULTS

A. Influence of Guidelines on experienced Team Effectiveness

First, it was of interest to see whether and in how far the guidelines for cooperation had an influence on the subjective evaluation of team effectiveness. Descriptive data, separated for each team, are shown in Fig. 4. Overall, rating for team effectiveness in runs with a free structure was mean = 3.6, (sd = 1.0) and in runs with guidelines mean = 4.1 (sd = 1.1). As shown in Fig. 4, the mean value of team effectiveness is higher within each team when using the guidelines compared to simulation runs without the guidelines.

The rather high standard deviations in team 1 and team 4 (cf. Fig. 4) also highlight that there are strong inter-individual differences in the evaluation of team effectiveness. Therefore, to control for these differences, a repeated measurement ANOVA with factor free structure vs. guideline was calculated. The difference in the ratings reached the required level of significance (F(1,12) = 9.35, p = 0.01, η² = 0.44). Independent of the team, participants rated team effectiveness with guidelines significantly better.

When comparing ratings for single items, the top three biggest differences in the evaluation caused by the guidelines were related to:

- the team has clear agreements about how decision will be made (mean_free = 3.13, sd = 1.16, mean_guide = 4.19, sd = 1.22, Δ = 1.06)
- with guidelines there are effective procedures to guide team functioning (mean_free = 2.97, sd = 1.15, mean_guide = 3.81, sd = 1.05, Δ = 0.84)
- the team works constructively on issues until they are resolved (mean_free = 3.38, sd = 1.45, mean_guide = 4.06, sd = 1.39, Δ = 0.68)

B. Influence of Guidelines on Interaction

1) Influence on Interaction Quantity

All simulation runs lasted for 45 minutes. Within this time, the observed interaction quantity ranged from a minimum value of 77 interactions to a maximum of 153 interactions. The number of interactions per team is shown in Fig. 6. As it can be seen, teams and runs differ strongly regarding the interaction quantity. Furthermore, there is no consistent trend regarding the development of the interaction quantity. Whilst team 2 and team 3 reduced interaction quantity over three runs, team 1 increased quantity and team 4 had no linear trend. However, a reason could be an order effect caused by the different scenarios. The order of the three different scenarios was randomized between the teams, but teams 2 and 3 had the same order of scenarios.

![Figure 4. Results of the team effectiveness survey](image)

![Figure 5. Bar plots with the quantity of interactions per 45 minutes per team and simulation run](image)
The percentage of interactions within the three functional categories was determined. Overall, 8% of all interactions (sd = 4.5) had a socio-emotional function, 13% (sd = 8.2) had a control function and the vast majority was related to knowledge combination (83%, sd = 27.6). As interactions can have multiple functions, the sum of categories is larger than 100%. It becomes apparent that in average guidelines for cooperation mainly influenced the knowledge-combination function of interaction, the absolute and percentage numbers of socio-emotional and control function was rather unaffected by guidelines.

2) Conformity with Guidelines

It was of interest whether teams applied the structure and interaction paths suggested by the guidelines in the respective simulation runs. The percentage of normative behavior per simulation run and per team can be seen in Fig. 6.

The conformity differs between teams and is very likely influenced by additional factors like personality and experience.

3) Style and Manner of Knowledge Combination

Knowledge combination was the most frequent function of the team’s interactions (mean = 83%, sd = 28). It was of interest, in how far the guidelines for cooperation influence the style how knowledge combination is conducted. With regards to the overall frequency, in runs with free structure 95 interactions were related to knowledge combination and 76 in runs with guidelines.

In Tab. 4 relative frequencies per sub-category for runs without and with guidelines are shown. Tab. 3 matches these numbers with the absolute frequencies. In both conditions, free structure and guidelines, the amount of information shared within the teams is quite similar, with 36 information without guidelines (sd = 14) and 39 interactions in the conditions with guidelines (sd = 10). As can be seen, only the absolute amount of questions raised is nearly halved in conditions with guidelines (28, sd = 7 vs. 16, sd = 5). The relative frequencies in Tab. 4 show the difference with regards to percentage of information (meanfree = 37%, sd = 9, meansguide = 51%, sd = 8) and question (meanfree = 31%, sd = 6, meansguide = 21, sd = 8) when applying the guidelines to decision making process.

When analyzing the raw data, in runs with a free structure the ratio for pro-active communication is 1.65 (sd = 0.34), in simulation runs with guidelines it reaches 3.49 (sd = 1.58). Concluding, whilst in both conditions knowledge combination had a pro-active style, this behavior was more prominent when applying guidelines.

C. Mitigation of individual Characteristics by Guidelines

Behavior of individuals within teams is determined by numerous factors. Within this study it was expected that guidelines for cooperation could standardize individual and therefore team behavior, meaning that the influence of individual and personality factors could be suppressed or mitigated.

As one example for individual communication behavior active and passive interaction behavior was determined. For
each team member his/her individual ratio was calculated (according to the steps explained in section 4 in this paper). If the person reached a value larger than 1, this behavior was rated as active, a value lower than 1 was rated as passive. Summarized over all runs, in 30 cases the participants had an active communication style and in 18 case a passive style. Hence, in each run, between 31 and 43% participants had a passive interaction behavior, so all runs were quite comparable.

An analysis of variance for the team effectiveness was calculated with the factor active-passive. Over all runs, persons with a passive communication behavior rated teamwork significantly better than individuals with an active communication behavior ($mean_{active} = 3.49$, $sd = 1.15$, $mean_{passive} = 4.16$, $sd = 0.67$, $F(1,46) = 5.00$, $p = .030$, $\eta^2 = .098$).

