# Functional Analysis of Human-Human Interactions during Collaborative Decision Making in Flight Operation

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***Abstract*—The objective of this study is to understand the cooperation building process within Human-Human Interaction (HHI) during Collaborative Decision Making (CDM) at a distributed decision making environment across objective functions. It is based upon functional HHI analysis within typical Air Traffic Management (ATM) operation situations.[1]**

**In this paper, different flight and turn-round operation situations are compared and characterized by: (1) a synchronous interaction mode, where all participating operators interact with each other at the same time, and (2) an asynchronous interaction mode, where the participating operators interact with each other at different times. In both situations, only HHI which require cooperation among operators across different locations and objective functions are contemplated. Interactions take place through a written text or speech. Task and decision making for all situations is distributed between operators. The aircraft pilot's perspective and their information requirements during these flight and turn-round situations are used to identify critical information processing during CDM: All situations are usually time constrained, change quickly, and require a highly dynamic information transfer. Thereby, information sharing for decision making can be either homogenous having all operators the same information required or heterogeneous where information is not equally shared among operators.**

**This study relies on a structural model of team collaboration, developed for analysis on the cognitive mechanisms of CDM, and to handle both synchronous/ asynchronous and collocated/ distributed collaboration environments like in geographically distributed and time delayed situations of the military or flight operation.**

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***Index Terms*—Air traffic management, asynchronous distributed collaboration, collaborative decision making, human-human interaction**

## I. INTRODUCTION

UPDATED from ealier projects in United States, the European CDM approach was introduced during field trials at selected European airports with the aim to achieve cooperation at *planning level* via information sharing and common situational awareness (CSA). However, from aircraft pilots' perspective on current air traffic operation, many problems encountered with CDM arise from human-human interactions (HHI) at *action level*; whereby HHI at *action level* refer to interactions with a shorter time span and less abstraction than HHI at *planning level* (Hoc, 2000). Further problems for CDM operation are conditioned on the specific situation of decision making in an *asynchronous*, *distributed* collaboration environment like it can be found in ATM operational decision making. Operators like aircraft pilots or ground handlers communicate with the operational centers of the airlines, ATC, and the airport through speech (e.g. via phone or radio) or written text (e.g. via ACARS). Hence it will be addressed, how the airport CDM information sharing process is influenced by the following variables:

- Interaction Mode (synchronous versus asynchronous)
- Information Distribution (homogenous versus heterogenous)

This functional analysis of flight situations also includes *micro* level (neural-cognitive) aspects on CDM. Even little understanding of operators think during CDM in asynchronous, distributed environment exists [25], an analysis of HHI within CDM via the perspective of a single operator (aircraft pilots) is used in order to cope with the still very inadequate mechanisms of collaborative problem solving during operators' decision making. According Ferber [1], HHI situations can be classified as antagonistic, cooperative, or indifferent depending on three main variable components like *aims*, *resources*, and *abilities*, hold by each participating operator. This classification is applied in order to understand micro level cognitive aspects of HHI in Airport CDM flight operation situations. The advantage of using aircraft pilots as


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reference group is that there is a non punishment philosophy against pilots in dealing with punctuality problems: The presently use method of *delay assignment* intends to find out the reason of delay and assign the responsibility to a single operator via delay codes. Usually each operator tries to avoid assignment of a delay because a pay deduction has to be expected.

In this paper, prototypical HHI situations between all operators involved in flight and turn-round operation are introduced. They all take place in a distributed collaboration environment. Four proposed situations concern the turn-round of aircraft, where coordination of processes is necessary; processes include parking, ramp side, land side, and special ground handling processes. Within these situations, cooperative HHIs are mandatory: pilots have to coordinate processes with other operators like representatives of the ground handling companies, airport, airline, air traffic control, and Central Flow Management Unit. Cooperation and decision making is distributed between pilots and other operators: Decision making for the begin of all turn-round process which are in direct relation with the aircraft (e.g. boarding, de-boarding, refuelling, cleaning..), is within responsibility of the pilots: other operators are concerned with decision making for coordination and execution of these processes, and again cooperate with each other. While any delayed process start can result in an overall delay of the subsequent flight, coordination of a standard turn-round (defined as a reference model) is usually predetermined.

