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What to say when: Guidelines for Decision Making

An evaluation of a concept for cooperation in an APOC

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***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 the airport have different goals for their specific operations, resulting in a variety of (latent) conflicts
- thus, cooperation between stakeholders is affected
- the better the coordination between stakeholders at the airport, 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. defined control centers as a socio-technical system, where operators act in different roles. They spatially and temporarily coordinate the resources required for their operations (staff, technology) and by doing this they either follow a schedule, or react upon an unforeseen event [1]. A control center consists of both - human operators and technology, assisting the human operator. The human factor therefor is crucial for defining and installing an APOC.

B. Existing Concepts and Ideas for Airport Operation Centers

As was shown in the previous section, 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 every 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]). In 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].

C. Gudelines for Cooperation and their Impact on Decision Making and Interaction

The work resulting in this paper differed from the aforementioned approach by starting with job and task analyses for each airport stakeholder. Within DLR's internal project P-AIR-FORM job shadowing was done on different German-speaking international airports. Stakeholders like airlines, airports, ANSPs and ground handlers have been visited for one to two days each and aspects related to the job, procedures and organization were explained and questions were answered using a semi-structured interview [14][15]. The analyses revealed that a lack of information exists on airports, especially regarding coordination between different stakeholders and timely information sharing. Stakeholders asked for better transparency regarding the consequences of actions of other stakeholders on their own plans (see [3] for details). From these results it became clear that a structured communication guideline is needed in APOCs to overcome existing communication and collaboration shortcomings. The results of the analyses provided a basis to formulate communication guidelines.

For this purpose a guideline for a chronological arranged execution of operational processes has been developed to fulfill a defined goal (workflow). All stakeholders involved in a task work together and include information of others in their own processing and provide information and decisions which are used by the other stakeholders.

Today, comparable checklists exist for situations like a heavy thunderstorm or snowfall at the airport. They regulate the information flow so that the event is known to all concerned stakeholders. The guidelines for cooperation broaden this idea, so that further information and decisions relevant for airport performance, are shared in a structured manner between stakeholders.

II. Background and Theory

A. Cooperation and relevant Mechanisms

Within the socio-technical system APOC, it is of importance how stakeholders work together. Cooperation, as a term, is also defined as the output of teamwork processes [16] and describes the quality of working together [17]. In order to establish a cooperative manner of working together, a mutual goal is required towards which stakeholders work [18].

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.

B. 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 where 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. The guidelines standardize the 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 proceses in the APOC does not only ensure the flow of the 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 the APOC decision making concept. A great advantage of human operators is their flexibility and creativity in finding solutions to 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 creatively 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 decision making within an airports operations center. 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 the 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*

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]).

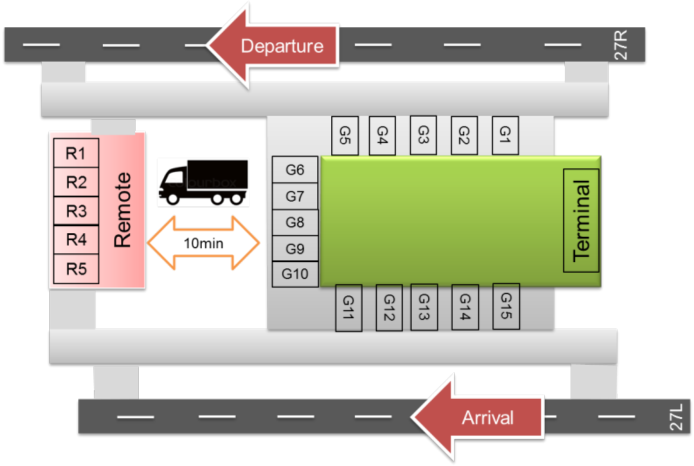

Figure 1. Scheme of the airport model and the resources

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.

For this experiment a virtual 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 longer than at terminal stands.

