CRANFIELD UNIVERSITY

MATTHIAS GROPPE

INFLUENCES ON AIRCRAFT TARGET OFF-BLOCK TIME PREDICTION ACCURACY

SCHOOL OF ENGINEERING
DEPARTMENT OF AIR TRANSPORT

PhD THESIS
Academic Year 2006- 2011

Supervisor: R.Pagliari
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Supervisor: Romano Pagliari

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This thesis is submitted in partial fulfilment of the requirements for the degree of
Doctor of Philosophy

I. ABSTRACT

With Airport Collaborative Decision Making (A-CDM) as a generic concept of working together of all airport partners, the main aim of this research project was to increase the understanding of the *Influences on the Target Off-Block Time (TOBT) Prediction Accuracy* during A-CDM. Predicting the TOBT accurately is important, because all airport partners use it as a reference time for the departure of the flights after the aircraft turn-round. Understanding such influencing factors is therefore not only required for finding measures to counteract inaccurate TOBT predictions, but also for establishing a more efficient A-CDM turn-round process.

The research method chosen comprises a number of steps. Firstly, within the framework of a Cognitive Work Analysis, the sub-processes as well as the information requirements during turn-round were analysed. Secondly, a survey approach aimed at finding and describing situations during turn-round that are critical for TOBT adherence was pursued. The problems identified here were then investigated in field observations at different airlines' operation control rooms. Based on the findings from these previous steps, small-scale human-in-the-loop experiments were designed aimed at testing hypotheses about data/information availability that influence TOBT predictability. A turn-round monitoring tool was developed for the experiments.

As a result of this project, the critical chain of turn-round events and the decisions necessary during all stages of the turn-round were identified. It was concluded that information required but not shared among participants can result in TOBT inaccuracy swings. In addition, TOBT predictability was shown to depend on the location of the TOBT turn-round controller who assigns the TOBT: More reliable TOBT predictions were observed when the turn-round controller was physically present at the aircraft.

During the experiments, TOBT prediction could be improved by eight minutes, if available information was cooperatively shared ten minutes prior turn-round start between air crews and turn-round controller; TOBT prediction could be improved by 15 minutes, if additional information was provided by ramp agents five minutes after turn-round start.

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I. LIST OF ACRONYMS AND DEFINITIONS

1 Acronyms

ACARS	Aircraft Communication Addressing and Reporting System
A-CDM	Airport Collaborative Decision Making
ACIS	Airport CDM Information Sharing
ACISP	Airport CDM Information Sharing Platform
ADEP	Aerodrome of Departure
ADES	Aerodrome of Destination
A-DPI	ATC-Departure Planning Information Message
ADS	Aeronautical Decision Making
ADS	Abstraction-Decomposition Space
AEGT	Actual End of Ground Handling Time
AGHT	Actual Ground Handling Time
AHM	Airport Handling Manual
AIBT	Actual In-Block Time
ALDT	Actual Landing Time
AMAN	Arrival Manager
ANSP	Air Navigation Service Provider
AO	Aircraft Operator
AOBT	Actual Off-Block Time
AOC	Airport Operator Committee
AOC	Airline Operation Centre
AOT	Airport Operations Team
APT	EUROCONTROL Throughput Division Airport
ARDT	Actual Ready Time (for Movement)
ARTCC	Air Route Traffic Control Centres
ASAT	Actual Start-Up Approval Time
ASBT	Actual Start Boarding Time
A-SMGCS	Advanced Surface Movement Guidance and Control System
ASRT	Actual Start-Up Request Time
ATA	Air Transport Association
ATC	Air Traffic Control
ATD	Actual Time of Departure
ATM	Air Traffic Management
ATFCM	Air Traffic Flow Capacity Management

ATFM	Air Traffic Flow Management
ATOT	Actual Take-Off Time
ATTT	Actual Turn-round Time
AXIT	Actual Taxi-In Time
AXOT	Actual Taxi-Out Time
CDM	Collaborative Decision Making
CEDM	Cognitive Engineering and Decision Making
CFMU	Central Flow Management Unit
CODA	Central Office for Delay Analysis
CPDLC	Controller Pilot Data Link Communication
CRM	Crew Resource Management
CSA	Common Situational Awareness
CSCW	Computer Supported Cooperative Work
CSE	Cognitive Systems Engineering
CTA	Cognitive Task Analysis
CTOT	Calculated Take Off Time
CTRP	CDM Turn-Round Process
CWA	Cognitive Work Analysis
DAA	Delivery at Aircraft
DDM	Distributed Decision Making
DEP	Departure
DMAN	Departure Manager
DMEAN	Dynamic Management of European Airspace Network
DPI	Departure Planning Information message
DSA	Distributed Situational Awareness
DSS	Decision Support System
DTM	Direct Mode Turn-round Management
EATM	European Air Traffic Management
ECAC	European Civil Aviation Conference
EIBT	Estimated In-Block Time
EID	Ecological Interface Design
ELDT	Estimated Landing Time
EOBT	Estimated Off-Block Time
ETOT	Estimated Take Off Time
ETTT	Estimated Turn-round Time

EXIT	Estimated Taxi-In Time
EXOT	Estimated Taxi-Out Time
FAA	Federal Aviation Administration
FADE	FAA/Airline Data Exchange
FMP	Flow Management Position
FUM	Flight Update Message
GEMS	Generic Error-Modelling System
GH	Ground Handler
GUI	Graphical User Interface
HHI	Human-Human Interaction
HCI	Human-Computer Interaction
HMI	Human-Machine Interface
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
IDSS	Intelligent Decision Support System
IFPS	Integrated Initial Flight Plan Processing Unit
IOSA	IATA Operational Safety Audits
ISO	International Organization for Standardization
KBB	Knowledge Based Behaviour
LTM	Local Turn-round Management
MTTT	Minimum Turn-round Time
NAS	National Airspace System
NBAA	National Business Aviation Association
NDM	Naturalistic Decision Making
PAX	Passenger
RAA	Regional Airline Association
RBB	Rule Based Behaviour
RFID	Radio Frequency Identification
RP	Response Planning
RTM	Remote Turn-round Management
RWY	Runway
SA	Situation Assessment/ Situational Awareness
SBB	Skill Based Behaviour
SESAR	Single European Sky ATM Research Programme
SIBT	Scheduled In-Block Time

SJU	SESAR Joint Undertaking
SLA	Service Level Agreement
SME	Subject Matter Expert
SMR	Specialized Mobile Radio
SMGCS	Surface Movement Guidance and Control System
SOBT	Schedule Off-block Time
SSCT	Scheduled Service Completion Time
SSDT	Scheduled Service Deliver Time
STTTT	Scheduled Turn-round Time
SWIM	System Wide Information Management
TAM	Total Airport Management
TIBT	Target In-block Time
TLDT	Target Landing Time
TMA	Terminal Control Area
TMAC	Target Movement Arrival Entry Count
TMAT	Target Movement Area Entry time
TOBT	Target Off-block Time
TRCM	Turn-round Control Mock-up
TSAT	Target Start Up Approval Time
TSCT	Target Service Completion Time
TSDT	Target Service Delivery Time
TTOT	Target Take-off Time
UDPP	User Driven Priorisation
ULD	Unit Load Device
VTTC	Variable Taxi Time Calculation
WCH	Wheelchair
WDA	Work Domain Analysis
WLAN	Wireless Local Area Network
WIFI	Wireless Ethernet Compatibility Alliance

2 Definitions

For purpose of understanding, some terms applied in this project require definition because their interpretation of the meaning is often differs throughout the literature. Emphasis here is not placed on erroneous or correct interpretation, but on an unambiguous usage within this research project. Attention should be given to the definition of ‘collaboration’ versus ‘cooperation’ or ‘situational awareness’ (e.g. shared, common, distributed....) because of the tendency to use them interchangeably.

A-CDM: Airport Collaborative Decision Making is the concept aimed at improving Air Traffic Flow and Capacity Management (ATFCM) at airports by reducing delays, improving the predictability of events and optimising the utilisation of resources. Implementing Airport CDM allows each Airport CDM Partner to optimise their decisions in collaboration with other Airport CDM Partners, knowing their preferences and constraints and the actual and predicted situation. Decision making by the Airport CDM Partners is facilitated by the sharing of accurate and timely information and by adapted procedures, mechanisms and tools. The Airport CDM concept is divided into the following elements:

- Information Sharing;
- Milestone Approach;
- Variable Taxi Time;
- Pre-departure Sequencing;
- Adverse Condition; and
- Collaborative Management of Flight Updates.

Airport CDM is also the name of the EUROCONTROL project coordinating the implementation of the Airport CDM concept at European Civil Aviation Conference (ECAC) airports.

A-DPI: A Departure Planning Information (DPI) message sent by the CDM Airport to the CFMU notifying them of the Target Take-off Time (TTOT) between ATC time of pre-departure sequencing and Actual Take-off Time (ATOT).

Adverse Condition Concept Element: Adverse Condition Element consists of collaborative management of the capacity of an airport during periods of a predicted or unpredicted reduction of capacity. The aim is to achieve a common situational awareness for the Airport CDM Partners, including better information for the passengers, in anticipation of a disruption and expeditious recovery after the disruption. The concept elements Information Sharing, Milestone Approach, Variable Taxi Time, and Pre-departure Sequencing need to be in place at the airport before the Adverse Conditions Element can be implemented successfully.

Airport CDM Information Sharing Concept Element: The Information Sharing Element defines the sharing of timely and accurate information between the Airport CDM Partners in order to achieve common situational awareness and to improve traffic event predictability. The Airport CDM Information Sharing Platform (ACISP), together with defined procedures agreed on by the partners, are the means used to reach these aims. Information Sharing is the core Airport CDM Element and the foundation for the other Airport CDM Elements. It needs to be implemented before any other Concept Element.

ACISP: The Airport CDM Information Sharing Platform (ACISP) is a generic term used to describe the means at a CDM Airport of providing Information Sharing between the Airport CDM Partners. The ACISP can comprise systems, databases, and user interfaces.

Airport CDM Partner: An Airport CDM Partner is a stakeholder of a CDM Airport, who participates in the CDM process. The main Airport CDM Partners are:

- Airport Operator;
- Aircraft Operators;
- Ground Handlers (including push-back, catering, cleaning, etc.);
- De-icing companies;
- Air Navigation Service Provider (ATC);
- Central Flow Management Unit (CFMU);
- Support services (Police, Customs and Immigration etc.).

Alert: A system generated message which alerts the Airport CDM Partners of an irregularity and which normally requires one or more partners to make an active intervention to resolve the irregularity.

Arrival Manager (AMAN): An arrival flow management tool that optimises the traffic flow to a Terminal Control Area (TMA) and/or runway(s) by calculating Target LanDing Time (TLDT) taking various constraints and preferences into account.

Anticipation-action-comparison unit: An anticipation-action-comparison unit is a set of information components allowing to predict changes in the environmental input as resulting from our own actions and our changes in our position and posture.

A-SMGCS: System at airports having a surveillance infrastructure consisting of a Non-Cooperative Surveillance (e.g. SMR, Microwave Sensors, Optical Sensors etc) and Cooperative Surveillance (e.g. Multi-lateration systems).

ATFM: A service established with the objective of contributing to a safe, orderly and expeditious flow of air traffic by ensuring that air traffic control capacity is utilised to the maximum extent possible, and that the traffic volume is compatible with the capacities declared by the appropriate Air Traffic Services authority. (ICAO Annex 11, Chapter 1)

CDM Airport: An airport is considered a CDM Airport when Information Sharing, Milestone Approach, Variable Taxi Time, Pre-departure Sequencing, Adverse Conditions and Collaborative Management of Flight Updates Elements are successfully implemented at the airport.

Cognition: Human thought processes and their components such as perception, memory and decision-making.

Cognitive Task Analysis (CTA): The framework and methods used to analyse cognitive structures and/or processes that support job performance. CTA differs from traditional task analysis in many ways, including the goals, methods used, and data produced.

Common Situational Awareness: CSA is used here as defined by EUROCONTROL (2008b) to describe the desire that all relevant up-to-date flight progress information is freely and universally available to all participating airport partners via the ACISP which allows them to improve their pre-tactical and tactical planning processes. CSA does neither account for the fact of *how much* information is required by individual airport partner nor *how* it should be presented to support decision making (EUROCONTROL, 2008b)

Collaboration: The process of two or more people/machines working together by in an intersection of common goal(s). Unlike cooperation, collaboration can also take adversarial forms thriving on differences and dissents among participants. It seeks divergent insights and spontaneity, rather than structural harmony and uses this information to create something new.

Collaborative Management of Flight Updates Concept Element: The Collaborative Management of Flight Updates Element consists of exchanging Flight Update Messages (FUM) and Departure Planning Information (DPI) messages between the CFMU and a CDM Airport, to provide estimates for arriving flights to CDM Airports and improve the ATFM slot management process for departing flights. The aim is to improve the coordination between Air Traffic Flow and Capacity Management (CFMU) and airport operations at a CDM Airport. The Concept Elements such as Information Sharing, Milestone Approach, Variable Taxi Time, Pre-departure Sequencing, and Adverse Conditions need to be implemented at the airport before the Collaborative Management of Flight Updates can be implemented in cooperation with the CFMU.

Communication: The process of transferring data/information/knowledge from one entity to another including the way of the interchange forms, not only just facts, but also policies, prospects, failures, and human experiences.

Complexity: For the A-CDM context, complexity refers to the large number of dependencies that intentionally or not are built within the various items of the system.

Cooperation: The process of working together versus separately and in competition.

CTOT: A time calculated and issued by the appropriate Central Management Unit as a result of tactical slot allocation at which a flight is expected to become airborne. (ICAO Doc 7030/4 – EUR, Table 7)

Decision Making: Decision-making is one of the basic functions of Turn-round monitoring. It is an active cognitive process which selects one out of a set of possible courses of action. It includes a weighing-up of the pros and cons of different alternatives.

Decomposition: A structured analysis that breaks down higher level units based on categories, such as consistent components, decision required, or concurrent tasks. Decomposition is useful in most types of analyses.

Distributed Situational Awareness (DSA): DSA defines SA as a dynamic, and collaborative process among actors on a situational basis. It regards different systems as having different purposes and different partners as having different domain knowledge. This requires in turn all participating to actively create an understanding of the situation from the information available.

DMAN: DMAN is a planning system to improve the departure flows at an airport by calculating the Target Take off Time (TTOT) and Target Start Up Approval Time (TSAT) for each flight, taking multiple constraints and preferences into account.

Ground Handling: Ground Handling covers a complex series of processes and services that are required to separate an aircraft from its load (passengers, baggage, cargo and mail) on arrival and combine it with its load prior to departure.

IFPS: A system of the CFMU designed to rationalise the reception, initial processing and distribution of IFR/GAT flight plan data related to IFR flight within the area covered by the participating States. (ICAO Doc 7030/4-EUR, paragraph 3.1.1)

Mental Model: Mental models are the cognitive processes/representations whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observed system states and predictions about future system states (according to Rouse and Morris, 1986).

Mental Picture: The actual mental picture of a situation represents a moment-to-moment snapshot of the actual situation based on the mental model and the actually perceived external cues. A series of mental pictures represents the actual mental model including the actual parameterisation (Whitfield & Jackson, 1982).

Milestone: This is a significant event that occurs during the planning or operation of a flight. A successfully completed milestone will trigger the decision making process for downstream events and influence both the further progress of the flight and the accuracy with which the progress can be predicted.

Milestone Approach Concept Element: The Milestone Approach Element describes the progress of a flight from the initial planning to the take off by defining Milestones to enable close monitoring of significant events. The aim is to achieve a common situational awareness and to predict the forthcoming events for each flight with off-blocks and take off as the most critical events. The Concept Element Information Sharing needs to be in place at the airport before it can successfully implement the Milestone Approach. The Milestone Approach combined with the Information Sharing element is the foundation for all other Concept Elements.

Monitoring: Monitoring is a process of continuous or discrete comparison between the actual state of the system and the expected state of the turn-round situation. Monitoring is a top-down process governed by the expected state of the system.

Pre-departure Sequencing Concept Element: The pre-departure sequencing is the order by which aircraft are scheduled to depart from their stands (push off-blocks) taking into account partners' preferences. It should not be confused with the pre-take off order whereby ATC organise aircrafts at the holding point of a runway. The aim is to enhance flexibility, increase punctuality and improve slot-adherence while allowing the airport partners to express their preferences. The concept elements Information Sharing, Milestone Approach, and Variable Taxi Time need to be implemented at the airport before the Pre-departure Sequencing can be implemented. The Pre-departure sequence can also be derived by a departure manager (DMAN) which calculates the take off time TTOT based on demand and derives the TSAT from the runway sequence. Airports can implement different solutions to achieve the pre-departure sequence, depending on local traffic complexity and surface congestion.

Situational Awareness (SA): SA is the perception of environmental elements within a volume of time and space, the comprehension of their meaning, the projection of their status in the near future, and includes a prediction of how their behaviour may affect the environment (Endsley, 1995). Situational awareness is often used in the literature with confusing meanings and terms like Individual versus Shared Situational Awareness, Common Understanding, Team shared Awareness, Shared Understanding, Distributed Cognition, Distributed Understanding, Group Situational Awareness, Shared Cognition, Shared Visualization, Team Awareness, and Coherent Tactical Picture are often used interchangeable. For the purpose of this research project, only the terms ‘common’ versus ‘distributed’ situational awareness are used, compared with each other, and determined how they are used for this project.

System: A system in A-CDM context denotes the set of all features required for the performance during the time of a certain function. These features include humans, machines, interfaces, data, computers, procedures, and processes.

TOBT: The time that an Aircraft Operator or Ground Handler estimates for an aircraft to be ready, all doors closed, boarding bridge removed, push back vehicle available and ready to start up/ push back immediately upon reception of clearance from the TWR .

TSAT: The time provided by ATC taking into account TOBT, CTOT and/or the traffic situation that an aircraft can expect start up/ push back approval. Thereby, the Actual Start-up Approval (ASAT) can be given in advance of TSAT.

Variable Taxi Time: Variable Taxi Time is the estimated time that an aircraft spends taxiing between its parking stand and the runway or vice versa. Variable Taxi Time is the generic name for both inbound as outbound taxi time parameters, used for to calculate TTOT or TSAT. Inbound Estimated Taxi Time (EXIT) includes runway occupancy and ground movement time, whereas Estimated Outbound Taxi Time (EXOT) includes push back and start up time, ground movement, remote- or apron de-icing, and runway holding times.

1 INTRODUCTION

1.1 Development of A-CDM

The European Civil Aviation Conference (ECAC) adopted a strategy in the 1990s with the overall objective *'to provide increasing airspace and control capacity urgently…while maintaining a high level of safety'*. As a consequence, the European Air Traffic Control Harmonization and Integration Program (EATCHIP) and Airport/Air Traffic System Interface (APATSI) were introduced (EUROCONTROL, 2009b). These, together with the implementation of the Central Flow Management Unit (CFMU), should help to improve capacity and efficiency. However, these improvements have been overtaken in recent years by continuing increase in demand. The ECAC Air Traffic Management (ATM) Institutional Strategy from 14th February 1997 was superseded by a comprehensive Gate-to-Gate oriented ATM Strategy for the years 2000+ in order to meet future air transport needs. The principal characteristics governing the new concepts of the ATM Strategy 2000+ include strategic organisation and enhanced predictability, flight management from gate-to-gate, enhance flexibility and efficiency, collaborative decision making, responsive capacity management to meet demand, and collaborative airspace management. The Airport CDM Project and the Airport CDM Concept support these characteristics directly or indirectly by facilitating better decision making and improved predictability.

Many individual initiatives towards improved co-operation, communication, and information sharing are currently undertaken in the European ATM community. The EUROCONTROL Experimental Centre has been involved in CDM through many studies that have opened the perspectives for Collaborative Decision Making. These include ATFM Priorities (1998), CDM Expert Group (1999), FASTER Study (1999), CDM Applications (1999), ATFM Improvement (2000), and the A-CDM-D Evaluation (2000).

The Airport CDM Information Sharing and the Turn-round Process (Milestone Approach) concept developments were based on experimental work conducted at several major European airports during trials at Brussels, Barcelona, Helsinki, Stockholm, and Milan.

An Airport CDM Task Force has been created under the European Air Traffic Management (EATM) Airport Throughput Division Airport (APT) to guide the Airport Operations Team (AOT) in Airport CDM issues and undertake specific work. This task force has now initiated additional projects in other airports such as London Heathrow, Lisbon, Budapest, Athens, Zurich, and Munich where the various Concept Elements are being tested, taking into account local constraints and requirements.

The A-CDM concept was established within an Airport Operations Plan having five key areas like A-SMGCS, Airport CDM, ACE, Airport Safety, and Wake Vortex. Since then, the EUROCONTROL Airport CDM team in Brussels coordinated the initial trials at selected airports and is now responsible for ensuring standardisation and dissemination of best practice of Airport CDM implementation at European airports. Meanwhile, the A-CDM concept is also an integral part of both the Dynamic Management of the European Airspace Network (DMEAN) and the Single European Sky ATM Research (SESAR) program. Within the SESAR proposed operating principles, Airport CDM, System Wide Information Management (SWIM), Network management function in support of User Driven Priorisation Process (UDPP), and the Total Airport Management (TAM) have been introduced as the main enablers to support such airspace/airport users' requirements (EUROCONTROL, 2008b)

A number of common objectives for A-CDM are defined which include:

- improvement of on-time performance and predictability;
- enhance/optimize use of ground handling resources, stands, gates and terminals;
- reduction of ground movement cost;
- optimize the use of the airport infrastructure and reduce congestion;
- reduce ATFM slot wastage;
- flexible departure planning; and
- reduce apron and taxiway congestion.

1.1.1 The European Airport-CDM Concept

Different CDM concepts have been proposed in the US and Europe. Within Europe, the CDM concept is called Airport-CDM (A-CDM) and a number of A-CDM concept elements are defined aiming at achieving greater operational efficiency.

For the implementation of A-CDM, *different phases* through a bottom-up concept are described:

- *Information Sharing:* is the essential part that forms the foundation for all the other elements and must be implemented first. This should be achieved by creation of an Airport CDM Platform for information sharing between partners with a *standardised format*. This includes *real-time data* and *alert messages* to all partners available via interdependent user displays or HMIs allowing *generic or local processes a direct link* to the A CDM Platform. All airport partners contribute to the Information Sharing:
    - Aircraft Operator/ Handling Agent: delivers planning data, turn-round times, flight plans, movement data, priority of flights, aircraft registration and type changes, TOBT, and movement messages.
    - Air Traffic Control: contributes information like Estimated Landing Times, Actual Landing Times, Target Start up Approval Times, Target Take off Times, runway and taxiway conditions, taxi times, SID allocation, runway capacity.
    - Airport Operations: stand and gate allocation, environmental information, special events, reduction in capacity, airport slot data, ADES, Scheduled Off-Block Times.
    - CFMU: data from flight plans, SAMs, SRM, CHG, CNL, changes or cancellations, actual movement messages, ELDT, FUMs.
    - Service Providers: de-icing companies, MET office with weather forecast or actual weather, others including police, customs, fuel, etc..)

- *Milestone Approach:* is often referred as Turn-Round Process aims at achieving a common situational awareness by tracking the progress of a flight from the initial planning to the take off via a continuous sequence of different events. Different airport partners can be responsible for different milestones; significant events are determined in order to track the progress of flight via these key events. Implementation of these milestones requires a technical infrastructure and hence information sharing with agreement on the required processes in place and working properly. A total of 16 milestones have been defined, however, more milestones may be needed to cover for extra updates on key events, e.g. de-icing. Local procedures may substitute milestones; therefore not all milestones are *highly* recommended.

TABLE 1: THE A-CDM MILESTONES (SOURCE: EUROCONTROL, 2009)

NUMBER	MILESTONES	TIME REFERENCE	EXPLANATION
1	ATC Flight Plan Activation	3 hours before EOBT	First point of Awareness
2	EOBT – 2h	2 hours before EOBT	CTOT Allocation in case of airspace or local constraints
3	Take-off from Outstation	ATOT from Outstation	Most commonly transferred via Movement Messages
4	Local Radar update	Varies according to Airport	Arrival Manager builds sequence
5	Final Approach	Varies according to Airport	Usually the trigger for ATC to set the first TOBT according to MTTT
6	Landing	ALDT	Aircraft now under Local Management
7	In-block	AIBT	Trigger for Ground Handling start
8	Ground Handling Starts	ACGT	Aircraft Operator now provides information to the Partners
9	TOBT Update prior TSAT	Varies according to airport	Most accurate TOBT should be provided
10	TSAT Issue	Varies according to Airport	ATC issues TSAT based on latest TOBT
11	Boarding Starts	Varies according to Airport	Trigger independent from mode of boarding (e.g. air-bridge, stand)
12	Aircraft Ready	ARDT	Aircraft is physically ready to move
13	Start-up Request	ASRT	Flight crew ask for start-up clearance
14	Start-up Approved	ASAT	Start-up approval by ATC
15	Off-block	AOBT	Aircraft starts push-back or taxi
16	Take off	ATOT	Aircraft takes off from the runway

- *Variable Taxi Time:* is the key to predictability of accurate take-off and in-block times especially at complex airports. This is also used by the CFMU in order to calculate the CTOT and due to the complexity of airports taxi time may vary significantly depending on the parking position or runway configuration.
- *Pre-departure Sequencing:* Establishing a pre-departure sequence for the off-block time taking operators' preferences and operational constraints into account in order to replace the common principle of 'first come first serve'. This allows avoiding

long waiting times at the runway and ATC to provide a TSAT which places each aircraft in an efficient pre-departure sequence for the off-block time.

- *CDM in Adverse Conditions:* achieves Collaborative Management of partners during periods of predicted or unpredicted reductions of capacity, because different events either planned or unplanned can disrupt the normal operation of an airport far below normal operation. Such conditions may be snow, industrial action which means adverse conditions can be foreseen with more or less accuracy. A manager should be employed who is able to collaboratively reduce capacity in the most optimal manner and to facilitate a swift return to normal capacity once adverse conditions no longer prevail. This includes increased predictability during de-icing processes.
- *Collaborative Management of Flight Updates:* as an information exchange of flight updates between CFMU and CDM Airport, it enhances the quality of arrival and departure information. Within this scope, the goal is to enable flight punctuality and efficiency having regard to the available resources with emphasis on optimizing the network capacity. This strategy does not look for imposing ATFCM solutions to airspace users through ATFM delays, but rather through a robust and comprehensive collaborative decision making process that will allow widespread dissemination of relevant and timely information. This is realized through Departure Planning Information Messages (DPIs) from the airport to the CFMU or Flight Update Messages (FUMs) from the CFMU to the airports concerned.

With all these concept elements in place the local airport is regarded as a *CDM Airport*. Additionally, there are advanced concepts available. As yet undefined, these Elements will enhance and extend common situational awareness and increase collaboration between airports by utilizing advanced technologies and linking with advanced tools, e.g. A-SMGCS, AMAN/DMAN:

- DMAN: is a planning system to improve departure flows at an airport by calculating the TTOT and TSAT for each flight, taking multiple constraints and preferences into account. It is the technical enabler developed by several industrial companies, using the data elements provided by Airport CDM and A-SMGCS concept. However, its application within European has not yet been harmonized and it must also be considered reliable before considered by operational controllers.

- AMAN: is a planning system improving arrival flows by optimal throughput, considering relevant constraints like airspace structure, runway system, wake vortex category, speed, restrictions, wind, etc.
- A-SMGCS: Advanced Surface Movement Guidance and Control System. The main functions of A-SMGCS as they are defined in the ICAO A-SMGCS Manual are:
    - Surveillance, which provides controllers (eventually flight crews and vehicle drivers) with situational awareness on the movement area (i.e. a surveillance display showing the position and identification of all aircraft and vehicles).
    - Control, providing conflict detection and alerting on runways (and eventually the whole movement area).
    - Routing, through which manually (eventually automatically) the most efficient route is designated for each aircraft or vehicle.
    - Guidance, giving flight crews and drivers indications enabling them to follow an assigned route.