During normal turn-round operation, *interactions* between pilots and other operators are usually *synchronous*. Coordination of actions takes place via predetermined key events (*milestones*) [8], organized as a sequence of interactions between operators within the airport operation centre; if a non-standard situation like aircraft change, technical repair, adverse weather operation, etc. occurs, ad hoc coordination of all necessary events *via face-to-face* communication between pilots and ramp agents or via radio/ phone between pilots and other operators coordinating from airport operation centre takes place. The *milestone approach* used for CDM, includes *all* events which are necessary for an uninterrupted turn-round process, whereby some key events take place already far ahead of the turn-round itself. Information distribution during turn-round is mainly *heterogeneous* between participating operators on *action* and *planning* level caused by the information dynamics in the highly dynamic environment of the turn-round operation and the varying tasks in the different domains itself. However, in order to cope with the usually limited time span for turn-round operation, CDM targets *homogenous* information processing to achieve a CSA between all participating operators and to avoid departure delay caused by non-standard operation.

Another four proposed situations concern the *flight*, starting from aircraft leaving the parking position until reaching parking position at destination. Coordination here is also necessary for departure and arrival sequencing with other aircraft, usage of taxiways, airways and airspace/ sectors. It is pilots' responsibility to execute the flight according defined rules under consideration of highest degree of safety possible.

Other operator involved during flight for coordination of traffic is air traffic control (ATC) by keeping safe separation distance between aircraft and managing air traffic flow by issuing clearances to the pilots. The different level of control between pilots and other operators like ATC in this situation is that ATC has authority about assigning the airspace in form of clearances to the pilots and again depend on cooperation from pilots, to adhere to these clearances. Decision making is shared between pilots and ATC within their domain relative to the situational need, but has to be executed under mentioned safety constraints. Other operators like the airline company or CFMU are only marginally involved in decision making during flight operation.

During flight operation, interactions between pilots and air traffic control are *synchronous* or *asynchronous* via radio during flight through one sector or when ATC issue clearances to the pilots; interactions between different ATC sectors can also be *synchronous* or *asynchronous*, resulting in a non-coordinated flight through different sectors; interactions between pilots and other operators during flight are usually *asynchronous* and *distributed*. They are coordinated by *milestone events* within the airport control centre. Information distribution for clearances concerning airspace and routing is always homogenous, while information distribution for e.g. reasons of deviations from clearances can be homogenous or heterogeneous depending of the impartation willingness or time in hand from ATC and aircraft pilots.

Like during turn-round operation, the highly dynamic environment of the flight operation results in high dynamic information content. Some information dynamics like variations in flight progress occur on standard basis and changes are automatically accessible to all participating operators via data link transmission. However, non-standard information dynamics like operational changes or technical issues are transferred by non-synchronized interactions and need to be manually transferred between operators. This requires cooperation among operators' interactions and defines the need to achieve a CSA among all operators.

The resulting objectives for the study are:

- To understand the cooperation building processes of the HHI during day-to-day flight operation which are necessary in context of an distributed collaborative decision making environment across objective functions of all operators.
- To identify the information sharing components which should be employed to optimize the CDM concept in ATM typical standard & non-standard flight situations.
- To understand how agents can support humans in achieving collaborative knowledge during distributed collaborative problem solving.

As a result of study, a new CDM process design will be evaluated during quasi-experiments in the natural CDM setting at Munich International Airport which aims at achieving cooperation of all partners involved.


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## II. Theoretical Background

In our context of flight operation, HHI are seen as dynamic relations between pilots and other operators via a number of mutual actions. Each action by one operator has consequences which influence the behavior of the prospective behavior of the operators. Series of actions form events, and a number of events form the turn-round or flight situation (e.g. ATC assigns a parking position for the aircraft to the pilots (event) via mutual communication usually by two-way radio communication (HHI) in a turn-round situation). Ferber [9] defines interaction situations as *a number of behavioral patterns which evolves from a group of agents, who have to act in order to reach their targets and thereby have to regard their more or less limited resources and capabilities*. By using this definition, interaction situations can be described and analysed, because it defines abstract categories like cooperation, antagonism, and indifference via differentiation of observed key commonalities and different interaction situations. The relevant components for classification of interaction situations are the aims and intentions of the different agents, the relations of the agents to available resources, and abilities of the agents in regard to their assigned task. These criteria are used to define different types of interaction situations (*Figure 1*).