The scenario consisted of 45 arrival flights and their connected departure flights scheduled for takeoff in a period of approximately two hours. Fig. 2 shows the distribution of the demand per 15 minutes. The red rectangle indicates the 30-minute interval, where capacity at the airport was reduced due to an external event, e.g. in one scenario a heavy thunderstorm. The departure demand thus was shifted to later time intervals. Because the shifted demand added to the scheduled demand, the overall demand was too high for the capacities available, so delays occurred. The stakeholders had to decide on an adapted departure sequence which minimized delay and takes into account their individual goals.

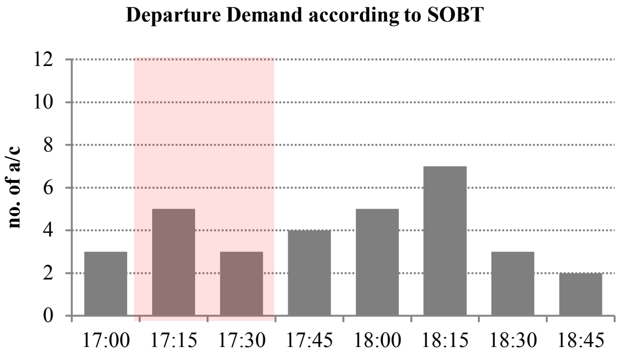

Figure 2. Bar plot of the departure demand in the simulated traffic scenario. Red rectangle indicates the time-interval of the external event.

Within this experiment a subset of the user roles was provided:

- Two airline dispatcher: Both dispatchers were responsible of defining target off block times (TOBT) of their flights and the rotation schedule.
- Airport operations: Responsible for stand and gate allocation
- Ground handling staff manager: Responsible for allocation of ground handling teams. Depending on team size, the staff manager was able to influence turn around duration by varying the team size
- Supervisor: Taking over the role of the tower supervisor, responsible for departure planning (using a pre departure planner).

All users of the airport management simulation were able to access flight and airport data in the data base. Thereby the information sharing concept of A-CDM is implemented. The access to the database is provided by different graphical user interfaces. All of these 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 stakeholder from different airports to familiarize quickly with the interface.

Upon initialization, the scenario was loaded into the airport management simulation. The supervisor informed the other users about the occurring problem (e.g. thunderstorm – no ground handling, construction site – multiple stands out of operation, ATC software failure – reduced departure rate). The concerned resources were then marked as blocked by the event and all stakeholders started negotiating on the best suitable actions and decisions to overcome the problem. At the latest, after 45minutes participants were asked to enter their final solution.

The focus of the experiment was to use the airport management simulation for a planning task without dynamic aspects like movements of aircraft. So, the departure sequence and the rotation were only updated in case a stakeholder sent a change of the TOBT to the database. In principle the airport management simulation provides a simulation dynamic (cf. [30]) calculating airport and flight processes and setting A-CDM milestones. This could have been used if further events were meant to occur or if the rotation of the airlines should be regarded further.

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 the 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.

Each observer coded all interactions sent and received by the stakeholder under his/her observation. For each single unit of meaning the time 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 questions, 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. 3.