1.1.2 The US CDM Concept

Starting in 1993, experiments with data exchange between the Federal Aviation Administration (FAA) and the airlines (FADE experiments) where airlines sent updated schedule information, the FAA proved to positively impact air traffic management decision making. CDM has evolved from this same principle, based on the belief that shared information on all sides will create a National Airspace System (NAS) that is beneficial to everyone. CDM brings together airlines, government, private industry and academics in an effort to improve air traffic management through information exchange and data sharing. This philosophy of collaboration promises to become the standard in aviation (FAA CDM Webpage, 2009). A stakeholder group consisting of the Air Transport Association (ATA), National Business Aviation Association (NBAA), Regional Airline Association (RAA), and the Federal Aviation Administration (FAA) provides recommendations to the FAA. A number of sub-teams like the Flow Evaluation

Team, Future Concepts Team, Surface CDM Team, Enhanced Ground Delay Program, Special Traffic Management Program, Weather Evaluation Team, Fuel Team and CDM Training Team are established to address specific issues in a focused group of experts. Additionally, joint initiatives are undertaken and aimed at exchanging ideas that will mutually benefit both European and American CDM organizations. These initiatives include mutual exchange programs of CDM team members where interest was raised by the FAA to build on expertise from European Concept of A-CDM.

1.1.3 The Differences between the European and the US CDM Concept

While both the European and the US CDM concepts are aimed at increasing the predictability and reliability of air traffic, differences between the two approaches evolve from the regulatory environments and the different measures as they are established in Europe, respectively the US. The main difference between both approaches is the non adoption of Target Start-up Approval Time (TSAT) as a means to control the traffic flow on the ground in the US. Instead, ATC provides the Target Movement Arrival Entry Count (TMAC), a number of slots to that spot when ATC takes over with aircraft start taxiing to the runway. A Target Movement Area Entry time (TMAT) is allocated by Departure Reservoir Management (DRM). The reason for this is that in the US the Aprons are controlled by the airlines and not ATC.

In Europe, focus is applied to monitoring of delays through key monitoring stages because airports are getting increasingly congested and parallel planning exists between airports and Air Traffic Flow Management (ATFM). Consequently, the harmonisation between the various local airport partners and the CFMU has initially been in the spotlight in Europe, while the US CDM has established their focus in the various sub-teams. As a result, the collaboration among participating partners at strategic, tactical and operational level has developed quite differently during day-to-day flight operation.

1.1.4 A-CDM Implementation

There are four distinct and fundamental phases defined for the implementation process which are the Information Phase, Analysis Phase, Implementation Phase, and the DPI Operational Implementation Phase. To ensure data quality, a validation process will take place before to assess level of CDM implementation at the airport.

EUROCONTROL offers far ranging assistance to support the local implementation including CBA at airport sides, gap analysis, dedicated website, CDM document library, multiple subgroup meetings, and yearly coordination group meetings.

Collaborative Decision Making (CDM) has now been established as a concept of working together of all airport partners who are best placed for operational decision making. Partners recognized as required for CDM include airport operators, aircraft operators, ground handlers, Central Flow Management Unit (CFMU) in Brussels, and Air Traffic Control (ATC). CDM aims at improving operational efficiency at airports by reducing delays, improving the situational awareness during the progress of the flight, and optimizing the utilization of resources. The inherent aim is to make improved decisions based on more accurate and timely information that result in all airport partners having the same operational picture, with the same meaning to all involved. By knowing possible constraints of the actual or predicted situation, each airport partner is able to improve own decisions in collaboration with other partners by applying own preferences. The improved decision making by all airport partners will be facilitated by the sharing of accurate and timely information (EUROCONTROL, 2009a).

With CDM in place, also the ATM network benefits from more accurate information about the flight status. This allows deriving ATFM slots based on the actual situation and reducing the current buffer capacity for the en-route phase of the flight.

For the implementation of CDM, operational procedures, automated processes and tools have to be established at the participating airports. The EUROCONTROL Airport CDM team is responsible for proposing standardization and dissemination of best practice Airport CDM implementation guidelines at European airports, but does not have regulatory power.

1.2 The Milestone Approach Concept Element (Turn-round Process Element)

The Milestone Approach Element has traditionally been called ‘CDM Turn-round Process Element’ (CTRP) and describes the progress of a flight from the initial planning to the take off by defined *milestones* that allow close monitoring of significant events. Turn-round operation has so far been viewed as a standalone process with responsibilities shared between airline and airport. *SESAR Air Traffic Management (ATM)* research however aims at eliminating today’s fragmented approach to European air traffic management by synchronising all stakeholders and network resources. Because successive flights depend on each other, today's ATM concept links the arrival phase, turn-round, and departure phase of a flight as one entity, The ground process and en route traffic are now considered as part of a time-dependent chain. *Airport Collaborative Decision Making (A-CDM)* is used as the mechanism to integrate airports into the ATM network. An airport is considered a CDM airport when the *Information Sharing, the Milestone Approach, the Variable Taxi Time, the Pre-departure Sequencing, the Adverse Conditions, and the Collaborative Management of Flight Updates* concept elements are successfully implemented at an airport (EUROCONTROL, 2009b).

Figure 1 shows the milestones within the different phases - arrival phase (inbound), turn-round phase, and departure phase (outbound). Flight Update Messages (FUMs) and Departure Planning Information (DPI) are in place to inform all participating CDM partners of the flight progress, thus improving ATFM slot management process for departing flights (*Collaborative Management of Flight Updates Element).*

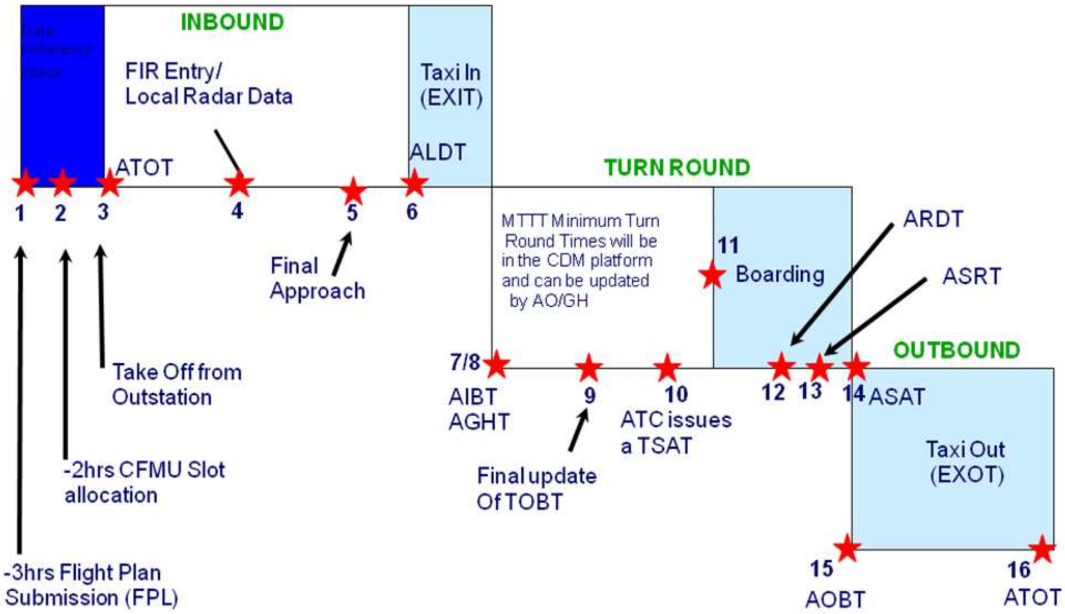


FIGURE 1: AIRPORT CDM GENERIC MILESTONES (SOURCE: EUROCONTROL, 2006)

Among the milestones used for monitoring the flight progress, the period of the flight between milestone 7 (actual in-block time) and milestone 15 (actual off-block time) is called *Turn-round.* Monitoring this turn-round phase is a complex task, because situational awareness has to be established across various subsystems of different organizational and operational structures with their own causal and intentional domain constraints. Subsystems are here referred to as participating partners and include airport operator, airline company, air traffic control, ground handler, service provider and Central Flow Management Unit (CFMU). Additionally, many terminal and ramp processes have operational interdependencies, e.g. processes that normally cannot be done in parallel, as well as legal requirements, e.g. one side of the aircraft has to be clear of obstructions to ensure that fire fighting access is always possible (Fricke et al, 2008). In order to increase situational awareness during turn-round, a number of agreed trigger events are defined by the A-CDM concept to inform all partners of updates to estimates and/or aircraft turn-round status. A CDM compliance alert will appear on the Airport CDM Information Sharing Platform (ACISP) in cases of disruptions. Any internal or external disruption at these milestones generates an alarm and has to be communicated to all partners in order to maintain situational awareness.

Due to the complexity, size, speed, and functionality of the ATM network between all airport partners during this turn-round phase, it is important to understand *how* operators monitor the turn-round operation, the *challenges* they face in the monitoring task, and the *tools* they use for monitoring and decision support. Designers can use this information to create interfaces that not only enhance operation monitoring, but also alleviate information overload, integrate or highlight required information, decrease response time, and thereby increase efficiency by providing an intelligent decision support for turn-round related decision making. Failures during turn-round monitoring can result in insufficient situational awareness with negative consequences on TOBT reliability.

1.3 The Role and Importance of TOBT

Within A-CDM, the Target Off-block Time (TOBT) represents the time that an airline or handling agent estimates an aircraft to be ready, all doors closed, boarding bridge removed, push back vehicle available, and ready to start up or push back immediately upon receiving clearance from air traffic control (EUROCONTROL, 2009b). The airline or airline representative (referred to here as ‘turn-round controller’) issues the TOBT and is ultimately responsible for its accuracy. The turn-round controller controls and monitors the CDM turn-round process. He can update the TOBT up to 15 minutes before Estimated Off-Block Time (EOBT), but needs approval from the airlines' dispatch manager if deviation from EOBT is greater than 15 minutes.

The TOBT is an important trigger for all airport partners in departure management because ATC issues a Target Start-up Approval Time (TSAT) based on the TOBT to inform the flight crew and all partners of the time when the aircraft can expect start-up and/or push back approval. Such a TSAT also takes into account a possible Air Traffic Flow Management (ATFM) slot delay, and/or the actual traffic situation at the airport. As such, the TOBT is not only the key indicator for all participating actors and operators: But it is also used by the airport and ground handlers as a basis for resource planning, by the CFMU to assess airspace congestion, by local ATC to build pre-departure sequence, and by the passengers as the expected departure time of the flight. The large number of participants who depend on accurate TOBT predictions reveals the importance of this milestone for the success of an efficient and reliable flight operation. Airport partners are also referred to as 'decision makers' at the tactical level; individuals participating at the airport terminal or the ramp are referred to as 'actors', and encompass flight managers, pilots, ramp agents, loaders, cleaners, catering personnel, vehicle drivers, and fuelling personnel.

The crucial role of milestone 9 (Final Update of TOBT) within all other milestones has to be emphasized. While all other milestones can potentially be important to increase the situational awareness among A-CDM decision makers, milestone 9 requires the highest accuracy because it ties up the largest number of resources including airspace, ground handling equipment, airport facilities, personnel, and passengers' time.

As a consequence of predictable and accurately assigned TOBTs, ATC is able to reduce time buffers between period of milestone 14 (Actual Start-up Approval Time ASAT), and milestone 16 (Actual Take-off time ATOT). Due to the continuing instability in predicting TOBT, it is common practice for ATC to build time buffer into the period between milestone 14 and milestone 16 in order to account for irregularities that emerge during turn-round. Consequently, better predictability and accuracy in TOBT assignment enables ATC to reduce these time buffers.

When TOBT is more reliable, Actual Take-off Time (ATOT) also becomes more predictable and other positive network benefits can be expected. A study has shown that a broader implementation of A-CDM could increase sector capacity, reduce en-route delays, and reduce the number of regulated flights (EUROCONTROL, 2008a). Other advantages of reliable TOBT predictions include reduced taxi times, environmental benefits, improved resource planning, and last, but not least, increased passenger satisfaction.

A prototypical situation showing the importance of the TOBT is a flight constrained by a Calculated Take-Off Time (CTOT). Central Flow Management Unit (CFMU) is the enforcing power for delaying flights based on a calculated airspace sector overload or restrictions that emerge before the departure by imposing a CTOT on the flight. Such CTOT requires the flight to get airborne within a 15-minute-window [-5;+10 minutes] This CTOT is based on the TOBT resulting from the Departure Planning Information (DPI) that the airline forwards to the CFMU. If the TOBT is inaccurate the flight fails to depart within the CTOT window and the airspace reserved for this flight gets redundant because it cannot be assigned to another flight anymore that has also been delayed. This example shows the key role of the TOBT in coordinating the turn-round phase with the en-route phase of the flight.

1.4 Characteristics and Dynamics of the TOBT

TOBT decision making has the characteristics of an evolutionary approach within a dynamic environment: The task of assigning the TOBT is only *one* component of a larger decision making problem that does not simply end with a TOBT assignment. It requires continuous monitoring of the turn-round situation, because any unanticipated event can affect the TOBT significantly. Thus, coordination of actions is mandatory: depending on the required response to a single turn-round process or any unexpected situation, a long sequence of subsequent process coordination or remedial decision making may be necessary. Such response may include actions like data exchange or sharing information up to jointly creating contingency plans via numerous interactions between actors or operators involved.

During flight operation at congested airports, the minimum time available for turn-rounds is often restricted by predefined minimum periods called *Minimum Turn-round*

Time (MTTT). However, such MTTTs are not based on the actual turn-round duration required, but are a fairly arbitrary choice of the airline. If only MTTT is available, the TOBT needs to be updated even when only *one* turn-round process is delayed during the so called *critical path* of the sequential turn-round processes: While a number of turn-round processes can be executed *simultaneously*, the critical path stems from the *sequential* sub-processes, where a delay can propagate across the turn-round, thereby affecting the TOBT. Therefore, not only close monitoring of this critical path is required, but also predictions are required for each single turn-round process, since TOBT accuracy depends heavily on the exact prediction of *all* sequential sub-processes.

However, until today no unified approach has been found on what time, space, individuals or units are required during turn-round management or whether decision making should be centralized or distributed among participants. Examples of *who* is responsible for forwarding information, *when* should information be shared, or *how* the nature of the distributional network should look like because accountability in decision making is an inherent point of conflict between the various actors and participants. Additionally, the influence of external factors like time pressures during turn-round, interruptions in the ATM network, or the consequences resulting from the uncertainty of situations have not been systematically investigated so far. Such characteristics and dynamics of the current approach to turn-round decision making reveal opportunities for an improvement in the overall TOBT prediction.

1.5 Motivation for this Research

Sections 1.3 and 1.4 have outlined how TOBT plays a key role for all airport partners, not only as a benchmark time for the execution of all ground services, but also as the reference time for the airport, ATC, CFMU, the passengers and the aircrews. This importance for all involved together with the little attention that TOBT has gained so far marks the motivation for this research project.

Moreover, the issue of TOBT accuracy has not been systematically investigated at airports thus far. A number of reasons may explain this fact:

- Operational A-CDM airports: only a few airports in Europe have officially introduced A-CDM and are using the milestones as outlined in the A-CDM implementation manual (EUROCONTROL, 2009b).

- The importance of TOBT predictability has not yet been sufficiently emphasized when considering the introduction of A-CDM at an airport; focus has always been applied on other CDM implementation issues.

- Lack of awareness required for TOBT during A-CDM: due to insufficient dissemination of working rules and guidelines of the CDM procedures, turn-round managers are not fully aware of the newly implemented procedures not directly affecting their *own* working environment. TOBT awareness however, has to be established via an interdepartmental information exchange.

- Airlines and ground handlers are worried about possible negative consequences when sharing their internal data to allow accurate TOBT predictions: precise information on expected turn-round completion may also potentially reveal ground handling irregularities. Communicating such information demands a culture change by the airline or the representative ground handler, because penalties from providing poor turn-round service have to be expected, e.g. IATA delay code assignment or payment deductions. Finally, airline agents often remain hopeful that delay encountered during turn-round might be compensated for by accelerated working procedures: In such cases, providing a late TOBT early would be disadvantageous for the airline.

1.6 Aims, Objectives and Research Questions

The overall aim of this project has been defined as:

Identifying measures that can increase TOBT prediction accuracy.

A number of objectives were derived from this aim for the research project:

- *Understanding the environmental constraints influencing TOBT decision making.*
- *Identifying unexpected situations critical for TOBT adherence.*
- *Understanding how major European airlines actually assign TOBT today.*
- *Determining countermeasures for dealing with unanticipated situations and*
- *Identifying strategies and decision support systems able to predict accurate TOBTs.*

Taking the environment within today's A-CDM context into consideration, the first research questions looked at the social and organizational aspects of the turn-round and were formulated:

- What are the fundamental constraints that are imposed on TOBT decision making?
- What are the specific environmental factors that influence TOBT decision making?

The perspective of the flight crews was used to describe situations critical for TOBT adherence:

- Which situation can arise unexpectedly that is critical for TOBT adherence?
- Within the identified situations, does cooperative behaviour of participating actors have an influence on TOBT adherence?

The next questions were aimed at zooming closer into the actual TOBT decision making process and include:

- What are the different modes for monitoring the turn-round and what are the current strategies used to predict the outcome of the turn-round via the assignment of the TOBT?
- What cognitive strategies have operators developed to facilitate early detection and resolution of a critical TOBT adherence situation?
- What factors contribute to turn-round monitoring difficulty because key indicators for emerging problems are not available?

The underlying motivation for the next questions was to find countermeasures for the identified problems, formulated as:

- How can provision of cooperative information increase TOBT prediction accuracy?
- Is cooperative information sharing able to identify strategies that can be applied during unexpected turn-round situations?
- Is it possible to get more accurate TOBT predictions already earlier than today?

1.7 Organization of the Thesis

The scope of the thesis is delimited to the A-CDM Information Sharing and Milestone (Turn-round Process) Element of the A-CDM concept. While it was realized that also other concept elements are useful to be included, this boundary was chosen because the overall aim is to identify measures that are able to increase TOBT prediction accuracy by kind, but not by quantity. This means, it was preferred to find suitable measures that can be transferred to other A-CDM concept elements. While the concept element of CDM in Adverse Condition (e.g. de-icing) was deliberately not included, interactions with Air Traffic Control were initially considered (e.g. Flight Crew Survey), but later disregarded as not being useful to be included in the experiments.

The conceptual research framework was selected based on the specific characteristics of today’s turn-round management and its influence on TOBT prediction, while considering the specific environment and the identified constraints that are shaping turn-round management and TOBT decision making.

For such problem setting, the theoretical framework being used should be able to provide a method for analysis, evaluation, and design of a decision support system that can aid decision makers during turn-round operation. For example, how can the required information be displayed, which format should be used to display information in order to facilitate cooperative working behaviour and effective decision making? How should the tasks be effectively distributed across manual or automated systems? The proposed system design should be evaluated at a later stage to determine its usability and effectiveness, and whether it leads to enhanced performance.

Therefore, the literature review was performed with three major goals in mind: First, the environment of the A-CDM turn-round should be captured. While legal, operational, or cognitive perspective that may influence the turn-round operation, and consequently also the TOBT, should also be considered. Second, the design criteria for a system that could support reliable TOBT decision making should be identified. Third, a suitable framework for the analysis of the research objectives should be chosen. The following chapters are therefore organized as follows:

Chapter 2: This chapter provides a review of the overall A-CDM turn-round environment, outlines how turn-round is managed, and looks at the processes required for its execution. This includes a review on the identified shortcomings of the turn-round processes as well as the legal aspects shaping the turn-round management.

Chapter 3: provides the theoretical approach towards A-CDM. It begins by looking at the design lessons from *decision support literature* and identifies some challenges in designing of a human-computer interaction system that could potentially support TOBT decision making. Subchapter 2 describes the disciplines of *Decision Making and Information Sharing* with concepts that are available to support effective human-computer systems, while focus is placed on the *cooperative element* that supports decision making. Subchapter 3 describes the *cognitive element* as one of the interdependent elements between actors within the given decision making environment and how cognitive engineering can be used to find design criteria for decision support in the given environment. The following Subchapter 4 examines the first stages of a *Cognitive Work Analysis* that were used as the framework for the project and how it was applied as an overall modelling tool for capturing the cognitive constraints influencing the decision making environment. The results of the literature review were then used to determine the research methods.

The following chapters use the Cognitive Work Analysis as an overall framework. Four major studies were executed, each using a different research method and different mode of analysis. The research method used for each study was determined using the results from the previous literature review. The issues identified during the investigations were outlined in the relevant section of this paper.

Chapter 4: outlines the application of the Cognitive Work Analysis (CWA) to the A-CDM work system and turn-round management. First, the aims and objectives of this analysis are provided as well as the limitations of a Cognitive Work Analysis to be useful applied to the A-CDM work domain. Subchapter 3 provides the Work Domain Analysis as the first step of a CWA, while Subchapter 4 describes the Control Tasks Analysis as the second step of a CWA. Both steps rely on a methodology proposed by Naikar et al. (2005) who describes how the analysis should be applied.

Chapter 5: provides a flight crew survey and how it was used to identify the critical situations for A-CDM turn-round management. It includes the aims, objectives, method, findings, and concluding aspects of the study. The study shows how flight crews are involved in decision making during turn-round, how cooperative behaviour of all participating affects the turn-round, and which situations are critical for accurate TOBT predictions.

Chapter 6: provides a study via field observations during turn-round management with the aims, and method applied. Details are given that describe how turn-round management is established at major European airports and how the outcome of the turn-round is assessed by the various turn-round representatives. Due to the quantity of identified data/information during the observations, the findings of the study were integrated into a qualitative cognitive model that was used to identify critical areas for data/information flow. Identified data/information was seen as essential for accurate TOBT predictions.

Chapter 7: As a central part of the investigations, small-scale human-in-the-loop experiments outlined here were proposed in order to find measures to counteract inaccurate TOBT predictions. A Turn-round Control Mock-up that was exclusively developed for the experiments is described as well as details on the participants, the experimental design, the method applied, and the analysis of the collected data, are given. This Chapter concludes with a discussion about the validity and limitations of the experiments.

Chapter 8: presents a summary and conclusions drawn from the overall results, offers recommendations, suggests possible areas for future research, and discusses the limitations encountered. While some concluding aspects are given for each of the studies at the end of the relevant Chapter, the conclusions given here draw a line from the initial development of the research concept to the specific details of the final results.

Chapter 9: Publications and References

Chapter 10: includes appendices with further details on A-CDM, theoretical aspects of cooperation, distributed decision making, and turn-round management. These are in particular the A-CDM concept with the mandatory or recommended milestones, the design of the flight crew survey, the IATA Delay Code Table, turn-round tools that are currently used in Europe, further results of the literature studies on cooperation and the Cognitive Work Analysis, and details of the Games-Howell Test.

1.8 Potential Contribution to Knowledge

Prior to a more detailed discussion of the literature review, this section provides the main areas of this project that are aimed at contributing to the existing body of knowledge.

- Despite the connotation of A-CDM as highly relevant to the success of airport operation, a surprisingly small amount of research has been dedicated to the domain specific problems of aircraft turn-round operation.
- Furthermore, no research project has been found to date that applies a cognitive engineering approach to investigate the factors influencing the predictability of aircraft off-block times.
- In addition, following the Cognitive Work Analysis framework outlined by Vicente (1999), a concept of human-information work interaction analysis has been applied to turn-round management for the first time.
- Finally, a major effort has been dedicated to cooperation analysis of the work domain being investigated. In order to better understand the specific aspects of the A-CDM turn-round process management, two alternative forms of cooperation analysis were integrated into the research framework, by way of a descriptive and an experimental form of investigation. Such an approach has not been taken in this turn-round management environment thus far.

2 THE A-CDM TURN-ROUND PROCESS

2.1 Introduction

A number of issues that frame the management of the turn-round relate to the environment in which the turn-round takes place. Such issues include organizational as well as legal aspects. They are outlined here in order to understand the specific constraints that influence the A-CDM processes including TOBT decision making.

2.2 The IATA Airport Handling Standards and the Airline Standards

Historically, airports were managed and owned by federal governments around the globe. However, the development and adoption of standards for airport handling arose in Europe where an overlap of many different airlines resulted in the necessity for airlines to arrange handling contracts with each other (IATA, 2004). These standards were developed under the auspices of the International Air Transport Association (IATA) over a period of thirty years and have been established as procedures for passenger and aircraft handling during turn-round. As of August 2009, more than 230 airline or ground handling companies are members of IATA and have to adhere to these standards. IATA Operational Safety Audits (IOSA) are performed to assess the operational management and control systems of the airlines. In the Airport Handling Manual (AHM) all standards are lined out affecting passengers, cargo/mail, aircraft handling, load control, airside management and safety, aircraft movement control, and ground handling agreements including the handling of ground support equipment. Service Level Agreements (SLAs) are in place to act as a structure for measuring the service quality of ground handling service providers. Finally, the airlines themselves develop their own standards to ensure that ground handling performance is maintained during the turn-round processes.

2.3 The EU Directive on Ground Handling in Europe

In 1996, 15 member states of the European Union adopted a Directive to encourage competition in ground handling services at European airports. In a number of member states, ground handling services had historically been provided on a monopoly basis, either by the major base airline (e.g. Iberia, Olympic) or by the airport operator itself. This was a common model in Austria, Germany and Italy. However, many problems arose from the new arrangement created by this Directive (Smith, 2001). Smith outlines the different configurations of stakeholders’ interests which may result from the various combinations of circumstances. These configurations range from a simple model where the airport operator is responsible to appoint third party ground handlers while taking the interests of the various airlines into account to more complex models where airports and airlines provide ground handling services at the same airport. Since governments are frequently shareholders of the airport, such configurations of handling responsibilities may create potential for conflicting interests. Airport operator involvement in ground handling services creates suspicion in the minds of other ground handlers who feel disadvantaged in terms of access to facilities (e.g. air bridge served parking stands) or a centralized infrastructure (e.g. baggage handling system or even terminal building).

2.4 The IATA Delay Code System

As part of the Airport Ground Handling Manual (AHM), the IATA Delay Codes were established to help the airlines with standardization of the delay causes from their commercial flights. Traditionally, airlines were using their own delay assignment system; The IATA however standardized the transmission format of delay information into delay codes. Such delay codes assign the responsibility and time of the delays to a function that is seen as the cause of the delay. As a consequence, the airlines may penalize the service company or other partner according to the contract or Service Level Agreement (SLA) in place. Airlines often use bonus-penalty or other incentive systems that affect the remuneration for services provided.

Several groups of delay codes exist that group the delays into categories like passenger processing, baggage handling, or aircraft defects (See Appendix III). The delay can also be attributed to several sources, if more than one cause of delay was determined.

However, identifying the function where the delay originates is not always easy because delays are often reactionary. Moreover, during turn-round, restrictions to providing service may not be visible at first glance, or the background of the delay reason is not available to the function which is responsible for assigning the delay code. Although service providers may encounter restrictions or face hurdles from other participants, the delay code is assigned to them. For instance, hindrances to start the service may be caused by another ground handling service or a blocked equipment. These factors are often not visible from the location where the delay code is assigned. It is questionable whether an accurate code can be attributed to delays encountered away from the physical locations of their emergence. According to EUROCONTROL (2007), there are suggestions that delay statistics are compromised if they are gathered by airlines, because of the temptation to assign blame and the attempts by one or more of the direct contributors to hide their influence on the delay caused. Delay statistics collected by aircraft operators are used primarily to direct improvement efforts. However, airlines tend to focus on infrastructure deficiencies that serve their individual needs. Differences can be observed when comparing Central Flow Management Unit (CFMU) and Airline delay statistics (see Figure 2).

Conversely, for delay codes 81-84 and 89 (Air Traffic Flow Management (ATFM) and airport delays), EUROCONTROL realized a tendency that airlines are keener today to solve the problem accurately. So the relationship between airspace users and airport service providers has become more cooperative: Regular statistics from EUROCONTROL's Central Office for Delay Analysis (CODA) compared with those recorded by operators' shows that although absolute values vary slightly due to the comparison of sample data to full data, the trends nonetheless match exactly (EUROCONTROL, 2007).