| Aims | Ressources | Abilities | Type of Situation | Category |
|---|---|---|---|---|
| compatible | sufficient | sufficient | Independence | Indifference |
| compatible | sufficient | insufficient | simple working together | Indifference |
| compatible | insufficient | sufficient | blockade | Cooperation |
| compatible | insufficient | insufficient | Coordinated collaboration | Cooperation |
| incompatible | sufficient | sufficient | pure individual competition | Cooperation |
| incompatible | sufficient | insufficient | pure collective competition | Antagonism |
| incompatible | insufficient | sufficient | individual resource conflict | Antagonism |
| incompatible | insufficient | insufficient | collective resource conflict | Antagonism |

**Figure 1: Classification of Interaction Situations (Source: Ferber, 2001)**

Each type of interaction situation has its own relation towards cooperation: In an *Indepence* situation, no interaction takes place and sufficient resources and abilities allow a coexistence of operators without any constraint. This situation has no relevance for ATM at congested airports. A *Simple Working Together situation* defines a collaboration situation which does not require coordination between operators, while a *Blockade, Coordinated Collaboration, Pure Individual/Collective Competition* and *Individual/Collective Resource Conflict* are situations which are expected to dominate in our contemplated HHI situations. These situations require coordination between operators and, depending on resources, aims, and abilities, can result in cooperative or antagonistic behavior.

During flight operation situations, HHI are usually not binding relations between involved actors and no mutual influence is exercised between pilots and other operators; therefore social components of the interactions are not contemplated.

According Hoc [12], cooperation can exist within various levels in terms of distance from the action itself: A cognitive architecture of cooperation model classifies cooperation in abstraction level and process time depending on the proximity to the action itself (*Figure 2*).

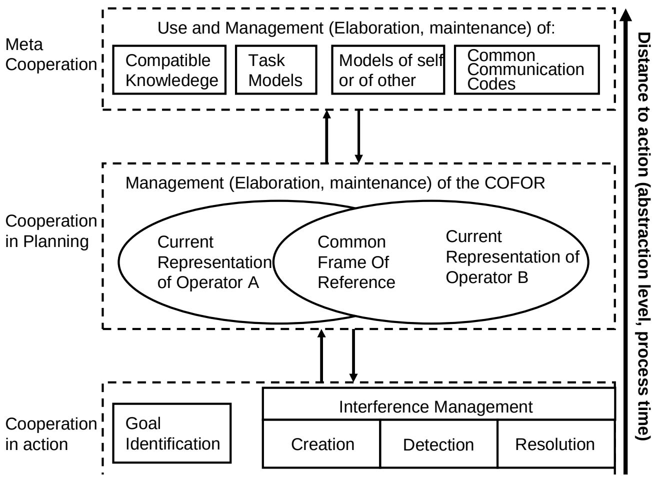


**Figure 2: Processing Architecture of Cooperation (Source: Hoc 2000)**

For the study of HHI situations, we focus on cooperation (or antagonism, if relevant) on action level. At *action level*, the operators perform operational activities related to their individual goals, resources, and abilities. Hoc [14] has defined four types of activities at action execution level which are interference creation (e.g. mutual control), interference detection, interference resolution, and goal identification (Goal identification also embodies identification of other operators goals). Cooperation at action level has short-term implications for the activity, as opposed to the more abstract type of cooperation at planning level. Interference creation relates to the deliberate creation of interactions; interference detection to the ability of detecting interferences, especially in non-deliberate interference situations; and interference resolution to the actual interaction in order to find a cooperative solution. Mutual domain knowledge is the basis for other operators' goal identification, to facilitate operator's own task, the other's task, or the common task.

At *planning level*, operators work to understand the situation by generating schematic representations that are organized hierarchically and used as an activity guide [13]. Schematic representations include the concept of situation awareness [23], and operators' goals, plans, and meta-knowledge [13]; therefore current approach to CDM operation

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in ATM is seen as an approach towards cooperation on planning level. De Terssac and Chabaud [7] use the term COFOR (Common frame of Reference) as a mental structure playing a functional role in cooperation and as a shared representation of the situation between operators likely to improve their mutual understanding [3]. The topmost level in Hoc's model, the meta-cooperation, as a level developed from knowledge of the other two levels, is not contemplated in the study.