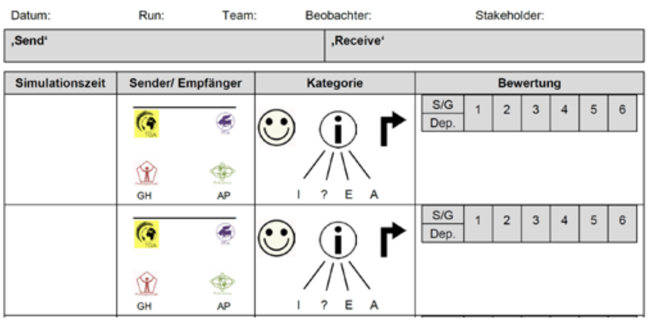

Figure 3. Part of the observation sheet used for capturing interaction data

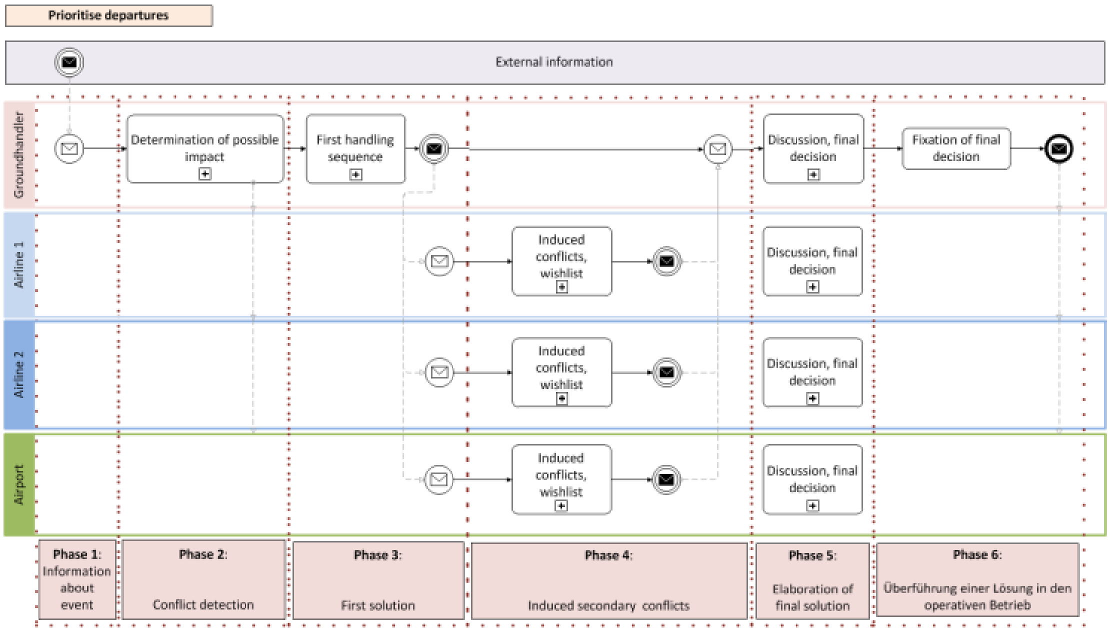

Figure 4. Generic phases of the simplified "guideline for cooperation" (example: "prioritise departures")

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. The double coded interaction can be used to calculate the inter-rater-reliability of the coding scheme. The combined data table was used to calculate metrics describing interaction and communication behavior.

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, the 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.

1) 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 in their information and decisions about priorities, resources and intention. It is assumed that today each stakeholder plans their resources independently but without knowing exactly the effects onto the plans of the other stakeholders. The impact is feed back into the airport data base only after the replanning has been conducted.

It is expected that with the guidelines, the consequences and interdependencies of the individual planning become apparent instantly. 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.4.

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 jointly plan for the sequence of TOBTs is agreed upon. Finally the ground handler fixates the joined 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 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 lager than three a favor for positive team behavior attributes.

b) quantitiy 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. Therefore, on basis of the interaction data table a transition matrix is created. The sum of all columns equals the overall interaction quantity. 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.

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 resembles 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 decision 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 back.

D. 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. This step also included a training scenario where participants could test all functions.

TABLE I. PROCEDURE OF STUDY FOR EACH TEAM

Duration	Step
60 min	Briefing on PBAM concept
80 min	Training with simulation environment + training simulation run
45 min	Simulation run + observation of interaction
	Team effectiveness questionnaire
45 min	Simulation run + observation of interaction
	Team effectiveness questionnaire
25 min	Briefing and training guideline
45 min	Simulation run with guidelines for cooperation + observation of interaction
	Team effectiveness questionnaire
30 min	Final debriefing

Afterwards there were two simulation runs; each lasted 45 minutes followed by 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.

E. 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 there 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 for cooperation on experienced 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 the team effectiveness. The descriptive data, separated for each team, are shown in Fig. 6.

Overall, mean 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 it can be seen in Fig. 5, the mean value of the team effectiveness is higher within each team when using the guidelines compared to the simulation runs without the guidelines.