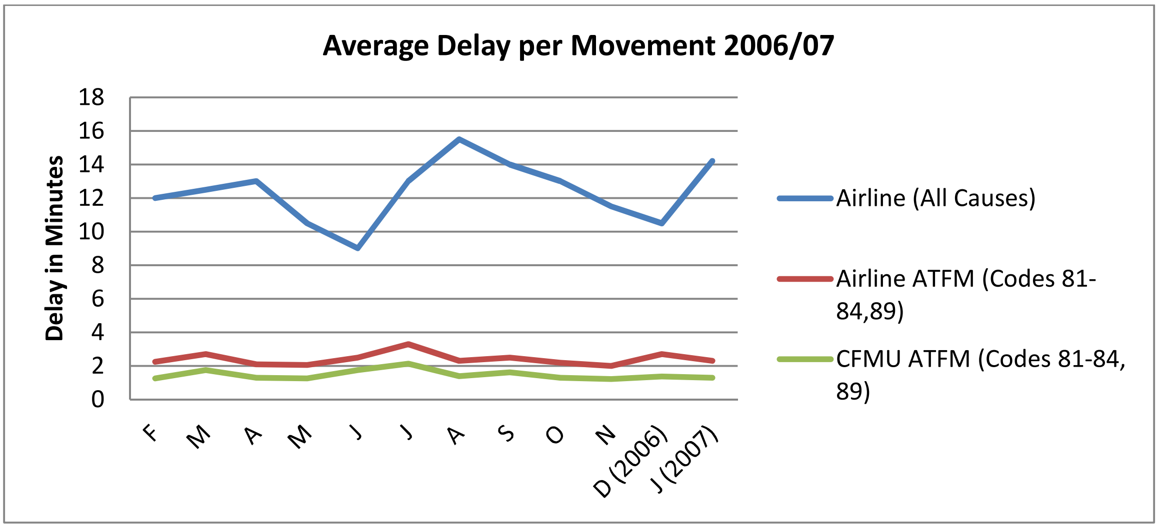


FIGURE 2: COMPARISON OF DELAYS (SOURCE: EUROCONTROL CODA, 2007)

2.5 Turn-round Complexities

A turn-round delay may have numerous causes. Even though each turn-round is unique in itself, there are complications occurring on regular basis that have to be taken into account when calculating TOBT. E.g. the company SITA (SITA, 2009) describing itself as the world's leading specialist in air transport communication and IT solutions, notes that aircraft turnaround complications can emerge from:

- processes that differ depending on the airlines and/or the aircraft;
- airports having different levels of capacity that impact turnaround performance;
- pressure to achieve the optimal long-haul passenger/ cargo mix;
- the shrinking window for receiving passengers/cargo prior to departure affects fuel truck availability and fuel requirements;
- reduced staff;
- pressure to utilize aircraft more efficiently and to limit ground time;
- zero excess fuel requirements (excess fuel is kept close to safe minimums);
- increased air traffic; and
- limited airport expansions (increasing need for operational efficiencies).

The complexities which arise from the differences between the turn-round processes are part of the focal point of this project. The analysis starts with a categorization of turn-round processes as either within the critical path of parallel or part of the sequential chain of turn-round events. While parallel turn-round processes can also cause delays, poor coordination or unawareness about the progress of sequential turn-round processes is usually responsible for a turn-round delay. Through the number and kind of processes can differ between airlines, airports, operators and situation. Figure 3 provides a general overview of the different sequential and parallel turn-round processes:

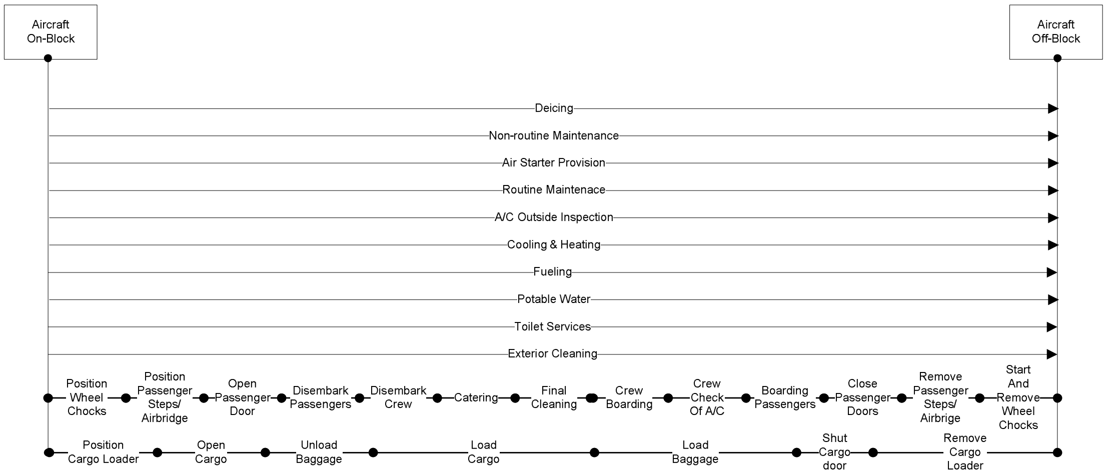


FIGURE 3: TURN-ROUND PROCESSES (SOURCE: WU, 2008 & SNELLING, 2002)

In order to get time estimates for turn-round process durations, each individual process has to be analysed. As illustrated by the example of *baggage loading* time, the issues that have to be taken into consideration when analysing process duration of *baggage loading* include size, amount, and weight of baggage, transit time available, nature of baggage, bulk, baggage per passenger, location of compartment, timing for loading, special passenger baggage, life cargo, available loaders, available equipment, amount of Delivery At Aircraft (DAA), Unit Load Device (ULD) or loose loading, distance and movement time from baggage check-in to aircraft to be loaded, etc. This is an example of the complexities arising from just a single process within this turn-round process chain that has to be considered in order to make estimates of the time when *baggage loading* is completed. Accurate process completion times for *all* turn-round processes however, are essential for making reliable predictions of the TOBT.

Additionally, the overall turn-round time varies from flight to flight because of the different passenger numbers or the amount of ground handling services required. A typical approach of airlines to managing the turn-round operation is by using a turn-round reference model, where pre-defined timeframes indicate the coordination of *all* ground handling processes towards the end of the turn-round. The reference model incorporates the different durations of ground handling services for different aircraft types.

The airlines assign ground handling services to third party companies. Service Level Agreements (SLAs) are negotiated between the airline and the ground handling company to reinsure that quality standards are maintained as required by the airline. Figure 4 shows a generic reference model of a turn-round at a remote position where the number indicates the time before EOBT in minutes; however depending on the specific turn-round situation the actual turn-round itself can be far more complex.

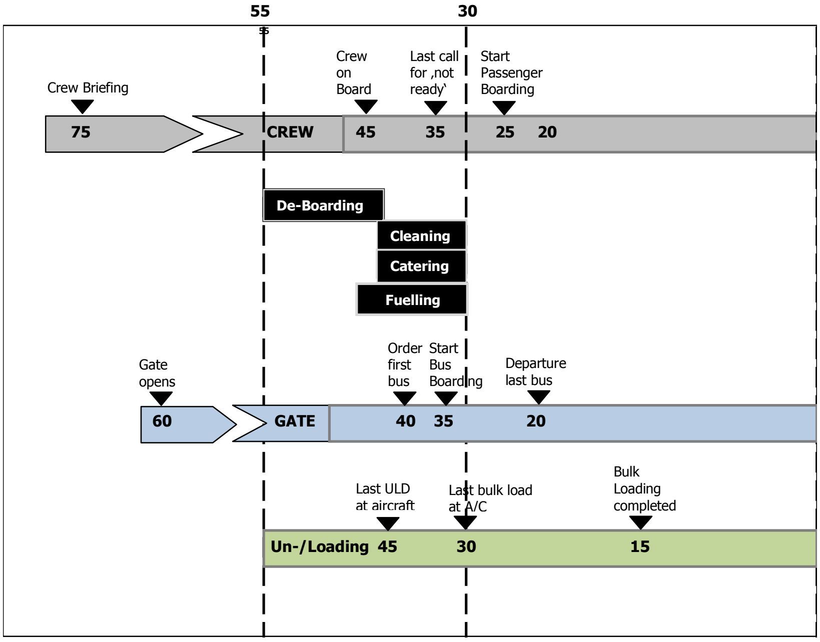


FIGURE 4: GENERIC MODEL OF TURN-ROUND TIMES

Different strategies exist among airlines for the execution of the turn-round. While low-cost carriers tend to use a 'team strategy' where a team is assigned to each turn-round to handle all turn-round activities, the prevailing strategy among incumbent airlines is to handle the turn-round through grouped processes and sequential work flows, where different units are responsible for individual flows, e.g. baggage handling, catering, cleaning, etc. This strategy however requires good coordination between the participating units. In general, the number of participating functions today is rising because the airlines are increasingly employing third party service providers for ground handling services. This complicates the coordination required during each turn-round with the consequence that the responsibility for the overall turn-round management is not visible or is lost among participants.

2.6 Turn-round Monitoring Systems

To counteract emerging delays resulting from increasingly complicated ground handling processes and the short time often available for the turn-round, airlines often use different turn-round monitoring systems which enable them to compile timestamps in real-time - either manually or automatically, e.g. via an *Aircraft Communication Addressing and Reporting System* (ACARS) or other sensors on-site. Such monitoring devices range from WIFI (Wireless Fidelity) hand held or WLAN (Wireless Local Area Network) systems with manual process tracing to fixed installations based on Radio Frequency Identification (RFID) technology and that often allow tracking each single ground handling process while using this data for monitoring the overall turn-round.

However, in order to understand how a single ground handling process can influence the overall turn-round performance, the effect of an individual turn-round process on the path of ground handling events (See Chapter 3.4) has to be taken into consideration.

Allegro or *HubStar* are tools that are used for monitoring the turn-round in the Airline Operation Centers (AOCs) or used as a ground handling data base. HubStar describes itself as a generic product able to adapt to any turn-round operation. It also claims being able to monitor the concatenation of correlated handling tasks for turn-round flights, arrivals and departures, to identify the critical path and in doing so, supplying all decision-support information required.ALLEGRO was developed to gather information with focus on timeliness of turn-round processes between in-block and off-block time. Landside and airside processes can be analysed in order to identify required measurement points where timestamps can be set (See Appendix IV). Such monitoring tools are named differently when used by different airlines; however, the functionalities of these tools are similar. Wu (2008) claims that application of such real-time monitoring systems makes turn-round operation more transparent, identifies potential delay sources, and helps to develop airline schedule optimization algorithms.

2.7 Turn-round Shortcomings during A-CDM

The Airport CDM Operational Document (EUROCONTROL, 2003) describes *shortcomings* of today’s operational processes. These include:

- Unsatisfactory information exchange between aircraft operators/ground handlers and ATC/FMP or airport operators. As a result, not only decisions regarding management of ATC and airport resources such as runway, taxiways, stands and gates are suboptimal, but also adherence to *Air Traffic Flow Management* (ATFM) restrictions and airport slots are likely to be compromised.

- Often no visible link between airborne and ground segment of the flight exists with the consequence that changes within one segment are not communicated to all participating partners. Hence, pre-planning of appropriate measures to re-schedule resources or other activities necessary cannot be done. This results in poor data quality or predictability of flights or segments of flights.
- At most airports today, default taxi times are used to calculate an in-block or off-block taxi time. However, due to the size of the airports and the weather at the airport that defines the runway configuration, taxi times can vary significantly and default values result in inaccuracies and hamper Calculated Take-off Time (CTOT) adherence. As a result, poor traffic prediction leads to inefficient use of existing en-route capacity, bunching or even sector overload.
- Ground processes and en-route traffic is not yet considered as a time-dependent chain and therefore, the impact on down-stream events is not evaluated. Aircraft operators compensate for this information lack by using their own fleet management systems. However, the picture gained of one aircraft operators' daily network operation is only a part of the entire network - often failing to include ATC and stand or gate management from airport of departure. Airport partners often do not believe that such information could be interesting for them. To tackle this problem, CFMU tries to obtain a view of the complete ATM network in order to identify bottlenecks and calculate regulations, if required. However, the quality of such regulations depends largely on the quality of available data. The major source of inaccuracy is the *Estimated Take-off time* (ETOT) derived from *Estimated Off-block Time* (EOBT) + default taxi time.
- The still prevailing principle of 'first-come-first-served' does not reflect the ATC situation or takes aircraft operators' preferences into account.
- Also an airport aiming for maximum efficiency can run into problems during events that require procedures different from standard operations or cooperation among partners. Even though operators have different methods of dealing with

such events, the overall operation can be affected if these methods are inconsistently applied or cooperation is poor. As a result, available capacity is not fully used at the time needed during such adverse conditions.

3 HUMAN DECISION MAKING AND DECISION SUPPORT

3.1 Decision Support Systems

3.1.1 Introduction

Human decision making is a crucial element of turn-round management and airport operation, but often shows conflicting demands among participating partners. As an answer to the increasing complexities at airports especially during aircraft turn-round, the A-CDM concept was established which considers decision making as one of the most critical activities for successful flight operation (EUROCONTROL Doc, 2009a). In order to provide support for all airport partners during turn-round decision making, the Airport CDM Information Sharing Concept has been created as one of the essential elements for decision support. This should be available during all phases of the flight, including the turn-round phase. The most crucial decision during this phase is the TOBT assignment and TOBT updates to the actual situation. However, the decision support that is required for TOBT assignment especially during the turn-round phase, has never been systematically analysed to the effect that TOBT prediction typically is based on oversimplified approaches leading to poor accuracy and stability of the predictions.

During management of the turn-round, every decision about the affected turn-round processes produces a TOBT. This target time marks the turn-round controllers’ estimate of the time that the aircraft is ready for push-back and start-up. This decision includes her/his opinion about completion of the turn-round and sharing this information via the A-CDM Information Sharing Platform. This decision can either be based on her/his sole opinion about the turn-round completion or on a shared opinion encompassing her/his own assessment and the inputs or turn-round updates which he receives from other participating actors like ramp agent, aircraft pilot, or flight manager.

The underlying question for the development of a Decision Support System (DSS) that aids TOBT prediction is now: What role and functions can be assigned to a DSS that as a result is then able to assist the turn-round manager in his task? Millot (1987) states a number of functions required by such a system if seen from user’s perspective which include ‘*assisting decision makers in their decision process during semi-structured tasks; supporting and enhancing rather than replacing managerial* *judgments; improving the effectiveness of decision-making rather than its efficiency; attempting to combine the use of models or analytical techniques with traditional data access and retrieval functions; specially focusing on features that make them easy to use by none-computer people in an interactive mode; emphasizing the flexibility and adaptability to accommodate changes in both the approach of the decision maker and the environment in which he acts'.*

However, even with the improvement of today's technologies for enhancing the performance of DSSs, the growing complexity creates a hurdle for the design of support systems incorporating these functionalities. Chalmers (2002) realizes this problem and proposes as a first step to describe the requirements for understanding decision makers by asking:

- What are the specific data needed, in what context, and when?
- How does it need to be processed and integrated?
- What should be its representational form?
- How should this form be encoded into sensory form and mapped to an interface for information extraction by the decision maker?
- What are the performance limitations of decision makers in accessing and decoding information?
- What proactive strategy is used by the decision maker in unanticipated situations?

The search for a suitable decision support system for turn-round management might also benefit from comparisons to the current shortfalls and functionalities of other decision support systems. O'Neill (1996) describes the limitations of current decision support in command and control environments which include:

- difficulty in eliciting tacit expert knowledge;
- decision makers' discretionary need for ordering tasks and determining task goals themselves based on their local, dynamic situations;
- difficulty in eliciting implicit expert knowledge about desired situation end states (goals) and impossibility of representing such knowledge as symbolic rules;

- difficulty, if not impossibility in particularly dynamic situations, to completely predefine information requirements;
- failure to incorporate knowledge about operational plans and context in which aid is provided;
- lack of mechanisms for supporting change;
- no formal facility for framing and solving ill-structured problems; and
- lack of support for informal communication among decision makers and for capturing the context of this communication for purposes of recall and reuse.

In order to accommodate these limitations O’Neill proposes the design of a highly flexible decision aid architecture that is able to support also emergent work behaviour and provide an answer to the inadequacy of the routine problem-solving method which is currently used for decision making. Examples of attempts to design methods to operate on routine basis are the ‘Turn-round Reference Models’ of the airlines (See Chapter 2.6); However, such standardized turn-round models are not able to accommodate for non-standard situations requiring flexible decision making aids.

3.1.2 Intelligent Decision Support for TOBT Assignment

The traditional A-CDM Information Sharing Concept does not provide a decision support that gives the flexibility required for the assignment of a realistic TOBT based on all available information. Existing systems provide extensive information and data; nonetheless, no concept for *structured* ways of dealing with complex turn-round situations can be found. In addition to the aspects hampering successful turn-round management as outlined in Chapter 1, the complexity of the relations between all airport partners, the number of decision makers and organisations involved, the amount of information sources available, and the decreasing time of the turn-round itself are contributing to the requirements for a DSS that is able to aid TOBT decision making.

Intelligent Decision Support Design is an approach that integrates human intellectual and computer capacities to not only provide passive information, but to actively improve decision making quality in semi-structured problem situations (Keen and Morton, 1988). It is particularly necessary, if the amount of information is so large or time constraint so high that human errors are likely (Gadomski, 1999). Especially when coping with unexpected situations, decision makers are required to immediately apply complex knowledge which - if not properly available - causes poor decisions. Gadomski (1999) proposes an Intelligent Agent Approach for the development of an Intelligent Decision Support System (IDSS).

According to Hollnagel et al. (1985), the development of an IDSS that is able to perform such cognitive tasks requires a corresponding shift in the multiple disciplines that can support effective human-computer systems. As a consequence, contributions from decision theory, systems engineering, cognitive engineering, and artificial intelligence have to be integrated into the development of an IDSS (Figure 5).

A minimum of two of such disciplines should be combined in order to develop a comprehensive description of an IDSS (Hollnagel, 1985). For this research study the disciplines of Cognitive Engineering (see Chapter 3.3) and Decision Theory (see Chapter 3.1) were chosen in order to describe and develop a decision support system that can support decision making in the A-CDM work system. While studying the literature some overlaps of the cognitive engineering and systems engineering disciplines were found.

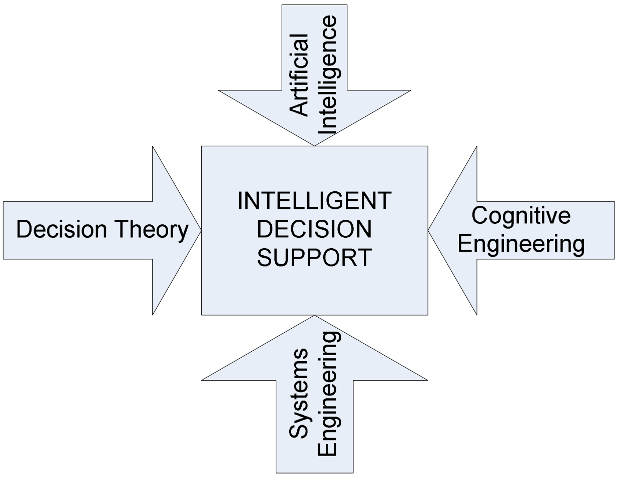


FIGURE 5: DECISION SUPPORT IN PROCESS ENVIRONMENTS (SOURCE: HOLLNAGEL, 1985)

3.2 Decision Theory

3.2.1 Introduction to Decision Making

Decision making can be defined as an *outcome of mental processes (cognitive processes) leading to the selection of a course of action among several alternatives* (Mc Dermott, 2008). Decision making has been subject of active research from several perspectives, e.g. from a psychological perspective as the ‘individual decisions in the context of a set of needs, preferences and values of an individual are examined’ or from a cognitive perspective where the decision making process is regarded as ‘a continuous process integrated in the interaction with the environment’. From a normative perspective, the analysis of individual decisions is concerned with the logic and rationality of the decision-making.

This chapter does not intend to provide a comprehensive analysis of decision making perspectives or theories, but to introduce theoretical decision making aspects that could have an influence on the design of a possible decision support system for TOBT decision making. The aim hereby is to identify critical aspects for decision making related to the specific operational scenarios of the turn-round and the task of assigning an accurate completion of the turn-round by predicting the TOBT. The *Decision Making Theory* is one of the four pillars that have been chosen to develop an intelligent decision support for the A-CDM work system (See Figure 5).

Even though the A-CDM concept has already been established and realized as a key enabler for today’s turn-round operation, a number of theoretical decision making aspects can be identified that have not yet been sufficiently taken into account, but are necessary to understand how decision support in such a specific process environment can be provided. Due to the turn-round complexity and therefore limited possibilities to manage the turn-round processes - especially in unexpected situations, a structured way of decision support for turn-round monitoring and TOBT decision making is seen as beneficial.

According to Hollnagel (1985), decision making in complex environments no longer follows a single set of rules or strategy, but constant attention to the process is required, because its state can change dynamically. In addition, a process execution with optimized outcome depends more on the environment of the processes than on an optimized sequence (Boeckmann et al, 2008).

A number of aspects from decision theories that affect CDM during turn-round management with focus on TOBT decision making are lined out.

3.2.2 Situational Awareness during Decision Making

Situational Awareness (SA) can be defined as '*the perception of environmental elements within a volume of time and space, the comprehension of their meaning, the projection of their status in the near future, and including the prediction of how their behaviour may affect the environment'* (Endsley, 1988). Common Situational Awareness (CSA) has been proposed as a key enabler for successful A-CDM (EUROCONTROL, 2003) and describes the aim that flight progress information is freely and universally available to all interested parties within the A-CDM Information Sharing Platform. Although a common view of the flight progress is not essential as a core of information available to all users in the same form and for common awareness, many types of flight progress information are required that are able to turn out in an unique understanding and response by the particular airport partner or actor. For instance, the airport focuses on a picture of the flight progress for taxi guidance or parking stand assignment, while the airline focuses on a picture of the aircraft and passenger flows.

SA has become a central model of many real-time decision making problems within dynamically alterable environments where information is constantly changing and frequent monitoring is necessary to grasp the current state of knowledge (Endsley, 1988). Stewart et al (2008) argue that SA should be examined in a system-wide perspective rather than individual-oriented. She proposes the novel characterisation of Distributed Situational Awareness (DSA) in a teamwork context based on the argument that cognitive processes in distributed teams occur at a systems rather than an individual level. Relevant cognitive factors include the representation, transformation, and manipulation of information. As a consequence, each individual member of a team uses the information in a way that supports his/her own mental picture of the situation. Stewart (2008) defines Distributed Situational Awareness (DSA) therefore, as activated knowledge for a specific task within a system. The DSA theory was developed by Stanton et al (2006) and is based on six basic propositions:

- SA is held by both human and non-human agents.
- Communication between agents may be in the form of non-verbal behaviour, customs, and/or practice.
- Non-overlapping and overlapping SA depends on the agent’s goals.
- There are multiple facets of SA pertaining to the same scene held by different agents.
- One agent may compensate for degradation in another agent’s SA.

3.2.3 The Aspect of Time

While process environments are characterized by time constants, Volta et al. (1986) points out that decision theories traditionally do not contain any element of time and therefore fail to recognize an essential attribute of process environments. However, decisions can be viewed as separation or cut in time. Before and after a decision has been made, things may look different. Volta also connects space and time as phenomenological dimensions. When viewed from the perspective of experience, decisions can be completely different and so has to be linked with the decision making process as part of the decision making structure, if time is a factor. Although historically, preference has been given to static models of decision making and the time dimension has been realized, the dichotomy between the subjective/perceived and objective/physical time aspects remains a challenge when modelling time aspects in decision making processes.

Recognized time aspects during TOBT decision making are the dynamical changes of the turn-round process state requiring constant attention by the decision maker. Decision making trade-offs result from the number of turn-round processes that require a decision and the time available for monitoring the processes in order to make the decision. Control loss has to be expected, if decision maker fails to maintain attention. Available knowledge bases are required in order to consult the decision makers - assuming time is sufficient. Another time aspect is the moment itself when the information required for TOBT decision-making emerges. The significance of the moment that this information is available and then *directly* used for TOBT decision has not been analysed yet, but may affect TOBT decision making significantly. Interactions for such information exchange between participating airport partners and actors with time aspects are referred to here as ‘asynchronous’ and ‘synchronous’ interactions.

3.2.4 Turn-round Dynamics: The Uncertainty Aspect

Another characteristic of turn-round management is the uncertainty about data and information arising from the complexity and dynamics of the turn-round. Since time can be critical during turn-round management, required knowledge for the process must be directly available, if a decision is required. Thereby, knowledge is seen as a set of flexible and adaptable skills allowing the actor or decision maker involved to wield and to apply information as required to the specific turn-round situation/problem. Such skills are in part, what differentiates information or data from knowledge. On the other hand, the information/data available has to be shared between partners involved where required, and procedures need to be established for standardized sharing of such information/data opposite to sharing information/data accidentally as it is predominant during real time operation. The amount of processes and number of actors involved for each turn-round process can be so high that failures in sharing information during a single turn-round process can jeopardize the overall turn-round.

Another uncertainty aspect is the inherent risk of unanticipated events resulting momentarily in a heterogeneous information sharing situation, e.g. the captain detects a technical failure during the outside visual inspection of the aircraft, but so far no one else is informed about it. This however, can happen even shortly before passengers start boarding, but during normal turn-round operation flight crew members are generally not directly involved in turn-round process coordination. Therefore, this information has first to be transferred to the turn-round controller in order to be reflected in the TOBT decision. Since such necessary interactions between actors and airport partners can arise at any time during turn-round, optimized coordination of the processes is required in order to make reliable TOBT updates.

3.2.5 Human-Information Interactions during Decision Making

A. Introduction to Human-Human Interactions

The design of interfaces for intelligent decision support systems requires an understanding of the human-human information interactions taking place within the system under analysis (Belkin, 1985).The concept of A-CDM elicits only information interactions between the recognized airport partners via the *Information Sharing and Milestone Approach* (See Appendix I). Interactions between airport partners are here referred to as *Human-Human Interactions* (HHI) and *Human-Computer Interactions* (HCI) at the planning level. However, many interactions required for information exchange during the turn-round arise from HHI at the action level or HHI between the action *and* planning levels: whereby, HHIs at the *action level* refer to interactions that can be found among actors like pilots, ramp agents, service providers or others. Usually they have a shorter time span and less abstraction compared to HHIs at planning level.

In this context it will be investigated, how the interactions between the action level and the planning level are established during turn-round and whether they create the situational awareness required by *all* participating. Focus is applied to HHI situations between aircrews and other airport partners during turn-round where cooperation is required for the coordination of processes. All processes between Milestones 7 and 14 should be regarded where interactions between the action and planning levels are mandatory. Examples include not only interactions during all turn-round processes like boarding, loading, catering, fuelling, cleaning, but also those interactions with ATC: Starting from aircraft leaving the parking position, coordination with other departing aircraft is necessary prior off-block for the usage of taxiways, runways and airspace. While it is the responsibility of the pilots to execute the flight according to defined rules aiming at the highest degree of safety possible, ATC is responsible for flight safety by keeping sufficient separation between aircraft already during taxi and take-off, and managing air traffic flow by issuing clearances to the pilots. Differences in the level of control between pilots and operators like ATC in such situations are that ATC has authority over assigning the taxiways, runways, and airspace in form of clearances to the pilots and again depend on cooperation from pilots, to adhere to these clearances.

The results gained from the literature research of this Chapter have largely influenced the design of the experimental study on cooperative information sharing (See Chapter 7).

B. Incomplete and Asynchronous Information-Interactions

The designers of the turn-round process control also have to determine the level and timing of information required allowing for adequate situational awareness. They need to determine what kind of information has to be shared and when. However, Parasuraman et al. (1996) argues that as far as humans are involved in information provision and creation, failures may occur resulting in drifts of perception and not established situational awareness having obvious consequences on process reliability.

To share information, operators like aircrews, ground handlers or other airport partners communicate with each other either verbally (e.g. via phone or radio) or through written text (e.g. via ACARS) while Controller Pilot Data Link Communication CPDLC is only used during en-route phase of the flight. Hence, how the airport CDM information sharing process is influenced by the following variables, has to be analysed:

- Synchronous versus asynchronous interactions: synchronous interaction means that all actors and airport partners share the information required for TOBT decisions at the time that the information arises using any available interaction tool as opposed to asynchronous interactions where a time delay arises between emerging and passing on of information.

- Homogeneous or heterogeneous information distribution: actors and/or airport partners do not have the same information available (heterogeneous) as opposed to homogeneous information where all involved share the same information.

During turn-round process management, *interactions* between participating actors or airport partners can be *synchronous* or *asynchronous*. Coordination of actions takes place by way of predetermined key events (*milestones*), organized as a sequence of interactions between airport partners; if a non-standard situation (like aircraft change, technical repair, adverse weather operation, etc.) occurs, ad hoc coordination through face-to-face communications or via two-way radio/mobile phone between the affected actors has to take place. However, because of the information dynamics in the volatile environment of the turn-round processes and the varying tasks of the different participating actors/airport partners' information distribution during the turn-round process is still *heterogeneous* between participating airport partners and actors.

Homogeneous information sharing is not always easy to achieve because barriers to sharing information can exist.