Also Piaget [20] distinguishes between cooperation seen from structural (e.g. network organization) or functional point of view which looks at cooperation as activities performed by individuals within a team in real time. Two minimal conditions must be met in cooperative situations: (1) each actor strives towards goals and can interfere with other actors on goals, resources, and procedures. (2) Each actor tries to manage interference to facilitate individual activities or common task. Both conditions are not necessarily symmetric, because goal orientation or interference management depend on individual behavior or time constraints.

Hoc [12] argues that current air traffic management (ATM) is more concerned with operators' plans, goals, or role allocation instead of common situational awareness. But Lee [17] determines situational awareness, responsibilities and control, time, workload, and safety constraints as key factors driving collaborative behavior in air traffic control operation: *To have proper awareness of the situation, a controller and/or pilot needs to initiate or be informed of actions taken by other operators*. But time pressure and safety issues have negative effect on communicative behavior and therefore also cooperation or common situational awareness.

Share of responsibility and control are often different but determined through situation (e.g. air traffic controllers issue clearances which have to be executed by pilots). Nevertheless, *the more assistance, the more anticipative the mode of operation in controllers and the easier the human-human cooperation* [13].

Collaborative Decision Making means *applying principles of individual decision making on groups, whereby groups are established with the aim to show collectively a specific behavior* [15]. This implies that cooperation of participating individuals should be beneficial for CDM operation, also in air transport management. But how does cooperative work look like at day-to-day basis? Cooperation has *a wide variety of connotations in everyday usage* [24]. Do people only cooperate, if they are mutually dependant in their work or is mutual dependency sufficient for cooperation to emerge? In context of CDM operation, confrontation and combination of different perspectives of cooperation is an issue: how is pilot's perspective embedded in the current CDM approach? For Schmidt [24], the multifarious nature of the task can be matched by application of multiple perspectives on a given problem via articulation of the perspectives and transforming/ translating information of different domains.

The challenge of CDM operation in ATM is the unique cognitive mechanisms in a distributed and highly dynamic environment like it can be found in flight operation. Similar situations can be found in military teams with asynchronous, distributed teams for mission planning and mission execution, but in general it is a relatively new area [16]. Other domains which have related aspects to asynchronous distributed collaboration are not contemplated. Warner [7] describes the major factors impacting collaboration which are the *collaborative problem environment, operational tasks, collaborative situation parameters,* and *team types (Figure 3).*

**Problem Area Characteristics**

***Collaborative Situation Parameters:***

**time pressure**
**information/knowledge uncertainty**
**dynamic information**
**large amount of knowledge (cognitive overload)**
**human-agent interface complexity**

***Team Types***

**asynchronous**
**distributed**
**culturally diverse**
**heterogeneous knowledge**
**unique roles**
**command structure (hierarchical vs. flat)**
**rotating team members**

***Operational Tasks***

**team decision making**
**develop shared understanding**
**intelligence analysis (team data processing)**

**Figure 3: Problem Area Characteristics for Collaboration (Source: Warner, 2003)**

His structural model of collaboration focuses on *team decision making, course of action selection, developing shared understanding*, and *intelligence analysis*. Thereby, various parameters can influence the collaboration performance [26]. The collaborative decision parameters can be adapted to fit the specific environment of CDM in other domains using the respective characteristics under *operational tasks*, *collaborative situation parameters*, and *team types*. Werners' structural model of team collaboration uses the minimum number of unique stages identified in team collaboration literature and the results from a Collaboration and Knowledge Management Workshop *(Figure 4*).

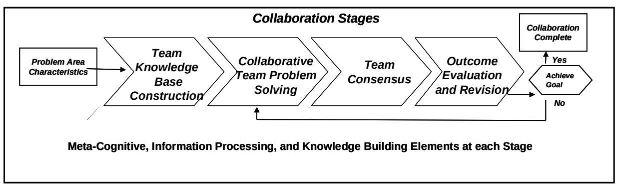


**Figure 4: Structural Model of Team Collaboration (Source: Warner, 2003)**


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This structural model is based on the meta cognitive processes of an information processing and communication approach. For Davidsen [24], meta cognition is the knowledge of one's own cognitive processes in explaining how human cognitive processes are used for problem solving. According Werner, there is 'no generally recognized unified theory of human cognition'. By implementing Ferbers' component approach, a micro level cooperation perspective is applied into the structural collaboration model. This approach allows to adapt the structural model of team collaboration to an distributed decision making environment under consideration of decision making across objective functions (e.g. like Airport CDM).