Afterwards, the correlation between this activity ratio and the subjective evaluation of team effectiveness was calculated separately for each simulation run. The statistical values are summarized in Tab. 5. In general, the results replicate that there is a negative correlation between activity and evaluation of team effectiveness ($r$ coefficients in column 2). Passive team members (those who receive more interactions than sending out interactions) tend to be more satisfied with the team effectiveness. This correlation furthermore tends to be significant for the second freely structured run, but not for run 1 and run 3 with guidelines.

| TABLE V. CORRELATION OF SENDER-RECEIVER-RATIO AND SUBJECTIVE TEAM EFFECTIVENESS |
|---|---|---|---|
| Run | $r$ | $R^2$ | $p$ |
| Run 1 (free structure) | -0.57 | 0.14 | .16 |
| Run 2 (free structure) | -0.48 | 0.24 | .06 |
| Run 3 (guidelines) | -0.40 | 0.16 | .12 |

Research on teamwork assumes that teams develop over time and norm their behavior according to the specific characteristics of their work. In case an individual team member tends to have an active communication style this might become more apparent over the course of time but not at the first time the team is working together. This might explain the stronger correlation in the second run compared to the first run. When introducing the guidelines for cooperation, this trend is discontinued. The statistical values are comparable to the first run. Consequently, when applying the guidelines for cooperation also team members with a more active communication style tend to rate team effectiveness better.

VI. CONCLUSION & OUTLOOK

This paper proposed guidelines for cooperation to structure the decision making process in an airport operations center. These guidelines were designed to overcome the problem of missing, irrelevant and late information in current airport coordination. An airport simulation was set-up and a planning task was created where stakeholders had to agree on an updated departure sequence whilst following their individual, competing goals. The decision making process with the guidelines applied was compared to decision making with a free structure. Satisfaction of stakeholder teams was assessed, as well as in how far the guidelines were applied and whether they could mitigate the influence of individual interaction behavior.

First, the results show that with guidelines participants rated team effectiveness of the decision making process significantly better. Even though the teams in this study demonstrated quite different interaction behaviors, in all teams the guidelines received better results than the free, unstructured process.

With regards to the observable team interaction behavior other factors seem to have a stronger influence than the guidelines. For instance, team members’ personality is likely to influence interaction quantity stronger than the proposed guidelines. Conformity with the guidelines also seemed to be dependent on individual attitudes and team composition.

Data on individual’s personality was gathered in the study but was not used for this research question. Further analysis needs to be conducted to assess whether it is possible to mitigate potential negative effects of personality by means of guidelines.

There is a first descriptive trend that the guidelines reduce the amount of interaction needed to combine knowledge within the team by reducing questions. It could be shown that by applying the guidelines, information sharing within teams was more pro-active. This result is encouraging as this behavior could overcome the deficits of today’s stakeholder interactions at an airport. Furthermore, pro-active information sharing is more efficient compared to a situation where each stakeholder needs to extract information from the abundance of data available at an airport. Because of that, guidelines are a promising approach for the collaboration in decision making.

With regards to team interaction processes, the study revealed that team members with an active communication behavior tended to rate team effectiveness worse than team members with passive interaction behavior. Whilst it is beyond the scope of this study to fully understand the reasons behind this, it could be shown that guidelines have the potential to mitigate this effect up to a certain degree. Guidelines for cooperation might be a mean to ensure satisfaction with operational procedures when being applied in everyday operations.

It has to be mentioned that scenarios were designed and individual goals were selected in a manner that not all individual goals could be accomplished. Within the simulation, costs of delay for ground handler and airlines were calculated based on planned time stamps and their deviation to the original schedule. This data could be used as an objective indicator for stakeholder’s performance and is currently analyzed. However, the simulation set-up was not designed to conduct a performance assessment of overall airport operations but to enable the decision making process. Aspects not covered in the scenario and simulation set-up are airport network management and passenger flows. Furthermore, to reduce complexity of the problem, arrivals were not affected by the events.

The authors do not assume that guidelines for cooperation always lead to a mathematically optimal decision. Whether cooperative behavior in the planning phase actually affects
airport performance positively is likely to also depend on factors like airport size, traffic numbers and network effects, to name a few. There is research and evidence that improved information sharing also improves airport performance indicators in a simulated environment [34] as well as in real operations at airports where A-CDM is implemented [35]. The results of this study support the thesis that guidelines for cooperation enable information sharing and decision making in a structured manner between stakeholders with competing goals. Further research should investigate whether the guidelines can be applied to teams with more than four members and in situations where power and hierarchy is less balanced. The results cannot be extrapolated to other European airports since cultural aspects were not considered.

The influence of personality on collaborative decision making processes should also be analyzed in more detail. The guidelines for cooperation did not lead to an overall standardization of the interaction process. Hence, selection of personnel for control rooms is additionally required to ensure effective and efficient decision making processes and thus enable cooperation at an airport.

ACKNOWLEDGMENT

We want to thank Franziska Koch, Lea Höfer, Johanna Günzl, Joshua Ehrlich, Christina Stricker, and Malica Tölle for their support in the preparation of these guidelines, the support in setting up the study and in data analysis.

REFERENCES


**AUTHOR BIOGRAPHIES**

**Anne Papenfuss** is a researcher in the Human Factors department. She is investigating the interaction behavior of teams and develops concepts for successful teamwork in ATM.

**Nils Carstengerdes** is a researcher in the Human Factors department. He conceptualizes and conducts studies to evaluate novel concepts in ATM.

**Sebastian Schier** is a researcher in the Air Traffic Simulation department. He designs and set-ups high-fidelity simulation environments for ATC and airport concepts.

**Yves Günther** is a researcher in the Air Transportation department and analyses and develops concepts to improve air transport performance.