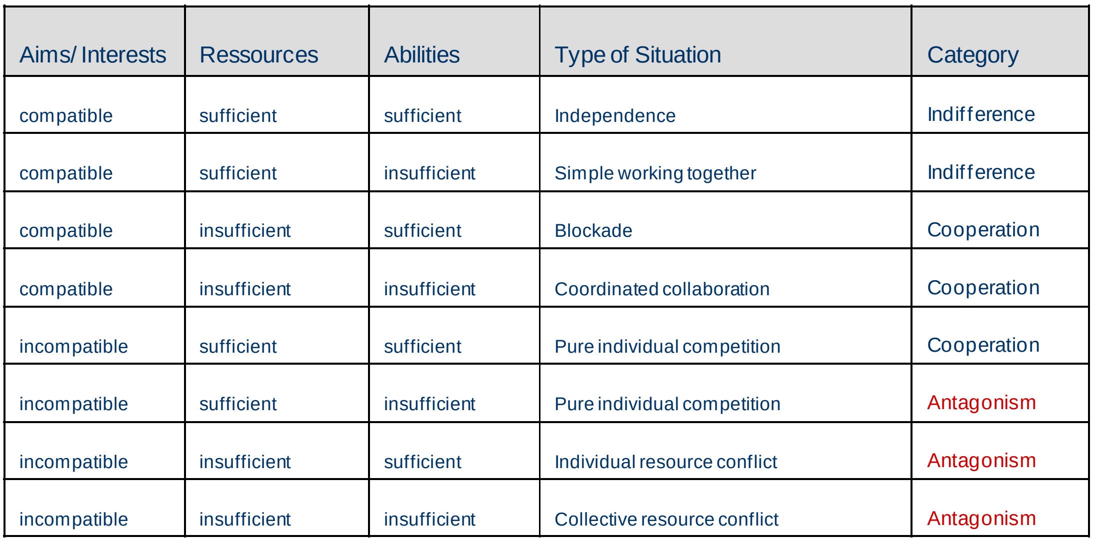
C. The Notion of Cooperation during Human-Human Interactions

According to Ferber (1995), three variable components of HHI are required to classify different types of interaction situations as cooperation, antagonism, and indifference situations. These components are the *aims*, *resources*, and *abilities* inherent in the minds of all participating actors. Depending on the distribution of the components among actors it can thus be analysed whether a contemplated turn-round situation is cooperative or non-cooperative in itself (see Figure 6). The question is whether the individual aims of the participating actors are compatible or conflicting, the resources sufficient or limited, and the abilities of the participating actors sufficient or insufficient to complete their assigned tasks.

The aim of the analysis here was to identify how the HHI are established between the pilots and the others during the turn-round and the extent of cooperative behaviour during the day-to-day turn-round operation among all actors. This was done during a survey study with airline pilots, which aimed at identifying critical situations for TOBT adherence (See Chapter 5). Cooperation is assumed to be necessary in the context of A-CDM and therefore, TOBT decision making.

D. The Emergence of Cooperation

In the context of turn-round operation, HHIs are seen as dynamic relations between pilots and other operators and are established through a number of mutual actions. Each action by one operator has consequences that influence the behaviour or the prospective behaviour of the other operators. Ferber (1995) defines interaction situations as *a number of behavioural patterns which evolve from a group of agents, who have to act in order to reach their targets; thereby, they 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 by differentiating 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 with regard to their assigned task. These criteria are used to define the different types of interaction situations (Figure 6).



Aims/ Interests	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 individual competition	Antagonism
incompatible	insufficient	sufficient	Individual resource conflict	Antagonism
incompatible	insufficient	insufficient	Collective resource conflict	Antagonism

FIGURE 6: CLASSIFICATION OF INTERACTION SITUATIONS (SOURCE: FERBER, 1995)

Each type of interaction situation has its own relation towards cooperation: In an *Independence* 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 because resources are sufficient, 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 behaviour.

According to Ferber (1995), the prerequisites for human-human interactions to take place are:

- a number of actors, who are able to act and communicate;
- situations where actors meet or act via telephone with each other;

- dynamic elements, which allow local, time limited relations between agents; and
- a certain slack within the relations between the agents, in order to not allowing them to maintain or get out of the relations.

According to Hoc (2001), 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 7).

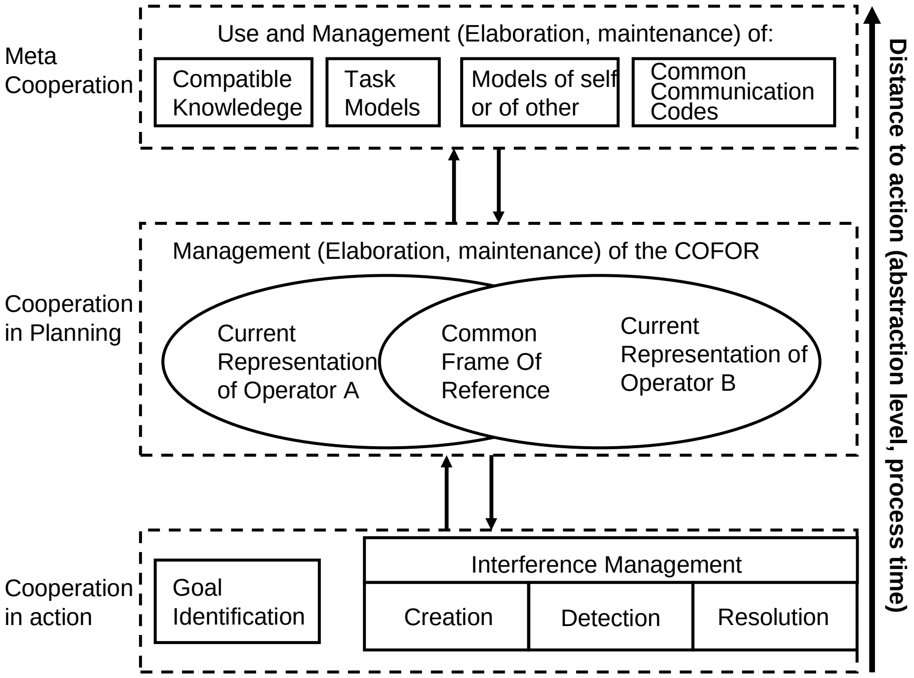


FIGURE 7: PROCESSING ARCHITECTURE OF COOPERATION (SOURCE: HOC 2000)

The main benefit from the study of HHI situations is expected from an identification of antagonistic situations on the action, planning, or between the action and planning levels. At *action level*, the operators perform operational activities related to their individual goals, resources, and abilities. Hoc has defined four types of activities at action level: Interference creation (e.g. mutual control), interference detection, interference resolution, and goal identification (Goal identification also incorporates the 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;

whereas interference detection to the ability of detecting interferences, especially in non-deliberate interference situations. Interference resolution relates 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 (Hoc et al, 1998). Schematic representations include the concept of situation awareness (Salas et al, 1995), and operators' goals, plans, and meta-knowledge (Hoc et al, 1998). Therefore, the current approach to CDM operation in ATM is seen as an approach with the aim of achieving cooperation on planning level. De Terssac and Chabaud (1990) use the term 'Common frame of Reference' (COFOR) as a mental structure playing a functional role in cooperation. As a shared representation of the situation between operators, a COFOR is likely to improve their mutual understanding (Carlier et al, 2002). The topmost level in Hoc's model, the meta-cooperation, as a level developed from knowledge of the other two levels.

A number of further theories on cooperation were found during the course of research that deserve attention, because of their potential to improve cooperation in complex environments. They can be found in Appendix V.

3.2.6 The Influence of Aircrew Decision Making

Aircrew decision making is usually seen in the context of (aircrew) team performance, Crew Resource Management (CRM), and team training. However, while the turn-round manager is primarily responsible for the turn-round operation planning, participating actors – including aircrew – are responsible to safely execute the turn-round processes: Dispatch of the aircraft is only possible, if the pilot deems all processes complete under the maximum possible safety considerations. In various situations, these considerations require interactions and interrelations between aircrew and other actors involved in turn-round operation, because relevant information required for TOBT can result from such aircrew decision making and has to be shared with the turn-round manager.

Redding et al (1983) mentioned the problem of not having a unified framework for sharing a common decision-making process with aircrews, but emphasises the importance of having a shared mental model for situational awareness and decision making.

For the design of a DSS that enables optimum decision making, it has to be analysed, how information sharing and situational awareness between aircrews and ground parties can be accomplished. Hence, these questions have to be addressed:

- How is required information delivered to the cockpit?
- How is required information delivered to cockpit on-time?
- How is the information, forwarded from cockpit handled by other actors?
- How long is the delay resulting from information that is not shared between cockpit and ground?

3.2.7 Modes for Sharing Information between Aircrew and Ground

Information-interaction tools available to the cockpit differ depending on whether the aircraft is on ground or in flight. Some possible means that are available during flight in the cockpit for providing information include:

- ACARS: interface to address information requests or to provide operational information directly to the turn-round controller at the arrival or departure airport. This can be used to address all issues concerning ground handling processes, especially those arising during flight. Other ground handling service providers can also be addressed directly.
- Direct voice communication can be established between aircraft cockpit and turn-round controller can also be established via two-way radio communication, if the aircraft is within the reception range of the ground stations.
- On Ground: Mobile phones with short-dial function are available for cockpit to contact turn-round controller or other ground handling service providers.
- Direct Information exchange with ramp agent.

3.2.8 Decision Aiding for A-CDM

Given the number of characteristics that may influence the outcome of the decision-making, the proliferation of decision aiding though consultants, analyses, or computer is not surprising (Humphreys et al, 1983; Stokey and Zeckhauser, 1978; Wheeler and Janis, 1980). A number of reasons can be attributed to the difficulty of individual decision making. These include identification of all possible courses of action, evaluation of attractiveness or possible consequences, assessment of the likelihood of each consequence, and the integration of all these considerations (Fischhoff, 1986).

While already individual decision making can be difficult, decision making becomes more demanding in complex systems where interdependent decision makers are responsible for overlapping portions of dynamic situations. If putting together the various perspectives of multiple decision makers, the notion of distributed decision making has been characterised and defined as any *situation in which decision-making information is not shared completely by those with a role in shaping the decision (Fischhoff, 1986).* A further characteristic of TOBT decision making is the spatial separation of decision makers, but only with a certain distribution of freedom to decision-making. Airlines’ control rooms provide a set-up to centralise TOBT decision making. However, it is still a form of decision making asking for future elaboration, because it has not yet been analysed how decision making at the various locations versus centralizing decision making has affected the outcome of the overall TOBT decision.

Common data sets are established among airport partners when introducing A-CDM. Such data sets include also process updates at the various milestones aiming at increasing the common situational awareness among partners and creating an overall picture of the situation. However, it has also never been analysed what parts of the overall picture is actually required by the individual decision maker at the various locations of airport in order to create a situational awareness that *he/she* requires for making his/her decision: do all partners really need to have the *same* overall picture or is it even better if each partner only possesses the information about the parts of the picture that he/she requires for making the decisions or is necessary for managing his/her own resources? Such considerations should also investigate what communication/interaction links are required so that the information can be best shared among actors.

It is also argued that distributed decision-makers should have a picture of the other participating actors’ aims and intentions in the relevant situation, because this picture will shape their situational awareness and communication behaviour and thereby affect the outcome of the decision making.

Complications increase even further with the *number* of individuals involved during turn-round management. This again calls for analysis of behavioural significant patterns about how the individual actors understand and manipulate their environment. This should be considered when designing an Intelligent Decision Support System.

3.2.9 Single versus Multiple Decision Makers

When centralizing turn-round decision making into a single-person decision making process, the risk of cognitive or personal biases increases because of the difficulties like those mentioned above. According to Fischhoff (1986), complications can arise through uncertainty factors like misperception or overconfidence in decision makers’ knowledge. In dynamic situations, undue adherence to favoured hypotheses or potential solutions can also be causes for poor decision making. When comparing these issues with those arising from multi-person decision making, observable arguments in favour of individual decision making include the multiple goals of participating individuals that have to be managed and the more views that have to be heard. Nevertheless, any participating actor’s experiences could significantly influence both, the affected process, as well as the overall turn-round process and should therefore be taken into account by decision makers.

A further aspect which should be mentioned in multi-person decision making situations is reliability whereby the source of failure can be external (e.g. disruption or equipment failure) or internal (e.g. disinterest or desire for autonomy).

The volume of information can have a double-sided effect: while too much information can create an overload condition with the risk of not being able to handle the situation anymore, a suitable amount creates situational awareness. Information volume also has an impact on the required communication for information exchange: if communication lines are not linked appropriately, it can become impossible to manage the coordination of information.

3.2.10 The Notion of Distributed Decision Making

Based on the identified characteristics of such multi-person decision making, the approach used for TOBT decisions requires modelling decision making situations with clear sharing of responsibilities and either centralized or decentralized ways of communicating the information and mechanisms to ensure the highest extent of reliability possible. For decision making in such an environment, the notion of Distributed Decision Making is used as a relatively new terminology in order to account for the changes in multi-person decision making that are possible through advances in technology. Such technology includes expert systems or computerized decision aids which not only increase the distance over which individuals share data, information or instructions, but also the amount and the automation of such exchanges. Fischhof (1986) proposes a number of design guidelines, if an approach to distributed decision making is used:

- The reality of all participating decision makers at each node should be regarded for the design (e.g. if designers are unfamiliar with the operation, they must first learn about it).
- Many group problems may be variants of individual problems.
- Problems attributed to technology are not necessarily caused by their novelty.
- Distributed Decision Making design requires detailed empirical work achieved by resisting simplistic design philosophies.

Nevertheless, approaches to implement such guidelines apparently failed when used to design decision support for complex technical systems (National Research Council, 1983; Perrow, 1999; Rasmussen and Rouse, 1981). Therefore, Fischhof et al. (1986) propose describing such problems, to devising possible countermeasures, and validating these through empirical tests. He identifies possible remedies like: making contingency plans more realistic, generating options for novel decision-making situations, improving accessibility of information via computerized databases, structuring judgmental tasks to make better use of people’s mental capabilities, and formulating policies that will be meaningful in varied circumstances.

Today, Distributed Decision Making (DDM) provides a framework within the Distributed Cognition Theory (see Appendix V) to study automated supervision systems in interaction with humans in complex networks (Rasmussen et al, 1990). It analyses the segregation and subsequent coordination of a complex decision problem. Such a problem may consist of one or more decision makers who may possess individual information. The DDM approach can be applied to a wide range of complex decision making problems; the focus here however is on problems of coordinating complex decision models for turn-round situations with multiple distributed decision makers having a synchronous or an asynchronous state of information. Whereby, during a synchronous state of information as all decision makers are having the same information at the same time available for decision making opposite to an asynchronous state where decision makers do not have the same information available. Such situations often illustrate problems with the hierarchical structures of decision making.

Physical separation of decision makers owning individual information critical for the affected turn-round process is a possessing problem facing decision makers during turn-round management. While various means exist to bridge this problem, the cognitive phenomena also have to be considered when designing interactions (Wellens, 1988; Daft and Lengel, 1984; Short, Williams and Christie, 1976) as well as the influence on problem solving and team performance when manipulating the communication structure (Leavitt, 1951; Shaw, 1964).

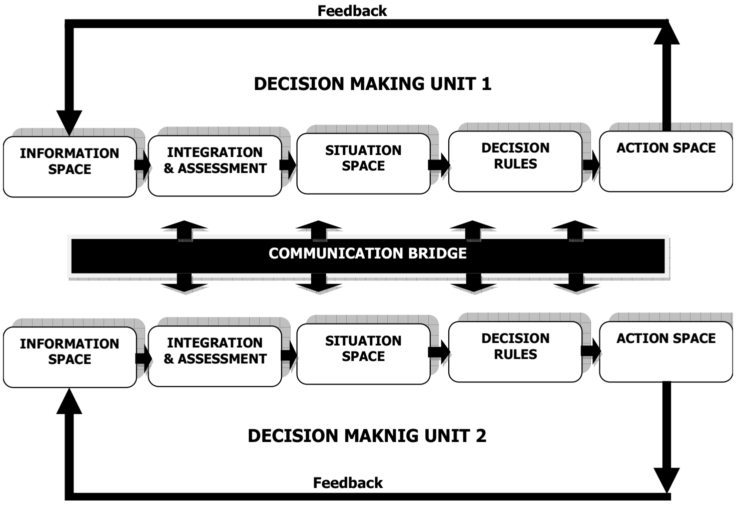


FIGURE 8: DISTRIBUTED DECISION MAKING MODEL (SOURCE: WELLENS ET AL, 1988)

3.2.11 Distributed Decision Making during the Turn-round Process

Despite the tendency to centralise decision making for TOBT decision to a single turn-round controller who monitors the turn-round in a control room using different data sources and interaction tools, the responsibility for the individual turn-round processes remains within a number of airport partners including the various service providers, ground handlers, airport operator, airline representatives, and participating actors. But not only the decision maker, also the information, authorities, and resources are physically distributed. Consequently, coordinating and making decisions suitable for TOBT accuracy as an overall process outcome and that serve the interests of all participants is fundamentally problematic. This reveals the underlying trade-off between controlling the individuals involved and the need to let them respond to their own demands. Other problems caused by such environments is the difficulty in creating an overall objective that is meaningful in the diverse or unanticipated turn-round situations and in creating an incentive system that motivates everyone participating.

Hence, turn-round management shows distinct characteristics of distributed decision making among airport partners and actors with diverse interests. The theoretical concept of Distributed Decision Making (DDM) is therefore used in order to model the A-CDM approach. DDM comprises numerous areas as part of different disciplines like operations research, computer science, organisational theory, psychology, sociology, and others. Research in human factors disciplines aims at anticipating and understanding such decision making in order to shape the design of the organisations and technologies involved. This means that skills from different contributing professions include psychology, industrial engineering, physical anthropology, applied mathematics, training, and sociology. Consequently, each problem requires from all of these areas expertise contributing to human factors. Collaboration among specialist experts from participating domains has to be established in order to analyse the environment where collaboration takes place. Despite existing differences between different systems or domains, they all have similar functions and challenges that make it possible to identify commonalities. These can be e.g. process coordination, allocation of resources, or responsibility and control.

Distributed Decision Making research has already been applied in areas like military command and control (Warner et al, 2002), fire fighting, and the development of shared software.

Schneeweiss (1999) provides a quantitative decision analysis approach to DDM for application to supply chain management, service operations, and managerial accounting. He describes three properties of distributed decision making systems like *anticipation* as the ‘base-level’s bottom-up influence on the top-level, *instruction* as the top-level’s decision, and *reaction* as the base-level’s reaction to the instruction. Reaction can be either a communication or negotiation process.

3.3 Cognitive Engineering

3.3.1 Introduction

Cognitive Engineering arose during the 1980s caused by the increased complexities and challenges faced by human operators, as computer technologies became ubiquitous in the workplace and changed the nature of work (Woods, 1987). Cognitive Engineering offers a principled approach to the design and development of human centred systems (Pfautz and Roth, 2006). Researchers in cognitive engineering have addressed problems like the decision making and problem solving support via computer systems in domains like military systems, aviation, manufacturing, process control, and medicine. Fundamental to the research is the emphasis on an interacting triad of humans, the system to be acted upon, and the manner in which the humans view and control the system (Woods, 1987; Woods and Roth, 1988). Thereby, the inherent goal of the interaction design is a mediation that augments rather than limits humans’ view and control of humans within the system (Bisantz, 2006).

Cognitive engineering is also an interdisciplinary approach to designing computerized systems intended to support human performance (Roth et al, 2008). It is concerned with the analysis, design, and evaluation of complex socio-technical systems (Andriole and Adelman, 1995, Rasmussen et al., 1994, Woods and Roth, 1988, and Vicente, 2003). The methods of cognitive engineering consider workers and the tasks they perform as the central drivers for system design and provide a framework of how people perform cognitive work.

Bonaceto and Burns (2003) describe a number of cognitive engineering methods for system design and/or system evaluation, and group them into categories according to their intended purpose. Each method can be organized into one of five primary categories: (1) describing cognitive/behavioural processes, (2) modelling/simulating cognitive processes, (3) modelling/ simulating behavioural processes, (4) modelling erroneous actions, and (5) modelling human-machine systems. While some methods overlap multiple categories, each method is assigned to a "primary" category (Figure 9).

COGNITIVE ENGINEERING METHODS		
Cognitive and Behavioural Processes	Described with	System Evaluation Methods
	Described with	Theoretical Frameworks
Cognitive Processes	Modelled with	Cognitive Task Analysis
	Simulated with	Computational Cognitive Modelling
Behavioural Processes	Modelled with	Task Analysis
	Simulated with	Computational Task Simulation
Erroneous Actions	Modelled with	Human Reliability Analysis
Human-Machine Systems	Modelled with	System-Oriented Methods
	Modelled with	Cognitively-Oriented Methods

FIGURE 9: COGNITIVE ENGINEERING METHODS (SOURCE: BONACETO AND BURNS, 2003)

Cognitive analysis also needs to satisfy a number of analytical aspects, if design information for innovative decision support is required (Potter, 2006). He mentions criteria like:

- Cognitive analysis must be far more than knowledge elicitation.
- Cognitive analysis must capture the fundamentals of the work domain and resulting decision making.
- Cognitive analysis must systematically transform knowledge elicitation into a set of complementary analytic artefacts.
- Cognitive analysis must serve as the basis for innovative decision support system design concepts.

Viewing the A-CDM implementation concept however reveals that so far focus has been placed on the *organisational* aspects. While such an approach is useful for the study of how the processes of information exchange and interactions with airports partners should look, it is argued that the confinement of cognitive aspects in these attempts could fundamentally contribute to turn-round problem solving: Given the fact that many work activities are inherently cognitive, e.g. decision makers have to process information, solve problems, predict TOBT, and make decisions, it is also argued that an understanding is required of how work activities are performed at current level of A-CDM implementation in order to design information systems that can support both cognitive activities and social interactions. Therefore, a cognitive analysis and engineering approach is proposed for the analysis of the A-CDM turn-round concept, because such an approach comprises a variety of methods to describe, model, and simulate cognitive and behavioural processes for the design of human-machine systems.

3.3.2 Selection of a Cognitive Engineering Method

In order to find the most suitable method for the objectives of this study, the range of factors that should be considered when choosing an engineering method as proposed by Stanton (Stanton et al, 2006) was evaluated. These include:

- the accuracy of the method;
- the criteria to be evaluated, such as time, errors, communications, movement, usability, etc;
- the acceptability and appropriateness of the methods to the people being analysed;
- the domain context;
- the resources available; and
- the cost-benefit of the method.

The selection of the method applied was also based on the factors proposed by Annett and Stanton (2000) that included:

- How deep should the analysis be?
- Which methods of data collection should be used?
- How should the analysis be presented?
- Where is the use of the method appropriate?
- How much time/effort does each method require?
- How much, and what type of expertise is needed to use the method(s)?
- What tools are there to support the use of the method(s)?
- How reliable and valid is/are the method(s)?

The engineering methods that were assessed for the analysis comprised of 11 categories and included

- data collection techniques;
- task analysis techniques;
- cognitive task analysis techniques;

- charting techniques;
- human error identification techniques;
- mental workload assessment techniques;
- situation awareness measuring techniques;
- interface analysis techniques;
- design techniques;
- performance time prediction/assessment techniques; and
- team performance analysis techniques.

The main aim during the selection was to find a method that is useful in providing a valid and reliable output. Thereby, a main selection criterion was the usage of the gained knowledge: while e.g. psychologists need to get a *better understanding* of the cognitive functioning, the usage for the research project however had *practical objectives*. The findings should contribute to provide intelligent decision support and countermeasures for inaccurate TOBT predictions. Therefore, each method was assessed against the characteristics inherent in the A-CDM work system and the possible output of the analysis applied. A process model proposed by Stanton (Stanton et al., 2006) was used as a strategy for deciding what methods to use in, and how to adapt to the domain context (Figure 10). Annett et al. (2000) points out that care and skill is required in developing an approach for analysing the problem, formulating the intervention, implementing the intervention, and determining the success of the intervention.

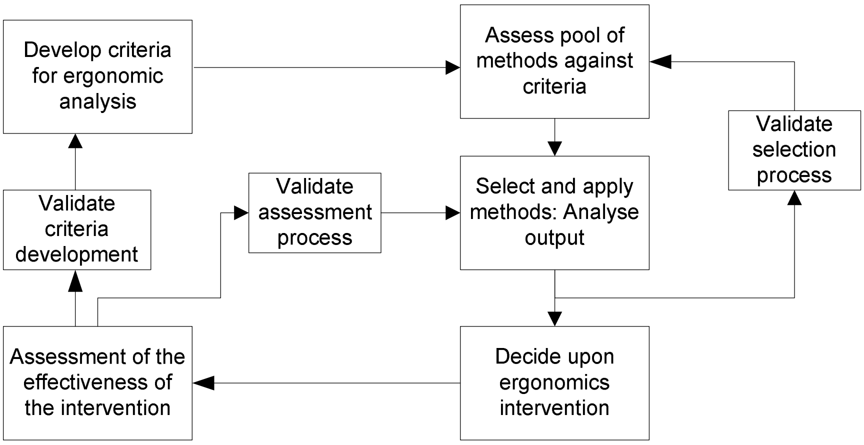


FIGURE 10: VALIDATING THE METHODS SELECTION (SOURCE: STANTON, 2006)

Hence, a method from the category *Human-Machine System* was used for the analysis of the A-CDM work system. Such a method considers how the entire system, consisting of all the machines and all the humans, is supposed to work *as a whole* in order to accomplish the overall system goal. In contrast, more traditional human factors approaches are primarily focused on determining what role *individual* human operators in the system will play (system-oriented methods).

From the category *Human-Machine Systems*, cognitively oriented methods such as the *Cognitive Work Analysis* (CWA) focus on the fundamental characteristics of the work domain and the cognitive demands that are imposed on humans operating in those domains. These methods complement the Cognitive Task Analysis and Knowledge Elicitation methods by mapping out the structure and purpose of the domain, allowing analysts to identify which cognitive strategies arise from actual domain demands and which are workarounds due to poorly designed systems (Bonaceto and Burns, 2003).

The CWA was therefore chosen as an overall framework and provided a conceptual structure for gathering, analysing, and structuring the required system knowledge and system functionality. Figure 11 shows the conceptual structure that was used as the basis for the analysis during the project:

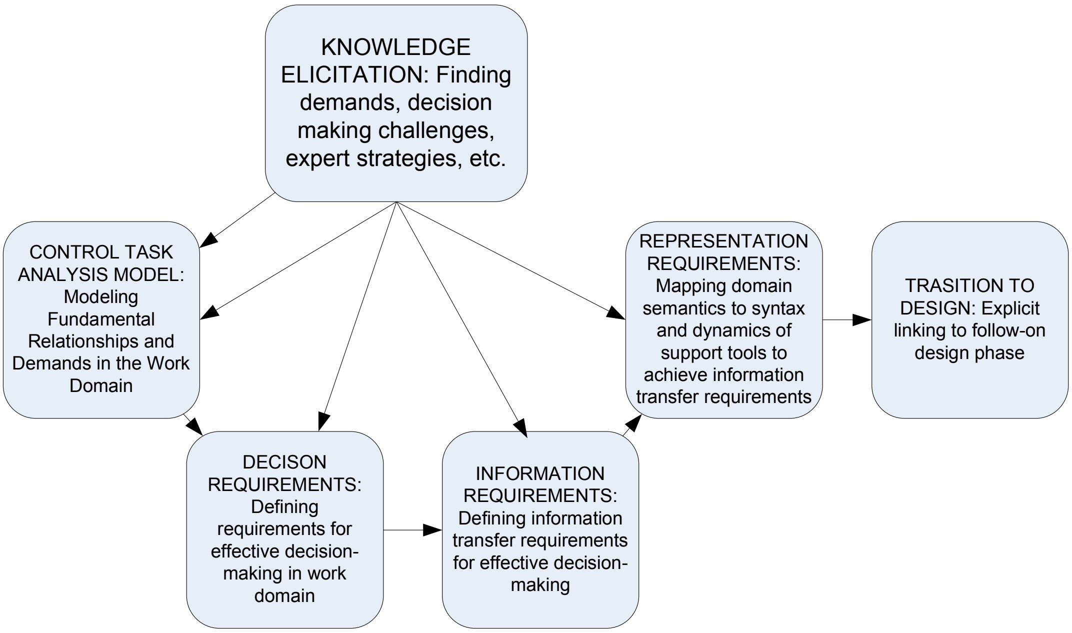


FIGURE 11: APPLIED CONCEPT FOR THE PURSUED ANALYSIS (SOURCE: POTTER, 2006)

The analysis of A-CDM turn-round process was thus performed at a whole-system level. The focus thereby is not the role of the individual operator within A-CDM, but the fundamental characteristics of the A-CDM work domain and the cognitive demands that are imposed on humans operating within the system.