## III. METHODS

A methodological approach is used for the analysis of the cooperative mechanisms within HHI. First, all flight & turn-round situations which are seen as critical for CDM operation in terms of punctuality are determined via in-depth interviews with senior commanders of different airlines. All situations were decomposed in elementary activities and thereafter grouped into event classes. The classes within turn-round situations include the subclasses gate assignment, standard ramp services, standard land-side services, and non-standard turn-round services. Flight situations include the subclasses clearance variations 'ground', clearance variations 'flight', information processing, and information forwarding. Some event classes have only one possible event as problem cause.

For each event class, the collaboration stages analogous Werner's structural model were identified. To understand how participating operators think during each stage, a self-administered questionnaire was developed which aims to get knowledge about information processing (meta-cognitive level) and interaction components (micro cognitive level) between participating CDM operators within distributed collaborative decision making. All questions were designed from the perspective of the airline pilots as members of distributed airport collaborative decision making. (Perspectives of other operators could also usefully be researched). As reported by airline pilots, all event classes have critical elements concerning collaboration. Therefore the questions are designed to find the most problematic stage within the collaboration process.

*Team Knowledge Base Construction* is the first stage in team collaboration and includes steps like identifying relevant domain information, selecting team members, setting up the communication environment, individual team' members own mental model of the situation, and developing individual and team task knowledge. In ATM, information processing is established in day-to-day operation via various communication modes like phone, ACARS, or radio. Whereby, agreed methods of information sharing or filtering are established among all operators within the airport operation centre, while information sharing between distributed operators like airline pilots or air traffic control is not taking place on an agreed standard. Therefore, an overall cognitive process of how to understand elements, relations, and conditions that compose the emerged problems, is not established among operators (meta cognitive), even some operators may have a mental model of situation parameters and their relationship. The airline pilots as operators of distributed site are asked to state, if information sharing for this stage is seen as sufficient for knowledge building and how important information sharing is for them. No further details like *how* or *which* information should be collected, how to understand problem task, or how communication mechanisms should be established, are analysed at this stage of research.

For the stage of *Collaborative Team Problem Solving* a closed-end question is designed to again catch the overall airline pilots' perspective from distributed participation in CDM. This stage can only successfully be accomplished, if a shared situational awareness of the emerged problem exists, because it builds on the identified and understood problem among all operators. This stage starts after information are processed among operators and has the aim to find a viable problem solution. Since each participating operator has its' unique domain constraints, the definition of a global goal and solution alternatives among all operators is the challenge for this collaboration stage. For the functional analysis, an approach at micro cooperation level is pursued and questions are developed analogous Ferbers' component model, which are *commonality of aims* among participating operators, *amount of resources available*, and *ability of function* to perform assigned task. All three components together form different interaction categories and give evidence about cooperation (or antagonism).

The stages of *Team Consensus* and *Outcome Evaluation and* Revision will not be used for this first phase of research.

The components from Ferber [9] which classify the interaction situations are:

- *Compatibility and Incompatibility of aims:* Effect on cooperation can be negative, if aims are not compatible. Therefore critical activities during turn-round and flight are questioned for possible conflicting goals between pilots and other operators.
- *Availability of resources*: Resources are limited, therefore conflicts can arise which result in disturbances of HHI. Increasing airport congestion and abridged turn-round time of aircraft contribute to possible shortage of resources and result in reduced latitude of action or even individual competition between operators. Questions are out to test, if resources in terms of the time available for ground processes are aligned with the operational and safety requirements. Current approach on CDM operation is an attempt to challenge resource constraints via coordination of actions.


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In this context, information is also seen as a *resource* which has to be available to each operator in order to execute individual task: Information has to be shared between pilots and other operators to achieve common situational awareness. Initial data from interviews relate numerous problems regarding to cooperation on failures in information sharing. A number of elementary activities/ events are used to obtain data about possible reason for failed cooperation and effects on flight punctuality caused by information sharing problems. Questions are out to test, if there is a relation between failures in information sharing and delay (departure or arrival delay). Failure is seen, if a part of information is missing or if information is not delivered on-time.