The rather high standard deviations in team 1 and team 4 (cf. Fig. 5) also highlight that there are strong inter-individual differences in the evaluation of the team effectiveness. Therefore, to control for those differences, a repeated measurement ANOVA with the factor free structure vs. guideline was calculated. The difference in the ratings reached the required level of significance ($F(1,12) = 9{,}35$, $p = 0.01$, $\eta^2 = 0.44$). Independent of the team, all participants rated team effectiveness with guidelines significantly better.

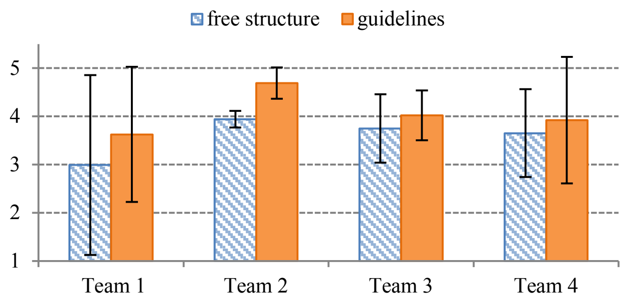

Figure 5. Results of the team effectiveness survey

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

- 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 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)
- the team works constructively on issues until they are resolved ($mean_{free}$ = 3.38, *sd* = 1.45, $mean_{guid\ e}$= 4.06, *sd* = 1.39, Δ = 0.69)

B. Influence of guidelines on interaction

1) Influence on interaction quantitiy

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 the interaction quantity over the three runs, team 1 increased the quantity and team 4 had no linear trend.

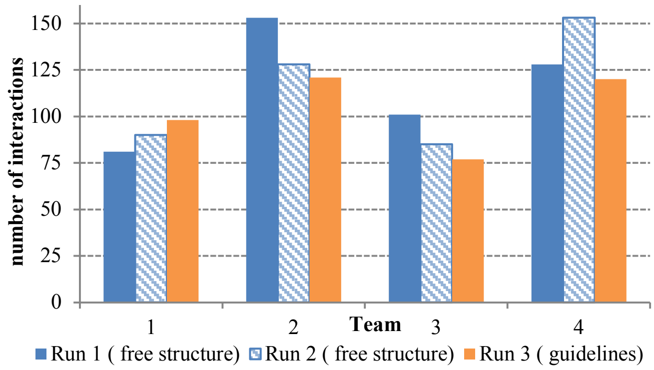

Figure 6. Bar plots with the quantity of interactions per 45 minutes per team and simulation run

In average, teams interacted 115 times per run with a free structure (*sd* = 30), and 104 times in runs with the guidelines (*sd* = 21). The analysis of the descriptive data supports the hypothesis that guidelines might lead to a standardized behavior that is less influenced by specific factors of the team and its individual team members or the scenario itself.

In addition to the overall quantity of interactions as a metric of activity within the team, the quantity within the functional categories was calculated. The numbers are summarized in Tab. 2. The most right columns indicate the descriptive trends observed.

The percentage of interactions within the three functional categories was determined. In the overall mean, 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 the guidelines for cooperation mainly influenced the knowledge-combination function of interaction, the absolute and percentage numbers of the socio-emotional and control function was rather unaffected by the guidelines.

TABLE II. QUANTITY OF INTERACTION AND THEIR FUNCTION

	free structure	sd	guide-lines	sd	*
Interaction	115	(30)	104	(21)	▶
Knowledge Combination	95	(27)	76	(13)	▼
SocioEmotional	8	(5)	8	(3)	▶
Control	14	(11)	14	(4)	▶
%_KnowledgeCombination	82	(8)	74	(6)	▼
%_SocioEmotional	8	(5)	8	(3)	▶
%_Control	12	(7)	13	(2)	▶

* descriptive trend of the difference between free structure and guidelines

2) *Conformity with guidelines*

First, 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. 7. First, the percentage differs strongly between teams. All teams followed to a certain degree the normative behavior, even without having the guidelines implemented. Team 2 did not use the proposed structure in runs with guidelines, whilst team 4 applied the structure to a high percentage ($mean_{\text{guidelines}} = 30\%$). Teams 1 and 3 had in the third simulation runs (with guidelines) only slightly more conformal transitions as in the first run.