3.4 Cognitive Work Analysis

3.4.1 Introduction

Cognitive Work Analysis (CWA) is a framework that emerged as a principal conceptual and methodological tool in the approach to cognitive engineering and uses the distributed cognition as its underlying theory. While the primary aim of Chapter 3.4 is to introduce the CWA, the distributed cognition concept is outlined in Appendix V.

CWA is a systems-based approach to the analysis, design, and evaluation of human-computer interactive systems that unifies psychological and technical considerations, cognition and the environment where cognition takes place. While traditional human-computer interaction and system design models are not able to adequately assess user needs or to design efficient computer-based information support systems, modelling concepts from engineering, psychology, cognitive science, information science, computer science, and cognitive systems engineering are taken together and aimed at providing a much broader and dynamic framework for analysis. CWA has recently grown in popularity for application in various domains, e.g. for the conceptual and empirical work of Vicente and Benda at University of Toronto, Lintern and Sanderson at the University of Illinois, Higgins, Watson, Skilton, and Camerion at the Swinburne Computer-Human Interaction Laboratory, and Lintern and Naikar at the Aeronautical and Maritime Research Laboratory at Fishermens Bend, and Stanton at the University of Southampton.

Using from the problems faced in nuclear power plant control in the 1970’s as a backdrop, Rasmussen (1986) developed the analytical framework of a Cognitive Work Analysis (CWA) at the Risø National Laboratory in Denmark in order to facilitate a human-centered design of technologies that people use in their work.

CWA is able to provide the basis for the design of decision support systems in complex socio-technical environments, which is essential for the design of information systems. The rapid development of all types of technologies causes an increasing number of recorded failures, because these technologies were not designed to fit the work practices of their users.

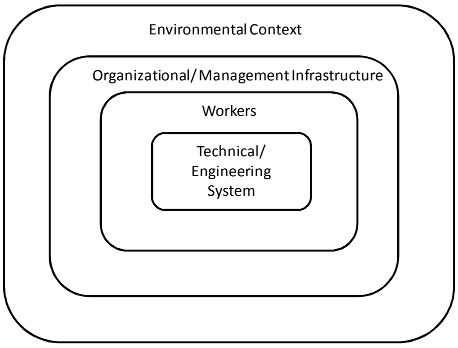


FIGURE 12: THE LAYERS OF A COMPLEX SOCIO-TECHNICAL SYSTEM (SOURCE: RASMUSSEN, 1996)

CWA uses a range of methods to analyse the various constraints that are imposed on the activities of a particular system. For the analysis of a system design, it is necessary to understand not only the work actors do, but also their information behaviour in the context of their work and the reason for their actions. This allows an application to specific situations.

According to Rasmussen (1994) and Vicente (1991), CWA differs from techniques commonly found in human-computer interaction because it combines a number of factors including:

- CWA is using methods from multiple disciplines rather than just connecting to a single discipline.
- The approach of CWA is system oriented rather than psychologically oriented.
- CWA is an ecological approach rather than modelling activity and uses mental models as a basis for design. This is also true for the context in which the activity takes place.
- The design of new systems is relatively independent of technical solutions; therefore it is called a ‘formative approach’.
- It is able to handle unexpected situations - particularly situations that may involve high risk.

Issues showing the relevance of CWA towards A-CDM include the fact that the courses of events in the A-CDM work system can often not be anticipated, e.g. aircraft arrival delays, technical failures requiring flight cancellations, etc. This means that interfaces must be designed to support the adaptive and flexible behaviour of participating workers. Another issue is the technology used during A-CDM. New developments like turn-round monitoring control rooms should allow a radically new approach to the way how the turn-round is managed. However, designers still fail to take the advantages of new opportunities into account, because *they are caught in an evolutionary task-artefact cycle in which existing work practices are allowed to constrain the options for new designs* (Naikar, 2002). Moreover, the fundamental constraints in the workplace of all participating during A-CDM have not yet been analysed; so far, focus has only been applied to the human cognitive system instead of the complex socio-technical system.

3.4.2 Cognitive Work Analysis and Information Science

According to Fidel et al. (2004), the CWA is useful for the study of human-information interactions and the design of information systems because:

- CWA provides a holistic approach that allows accounting for several dimensions simultaneously.
- CWA is able to facilitate an in-depth examination of the various dimensions of a context. A study of a particular context is, therefore, an interdisciplinary investigation aimed at understanding the interaction between people and information in the work context.
- CWA provides a structure for the analysis of human-information interaction, rather than subscribing to specific theories or models. It is possible to employ a variety of conceptual constructs or tools that may be useful for the analysis of the specific situation.

Using this framework in Information Science, CWA first evaluates the system already in place, and then develops recommendations for design. As such, the evaluation is based on the analysis of information behaviour in context (Fidel et al., 2004). For the design of a system, it is necessary to understand the work actors do, their information behaviour, the context of their work, and the reasons for their actions.

As a conceptual framework, CWA allows for analysis of the forces that shape human-information interactions via the application of conceptual constructs rather than the testing and verification of models and theories (Fidel et al, 2004). It is work-centred rather than user-centred and considers people who interact with information as actors involved in their work-related actions, rather than as users of the system.

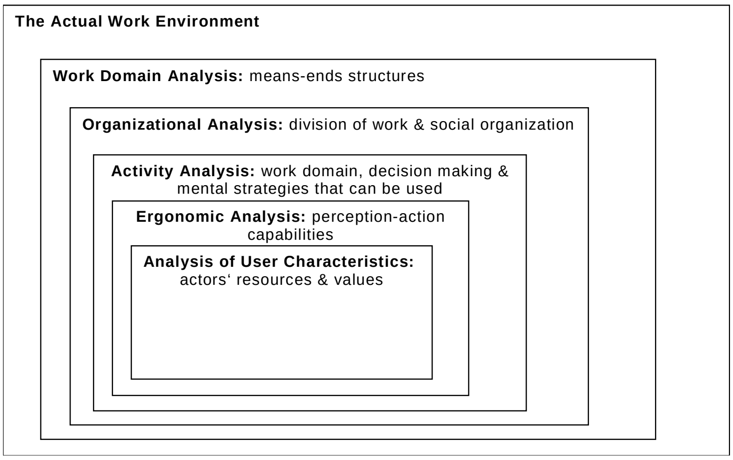


FIGURE 13: THE DIMENSIONS OF THE CWA (SOURCE: FIDEL ET AL, 2004)

Figure 13 shows the dimensions of the CWA, where the different dimensions represent the constraints on information seeking. The analysis starts with the external environment of the work place and moves up to the individual resources and values of the actors. As such, each dimension creates the constraints for the one nested in the dimension under analysis.

3.4.3 Research Related to A-CDM

A. Research in Other Domains

CWA has already been successfully applied to many other complex domains. The majority of studies on CWA have focused on its application to interface design (e.g. Burns, 2000; Burns, Bryant and Chalmers, 2000; Dinadis and Vicente, 1999; Gualtieri, Elm, Potter and Roth, 2001, Naikar, Hopcroft and Moylan, 2005).

CWA has been applied to existing systems like, e.g. for process control (Vicente 1999; Jamieson and Vicente, 1998), to design interfaces or to design teams (Gualtierir, Roth and Eggleston, 2000; Naikar, Pearce, Drumm and Sanderson, 2003), to evaluate design proposals (Naikar and Sanderson, 2001); to analyze training needs (Naikar and Sanderson, 1999); and to develop specifications (Leveson, 2000).

The relevance of Cognitive Work analysis for aviation was lined out in a special issue of the 'International Journal of Aviation Psychology' (Volume 9, Number 3). In particular, relevance was demonstrated in the complex information system exemplified by modern aircraft cockpits (Lintern, 1999).

Naikar (2006) emphasizes the applicability of CWA to applications other than interface design. These applications include the use of WDA to identify training needs and training system requirements, to evaluate alternative system design proposals, to develop team designs, and finally to identify training strategies for managing human error. Often organisations assume that simply purchasing expensive training devices will reduce training costs, increase levels of skill in the workforce, and reduce the risk of accidents on the job. For Lintern and Naikar (2002) however, limited attention has been placed on the systematic specification of training-system requirements and training needs.

Lintern et al (2002) proposed WDA for the development of a virtual information-action workspace that is able to organize information for effective actions. Such a tool requires an understanding of the information everyone needs for their jobs with this information presented in a desirable form of abstraction, suitably organized, and including the modes required for acting on it. For instance, vessel command and control has numerous information support requirements: Burns et al. (2000) presents an iteration of WDA models based on these information requirements for application to decision support of the vessel command and control system.

Ahlstrom (2005) also used WDA for an aviation related problem that results from weather displays used by air traffic controllers. Adverse weather conditions create safety hazards for pilots, constrain the usable airspace for air traffic control, and reduce the overall capacity of traffic. However, it is currently unclear what weather information would be beneficial for tactical operation (Ahlstrom, 2005). For this reason, he applied a WDA for the assessment of weather information needs for terminal controllers.

Reising et al. (2002) extended Rasmussen's abstraction hierarchy to describe where sensors should be placed in a system if reliable higher-level information about the system, e.g. for display design, is to be derived, while Watson et al. (1998) evaluated human interactions with anaesthesia alarm systems.

B. Research in Domains Having Characteristics of the A-CDM Work System

Fidel et al. (2004) used CWA during field studies for the design development of a new collaborative work task that did not yet exist. The challenge of this study was to determine the constraints and possibilities for collaboration among actors in different organisations over different countries. The new task is about work with censorship documents that has never been conducted as a collaborative task, with neither national nor international censorship material available in one central location. A-CDM also requires collaboration among different organisations within different countries. Therefore, Figure 14 provides an overview of the methods used for this analysis which might also be useful also when analysing the A-CDM work system.

CWA Framework	Analysis of Cooperative Work	Empirical Techniques
Work Domain Abstraction Hierarchy Goals and constraints Priorities Functions Work processes Objectives and Tools	Policies, Strategies, Visions Prototypical National and International Collaboration Databases, communication tools, Products	Focus Group interviews Semi-structured Interviews Analysis of archive materials, products and tools
Tasks Abstraction Hierarchy	Research, collaboration, Information retrieval, Indexing, Annotation cataloguing, Preservation	Semi-structured Interviews Observations Meetings Telephone Interviews Emails
Decision Making Decision Ladder Abstraction Hierarchy	Analysis, Comparison, Evaluation, Selection	Expert Talks Decision Making using tools Working with prototypes
Strategies Paradigms Decision Ladder Abstraction Hierarchy	Entity focused procedural strategies Analytical, Problem exploration strategies	Collaboration among experts using prototypes Work stories
Organisation, Management, Role Allocation Abstraction Hierarchy	Collaborative Tasks and Institutions Research, Information retrieval, Indexing and Annotation, Preservation	Focus Group interviews, Semi-structured Interviews with managers and staff
Actors’ Knowledge Preferences	Heterogeneous competence and values	Questionnaires, Interviews

FIGURE 14: EMPIRICAL ANALYSIS TECHNIQUES FOR A CWA (SOURCE: FIDEL ET AL, 2004)

Another approach to CWA constitutes the application to Manufacturing Scheduling as proposed by Higgins (1998). The study explores the problems that arise with an intentional system rather than a system with physical constraints. Higgins points out limitations in using the Decision Ladders because of the difficulties to integrate the sub-goals towards the systems’ desired goal state. This characteristic phenomenon is comparable with the A-CDM system, because A-CDM also includes predominantly intentional constraints inherent at the participating actors. Therefore, his approach of integrating a goal theoretic approach from Hacker et al. (1982) could also be useful also for A-CDM system analysis.

3.4.4 The Work Domain Analysis

Primary focus of a Cognitive Work Analysis is originally on the work domain. The first phase of the analysis identifies a fundamental set of constraints imposed on the actions of any actor, and develops an event-independent representation that can be used to cope with novel situations. However, a clear distinction between the different types of hierarchical relations within the work system is necessary for a proper Work Domain Analysis (WDA) (Vicente, 1999). The decomposition (part-whole) hierarchy and an abstraction (means-end) hierarchy together form a two-dimensional Abstraction-Decomposition Space (ADS) that is able to show the generic properties of a complex system. While the bottom two layers of the abstraction represent the physical context in which the workers operate, they describe the functional capabilities and limitations of physical objects. The ADS is independent of specific devices, events, or workers, and is valid for many different situations including unanticipated events. This adds unique value for understanding the system, and the ADS is used here as a modelling tool to develop a schematic representation of the A-CDM domain. The important feature of the ADS is the *way* it provides a representation of the complex system and also *how* it provides a *basis* for identifying the information actors need, in order to deal with unanticipated events.

Problem solving using the ADS can be carried out via the identification of constraints by starting at a high level of abstraction and then deciding which lower level function is relevant to the current situation. This iterative “zoom-in” supports goal-oriented problem solving through “why, what, or how” questioning. For example, the present level of observation defines the *what* level, while the level above specifies *why* or the level below *how*.

However, the greatest value of this framework can be derived from its ability to identify information needs that are required to cope with unanticipated events. Although some researchers argue that it is not possible to identify such information (Mitchell, 1996; Shepherd, 1993), Rasmussen (1974) disagrees by laying out the rationale of complex systems control requirements imposed by unanticipated events. This leads to the design requirements of information representation for actors’ needs during such events.

Salmon et al. (2006) applied WDA to analyse the road transport system in Victoria/Australia. Implications for the vehicle design were taken from driver information requirements and driving tasks. Naikar et al. (2005) contributes to the development of a coherent and methodological approach towards WDA with a detailed report on the differences in the approaches to WDA taken by Rasmussen, Pejtersen, and Goldstein (1994) and Vicente (1999). He also proposed a methodology for performing a WDA and illustrates the theoretical concepts and methodology for WDA with a work domain of a home.

3.4.5 Control Task Analysis

A. Introduction

The Control Task Analysis (CTA) is the second phase of the CWA and complements the WDA by identifying the activities that are necessary to achieve the purposes and functions of the system domain under analysis with the given set of physical resources. It is able to identify the requirements for control tasks associated with known or recurring situations (Vicente, 1999). This includes identification of the constraints on *what* needs to be done independently by *whom* or *how*.

While the WDA describes the functional structure of the system domain under analysis, the CTA seeks to identify the requirements associated with the classes of events in the domain. This means that having identified the general functions of the work domain, the control tasks should now be analysed. Control tasks include work functions and work situations. In decision making terms, these are the decision-making functions. Latest literature reviews refer to decision-making functions as control tasks. Therefore, this term will also be used for the analysis here.

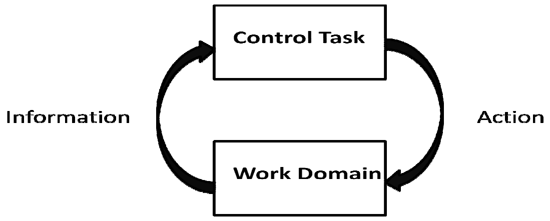


FIGURE 15: RELATION BETWEEN CONTROL TASK AND WORK DOMAIN (SOURCE: VICENTE, 1999)

The difference of control task analysis compared to traditional task analysis techniques (e.g. Kirwan and Ainsworth, 1992) is the *constrained based* approach versus the *instruction based* approach of traditional task analysis techniques. Vicente (1999) mentions also that some traditional techniques do not separate the question of *what* needs to be done from those of *how* it is done or by *whom*. Furthermore, while traditional methods only allow information processing via a linear sequence, studies have shown that experts rarely follow such a linear sequence. Rather, they can develop routines based on experience or training that can be linked in different ways in order to tackle diverse situations.

The methodological guidelines developed for the CTA by Naikar et al (Naikar, Moylan and Pearce, 2006) consolidate the approaches of Rasmussen and Vicente (Vicente, 1999). The guidelines outlined by Vicente (1999) include the decision ladder (Rasmussen, 1974) as the most commonly used modelling template for this stage of analysis. However, a number of critical aspects were identified that revealed problems in the application of the decision ladder to the A-CDM turn-round system (see Appendix VI). Therefore, the CTA was confined to identify the contextual activities that are relevant for the critical path of the turn-round.

B. Method

The CTA decomposes turn-round activities into a set of recurring work situations to deal with and/or a set of work functions to perform (Naikar, 2006). Activities are characterized as a combination of recurring work situations and work functions within their contextual relationships. Therefore, Naikar (2006) introduces contextual activity templates for representing activities in work systems that are characterized by work situations and work functions. The work situations are shown along the horizontal axis and the work functions are along the vertical axis in below. The circles indicate the work functions and the boxes around each circle indicate all of the work situations in which a work function *can* occur (as opposed to *must* occur). The bars within each box indicate those work situations in which a work function will *typically* occur. The work situations and work functions of the turn-round process can occur combined in various ways and as such, impose qualitatively different sets of cognitive demands on actors.

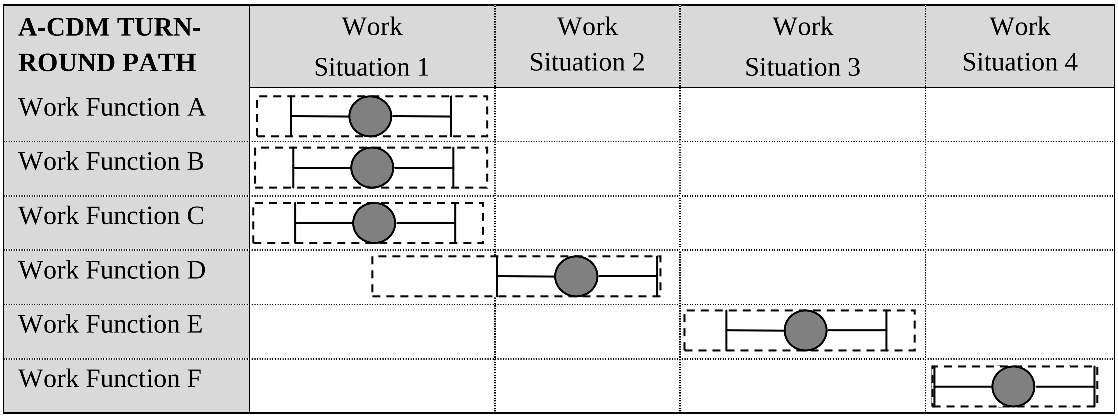


FIGURE 16: THE CONTEXTUAL ACTIVITY TEMPLATE (SOURCE: NAIKAR, 2006)

Figure 16 depicts the template as it was applied to the turn-round work functions. Discussions with subject matter experts were used to identify which functions cannot be executed in parallel, but have to be done in a sequence, because they depend on each other. During turn-round, these functions are especially critical, because any failure during one work function has consequences on the following functions. The contextual activity approach was used to summarise the underlying control tasks within each process of the critical turn-round path.

4 COGNITIVE WORK ANALYSIS ON A-CDM

4.1 Application and Limitations of the Cognitive Work Analysis (CWA)

The Cognitive Work Analysis will be used in the following sections as an integrated framework to the A-CDM work system with focus on turn-round management. Originally the CWA steps include (1) the Work Domain Analysis WDA, (2) the Control Task Analysis, (3) the Strategies Analysis, (4) the Social Organisation and Cooperation Analysis, and (5) the Worker Competencies Analysis.

The first stage of the CWA allowed for modelling the A-CDM work system with different levels of abstractions showing the mean-end relations, deriving domain constraints, as well as revealing operational information requirements. The following steps of the CWA however revealed to have some critical aspects. Therefore it was not expected to gain knowledge from these steps as defined within the project aims, because of the limitations inherent in the modelling templates that are proposed by the CWA. Nevertheless, the CWA framework itself remained useful for providing a conceptual model and so only the first two steps of the CWA were applied here. The limitations and shortcomings of the omitted steps are outlined in Appendix VI.

4.2 Aims and Objectives of the Analysis

The aim of the CWA was to identify constraints that can then be used as conceptual distinctions for the A-CDM work system and then be linked to particular types of systems design decisions (e.g. which milestones are required, who should participate in decision making, etc.). However, this study focused solely on identifying the conceptual distinctions related to TOBT decisions in order to tackle the particular problems relevant for TOBT decision making. Many other conceptual distinctions could potentially contribute to improving the A-CDM work system; however, this was not the intention of the project here.

As a result of this study a representation of design requirements should be created that is based on the existing physical A-CDM workspace of an Airline Control Centre This should be able to present design concepts and information processing requirements. Finally, a prototype or storyboard of an A-CDM decision making environement that is suitable to make more accurate TOBT predictions should be made.

4.3 Work Domain Analysis

This first phase of the Cognitive Work Analysis, called Work Domain Analysis (WDA) was aimed at finding the fundamental environmental constraints that are imposed on the A-CDM turn-round as well as the actions for all participating that are required during turn-round. As a result, an event-independent representation of the A-CDM turn-round work system was described that was used to deduct pilots' information requirements. A further benefit of such turn-round representation is the possibility to identify opportunities of how to cope with unexpected turn-round situations.

4.3.1 Method Applied

Naikar et al. (2005) describes a step-by-step methodology for the WDA that was applied in order to capture the generic properties of the A-CDM system.

Step 1: Establish the purpose of the WDA

This first step involved defining the purpose of the analysis. It included two parts - *defining* the problem and defining *how* WDA will be used to address the problem (Naikar et al., 2005). During analysis, two main purposes were identified which are to determine the information requirements of all operators during turn-round necessary to maintain turn-round process predictability, and to identify the underlying airport infrastructure needed to support these requirements. The WDA was used to develop such a functional model of A-CDM system from the viewpoint of the flight crews. They should be able to identify the different categories of information which decision makers require during aircraft turn-round, and the airport infrastructure that might be required to *support* decision making during A-CDM.

Step2: Identify Project Constraints

Not only the purpose, but also the *constraints* that may affect *how* the WDA is conducted have to be identified in order to maintain the desired scope and focus of the analysis. The main constraints to this analysis emerged from complexity of the problem environment, time, and expertise related constraints. The scope of the analysis depended heavily on the information made available by participating stakeholders.

Step 3: Determine the Boundaries of the WDA

The analysed work system of A-CDM can be defined as ‘the *processes and information necessary to maintain situational awareness during turn-round in order to achieve a reliable TOBT’*. During this step, the analysis was limited to the timeframe between milestones 6 and 15 and included the human-human or human-computer interactions related to operational information sharing of all information required to assign an accurate TOBT. The purpose of this artificial boundary was to keep the WDA in a useful and achievable scope. There are numerous elements *outside* the focus system which influence elements *within* the focus of the analysis, e.g. weather, legal requirements, but for practical considerations they will be excluded from the analysis.

Step 4: Identify the Nature of Constraints

According to Naikar (Naikar et al., 2005) it is necessary to identify the location of the focus system on the causal-intentional continuum, because the *nature of* the constraints that should be modelled in the Abstraction-Decomposition Space (ADS) has to be identified (Hajdukiewicz et al., 2004). Categories defined by Rasmussen (Burns, 2000) are used as a basis to determine the nature of the constraints of the proposed problem space. It was concluded that A-CDM has major attributes of a system governed by actors’ intentions and the nature of constraints modelled by the WDA are *intentional* constraints based on organisational policies, legislation, and other forms of regulation, social laws or conventions, and actors’ intentions or motives. This is in line with the defined purpose of the WDA.

Step 5: Identify Potential Source of Information

The potential sources of information have to be identified to construct an ADS (Naikar et al., 2005). A large number of data/ information sources were found that could inform the A-CDM system domain. This is due to the presence of numerous and diverse participating operators in this system encompassing the airport representatives, airline companies, flight crews, air traffic control, technicians, ramp agents, loaders, airport and ramp personnel, Central Flow Management Unit and passengers. Major information sources are documents relating to legislation and company policies, training manuals, airport infrastructure, company reports, and the A-CDM generic procedures.

The work setting itself was used as the second source of information gathering, where observations of work scenarios were made with minimal interruptions to the observed activities. The items observed include the tools and interactions that participants use. Hajdukiewicz et al. (2004) recommends distinguishing between *exploratory* observations for understanding the work environment, and *focused* observations concentrated on particular aspects of a chosen system that should be made. Initially only exploratory observations were made for this first stage of analysis.

Focus group meetings, further observations, brainstorming, and interviews with pilots as SMEs also contributed to information gathering. Additional data was also gathered using talk-throughs, and tabletop analyses. For this phase of research, Rasmussen (1986) points out that the analyst should keep in mind that real constraints and actual reasons for behaviour are often hidden behind routines and rationalizations. Regardless of the source of information the analyser should stay aware of the constraints that shape the behaviour.

Step 6: Construct ADS- First Iteration

For a first iteration of the ADS, Naikar (Naikar et al., 2005) outlines the following five phases of development:

- identification of work-domain properties;
- defining the levels of abstraction and decomposition;
- developing a sketch of the ADS;
- evaluating which cells of the ADS to populate; and
- populating the selected cells of the ADS.

4.3.2 Results from the Work Domain Analysis

As a first result of following Naikar’s step-by-step methodology, a matrix was developed which populates all cells based on the identified work-domain properties, levels of abstraction, and levels of decomposition (Figure 17). This matrix describes a conceptual view of the A-CDM system and offers a conceptual level of resolution for viewing the A-CDM work domain. The three cells at the purpose-related functions level of abstraction is that of the possible functions of the A-CDM system. The three cells offer different resolutions for viewing the functions of the A-CDM which are the functions of the whole A-CDM Decision Making system, the functions of the CDM Turn-Round Element, and the functions of the different components of A-CDM like the milestones, Airport-CDM Information Sharing Platform (ACISP), and A-CDM Partners (Figure 17).

The five cells in the first column describe the A-CDM work system with an abstraction hierarchy that is defined by ‘a structural means-ends relationship between levels’ (Rasmussen, 1986). According to Rasmussen (1986), five levels of constraints have been found to be useful for describing domains: At the functional purpose level of the analysed domain, the lower level of abstraction can be identified by asking ‘how’; while the higher level of abstraction has to be justified by asking ‘why’. At functional level the *purpose* of the A-CDM is described and the abstract functional level represents the *intended causal structure* of the A-CDM work system in terms of information it intends to provide to all airport partners. At generalised functional level the *basic functions* are described that A-CDM is designed to achieve. The *characteristics* of the A-CDM components are described at physical function level, while the physical form level finally describes the *spatial location* of the components in the system.