- *Ability of operators in relation to their assigned task*: It can not be assumed that knowledge and abilities of operators are automatically sufficient for executing assigned task. This is of course also appropriate for pilots, but it is unlikely to get realistic results from questioning of pilots, if the person asked has to determine or admits its' own inability. On the other hand it is unlikely that pilots are familiar with all other domains involved and can determine necessary abilities from other operators. Therefore only random questions are out to test pilots' perspective in a few events like failed information sharing or unpunctual process execution.

Finally, semi-structured in-depth individual interviews with further representative commanders will be conducted to clarify the content of the questionnaire results. This is necessary to capture the meaning behind the essential results and to understand operators' attitude towards cooperation.

## IV. DEMONSTRATION

Data collection is still ongoing, only primary results are available to demonstrate usefulness and applicability of the survey.

### A. *The Environment of the Cockpit*

Activity analysis on flight decks of commercial aircraft shows two pilots sharing flying and other duties like communication with ATC, monitoring flight instruments and all other tasks necessary. While pilot flying is responsible for steering and navigation of the aircraft, pilot not flying disburdens him with all other duties necessary in order to maximize safety by clear task sharing, since primary responsibility of the pilots is to steer the aircraft from departure to destination airport under maximum possible safety considerations.

In various situations they encounter interactions and interrelations with other actors involved in ATM operation. Flight relevant and operational information is shared with them.

The environment of the aircraft specifies a special case of decision making: the commander of the aircraft has the topmost responsibility of all decision making on board the aircraft. This can be compared as decision making with an individual decision maker and a group of advisers. He can either use his position to listen to his various advocates of different positions or actions or execute a structured analysis by the use of help from experts or advisers (airline company, ATC, ground handlers….). It is his final responsibility to identify key uncertainties in decision making and either adhere to objectives for the organization or his personal goal. Conflicts can arise through levels of authority and responsibility between advisers and the cockpit. Further losses of efficiency in this kind of decision making may result from other players' interactions, lack of information or limited ability of decision making. The advantage from this individual decision making is that a group of advocates is involved and therefore has more resources available [21]. Decision making seen from cockpits' perspective is also distributed since a number of decisions necessary for the flight operation remain in responsibility of the advisers (ATC, airline company, airport….).

*Figure 5* shows a typical flow of HHI from cockpit's perspective identified from own experience: Aims, resources, and abilities form the basis for information exchange, decision making, and possible negotiation. Information exchange again is the basis for common situational awareness and coordination among operators. Decision making anticipates information exchange among actors which can also be used for mutual's goal identification.

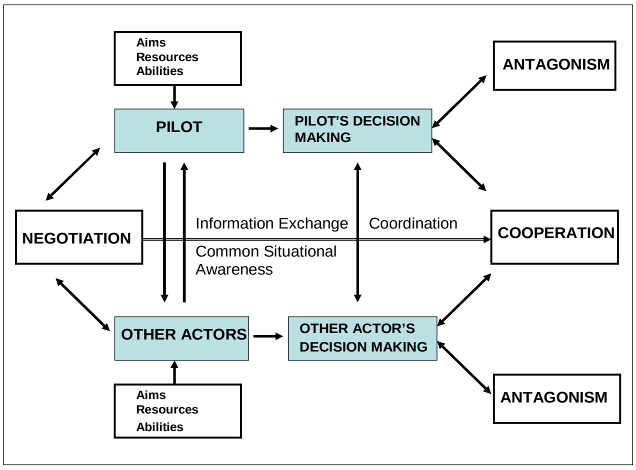


**Figure 5: Cockpit's Perspective of Human-Human Interactions in ATM (Source: Own Illustration)**

### B. *The Collaborative Decision Making Approach in ATM*

The basic Airport CDM includes *Airport CDM Information Sharing* and the *CDM Turn-round Process* as a requirement for all subsequent airport CDM applications. Information sharing uses existing infrastructure at airports, but combines


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data from different sources and operators. Quality of information at each phase of flight is determined by defined rules in order to establish a common situational awareness between all operators involved.