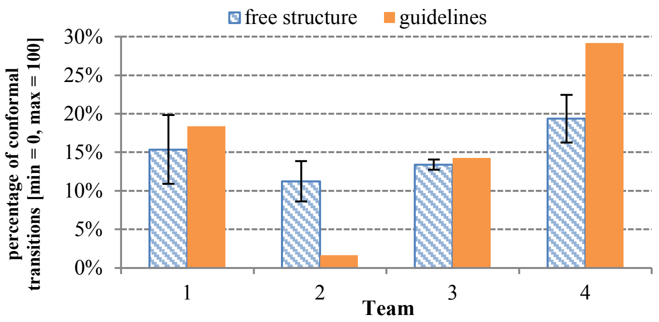

Figure 7. Bar plot of the percentage of normative behavior per simulation run

The conformity differs between the team 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.

TABLE III. ABSOLUTE FREQUENCY OF KNOWLEDGE COMBINATION CATEGORIES

	free structure	sd	guidelines	sd	*
Information	35,88	(14,19)	39,25	(10,63)	▶
Question	28,38	(6,59)	15,50	(5,26)	▼
Decision	11,25	(2,82)	9,00	(5,60)	▶
Coordiantion	19,00	(13,54)	12,25	(8,85)	▶
Sum	94,51		76,00		▼

* descriptive trend of the difference between free structure and guidelines

In Tab. 3 the relative frequency 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 percent on this conditions without guidelines (*sd* = 14) and 39 percent in the conditions with guidelines (*sd* = 10). As can be seen, only the amount of questions raised is halved in the conditions with guidelines (28%, *sd* = 7 vs. 16%, *sd* = 5).

Accordingly, the relative frequencies show that there is a difference with regards to the percentage of information and question when applying the guidelines to the decision making process. In runs with a free structure the ratio for pro-active communication is 1.65 (*sd* = 0.34), in the simulation runs with guidelines it reaches 3.49 (*sd* = 1.58). Concluding, whilst in both conditions the knowledge combination had a pro-active style, this behavior was more prominent when applying the guidelines.

TABLE IV. RELATIVE FREQUENCY OF KNOWLEDGE COMBINATION CATEGORIES

	free structure	sd	guidelines	sd	*
%_Information	0,37	(0,09)	0,51	(0,08)	▲
%_Question	0,31	(0,06)	0,21	(0,08)	▼
%_Decision	0,12	(0,04)	0,12	(0,08)	▶
%_Coordination	0,19	(0,10)	0,16	(0,09)	▶

* descriptive trend of the difference between free structure and 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 the guidelines for cooperation could standardize individual and therefor 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, the ratio of passively interacting individuals was between 31 and 43%, 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 ($mean_{passive}$ =3.49, *sd* = 1.15, $mean_{active}$=4.16, *sd* = 0.67, *F*(1,46) =5,00, *p*=.030, η^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**	**R²**	***p***
Run 1 (free structure)	-0,37	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. 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 participants rated team effectiveness significantly better for decision making with guidelines. Even though the team 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 likely 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. It could be shown that by applying the guidelines, the information sharing within the team was more pro-actively. 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 than a situation where each stakeholder needs to extract information from the abundance of data available at an airport. So, guidelines are a promising approach for the collaboration in decision making.

With regards to the team interaction processes, the study revealed that team members with an active communication behavior tended to rate team effectiveness worse than team members with a passive interaction behavior. Whilst it is beyond the scope of this study to fully understand the reasons behind this, it could be shown that the guidelines have the potential to mitigate this effect; even so they did not influence the actual interaction behavior. The guidelines for cooperation might be a mean to ensure satisfaction with operational procedures when being applied in every day operations.

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

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