	Total System **Airport Collaborative Decision Making**	**Sub-System** **CDM Turn-round Process Element**	**Component** **Milestones, ACISP, A-CDM Partners**
Functional Purpose	***Purposes*** **■ Improve working together at an operational level** **■ Efficient and safe daily flight operation with reliable information provision & Established Common Situational Awareness** ***External Constraints*** **■ Laws & Regulations by airport, national government, Europe, IATA, EUROCONTROL, ICAO** **■ Local Standard Operationg Procedures**	***Purposes*** **■ Provide the A-CDM partners with a common situational awareness** **■ Anticipation of disruptions & expeditious recovery through information sharing among all partners including passengers** ***External constraints*** **■ Distributed location between CDM partners and actors** **■ Laws & Regulations**	***Purposes*** **■ Milestones: To provide decision makers with information about flight progress and trigger decision making** **■ ACISP: To provide information sharing between the Airport CDM Partners** **■ A-CDM Partner Goals** ***External Constraints*** **■ No & design of Milestones, Alert**
Abstract Function	***Criteria*** **■ ATTT** **■ Turn-round compliance (STTT vs ATTT)** **■ TOBT/TSAT Predictability** **■ EIBT Predictability: EIBT vs time** **■ Ready Reaction Time: AOBT - ARDT**	***Criteria*** **■ ATTT** **■ Turn-round compliance (STTT vs ATTT)** **■ TOBT/TSAT Predictability** **■ EIBT Predictability: EIBT vs time** **■ Ready Reaction Time: AOBT – ARDT**	***Milestones*** **■ CDM Procedure Group Meetings** **■ Performance Assessments** ***ACISP & A-CDM Partners*** **■ User feedback & Performance Assessment**
Generalised Function	**■ Safe & efficient usage of available resources** **■ Effective law, regualation, procedure, and policy enforcement** **■ Redesign of airport operational procedures** **■ Implementation of CDM functions**	**■ Safe & efficient turn-round & flight** **■ Adherence to CDM procedures** **■ Efficient implementation of collaborative decisions at action level** **■ Enforcement of laws, regulations, procedures**	***Milestones*** **■ Data/ Information availability & Practicability of Information** ***ACISP & A-CDM Partners*** **■ Physical dynamics of user behaviour**
Physical Function	**■ Provision of reliable information for all CDM partners** **■ Collaborative operational decision making** **■ Increasing Situational Awareness** **■ A-CDM Information Sharing Platform (ACISP)**	**■ Efficient information provision & cooperation between operators & actors** **■ Distributed Situational Awareness at action level** **■ Efficient command & control structure between pretactical & action level of operation**	***Milestones*** **■ Functionality/capability/ limitations & status** **■ Inform all partners** ***ACISP & A-CDM Partners*** **■Functionalability/capability/ limitation** **■ Establish Situational Awareness**
Physical Form	**■ IT platforms with operational information sources, e.g. TOBT/ TSAT** **■ AMAN/DMAN** **■ Airport Operation Centre (APOC)** **■ Representative Decision Makers of all partners** **■ Meteorlogical features, e.g. adverse weather condition**	**■ Printed Information/ Data about TOBT/TSAT** **■ Information Screens for passengers** **■ Airport Infrastructure & Airspace Structure** **■ Alert Messages to all CDM partners via the ACISP** **■ Flight Update Messages (FUMs)**	**■ Electronic Data/ Information** **■ Software Applications** **■ HMIs, e.g. ACARS, Telefon, computer** **■ Computer Network** **■ Operation Room** **■ Passengers** **■ Actors**

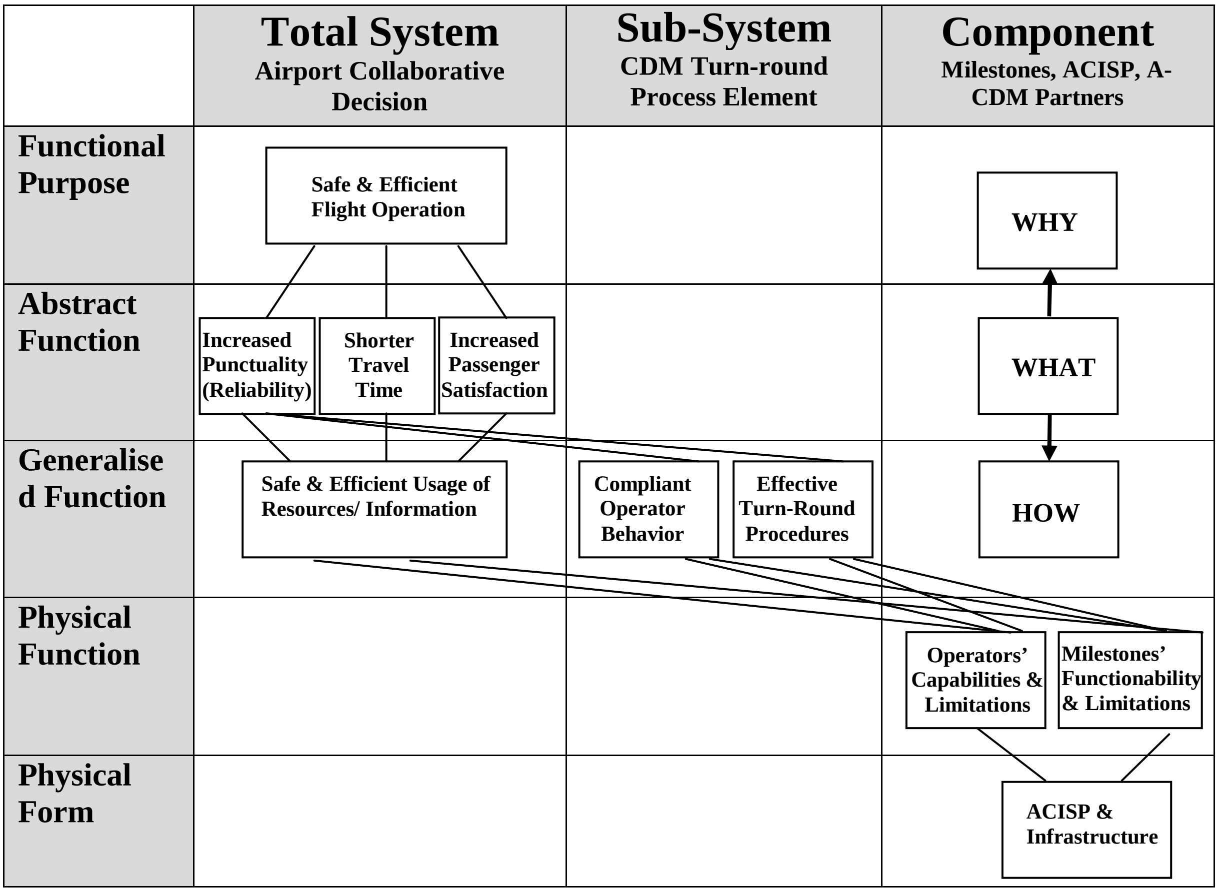
FIGURE 17: THE A-CDM CONCEPTUAL MATRIX

Step 7: Construct ADS- Second Iteration

For the second iteration of the ADS, additional information sources were used to further develop the ADS. Therefore, the following phases were repeated:

- focused field observations;
- walkthroughs and talk-throughs;
- interviews; and
- table-top analyses with SMEs.

The resulting ADS (Figure 18) involved reviewing the ADS with domain experts who agreed on the various elements of the ADS model including the levels of abstraction and means-end relations in the ADS, the level of decomposition and part-whole relations in the ADS, and the categories of constraints in each cell of the ADS. When moving from a higher to a lower level of abstraction or vice versa, it should be able to withstand a ’why’, respectively a ‘how’ question.



	Total System Airport Collaborative Decision	**Sub-System** CDM Turn-round Process Element	**Component** Milestones, ACISP, A-CDM Partners
Functional Purpose	Safe & Efficient Flight Operation		WHY
Abstract Function	Increased Punctuality (Reliability) Shorter Travel Time Increased Passenger Satisfaction		WHAT
Generalised Function	Safe & Efficient Usage of Resources/ Information	Compliant Operator Behavior Effective Turn-Round Procedures	HOW
Physical Function			Operators’ Capabilities & Limitations Milestones’ Functionability & Limitations
Physical Form			ACISP & Infrastructure

FIGURE 18: THE A-CDM ABSTRACTION-DECOMPOSITION SPACE

There are different possibilities of using the ADS. While it can provide a field description of the analysed work domain that allows mapping the activities of all participating as trajectories (Vicente, 1999), it was used here to derive information requirements of flight crews.

Step 8: Derive Flight Crews' Information Requirements from the ADS (Conceptual Matrix)

The next step was to draw implications from the ADS for possible information provision to flight crews and flight crews´ support for operational decision making during turn-round. These identified information requirements will later be mapped against results from a flight crew survey in order to confirm that the WDA is 'on track' and the ADS is valid.

Information requirements identified by the ADS include data that should be provided to flight crews for increasing situational awareness at the distributed location of the cockpit. Failing to present required data, presenting data in an inappropriate manner or presenting too much data can potentially have detrimental effects upon task performance (Salmon et al, 2006). These information requirements can then be used to inform the A-CDM design by specifying what data should be presented to the cockpit via available communication devices like ACARS, phone, or two-way radio. Salmon et al. (2006) has used the ADS to specify information requirements for a command and control knowledge wall display, or Ahlstrom (2005) used the ADS for determining the types of information that air traffic controllers require for effective performance during adverse weather conditions. Therefore it is argued that the ADS of the A-CDM system can also be used to identify different categories of information that flight crews require to support effective decision making during turn-round.

Information requirements were extracted from the ADS of A-CDM as they relate to purpose related functions of flight crew information requirements (Figure 19).

	Total System Airport Collaborative Decision	**Sub-System** CDM Turn-round Process Element	**Component** Milestones, ACISP, A-CDM Partners
Functional Purpose	■ A-CDM Information Sharing, e.g. TOBT, TSAT ■ Common Situational Awareness	■ A-CDM Information Sharing, e.g. TOBT, TSAT ■ Common Situational Awareness	■ Pilots`Goals ■ Safety Level ■ Airport Performance ■ Aircraft Technical Status ■ A-CDM Partner Goals
Abstract Function	■ ETTT ■ Turn-round compliance of Actors involved ■ TOBT/TSAT/TTOT/CTOT Creation ■ EIBT Predictability: EIBT vs proposed waiting time	■ Milestones 6 until milestone 15 ■ Not time & time related data ■ Aircraft operational statu ■ Variable Taxi Time Calculation ■ CDM Complicance Alarms	■ Economic Cost of Planned/ Alternative Turn-Round ■ Safety Level ■ Performance and Status of All Participating ■ Aircraft Requirements & Status
Generalised Function	■ Airport Apron Rules & Regulations ■ Warnings, e.g. airport policies & local restrictions ■ Behavioral recommendations, e.g. taxi time required,	■ TIBT & Stand Information ■ Ground Handling Start Delay ■ Runway in use ■ EOBT/TOBT/CTOT Complicance alarms ■ EXOT	■ Physical turn-round control task support ■ Cognitive turn-round control task support ■ Turn-Round Complicance control
Physical Function	■ Operational Information Sharing with Cockpit ■ CDM operating procedures ■ Information Sharing among particpating actors ■ A-CDM Information Sharing Platform (ACISP)	■ Information about Changes of TIBT & Stand ■ Information about Ground Handling Start Problems ■ Information about Runway changes ■ Information about EOBT/TOBT/CTOT changes ■ Information about scheduled EXOT, if relevant	■ Capability/ Knowledge Level of All Participating ■ Availability of Resources ■ Current task status in relation to goals
Physical Form	■ Access to ACISP from cockpit ■ Provision of TOBT/TSAT/TTOT to cockpit ■ Information about Passenger Boarding Time ■ Environmental Condition Information ■ Turn-Round disruptions	■ Access to ACISP from cockpit ■ Provision of TOBT/TSAT/TTOT to cockpit ■ Information about Passenger Boarding Time ■ Environmental Condition Information ■ Turn-Round disruptions	■ Current Component Performance & Status ■ Current Airport & Aircraft Condition ■ Other A-CDM users location & future movements

FIGURE 19: PILOTS' INFORMATION REQUIREMENTS

The information requirements that were derived from the ADS were grouped in categories like information already available, not available, or partially available to flight crews during current A-CDM turn-round operation (Table 2) and include:

- A-CDM Information Sharing elements, e.g. Target Take-Off Time (TTOT), Estimated Taxi Out Time (EXOT);
- A-CDM compliance alarms;
- airport warnings and recommendations;
- operational status information including disruptions and other actors' goals;
- participating actors' performance, status, and knowledge level; and
- availability of resources.

TABLE 2: PILOTS' INFORMATION REQUIREMENTS AS IDENTIFIED VIA ADS

INFORMATION REQUIREMENTS	Information is available			Information is provided		
	Yes	No	Partly	Yes	No	Partly
Information from ACISP		x			x	
TOBT/ TSAT	x			x		
ETTT	x				x	
Turn-Round Compliance of other actors	x				x	
CTOT	x			x		
TTOT	x				x	
Apron Rules and Regulations	x			x		
Infrastructure related warnings						x
Behavioural Recommendations		x			x	
Operational Information			x			x
CDM Operating Procedures	x			x		
Passenger Boarding Time	x				x	
Environmental Condition Information	x			x		
Turn-Round Disruptions	x				x	
Time related Data, e.g. changes in Traffic Flow, Weather	x					x
Aircraft Operational Status	x			x		
Variable Taxi Time Calculation	x				x	
CDM Compliance Alerts	x				x	
Target In Block Time	x				x	
Stand Information	x			x		
Ground Handling Start Delay	x				x	
Runway in Use	x			x		
EOBT/TOBT/CTOT Compliance alarms			x		x	
EXOT	x				x	
Airport Performance			x		x	
Aircraft Technical Status	x			x		
A-CDM Partner Goals		x			x	
Economic Cost of planned/ alternative Turn-Round			x			x
Performance and Status of all participating actors		x			x	
Aircraft Requirements and Status	x			x		
Physical turn-round control task support			x			x
Cognitive turn-round control task support		x			x	
Turn-Round Compliance control task support		x			x	
Capability/ Knowledge Level of all participating actors		x			x	
Available Resources, e.g. push-back, fuelling, catering, other s	x				x	
Current task status in relation to goals		x			x	
Current component performance and status	x				x	
Current airport and aircraft condition	x					x
Other A-CDM users location and future movements	x				x	

During current approach to A-CDM, focus has not yet been applied on *provision* of such information to the flight crews or *how* it should be provided. It is argued however that availability of this information could potentially contribute to an improved distributed situational awareness and thereby also improving turn-round time prediction accuracy.

Step 9: Derive Flight Crews' Information Requirements from Survey

A flight crew survey examined air crews' information requirements during typical turn-round operation situations that entail the risk of jeopardizing flight punctuality because of problems with information sharing between aircraft cockpit and operational decision makers. Pilots were asked to report recent experiences on failures to share operational information and the consequences onto the turn-round process, e.g. delay encountered during service delivery.

The survey was conducted on-line for a period of two months and pilots from different European airlines were invited to take part. 196 pilots who participated in the survey are from airlines such as Austrian (n=2), Air Berlin (n=16), Air France (n=9), Easy Jet (n=1), Lufthansa (n=167), and Transavia (n=1). 44.6% of the pilots were captains, 55.4% first officers. Average experience rates of 6.6 years as First Officer and 14.0 years as Captains were reported. The detailed questions that were asked to the cockpit crew members can be found in Appendix II.

Although the pilots were asked to report events that they experienced, most of the pilots used the *proposed* events. Table 3 shows the turn-round situations that were provided to the pilots with the frequency of the reported situation in percentage.

TABLE 3: INFORMATION REQUIRED BY PILOTS

Turn-round Situations with Flight Crew Information Requirement	Situation Reported in %
ATC Request	99
Availability of Parking Stand	95.1
Aircraft Change	63.1
Crew Proposal: Avoidance of A/C Change	47.5
Baggage Loading/ Unloading Delay	47.1
Crew Proposal: Necessary A/C repair	33.0
Crew Duty Change (new duty roster)	18.4
Boarding Delay	13.7
Ramp Transfer Bus (Passenger or Crew) Delay	11.8
Technical Repair	7.8
VIP Boarding	5.9
Crew Proposal: Connecting Passenger	5.8
Crew Other Proposal	5.8
Fuelling Delay	4.9
Airport Facilities break down	4.9
Other	3.9
Wheelchair boarding	3.3
Cleaning Delay	2.9
Delay though Security	2.0
Missing Flight Documents	2.0
Crew Change (new crew member)	1.9
Catering Delay	1.0
Late Check-In Passengers	1.0
Special Loading (e.g. musical instrument)	1.0
UM Boarding	0.0

4.3.3 Further Results derived from the ADS

A significant number of constraints could be derived from the ADS for the A-CDM turn-round process when mapping physical forms of the turn-round components to the abstract functions or functional purpose of the A-CDM work system. As these constraints appear to have influence on the functional purpose of the work system, they should be taken into account when making conceptual distinctions to attain a more efficient A-CDM system design. The constraints identified were then discussed with A-CDM experts who also shared details for each of the constraints. These are:

Number of participants involved: Airlines are increasingly outsourcing ground handling services to third party providers who are often new to the aviation business. This requires an identification of third party operators’ inherent goals, motivations, and skills because an adaption to the requirements and needs of the client airline and the network itself is mandatory. The airlines and the network also have to understand the constraints stemming from a multi-party turn-round process itself. Turn-round management requires focus on *coordination* of supporting turn-round processes between the different stages of the turn-round (See also **Error! Reference source not found.**). Particularly during the critical path of sequential ground processes where the associated processes cannot be done in parallel and often when a short turn-round time is only available *cooperation* among all partners responsible for controlling the supporting processes during critical path is essential.

Distributed location of partners: Short term coordination is required in the case of last-minute changes during turn-round, but service providers are usually physically located at *different* areas of the airport and communication has to be established via available channels. However, communication and coordination among parties is not standardized yet and coordination takes place on an ad hoc basis via the airline's operation centre or at pilots' initiatives through interactions with turn-round controller.

Resistance to sharing information: Competition not only exists among airlines; interests among airport partners also not necessarily converge. As a result, some partners may withhold information required by others and individual aims are placed above possible network benefits - especially if e.g. third party provider is owned by competitor. Resistance to share information increases even due to the current practice of delay code assignment (See Chapter 2.4).

Unanticipated events: Unanticipated events require efficient communication and coordination among partners involved. However, no procedures are established to forward short term turn-round process failures in a standardized format to partners and actors involved.

Not-established situational awareness: During flight, the aircrew often hold operational information or information affecting the following turn-round. This information is needed by the turn-round controller at destination operation control centre in order to prepare the next turn-round on ground, but pilots do not automatically have *awareness* about the need to share this information. Such information can include various issues, like technical problems or passenger related handling requirements occurring or emerging during flight. On the other hand, turn-round controllers fail to inform the *aircrew* of the status of turn-round and updates to turn-round process estimates. Often this is only a lack of awareness from the turn-round controllers that the information is required by the pilots.

Non-standardized acronyms and approaches to the CDM turn-round process at different airports: In order to achieve the required situational awareness between the airline cockpit and the turn-round controller *standardized* ways of information sharing and cooperation have to be established. EUROCONTROL has published a harmonized phraseology and acronyms for the A-CDM, but implementation of such harmonized procedures is still very fragmented in Europe. Airports, ANSP, airlines and ground handlers are still using different procedures and acronyms. Due to the large number of airports within Europe that are within the network of the major airlines, regional pilots are facing the challenge of familiarizing themselves with different airport procedures. As a consequence, awareness of the local turn-round procedures does not always exist. Introduction of new procedures like A-CDM is still greeted with scepticism by pilots because of frequent changes and the number of different approaches that airports and airlines have taken within the last years. In contrast, when A-CDM became operational at Munich airport in June 2007, the results of a study of 300 flight reports by pilots revealed increased acceptance of new CDM procedures already shortly after their introduction (Source: Lufthansa Internal Company Information, 2010).

Traffic Density: Low-cost carriers do not avoid major airports only because of higher landing fees; they are fully aware of how reliable turn-round operation affects airline profitability through higher aircraft utilization and lower exposure to unexpected delays. Legacy carriers however, often depend on major airports for their hub-and spoke business models and have to build in buffer times into the flight schedules to accommodate unexpected disruptions and any consequent delays. Since airlines have more control over the turn-round phase than over the flight phase, the scheduled ground times for turn-rounds are often used as a tactical means to stabilise aircraft rotations or to prevent reactionary delay via time buffers. Fricke et al (2008) note that time buffers are not applied systematically yet and suggests an optimisation of buffer times by integrating inter-process time buffers during the gate allocation planning phase. Given the complex resource connection mechanism between aircraft, passengers, and flight crews, not only the importance of such measure for airlines is realized during day-to-day flight operation, but also the cost that is inherent for such operations control.

4.3.4 Validation of the ADS

In order to make valid conclusions for the A-CDM work system a validation of the implicit constraints that were identified is required. This was done by mapping the various components on the ADS. Therefore, the results from an independent study were used to provide an early validation that the analysis is on track:

Step 10: Validation of the ADS via Mapping the Survey Results on the ADS

This step was aimed at determining whether the ADS is as accurate as possible. Naikar et al. (2005) proposes a number of possibilities for the validation of ADS. One possibility is to use the material already studied for the construction of the ADS- however it is not necessarily useful to employ the same sources of information for validating the ADS.

A better option is to use reasoning patterns of actors in various situations, e.g. incident reports that require decision making (Naikar et al., 2005). For this reason, the flight crew survey that was available from the second study was used in order to reconstruct inaccurate TOBT prediction situations as reported by the flight crews. Thereafter, the identified situations were examined for work-domain properties that characterized actors' reasoning patterns during these turn-round situations and then mapped in the form of *examples* onto the *Flight Crews' Information Requirements* (Table 1) extracted from the ADS. Thereby, it was examined whether the situations are captured by the different categories of constraints. Then it was analysed which parts of the decomposition space that are represented in the ADS, were involved. The relevant areas identified were highlighted in grey colour.

It could be determined that the particular information gained from the Flight Crews' survey followed the same functional relations as the ADS identified by the analysis. **Error! Reference source not found.** shows an example of the flight crew information requirement 'Target In-Block Time and Stand Information' before turn-round start.

	Total System Airport Collaborative Decision	**Sub-System** CDM Turn-round Process Element	**Component** Milestones, ACISP, A-CDM Partners
Functional Purpose	■ A-CDM Information Sharing ■ Collaborative Decision Making		■ Pilots`Goals ■ Safety Level ■ Airport Performance ■ Aircraft Technical Status ■ A-CDM Partner Goals
Abstract Function	■ ETTT ■ Turn-round compliance of Actors involved	■Milestones 6 until milestone 15 ■ Not time & time related data ■ Aircraft operational statu ■ Variable Taxi Time Calculation ■ CDM Compliance Alarm	■ Economic Cost of Planned/ Alternative Turn-Round ■Safety Level ■ Performance and Status of All Participating ■ Aircraft Requirements & Status
Generalised Function	■ Airport Apron Rules & Regulations ■ Warnings, e.g. airport policies & local restrictions ■ Behavioral recommendations, e.g. taxi time required	■ TIBT & Stand Information ■ Ground Handling Start Delay	■ Capability/ Knowledge Level of All Participating ■ Availibility of Ressources
Physical Function	■ Operational Information Sharing with Cockpit ■ CDM operating procedures ■ Information Sharing among particpating actors ■ A-CDM Information Sharing Platform (ACISP)	■ Information about Changes of TIBT & Stand ■ Information about Ground Handling Start Problems ■ Information about Runway changes ■ Information about EOBT/TOBT/CTOT changes ■ Information about scheduled EXOT, if relevant	■ Current Component Performance & Status ■ Current Aircraft & Airport Condition ■ Other A-CDM users' location & future movements
Physical Form	■ Access to ACISP from cockpit ■ Provision of TOBT/TSAT/TTOT to cockpit ■ Information about Passenger Boarding Time ■ Environmental Condition Information ■ Turn-Round disruptions		■ Current Component Performance & Status ■ Current Airport & Aircraft Condition ■ Other A-CDM users location & future movements

FIGURE 20: MAPPING OF FLIGHT CREWS INFORMATION REQUIREMENTS I

In such way it could be demonstrated (Figure 20) that information sharing with flight crews at generalized function level can be tracked through all levels of the ADS. The low level details of information about the capability/knowledge level of all participating at the physical function level can be traced back to the overall purpose of A-CDM Information Sharing. The physical form of the identified components which reveals a need for the current component performance and status, can affect other CDM related processes in a dynamic way as shown by the other active highlighted areas of the ADS (grey colour). Therefore it is argued that sufficient situational awareness has to be established through information sharing among all partners or actors involved.

Another instance of information not being shared was reported by flight crews regarding information updates by apron control. Because information about a runway change is not communicated to the flight crews, they require extra time for changing take-off performance calculations *after* clearance request and thereby run the risk of not adhering to TOBT and TTOT. Additionally, runway changes at short notices can also significantly change taxi times with the added risk of missing the CTOT. Therefore, such change of runway configuration has to be communicated timely to all participating. If the flight is regulated by a CTOT, the estimated taxi out time also has to be taken into consideration either by the flight crew or local ATC. Figure 21 shows the specific information requirements for such situations as identified from the survey mapped on the *Flight crews' Information Requirements* extracted from the ADS.

	Total System **Airport Collaborative Decision**	**Sub-System** **CDM Turn-round Process Element**	**Component** **Milestones, ACISP, A-CDM Partners**
Functional Purpose	■ A-CDM Information Sharing ■ Common Situational Awareness		■ Pilots`Goals ■ Safety Level ■ Airport Performance ■ Aircraft Technical Status ■ A-CDM Partner Goals
Abstract Function	■ ETTT ■ TTOT Creation	■ Milestones 6 until milestone 15 ■ Not time & time related data ■ Aircraft operational statu ■ Variable Taxi Time Calculation ■ CDM Compliance Alarms	■ Economic Cost of Planned/ Alternative Turn-Round ■ Safety Level ■ Performance and Status of All Participating ■ Aircraft Requirements & Status
Generalised Function	■ Airport Apron Rules & Regulations ■ Warnings, e.g. airport policies & local restrictions ■ Behavioral recommendations, e.g. taxi time required	■ Runway in Use ■ EXOT	■ Capability/ Knowledge Level of All Participating ■ Availibility of Ressources
Physical Function	■ Operational Information Sharing with Cockpit ■ CDM operating procedures ■ Information Sharing among particpating actors ■ A-CDM Information Sharing Platform (ACISP)	■ Information about Changes of TIBT & Stand ■ Information about Ground Handling Start Problems ■ Information about Runway changes ■ Information about EOBT/TOBT/CTOT changes ■ Information about scheduled EXOT, if relevant	■ Capability/ Knowledge Level of All Participating ■ Availability of Ressources ■ Current Task Status in Relation to Goal
Physical Form	■ Access to ACISP from cockpit ■ Provision of TOBT/TSAT/TTOT to cockpit ■ Information about Passenger Boarding Time ■ Environmental Condition Information ■ Turn-Round disruptions		■ Current Airport & Aircraft Condition ■ Other A-CDM users location & future movements

FIGURE 21: MAPPING OF FLIGHT CREWS INFORMATION REQUIREMENTS II

Figure 21 only shows *flight crews'* information requirements. A runway change that is not communicated also affects other A-CDM partners as well as it affects the environment.

These two examples only give a snapshot of the overall information requirements from flight crews during A-CDM. The other proposed situations follow a similar pattern throughout the ADS. However, it could be confirmed that the information requirements reported in the survey can be identified by using the ADS.

4.4 Control Task Analysis

4.4.1 Method Applied

A representation of the turn-round activities was seen to be useful for turn-round management because activities during turn-round are not clearly delimited in time and space; instead, activities are better characterized by their content – regardless of their temporal or spatial attributes (Vicente, 1999). Therefore, the activities during turn-round were decomposed into work functions such as passenger processing, aircraft dispatch, and monitoring activities, while the activities within a specific work situation were further delineated in terms of their functional content. For example, the turn-round process was decomposed into a set of recurring work situations including: de-boarding, boarding, unloading, loading and aircraft services. Activities within the work situation (i.e. boarding) were then further decomposed into a set of recurring work functions including: delivery of wheelchair passengers /unaccompanied minors to the cabin crew, open boarding doors, registering of boarded passengers, or loading the coach for the transfer to the aircraft at remote position. In this way, the control tasks for each work situation can be analysed in terms of when, by whom, and where the decision can be made.

4.4.2 Results from Control Task Analysis

The CTA was performed analogous to the consolidated approach described by Naikar et al. (2005). This approach includes two steps which are ‘identification of what needs to be done’ during critical turn-round in terms of *work situations* and *work functions*, and ‘identification of what needs to be done’ during critical turn-round in terms of *control tasks* for each work situation and work function. The contextual activity template (See Figure 16) was used to represent the results of the analysis. These steps are now described.

Result I: Identification of Work Situations and Work Functions

The first task of the consolidated CTA was to examine the work segmentation within the critical turn-round path. This was done by using the two-dimensional activity templates during focus group discussions with participating stakeholders in order to identify the valid critical turn-round path that shows the interdependencies between the work functions. Focus group discussions took place during three two-hour sessions with 15 participants consisting of flight crews and responsible SMEs of the relevant turn-round function that are normally at distributed locations during turn-round management.

This approach was useful because the work organized during turn-round takes place at various stages and at various places. However, particular functions need to be performed in a *pre-defined sequence* in order to adhere to the TOBT that was predicted for the off-block time of the aircraft. While other turn-round activities can be performed in *parallel* to the critical sequence (see also Chapter 2.5). Standard terminology that is predominantly used for turn-round management during A-CDM was applied to determine work situations. Three flight crews, three controllers, and one airport representative performed the activity analysis of the work function as representatives of the focus group. At an early stage, documented A-CDM turn–round procedures together with procedural descriptions from airlines like Lufthansa, Air France, and British Airways were used, updated from observation and validated using the stakeholders' experience on critical turn-round management. Descriptions from A-CDM documents contained the A-CDM turn-round process with the associated milestones as key monitoring events. Even with small variations that may be present at different airports, all stakeholders could agree on all work functions required for the critical turn-round path. All participating SMEs were asked questions like - 'Are these all functions occurring during critical turn-round path', 'Is the critical turn-round path correct as shown', 'Are the responsibilities during critical turn-round correctly depicted', 'Are there other locations/potential to better depict the critical turn-round path'.