The *Milestones Approach* defines the airport CDM turn-round process which links the flight and ground segments via a set of milestones in the aircraft turn-round process, ranging from planning of the inbound flight until the take off of the flight at the subject airport. Each milestone is monitored and allows participating operators to identify possible deviations from schedule by the use of an alarm system.

Subsequent Airport CDM levels are the *Variable Taxi Time Calculation* and the *Collaborative Management of Flight Updates (Level 2)*. Variable taxi time calculation aims the introduction of a realistic taxi time in order to increase punctuality and slot adherence. Collaborative management of flight updates aims an improved operation and flexibility by slot swapping and slot shifting to take aircraft operators' preferences into account.

A *Collaborative Predeparture Sequence (Level 3)* aims to replace the present 'first come first serve' practice by consideration of aircrafts' and airport operators' requirements. [8].

### *C. Shared Situational Awareness between Pilots and Other Operators*

Technological advances now allow communication and collaboration without being physically together. ATM systems today have adopted these technologies; however the highly dynamic environment of flight operation requires a fast and flexible adaptation to the changed situation. CDM is an answer to tackle problems with the short time span in hand for decision making, but no procedures are established to include interactions with airline pilots as standard CDM process. ACARS, phone, or radio are in place as possible collaboration support tools for synchronous or asynchronous decisions between airline pilots and other operators to contribute to the information sharing/ knowledge building process. Current approach to information sharing/ knowledge building is the issue of a Target Start Up Approval Time (TSAT) and a Target Off Block Time (TOBT). TSAT is a reference start up time for coping with air space constraints, TOBT has airport, airline and turn-round constraints as determining factors. Both should match as close as possible and be communicated to distributed decision makers. Constraining factors from airline pilots are not considered for calculation of TOBT or TSAT.

### *D. Critical Human-Human Interactions*

30 pilots from different airlines were asked during unstructured questionning to name processes with problems in regard to HHI during day-to-day flight and turn-round operation. From all mentioned examples, a number of nine situations were defined and *figure 6* provides an overview of critical HHI as reported by the airline pilots. The situations do not have any statistical relevance in terms of importance or frequency; the aim was to find a wide spectrum of possibly critical HHI.

| TURN-ROUND | COOPERATION/ NON-COOPERATION | COOPERATIVE COMPONENT | AIRPORT | FREQUENCY | RELEVANCE |
|---|---|---|---|---|---|
| Gate Assignment | Y/N | Aims/Resources/ Abilities | Hub/ Non Hub | Daily/Weekly/ Monthley | Avoidable Yes/No |
| Ground Handling/ Ramp | Y/N | Aims/Resources/ Abilities | Hub/ Non Hub | Daily/Weekly/ Monthley | Avoidable Yes/No |
| Ground Handling/ Land | Y/N | Aims/Resources/ Abilities | Hub/ Non Hub | Daily/Weekly/ Monthley | Avoidable Yes/No |
| Ground Handling/ Special | Y/N | Aims/ Resources/ Abilities | Hub/ Non Hub | Daily/Weekly/ Monthley | Avoidable Yes/No |

| FLIGHT | COOPERATION/ NON-COOPERATION | COOPERATIVE COMPONENT | AIRPORT | FREQUENCY | RELEVANCE |
|---|---|---|---|---|---|
| RWY/DEP Change | Y/N | Aims/Resources/ Abilities | Hub/ Non Hub | Daily/Weekly/ Monthley | Avoidable Yes/No |
| EAT | Y/N | Aims/Resources/ Abilities | Hub/ Non Hub | Daily/Weekly/ Monthley | Avoidable Yes/No |
| Clearnce Variation | Y/N | Aims/Resources/ Abilities | Hub/ Non Hub | Daily/Weekly/ Monthley | Avoidable Yes/No |
| Operational Change | Y/N | Aims/Resources/ Abilities | Hub/ Non Hub | Daily/Weekly/ Monthley | Avoidable Yes/No |

| PILOT | COOPERATION/ NON-COOPERATION | COOPERATIVE COMPONENT | AIRPORT | FREQUENCY | RELEVANCE |
|---|---|---|---|---|---|
| Information Forwarding | Y/N | Aims/Resources/ Abilities | Hub/ Non Hub | Daily/Weekly/ Monthley | Avoidable Yes/NO |

**Figure 6: Critical Information Sharing Situations (Source: Own Data 2007)**

### *E. Responsibility and control allocation between pilots and other actors*

'*The allocation of functions between humans and machines is a very old topic in human engineering*' [14]. Function allocation in terms of responsibilities and control has been identified as key factor for collaborative human-human behavior in ATM [17].