The critical turn-round path thereby developed includes all processes potentially required; however, depending on the given situation, not all work functions will necessarily take place during critical turn-round, e.g. crew change will not always take place or no catering on specific flights.

The decomposition of work situations and work functions during turn-round can be done at different levels of detail and granularity. As it concerns the work situations, a level was chosen that contemplates only the work situations within the critical path that are located at the ramp side of the airport or that directly influence the critical path of turn-round. These processes have to follow the described sequence, but other processes are taking place in parallel in the airport terminal as well as at other locations of the airport. Passenger or cargo handling working situations and functions remained outside of the scope of this project.

As a result of this analysis, the critical turn-round path can be depicted by using the contextual activity template (See Figure 22).

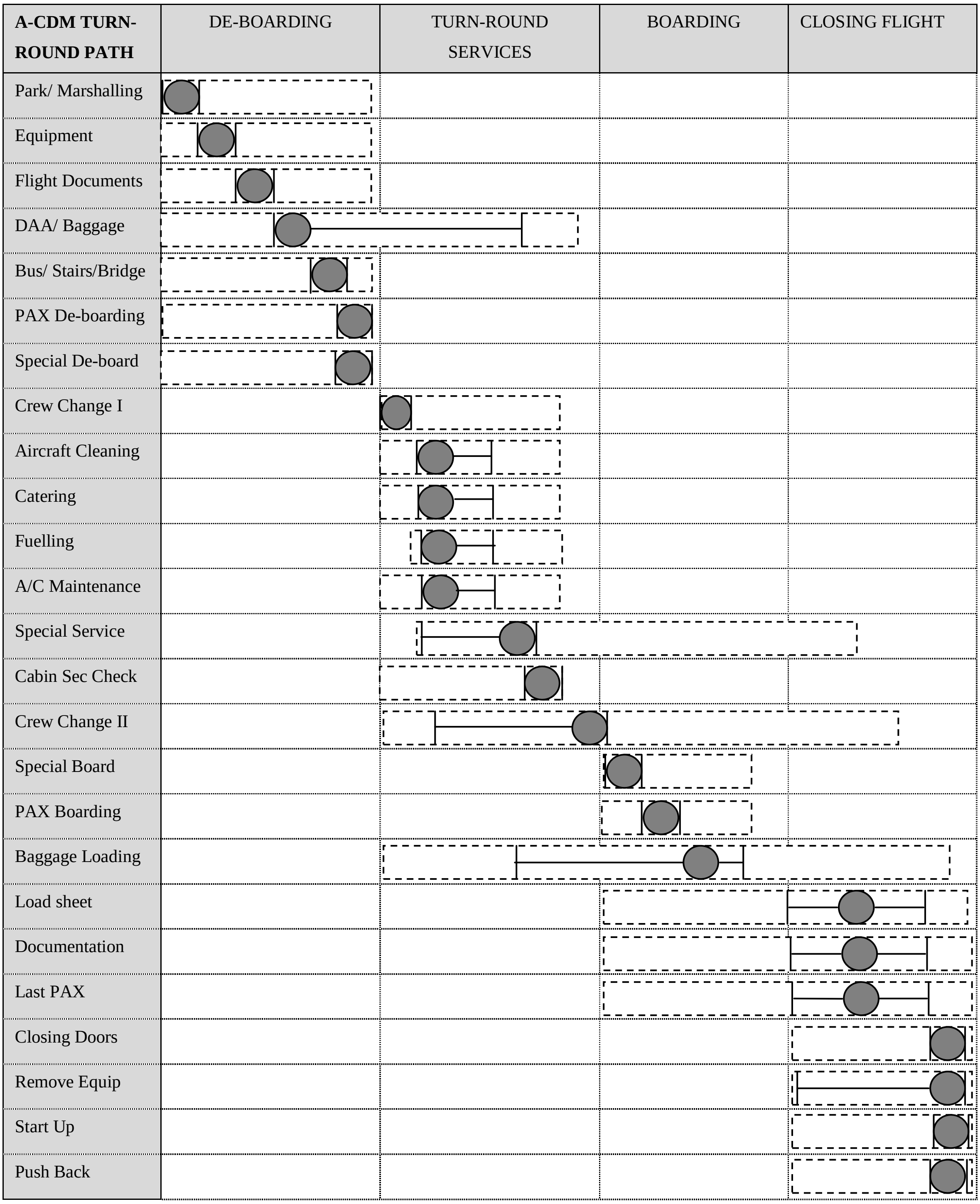


FIGURE 22: CONTEXTUAL ACTIVITY REPRESENTATION (NAIKAR, 2005 & SNELLING, 2002)

The boxes surrounding the work functions indicate all turn-round situations in which the work function can occur. The typical timing for the work function however, is indicated by the bars.

Result II: The Responsibilities within the Critical Turn-round Path

During the analysis of the critical turn-round path, the decisions that are required during these sequenced processes were also identified. Any decision within one of these supporting turn-round processes interacts with other supporting processes, especially during time-critical turn-round management.

During the three focus group meetings between aircrews from the German Regional Carrier, Lufthansa CityLine and turn-round controllers from Lufthansa German Airlines Control Centre, the specific order of the critical events during turn-round were determined and consensus reached on the sequence and responsibility of the processes. As already mentioned, not all turn-round processes take place during each turn-round. However, the proposed path includes *all* eventual decision making processes that can occur during turn-round. Different airlines might have alternative turn-round process models, but it was argued that the constraints are similar and do not affect the concept. The structure of the focus group discussions was modelled on a series of questions to gradually move the participants from an operational perspective of the turn-round processes to the control tasks that were necessary to perform the functions of these processes. The questions which were used for the discussions were:

- Does the proposed critical path include all turn-round processes as they appear during turn-round in the correct order?
- Who is responsible for each process: a single actor or multiple functions?
- Where is potential for improvement of the critical path?
- Who could contribute in improving the efficiency of each process?
- What are the major challenges and what are the problems associated with these processes?
- What are the control functions for each process?

In a second step, the results were analysed during table-top discussions (Kirwan and Ainsworth, 1992). Overall, it was agreed conclusively that the impact of a decision by only a single participant can have significant influence on the outcome of the overall turn-round because the outcome of the decision propagates throughout other processes. Therefore, a way of decision making has to be pursued that is able to coordinate the distributed decisions of participating functions into global decision making where all information is centralized for such control. Many airlines today have started to coordinate decision making in their operation centres. Decisions that cannot be transferred into a control room have to be regarded for the overall TOBT decision.

The discussions were also aimed at finding an agreement on *who* should be responsible for the work function. Today, distinctive functions are in place to either perform the work function or solve a specific problem during critical turn-round path. This means that control tasks for most of the work function are shared among actors executing the work functions and those monitoring the critical turn-round path. For instance, during normal turn-round flow the actor who executes the work function is decision maker. However, during unexpected situations, the actor monitoring the turn-round will take over the responsibility of deciding on a new target state.

As a result of the CTA, Figure 23 shows now the turn-round processes with the functions that are responsible for the necessary decisions within the processes.

Responsibilities within Critical Turn-round Path	
Airport Operator	• Availability of parking position • Availability of marshaller/ docking system • Provision of Passenger coach/bridge • Push-back environment
Airline/ Ground Handler	• Provision of pre-arrival information to the air crew • Ground handling equipment (GPU, stairs, truck...), handling personnel • Flight documents for next flight sector • Delivery at Aircraft (luggage) • Stairs • Passenger & cabin baggage de-boarding • Special de-boarding (WCH, UM, Load) • Crew change • Aircraft cleaning/ catering/ fuelling • Special catering/ other services • Special boarding (WCH, UM, Load) • Passenger & cabin baggage boarding • Baggage, cargo, Delivery at Aircraft loading • Loadsheet, documentation, and last passenger • Closing all doors • Removal of equipment & personnel • Provision of push-back & ground crew for engine start
Air Crew	• Crew change (cockpit & cabin) • Information on aircraft status • Cabin security check • Closing passenger doors
Mechanics	• Scheduling of turn-round maintenance

FIGURE 23: RESPONSIBILITIES WITHIN THE CRITICAL TURN-ROUND PATH (SNELLING, 2002)

4.5. Concluding Aspects

The CWA unveils a number of environmental factors that influence A-CDM turn-round management. It allows for deriving domain constraints of the A-CDM work system and operational information requirements of airline flight crews by means of a Work Domain Analysis. The results could be verified by mapping the data from the flight crew survey (See Chapter 5) onto the pilots’ information requirements extracted from the ADS. The analysis also revealed that a large quantity of information is lacking during day-to-day operation. Provision of such information could potentially aid in stabilizing the turn-round operation. This encourages its further application in identifying information requirements of other participating actors.

It cannot be claimed that the ADS is able to cover *all* system constraints, but evidence could be given that a significant amount of operational information required by flight crews is not yet provided to them.

As an essential part of successful turn-round management, the *critical turn-round path* could be derived from the CTA by using the contextual activity template. At a later stage of this project, the results of this analysis were used to model the turn-round scenarios and the design of a turn-round control mock-up in order to further investigate the influences on TOBT prediction accuracy (see Chapter 7).

Since the critical path is now defined, the next step of the project should analyse how the critical path is affected by turn-round events that hamper reliable TOBT predictions. The following chapter describes how such events were identified by a flight crew survey.

5 FLIGHT CREW SURVEY ON TURN-ROUND CONSTRAINTS

5.1 Aims and Objectives of the Survey

The aim of the survey was to identify and describe critical situations for TOBT adherence seen from the perspective of flight crews. The underlying objectives thereby were not only to demonstrate how frequently turn-round problems occur, but also to identify information requirements of flight crews and actors on the ground during such problems. Even though flight crews are not primarily realized as airport partners during A-CDM, information from the cockpit is used for TOBT assignment decisions.

If the information from the flight crew and their information requirements were known earlier, the influences on TOBT could be assessed systematically. As a consequence, such information would be useful in gaining insights for future TOBT decision making - especially during unexpected situations. Such information also yields benefits for a more efficient decision making with less tactical and strategic effort for all partners.

A further objective of the investigation was to gain information from flight crews about the relevance of various problems during ground handling processes. I.e. how do delayed ground services or late passengers affect the overall turn-round duration and consequently the TOBT, seen from the perspective of flight crews as users of the system. This also included capturing air crews’ views on cooperative/ non-cooperative behaviour during such situations. Analogous to the definition of cooperation (see VI: Definitions), cooperative behaviour is viewed here as the synchronous and homogeneous sharing of information required for operational decision making or for the creation of situational awareness required among participating actors.

5.2 The Design of the Survey

First, information about the critical events during the turn-round situations that are relevant for an interaction analysis between flight crews and other operators were obtained during in-depth interviews with experienced flight crews from different airlines. Airline flight crews were asked to brainstorm all possible turn-round situations by using a checklist in order to identify interactions during turn-round that are relevant for operational information sharing. All turn-round situations were then decomposed into elementary activities to identify where the behaviour of all participating can potentially be cooperative, antagonistic or indifferent (see also Chapter 3.2).

Next, a self-administered on-line questionnaire was developed with questions based on the interactions identified as outlined between flight crews and other operators, using the interaction model adapted from Ferber (1995) that is outlined in Chapter 3.2.5. The aim thereby was to identify the status of the relevant components aims, abilities, and resources in the interactions during the turn-round that were reported to be critical.

Compatibility and incompatibility of aims: Incompatible aims can negatively affect cooperation. Therefore critical activities during turn-round were assessed to discover conflicting goals between flight crews and other operators. Since decision making power can also be a reason for conflicting goals, flight crews were also asked to assess whether the currently used mode of sharing responsibility for decision making is suitable in the relevant situations. Questions were then asked, whether the decision maker is accepted by the flight crews in term of responsibility and control or if decision making causes problems because the decision maker is seen as inappropriate.

Availability of resources: Resources are limited; therefore conflicts can arise between all participating partners, if airport congestion increases or turn-round times are getting shorter. Shortage of resources may result in competition between operators. Questions were asked if resources - in terms of the time available for ground processes - are aligned with the operational requirements. An essential part of a CDM airport operation is to manage resource constraints through coordination of actions. Such an approach can be also beneficial in predicting conflicts (Ferber, 1995). Therefore, the survey also investigated how the current CDM approach is able to anticipate conflicts in order to resolve possible conflicting situations between flight crews and other operators. Conflicts should so be identified and quantified by occurrence and probability.

Ability of operators in relation to their assigned task: It cannot be assumed that operators' knowledge and abilities are always sufficient to execute assigned tasks. However, it is unlikely to get realistic results about abilities of other operators when asking airline flight crews. It was questioned that flight crews judge whether a decision-maker has required competence to make a decision, if it is made physically away from the aircraft. Therefore, the question that were asked in this context were not aimed at *identifying* insufficient abilities of the relevant actor or function, but *comparing* the competencies of the responsible decision-makers within the different turn-round problems from the perspective of an experienced user of the system. Such comparison was seen as useful to find trends between the contemplated situations.

Interviews with flight crews revealed numerous problems with information sharing that may have an effect on the turn-round process, and questions were therefore asked, whether there is a relation between failures in information sharing and off-block or turn-round process delay.

Overall, the survey aimed at examining the flight crew's perspective on current approach to A-CDM turn-round management. It described turn-round situations during A-CDM which entailed the risk to jeopardize flight punctuality by delayed turn-round processes caused by problems with information-interactions between aircraft cockpit and decision makers like airport partners at operation center or actors at the ramp. It is argued that homogeneous and synchronous information sharing enables all airport partners or actors to respond to the local context in real time: While some situations during aircraft turn-round operation can be pre-planned, decision makers at tactical or action level will always be faced with unanticipated situations resulting from unknown variables in the environment or technological capabilities. Therefore, each turn-round presents unique challenges for information sharing between all participating partners or actors.

Flight crews were asked to report recent experiences of non-cooperative information sharing behaviour, how it affected turn-round process duration, and if it resulted in a departure delay (if applicable).

Table 4 provides an overview of the different turn-round operation situations and the categories of questions which were posed to the flight crews.

TABLE 4: CATEGORIES OF TURN-ROUND SITUATIONS

TURN-ROUND	COOPERATIVE COMPONENT	FREQUENCY	RELEVANCE
Gate Assignment	Aims/Resources/ Abilities	Daily/Weekly /Monthly	Avoidable Delay
Ground Handling/ Ramp	Aims/Resources/ Abilities	Daily/Weekly /Monthly	Avoidable Delay
ATC Related Delay	Aims/Resources/ Abilities	Daily/Weekly /Monthly	Avoidable Delay
Operational Info From Cockpit	Aims/Resources/ Abilities	Daily/Weekly /Monthly	Avoidable Delay
Operational Info To Cockpit	Aims/Resources/ Abilities	Daily/Weekly/ Monthly	Avoidable Delay

After three 90-minute brainstorming sessions with 8 flight crews from Lufthansa CityLine, Air Berlin, and Deutsche British Airways (DBA) it was concluded that information sharing problems during turn-round can be manifold and each event can potentially be unique in a specific circumstance. However, a number of problems occur regularly and can potentially be attributed to a specific category of problem. Therefore, the questionnaire (See Appendix II) proposed to the flight crews included various situations with *all* partners and actors involved in operational information sharing. These are the airport operator, air traffic control, CFMU, airline company, ground handler, ramp agent, flight manager, check-in and boarding personnel, loaders for cargo, mail and baggage, and service providers like fuelling, catering, cleaning.

5.3 Data Analysis

For the data analysis, only situations were chosen where flight crews reported that an information-interaction problem has taken place with an impact on ground handling or on other service delivery during turn-round (Table 5). The problem must have taken place on a regular basis of at least once per month. The collected data was organised as follows:

- The situations reported by flight crews that require information-interaction between cockpit and others were summarised in Table 5.
- Actual events attributed to an information-interaction failure during turn-round are shown in Table 6, displaying the reported frequency of the four proposed turn-round situations of all flight crews and reported turn-round events.

- *Descriptive data analysis* was used to obtain measures of central tendency or dispersion about the delays that are avoidable seen from flight crews' perspective. Data was collected via a Likert scale (Figure 24).
- Correlation analysis was carried out between the turn-round process delay and the departure delay (Figure 25).

Statistical Analysis was performed with SPSS 17.0 and Excel. An α level of .05 was chosen as decision criterion. Non-parametric statistics were used with Spearman's rho as a measure of correlation.

TABLE 5: REQUIRED INFORMATION-INTERACTIONS DURING TURN-ROUND

Turn-Round Problem	Information Required
Availability of Parking Stand	Expected Delay /Reason of Delay for Parking
Baggage Loading/ Unloading	Delay: Expected duration, reason, No of baggage
Ramp Transfer Bus (Passenger or Crew)	Delay: Expected duration, reason
Catering	Delay: Expected duration, reason
Cleaning	Delay: Expected duration, reason
Fuelling	Delay: Expected duration, reason
Check-In	Delay: Expected duration , reason
Security	Delay: Expected duration, reason
Boarding	Delay: Expected duration, reason
Airport Facilities	Delay: Expected duration, reason
Wheelchair boarding	Delay: Expected duration, reason
UM Boarding	Delay: Expected duration, reason
Special Loading (e.g. musical instrument)	Delay: Expected duration, reason
VIP Boarding	Delay: Expected duration, reason
ATC Request	Delay: Expected duration, reason
CFMU Regulation	Delay: Expected duration, reason
Aircraft Change	Reason and status of new aircraft
Technical Repair	Reason and expected duration of repair
Crew Duty Change (new duty roster)	Timely Provision of Information
Crew Change (new crew member)	Timely Provision of Information
Crew Proposal: Connecting Passenger	Response and expected action
Crew Proposal: Necessary A/C repair	Response and expected action
Crew Proposal: Avoidance of A/C Change	Response and expected action
Other: No Flight documents delivered	Response and expected delivery
Other: No Ramp Agent available	Status of Service Delivery
Crew Proposal: Avoidance of A/C Change	Response and expected action

Flight crews were asked to choose their level of agreement between two statements entailing one of the information provision problems from table:

- I was informed of the problem in time (includes possibility to take appropriate action)
- I learned about the problem by observing that the process was not executed or I received information too late.

For each turn-round situation, the flight crews were then asked to rate (on a scale from 1 = very unlikely to 4 = very likely), whether the delay of the turn-round process was avoidable or not, as seen from their own perspective.

Additionally, the flight crews were asked to assess how many minutes of delay resulted from the turn-round process which deviated from established turn-round reference schedules, and how many minutes departure delay was encountered *after* that turn-round with this service failure. Only events reported to occur at least monthly were taken into account.

Flight crews were also asked to assess the possible reasons for the cause of service failure analogous to a cooperation model by Ferber (1995). The category of cooperation was determined by three components - the aims, resources, and abilities of participating actors (see chapter 3.3). The level of agreement on each of the three components was measured with 1 = very unlikely to 4 = very likely. This data was then used to identify non-cooperative situations corresponding to his model.

In all questions, multiple and equivalent choices were allowed, meaning that the flight crews could assign multiple causes of failures for each specific event.

5.4 Results from the Survey

5.4.1 Flight crews' General Information

The experience level of the flight crews participating ranged between 1 and 8 years (av. 6, 58; σ = 4, 40) for First Officers and for Captains additional flight experience between 1 and 20 years (av. 7, 37; σ = 5, 87) of experience. The average experience of the Captains includes First Officers' plus experience reported as a Captain.

5.4.2 Flight Crews' Information Requirements

The results concerning flight crews' information requirements are shown as a function of '*delays avoidable*'. This means, if the information was provided to flight crews or received from flight crews, a turn-round delay could have been avoided (1 = very unlikely, 2 = unlikely, 3 = likely, 4 = very likely). Figure 24 shows the mean values of 'information requirements' that all received high ratings from the perspective of the airline pilots:

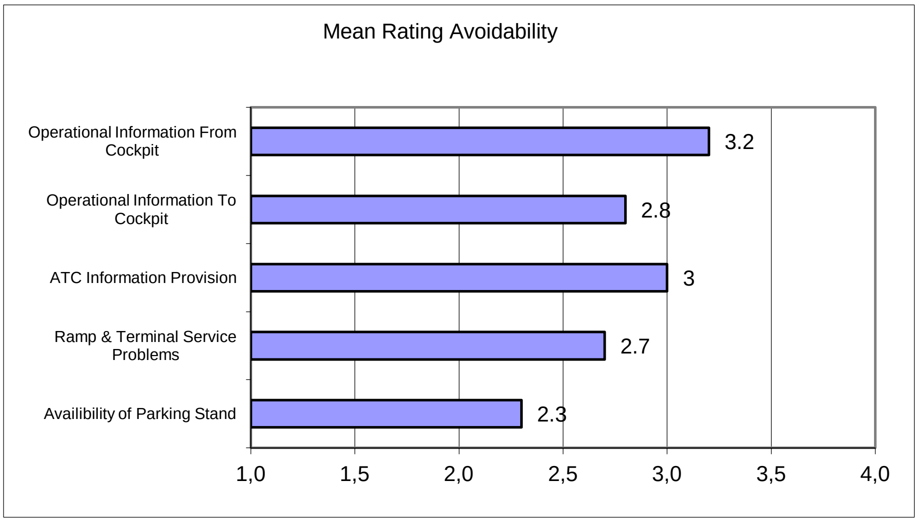


FIGURE 24: MEAN RATING 'DELAYS AVOIDABLE'

Highest ratings were assigned to the statement '*need to take the information into account which was proposed by flight crews'*, where flight crews see fewest options to avoid delays through '*timely notification of problems with parking stand assignment'*.

However, the initial assumption that 'reliable provision of operational information to the flight crews is correlated with 'delays avoidable' did not show statistical significance.

Flight crews were also asked to report about events of information sharing failures that they experienced; however, most of the flight crews used the *proposed* events in the questionnaire that were identified as critical for information sharing during focus group meetings. Table 6 shows the reported frequency of the five proposed turn-round situations and events from all participating flight crews as frequency in percentages. Only turn-round events were proposed between milestone 7 and 15; all other events are attributed to the concept element *A-CDM in Adverse Condition* (e.g. de-icing):

TABLE 6: CRITICAL TURN-ROUND EVENTS AS REPORTED BY FLIGHT CREWS

TURN-ROUND PROBLEM	FREQUENCY OF REPORTS
SITUATION I: Availability of Parking Stand (Totally Reported by 95.1% of Participants)	
Availability of Parking Stand	95.1%
SITUATION II: Delay of Ground Services (Totally Reported by 100% of Participants)	
Baggage Loading/ Unload	47.1
Ramp Transfer Bus (Passenger or Crew)	11.8
Catering	1.0
Cleaning	2.9
Fuelling	4.9
Check-In	1.0
Security	2.0
Boarding	13.7
Airport Facilities	4.9
Wheelchair boarding	3.3
UM Boarding	0
Special Loading (e.g. musical instrument)	1
VIP Boarding	5.9
Missing Flight Documents	2
SITUATION III: Operational Changes (Totally Reported by 95.1% of Participants)	
Aircraft Change	63.1
Crew Duty Change (duty roster updates)	18.4
Crew Change (new crew member)	1.9
Technical Repair	7.8
Other	3.9
SITUATION IV: Proposals by Flight Crew (Totally Reported by 95.1% of Participants)	
Connecting Passenger	5.8
Necessary Aircraft Change	33
Avoidance of Aircraft Change	47.5
Other	5.8

5.4.3 The Aircraft Cockpit as Information Source

The information that should be shared *from* cockpit via standardized status alarms with turn-round controller was also identified. Issues to create status alarms included:

- Technical: if a maintenance action is required at destination, mechanics should be employed to assess the expected duration of the necessary inspection or repair.
- Catering: Incorrect catering service (e.g. incorrect quantities or catering items planned for another flight) or additional required items.
- Fuelling: Required extra fuel due to route or flight plan changes.
- Cleaning: special cleaning required.
- Crew request: rest time requirements or health related problems.

- Cruising Speed: Due to technical reasons, cruising level changes or weather, speed changes may be necessary; (because flight updates are only calculated with standard speeds).
- Passenger requests emerging during flight (Pick-up request, health problems, or others).
- Bulk cabin loading: requires extra time for un-loading.
- MTTT or less: crew agreement to shortened MTTT.

This information together with the information held by the turn-round controller should feed into the decision making about the length of turn-round required at destination, e.g. is MTTT acceptable, and finally the decision about the TOBT.

5.4.4 Flight Crews' Strategies for Creating Situational Awareness

A number of strategies which are used by flight crews to create a situational awareness for operational issues occurring at the aircraft could be identified. While the majority of flight crews (70% of all participating flight crews) still argue in favour of more cockpit involvement in operational decision making, the novel approach to turn-round decision making is increasingly taking place at airline operation centres, however different airlines use different approaches to turn-round management (see Chapter 6.3).

A. Knowledge-Based Situational Awareness (SA)

Flight crews frequently engage in knowledge-based approaches to create SA of the turn-round. Rather than merely reacting to stimuli from turn-round processes, flight crews actively seek specific information, as a function to the given situation. Examples include:

- In-flight, flight crews actively sought status alarms that they communicate to turn-round control. Confirmation from turn-round controller for TOBT adaption is normally expected in this case.
- On the ground, flight crews contact turn-round controller to update/ confirm about passenger or turn-round process status. This is used to increase SA of turn-round manager and flight crews. This can be viewed as a way to

compensate for the non-existent standard information exchanges previously mentioned.

B. Facilitating Activities of Flight Crews

- Creating interference during standard procedures of the turn-round, like initiating a halt of passenger boarding: if flight crews observe unanticipated demand for extra turn-round time due to any reason, they can halt passenger boarding process and resume own responsibility for the length of turn-round. This requires exact tuning between cockpit and turn-round controller, because new TOBT has to be proposed based on cockpits' assessment of the situation.
- Requiring TOBT be adapted: if flight crews see reduced/increased demand for turn-round time, they propose TOBT adaption to the turn-round controller. This reflects the variables inherent in every turn-round process (e.g. amount of passengers, catering/ fuelling requirements…) and contradicts the initial A-CDM concept where air crews are not realized as A-CDM partners.
- Creating a new status alarm: often issues arise during the critical turn-round path that are not foreseeable. This status alarm will be shared with the turn-round controller who will then adapt the TOBT accordingly. Process planning gets more demanding, if alarms arise in the last minutes before TOBT and this requires exact coordination between all partners and actors. Failures to adapt TOBT often arise during this last minute coordination process where last minute problems were reported by airlines to vary between 8 and 15% on all flights.

5.4.5 Effect of Process Delay on Departure Punctuality

Figure 25 provides an overview with significant correlations that were identified between delayed turn-round processes (independent variable) from service processes in relation to the Off-block delay (dependant variable) which followed these delayed turn-round processes While the first column shows the amount of process delay in minutes, the second column shows the minutes that the flight left delayed from parking position. This indicates that the delays caused by these turn-round processes could not be compensated by spare time or accelerated other turn-round processes. Even more, the delay increased during the course of the turn-round.

However, since the values of both variables result from qualitative assessment of the situations, such analysis provides only subjective information..

Figure 25 shows the delayed turn-round processes parking stand assignments, operational information sharing *to* cockpit, and operational information sharing *from* cockpit that were particularly interesting, because of the this feature

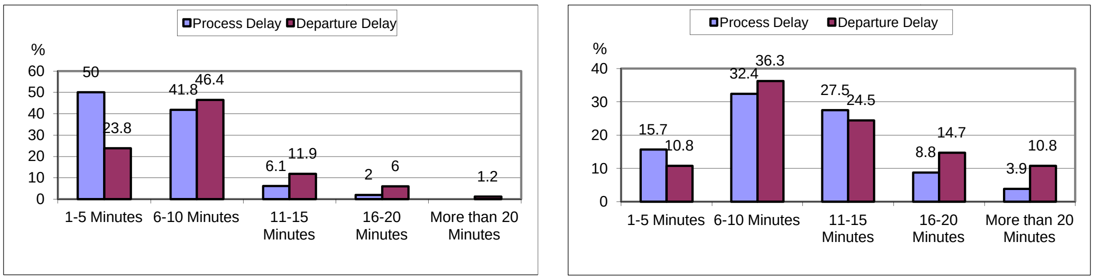


FIGURE 25A: PROCESS AND DEPARTURE DELAY FOR PARKING STAND ASSIGNMENT

(Spearman’s rho = 0.363, p=0.001, two tailed test, N=84)

FIGURE 25B: RAMP AND TERMINAL SERVICE DELIVERY

(Spearman’s rho = 0.424, p=0.000, two tailed test, N=102)

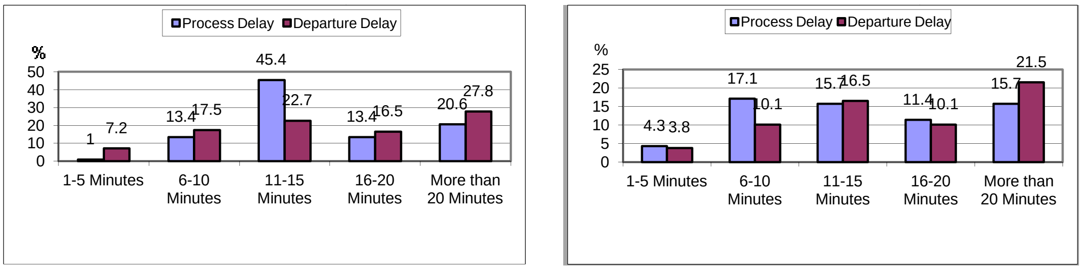


FIGURE 25C: OPERATIONAL INFORMATION TO COCKPIT

(Spearman’s rho = 0.760, p=0.000, two tailed test, N=97)

FIGURE25D: OPERATIONAL INFORMATION FROM COCKPIT

(Spearman’s rho = 0.854, p=0.000, two tailed test, N=79)

FIGURE 25: RESULTS FROM FLIGHT CREW SURVEY

Even though it is not possible to infer that the turn-round process delay alone caused the overall departure delay, it entails a high risk of being responsible for the delay since also the *amount* of delay correlates significantly between process delay and departure delay. It can be argued that this result is only flight crews’ assessments and not real data during turn-round. However, in all situations flight crews were always directly affected by the delay and were physically present where the turn-round took place.