While air traffic controllers are responsible to separate the aircraft during flight, the responsibility of the pilots is the safety of the aircraft. The environment of the aircraft is a special case of interaction mode: final decision making on board of the aircraft is not shared between equitable partners, but is in the hand of the captain of the aircraft. Other actors take the role of advisers for an individual decision maker. Nevertheless all actions and decisions are obligatory on achievement of safety. The captain may either use his position to listen to his various advocates of different positions, or executes a structured analysis by the use of help from experts or advisers (airline company, air traffic control, ground handler…) It is his final responsibility to identify key


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uncertainties in decision making and either adhere to objectives for the organization or his personal goal.

The research shows that antagonistic or cooperative behavior can arise through different levels of authority and responsibility between the captain and his advisers [21].

Responsibilities on ground are shared among actors: the flight manager is responsible for boarding and check-in processes, ramp agent for delivery of flight documents and other operational information. To achieve cooperation, all actors should have the same aim [14] which implies that HHI take place between *equitable* partners.

### *F. Modes of Information Sharing in Pilot – Other Operators' Relationship*

Central concern of CDM is information sharing and common situational awareness. Many studies have been devoted to information sharing at the airport control centre of CDM participating airports, but no focus has been made on exchange of information to the cockpit or receiving operational information from the cockpit.

Information sharing between airline pilots and other operators involves human activities, but as fare as humans are involved for information provision and creation, failures may occur and have obvious consequences on reliability [19]. Pilots were asked to identify different classes of information failures during all phases of turn-round and flight. From cockpit perspective, the main concern is how information sharing and common situational awareness between flight crews and ground parties is accomplished in order to achieve a predictability and punctuality during flight and ground operation. It has to be addressed:

- How all necessary information is delivered to the cockpit or weather it is jammed at any interface.
- If necessary information delivered on time.
- How the information, forwarded from cockpit, is handled by other actors.
- How much delay is encountered, if information delivery is late or not executed?
- Which information not delivered has the greatest risk of producing delay.
- Which information, forwarded by crew, has greatest risk of producing delay?

### *G. Time Constraints*

Time pressure can have opposite effect on cooperative behavior. During peak traffic and short turnaround, pilot workload is very high for several reasons: Available time for coordination of necessary ground handling processes on ground is short or voice congestion over busy radio frequency demands high attention. Any failures in coordination or any retarded process on ground holds the risk of encountering delay. During flight on busy frequencies, issued clearances by air traffic control need to be executed promptly and often no time is left for negotiation. Especially during approach, high workload does not leave much time to gain situational awareness. Air traffic controllers' constraints are normally not visible to the pilot, but also controllers' time is very limited during busy approach hours, and therefore not much time is left, to share situational constraints or negotiate with the pilot. Especially in these situations, controllers depend on cooperation from pilots.

## V. Conclusion

The analysis of micro level cooperative elements represented by the airline pilots' perspective within a distributed collaborative decision making environment across objective functions, is the first attempt to implement individual group members think into a structural decision making model within the domain characteristics of ATM operation. This study is expected to be useful, because the distributed CDM environment shows unique interaction characteristics and therefore requires a focus on operators' thoughts. The airline pilots' perspective is chosen because a non-punishment policy for pilots when causing flight delays is in place, opposite to other operators who have to expect pay deductions. De Ferbers' interaction classification identifies potential non-cooperative flight situations and results from questionnaire will be used for the design of experiments and possible further interactions in form of negotiations between operators. Experiments will also include modifiaction of interaction e.g. via representation models. The unique situation of individual operators' objective function distinguishes decision making in ATM from decision making in other environments like e.g. military.

Further outcomes of the study are expected to include empirically based elements or design characteristics for collaboration in a distributed decision making environment across objective functions including information processing components. Empirically gained data will be used for development of an agent support in airside flight operation situations.

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