5.4.6 Possible Failure Causes for Cooperation during Aircraft Turn-Round

Error! Reference source not found. provides flight crews' assessment of possible failure causes expressed in three components aims, resources, and abilities. Even though it was questioned whether it is possible for flight crews to identify or understand such failure causes objectively (See Chapter 5.2), the usefulness of the results for providing a meaningful comparison between different turn-round failures is likely for the following reason: flight crews have operational experience from a home base airport with which they are familiar. Since all participating flight crews fly for airlines having a large network operation, flight crews can easily compare turn-round services from other airports with their home base airport. **Error! Reference source not found.** therefore compares the different ratings of the three components aims, resources, and abilities as possible failure causes like reported by the flight crews:

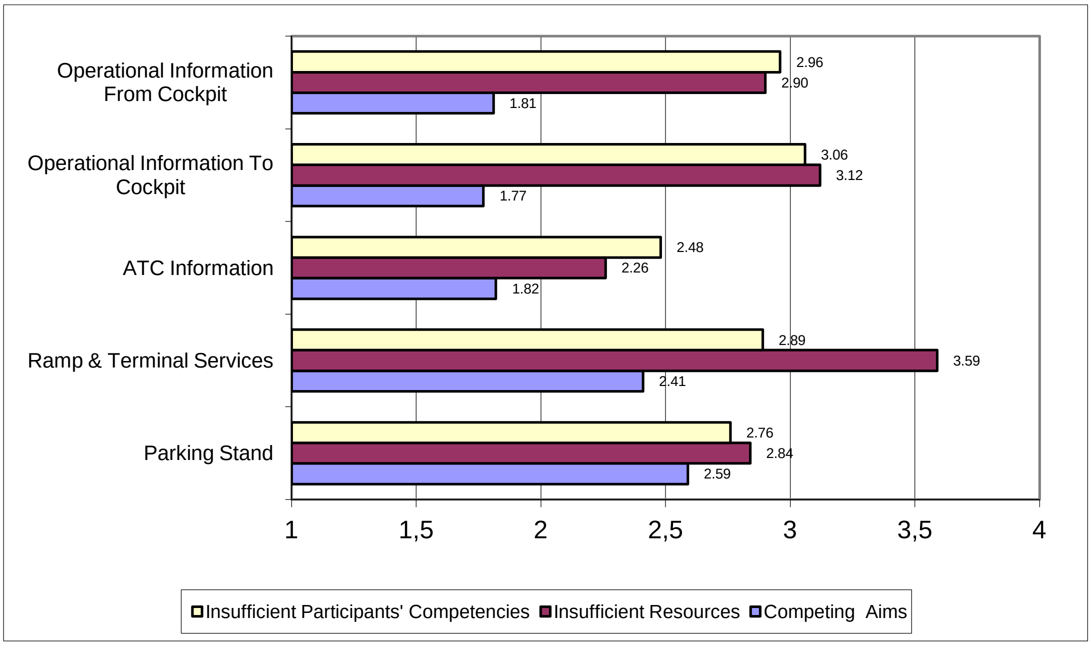


FIGURE 26: POSSIBLE FAILURE CAUSES DURING TURN-ROUND EVENTS

During all situations, except ATC information sharing, insufficient resources were seen as responsible for delays of the proposed turn-round situations with highest values assigned to ramp and terminal service processes. Remarkably high values were also assigned to insufficient abilities. The only non-cooperative situation from flight crews’ perspective and analogous to Ferber’s cooperation model is the assignment of parking stands.

Flight crews were also asked to report about possible other reasons for turn-round failures (Figure 27):

FIGURE 27: OTHER REASONS FOR TURN-ROUND PROBLEMS

The main reason reported refers to the turn-round time that is too short: If this is the case, there is not sufficient time to compensate any process delay. The second reported was the responsibility for decision making that was reported to be inappropriately shared. Further reasons mentioned were reason related to important information that is hidden among an overload of information provided to the flight crews, and also the inappropriate communication facilities that do not allow addressing concerns during turn-round.

Flight crews also had the possibility to mention other causes of problems in free text. Although some reported results correspond to the causes proposed in the questionnaire, they were stated explicitly using the free text option. Table 7 presents these responses.

TABLE 7: POSSIBLE CAUSES FOR TURN-ROUND FAILURES

Possible Causes	No of Reports
Not sufficient ground personnel	7
Motivation and competence of ground personnel	6
Lack of *competent* ramp agent	5
No situational awareness of airport partners and actors	3
Too many different decision makers	3
Not enough training of ground personnel	2
No clear sharing of responsibilities	1
No or inappropriate use of communication devices	1
Bad coordination of ground handling processes	1
Unrealistic scheduling of processes	1
Decisions outside of captain's assessment	1
Inappropriate delay code assignment falsifies real causes	1
Too much time pressure during turn-round	1
Information sharing with service providers	1

A further question to be answered aimed at identifying the flight crews’ perspective to decision making during turn-round was:

“Do you think it would be an advantage if the flight crew were more involved in decision making on operational issues during turn-round?”

From 93 flight crews who answered this question, 65 answered with “Yes” (representing 70 % of all valid answers) giving the following reasons (n = 28 or 30.1 % were against more flight crew involvement) listed below in Table 8.

TABLE 8: REASONS FOR COCKPITS’ INVOLVEMENT IN DECISION MAKING

Reasons in Favour of more Flight Crew Involvement	No of Reports
Situational Awareness best placed at aircraft	34
Earlier detection of problems and so earlier solutions possible	5
More information in hand	5
Crew has final responsibility for the flight	5
Dispatch too far away from action level	3
Fastest possible response + solution to arising problems	3
Better evaluation of possibilities in hand and time required	2
Captain should be place where information gather	2
Last minute problems only present at the cockpit	2
Often other decision makers do not have sufficient time in hand	2
Less mental stress through avoidance of 'surprises'	1
More experiences with similar situations	1
More flexibility	1
Dispatch not always competent enough	1
For specific situations, e.g. aircraft change, technical	1
Only, if decision making is *defacto* made by flight crew	1
Better teamwork instead of debating with dispatch	1
Only for decisions where judgement is better possible from cockpit	1

Flight crews who are *against* more involvement in decision making argue (Table 9):

TABLE 9: REASONS AGAINST COCKPITS' INVOLVEMENT IN DECISION MAKING

Reasons against Cockpits' Involvement	No of Reports
Crew has other tasks	4
Work load already too high	6
Against Flight Safety	2
Not sufficient Situational Awareness at Aircraft	12
Only shifting of responsibilities to cockpit	1
Not enough time	3
Not necessary, if appropriate processes are in place	2
If necessary, information can be forwarded	1
Too many different opinions	1

5.5 Concluding Aspects

Having identified the constraints framing A-CDM and turn-round management, the survey as designed to find the situations where these constraints occur during turn-round operation and result in service failures, process delays, and TOBT inaccuracy. Given the rising number of stakeholders and participants involved in even for a single turn-round only, it was assumed that a number of turn-round process failures could result from non-cooperative behaviour among participants. Therefore, an investigation was pursued that utilises qualitative data of aircrews because they are normally not blamed for failures during turn-round. However, seen from the perspective of the airline flight crews, the overall collaboration during day-to-day turn-round operation was perceived as cooperative. The only example that was captured as being non-cooperative is the assignment of parking stands (Chapter 5.4), if following the theoretical model of cooperation as proposed by Ferber (1995).

According to Ferber (1995) a cooperative situation is the prerequisite for successful collaboration and cooperation depends on aims, abilities and resources (see Chapter 3.2). In the context of turn-round operation, information was viewed as one of the resources that have to be provided to the TOBT decision maker. However, another result from the survey reveals that turn-round operation is limited by failures to share timely and relevant information with the airline flight crews, and also by not using the information that is provided by the flight crews. At the same time, the study was also used to identify which information is finally required to predict turn-round process duration and which can so be used for calculating TOBT predictions. Which information is already available that would allow making earlier and more accurate

TOBT updates was also analysed. These findings were later used to design the experiments (see Chapter 7).

The initial assumption that timely provision of information about turn-round service problems to aircrews could be beneficial in avoiding a turn-round process delay was not provable. However, the effects of information sharing failures on TOBT predictability could be demonstrated by comparing the delay caused by turn-round process failures with the overall delay of the turn-round: the relation between the turn-round delay and the process delay showed significantly higher values for the turn-round delays. This result was compared with the inaccuracy swing effect (bullwhip effect) as an analogy from the production industry where the network of service providers can oscillate in very large swings - if the process takes place within the critical path of turn-round events.

6 FIELD OBSERVATION DURING A-CDM TURN-ROUND

6.1 Aims and Objectives of the Analysis

The aim of this study was to develop a better understanding of how operators monitor the complex, dynamic aircraft turn-round operation and to identify the influences of the monitoring strategies on TOBT prediction accuracy. It outlines the currently used practice of turn-round monitoring of flights preferably having only minimum turn-round time available for the turn-round process. The analysis is expanded to consider:

- aspects of situational awareness required for turn-round management;
- problems identified in achieving an accurate and reliable TOBT;
- cognitive aspects that have influence on the turn-round process and TOBT prediction; and
- current modes used for information sharing among airport partners.

The underlying aim was also to identify whether TOBT predictions are influenced by the current approach to turn-round monitoring and whether TOBT predictions can be improved so that less updates are required and deviations from first assigned TOBT remain small.

6.2 Method

While some turn-round situations can be pre-planned, decision makers will always be faced with unanticipated situations resulting from unknown variables in the environment or technological capabilities. These situations can affect time estimates of turn-round processes resulting in an inaccurate TOBT prediction. However, since ATC uses the TOBT as a reference for building the pre-departure sequence, deviations from TOBT may interfere with the stability of the departure sequence. To counterbalance this unreliability, ATC has to build in extra buffers between TSAT and Target Take-Off Time (TTOT) with the consequence of poor TTOT prediction for the airlines and the overall network.

Therefore, field observations were conducted to capture how airline operators monitor the complex, dynamic turn-round process of aircraft, passengers, and cargo in normal operation in situ for a total of 122 hours. The observation time was different between airlines a, b,c,d, and e (a = 82h, b = 14h, c = 10h, d = 8h, e = 8h) because of the large differences among the airlines in managing the turn-round process. Observations took place in five different operation centres from Lufthansa German Airlines, British Airways, Air France, KLM, and Brussels Airlines. Focus was applied placed on monitoring turn-rounds with only minimum turn-round time available.

According to Su et al (2005), visualisation, situational awareness, proactive/reactive monitoring, and interactive capabilities are the four core elements necessary for effective human monitoring of complex systems. If one of these elements is missing, decision making will always involve handling uncertainties. The control room observations at the airline operation centres were carried out with focus on these core elements while keeping in mind that decision making is never fully predictable because of the imponderability from environment or operators intentions.

Turn-round operation is getting increasingly complex, because of interdependencies between third party ground handling service providers, the number of participating parties for each turn-round, size and dimension of airports, and the decreasing time available for each individual turn-round. How human operators monitor the quality of these networks not only has a great impact on the efficiency of the turn-round operation, but also flight punctuality and passenger satisfaction depend highly on a reliable turn-round process.

The method used for analysis evolved from this given situation. Observations (preferably with minimal interruption to activities) were carried out with the following questions as key drivers:

- What are the tasks of the turn-round controller and what does the practice of TOBT assignment look like?
- What are the current modes used for monitoring the turn-round?
- What are the monitoring and facilitating activities used by the turn-round controllers?
- What technological configurations are available for turn-round monitoring?
- What cognitive challenges are inherent in the turn-round monitoring task?
- What strategies do turn-round controllers use?

To organize the results, a model analogous to that of Vicente (1999) was applied that is able to capture the cognitive, monitoring, and the facilitating activities of the controller that he applies during turn-round. A detailed description of his model can be found in Chapter 6.3.8 that also provides the reason for its relevance for turn-round monitoring. High importance was assigned to the findings and therefore detailed results from control room observations are given in Chapter 6.3. They were also used as basis for designing the experiments.

6.3 Results

6.3.1 Current Modes of Turn-round Monitoring

For the benefit of the ATM network, the airline company is responsible for predicting an accurate TOBT. This task is usually delegated to the turn-round controller who monitors the turn-round process closely. Different *modes* of turn-round monitoring, based on airlines’ individual requirements and operational concepts could be identified.

Monitoring *activities* during turn-round process control very much depend on the actual situation and turn-round controllers’ strategies for responding to the local context. Controllers are often required to monitor multiple turn-rounds simultaneously, with the effect that the time available for each individual turn-round event can be very limited. In general, two different modes of monitoring the turn-round process were observed:

- Local Turn-round Management (LTM): a turn-round controller is assigned to an individual flight and is physically present *at the aircraft* where he directly controls the turn-round process. He can either prepare turn-round processes based on requirements of the airline, his own experiences and knowledge-based strategies, or simply react to problems arising. Local turn-round monitoring was traditionally used by the majority of airlines until cost pressure caused airlines to pursue less labour intense modes of monitoring.
- Remote Turn-Round Management (RTM): a turn-round manager controls turn-round *from an operation centre* typically at the airport, but remote from the aircraft. He is using automated data and inputs from different agents, e.g. flight

crews, loaders, flight managers. This approach is less labour-intensive and increasingly being used by airlines.

Which approach can most accurately predict TOBT (thus making it more reliable for the ATM network) has not yet been demonstrated. There are also other approaches to turn-round monitoring, e.g. like flight crew controlled turn-round monitoring, which were not observed during this study.

6.3.2 Current Practice of TOBT Assignment

The role of a turn-round controller can be described as monitoring the turn-round process while being responsible chief executive for all turn-round events assigned to him via coordination of all ground handling related processes aimed at achieving highest punctuality possible. If punctuality is a factor or turn-round processes cannot be handled as specified by airlines, he actively intervenes in the ground handling. The task of the turn-round control can be either performed by the airline operator directly or any contracted ground handling company. The main partners the turn-round controller interacts with are:

- cockpit crew (coordinates aircraft processes);
- ramp agent (coordinates ramp processes);
- airline representative (coordinates flight schedule, e.g. flight cancellations or equipment changes);
- gate manager (coordinates passenger flow);
- gate employee (coordinates passenger check-in and boarding);
- airport representative (coordinates parking position and ramp services);
- one or several external coordinator(s) (coordinates third party service deliveries).

The turn-round controller deals with all irregularities. He also coordinates the turn-round process with other controllers or coordinators responsible for the affected sub-processes. His responsibility is also to inform partners or actors involved about irregularities known to him and decision about possible strategies in case of arrival delays with consecutive turn-round having only MTTT available, e.g. initiate quick turn-rounds with special attention or leave baggage/ passengers behind.

The underlying aim of turn-round control is to dispatch the flight as close as possible to the SOBT.

Differences in assigned tasks exist between turn-round controllers during *Local Turn-round Management* and *Remote Turn-round Management* (see Chapter 6.3.1). While turn-round controllers at the ramp (Local Turn-round Management) are able to derive information for coordination of turn-round processes by *observing* real-time events, the controllers at the control room have to use available data *displayed* on computer screens as main information source, or initiate interactions via telephone, radio, or ACARS.

It was observed that Remote Turn-round Management controllers often have additional tasks compared to Local Mode Turn-round controller. One of the major tasks is monitoring data that may have consequences on flight punctuality because of:

- positioning crew delays or crew schedules changes;
- published CTOTs; or
- assigning delay codes to the airport partner who is responsible for causing the process delay.

A number of working processes are defined for Remote Turn-round Management controllers, but they differ depending on airline policies. These tasks include:

- loading of all required IT systems;
- preparing individual roster with assigned turn-rounds;
- checking for crew rotation;
- processing telexes received;
- creating movement messages;
- answering or forwarding data or voice messages;
- work the required aircraft changes in the schedule; and
- delegating operational tasks to participating actors.

Only a few processes have *predefined* procedures designed for necessary deviations from standard procedures, e.g. if delay is greater than a certain threshold value or aircraft/equipment changes.

However, for the ATM network and all Airport Partners, the most critical output of the Turn-round Process is the Target Off-Block Time (TOBT), because TOBT defines not only the coordination and controlling of all operational processes related to ground handling, but it is used as a reference time for ATC to issue the TSAT. TOBT is the mandatory time for all participating actors, where aircraft loading has to be completed, doors closed, and all ground handling equipment removed. If it becomes necessary that TOBT cannot be maintained, the turn-round controller is responsible for updating TOBT depending on the given conditions and considering of all logical requirements. Regardless of turn-round controllers' strategies, the process of TOBT assignment depends on local procedures defined by participating airport partners.

6.3.3 Monitoring and Facilitating Activities used by the Turn-round Controller

Now, turn-round controllers' actual monitoring activities – from indication of pieces of data to proactive acquisition of information are described here. The following list is a comprehensive set of resources that were provided by airlines during the observed modes of turn-round control, either at the ramp or in the control rooms. Not all airlines use all of the resources described, but those procedures and tools corresponding to their own requirements.

- *Actively conducted field monitoring:* as described earlier, different modes of turn-round monitoring are possible. In some cases, turn-round controllers were always physically present at the aircraft.
- *Monitoring turn-round status using cameras:* controllers obtain visual turn-round status information via cameras; while some controllers prefer to monitor individual aircraft parking stand, others used a more apron oriented camera perspective.
- *Monitoring aircraft status using displayed data*: controllers use data about aircraft status to obtain information of planned aircraft arrival times.
- *Monitoring turn-round status using displayed data:* controllers use displayed turn-round status data to obtain information about landside and airside turn-round status.

- *Monitoring passenger/baggage status using displayed data*: controllers use data about passenger check-in/boarding status and baggage location data to obtain information about airside and landside turn-round status.
- *Communication with field operators:* controllers communicate by phone or radio with actors at all relevant locations in the terminal building as well as on the ramp to obtain an indication of information about the turn-round status.
- *Communication with other airport partners:* controllers communicate via phone or face-to-face with other airport partners to obtain indications of information about the status of resources e.g. availability of parking position, manpower, equipment, and whereabouts of proceeding crews.
- *Monitoring alarm panels:* controllers obtain alarm messages automatically (by pop-up windows) for some missing indications of turn-round status data or critical crew proceedings - which in some cases- should be provided by participating partners.
- *Monitoring other turn-rounds:* controllers use status information about non-assigned turn-rounds in order to obtain information about resources that may be awaited, e.g. manpower or equipment.
- *Monitoring data link messages:* controllers use indications made available by flight crews to obtain information about operational processes at the aircraft.
- *Reviewing log records:* controllers use printed information with turn-round overviews and turn-round reference models to log or initiate actions/information required by participating partners.

A number of activities could be identified that are used by controllers to make monitoring more efficient. These activities reveal useful insights for analysing procedures or tools for future turn-round monitoring. Facilitating activities used by the controller to make monitoring more efficient include:

- creating external support by using their own strategies adopted from experience, training, or knowledge;
- initiating interactions with other partners or actors, e.g. via phone, radio, or ACARS;

- creating external reminders for monitoring including personal notes or coloured stickers;
- ignoring pop-up alarms, because situational awareness could be established earlier; and
- creating shared situational awareness with other participating actors through initiation of interactions.

Controllers also adjust their tasks in order to make monitoring more manageable. They achieve this by setting priorities, scheduling jobs, and allocating tasks to participating actors. Activities identified at this stage are very much knowledge-driven and the success of the turn-round depends on decisions made at this level. Su et al (2005) claim that controllers who are able to regulate their workload in order to make it well calibrated to *their* cognitive capabilities are less susceptible for failures or errors.

6.3.4 Technological Configurations Available for Monitoring

A number of data and information sources are available at airline operation centres depending on the airlines' requirements and the purpose of its intended usage.

During turn-round management, human-information interactions are established via human-human and human-machine interactions. These interactions require standardisation to accomplish turn-rounds defined by airline companies' pre-sets like the reference turn-round procedures models. However, during various key stages of the turn-round process, no standardised or automated process of information sharing could be observed, e.g. via procedural working standards or mandatory data exchange, so as to facilitate human-information interactions especially required during unanticipated turn-round process steps.

If e.g. unknown variables are encountered, predefined data has to be shared between actors like flight crews, turn-round managers, or mechanics. However, only rough guidelines exist about who should be informed and when. If standardisation is not used to the maximum possible extent, failures to share data, knowledge, or information during such situations can result in an inaccuracy swing of the turn-round delay (see Chapter 5.4).

Although these information interactions are often required *across* organisational boundaries involving airport partners and service providers, but so far they only take place spontaneously, depending on the actors involved and their information processing behaviour.

A. Human-Human Interactions during CDM Turn-round

Modes used for human information interactions among operators include telephone, two-way radio facilities, or face-to-face communication:

- Telephone facility: allows participating partners to call each other in order to exchange data/information and time estimates, data sharing with cockpit only between actual on-block time and actual off-block time.
- Radio facility: allows participating partners to contact each other in order to collect or forward data and time estimates already before actual on-block time.
- Face-to-face communication: allows participating partners to contact each other in order to collect or forward data and time estimates during turn-round.
- Typed Messages: flight crews and other participants can access computer terminals to download flight related data/information.

A.1 Interactions between Turn-round Manager and Cockpit:

During direct turn-round management, human-human interactions usually take place via face-to-face communication between the turn-round manager and flight crews. Whereby proactive behaviour by both turn-round manager and cockpit contributes not only to avoid turn-round process delay, but helps to avoid turn-round process delay and enables other partners to take appropriate actions by establishing a distributed situational awareness. Local Mode of turn-round management is also influenced by skill, rules, and knowledge-based behaviour by the turn-round manager.

During remote turn-round management, all interactions between cockpit and control centre take place in order to assure that situational awareness is shared between the turn-round manager and flight crew for standard and non-standard turn-round processes. However, the distance between the cockpit and turn-round manager creates a physical hurdle that has to be overcome by means of telephone or two-way radio communication. Hence, it is important that interactions are initiated because not *all* required data or knowledge is automatically shared between the turn-round manager and flight crews.

A.2 Interactions between Cockpit and Other Actors:

The flight crew possess the most knowledge relevant to the aircraft status. Therefore, operators involved at the ramp communicate directly with flight crews, while operators at the terminal usually communicate with the turn-round controller. Turn-round process coordination is provided by a turn-round manager or in some cases established as an automated process, e.g. boarding process starts at a predefined time before TOBT.

A.3 Interactions between Turn-Round Manager and Other Actors:

The number of interactions depends on the complexity of the specific situation (e.g. passenger numbers or composition, baggage volume etc) or inherent constraints (e.g. MTTT or resources available).

A.4 Human-Machine Interfaces during Turn-round

The *specific* configuration used for turn-round monitoring is determined by airlines' individual requirements and the emphasis it puts on turn-round management. Various software tools for turn-round monitoring exist; however, airlines use similar tools in different ways. As a consequence it is necessary that beside technological requirements also the user-specific requirements including cognitive demands are taken into account for the design of the communication and monitoring tools. The following list shows the HMIs that are available for turn-round control in the control rooms, aircraft cockpit, and at the ramp:

B. HMIs available at the Turn-Round Control Rooms:

- Airlines' operation control systems: can be accessed and updated with new information from all stations served by the airlines' network a level of detail depending on individual airlines' requirements. Examples of data usually received automatically by airlines' operation control systems include AOBT, ATOT, EOBT, ALDT, AIBT, EIBT. Movement and Delay messages are sent by interactions from outstations.

- ACARS Messages for communication with aircraft and flight crew (See also Chapter 7.4);
- fax/telex: electronically and automatically received messages from all partners;
- ARR/DEP overview of all flights, additionally stand number, TOBT, ELDT, and ALDT can be obtained;
- real-time baggage tracking information;
- real-time passenger processing information;
- real-time ramp processes tracking information;
- cameras for aircraft status monitoring;
- sequence planning tool with TSAT from ATC;
- CFMU interface for CTOT, FUM, and DPIs; and
- specific passenger information.

HMIs at the Cockpit:

- ACARS: sending and receiving data to and from turn-round partners. Turn-round information requirements can be communicated via ACARS, two-way radio, or telephone.

HMIs at the Ramp:

- Sending and receiving data from and to the airline operation centre. HMIs used here have real time capabilities and attempt to increase situational awareness as well as the proactive capabilities of actors at the ramp or terminal building.

6.3.5 Factors Contributing to Monitoring Difficulty

The remote mode of turn-round management is a relatively new approach to turn-round control; the factors that contribute to monitoring difficulty are now discussed:

- *Number of turn-rounds:* the total number of turn-rounds assigned to an individual controller determines the time available for monitoring each single turn-round process. A great difference could be observed in the number of turn-rounds which were assigned simultaneously to an individual controller among the different airlines where turn-round monitoring was observed, varying between 3 and 15 turn-rounds. It is questioned whether sufficient attention can be maintained to each individual turn-round, if the number of turn-rounds monitored by *one* controller in parallel exceeds a specific value and workload, whereat the workload again depends on a number of issues that have require attention (See chapter 2.5).

- *Multiple parties with differing goals involved:* Multiple parties responsible for the various supporting turn-round processes during a single turn-round process with each party having its own resource constraints and inherent intentional goals. However, understanding individual actors' goals is necessary to establish a *global* goal among all participating actors and airport partners. It is also unlikely that in case of individual goal sets *different* from a global goal, actors will share their goals with others. Individual actors' goals can range from personal interests to achieving advantages for the own company. Therefore, in order to enable successful monitoring, it is necessary to identify the inherent goals and motivations of *all* participating operators and the constraints within the different domains during A-CDM. This information should then be used to identify and apply cooperation-building factors to day-to-day turn-round practices.
- *Reliability of information:* information provided by supporting actors is not always as available as required because of the different approaches and procedures towards information sharing established by the individual operators. Even when required, operational information from the action level is not necessarily available at the monitoring level due to the failure to establish standardised processes of information sharing, e.g. information about boarding status is not shared or actors forget to feed their data into the tools established for monitoring the flight/turn-round progress.
- *Incomplete process status data:* due to the complexity of the handling processes at some major airports, operators' resource constraints or companies' internal regulations, not all turn-round processes can be tracked automatically yet. As a consequence, required data for monitoring is not provided and turn-round controllers have to make decisions based on an incomplete picture of the situation.

- *Degree of automation support:* 'Self-procurement' of data e.g. via telephone or radio is not only time-consuming, there is high risk of missing key indicators or focusing on minor items, while critical data is hidden within turn-round complexities.
- *Cognitive demands:* cognitive workload of controllers depends on the level of automation, individual knowledge, and workload regulation activities. While cognitive capabilities vary among controllers, workload regulation activities are used very much by controllers and so determine turn-round success. If the workload is too high, the possibility for controllers to develop their own regulation strategies is reduced.
- *Feedback from actors*: controllers require feedback from actors and operators on the ramp or terminal building for monitoring, e.g. about execution of services or availability of resources. No standardised feedback processes could be observed because actors' individual goals do not necessarily correspond to the controllers' need for feedback.
- *Number of third-party providers:* an increasing number of participating service providers also increases monitoring complexity. This in turn imposes a challenge for the turn-round controller to identify the service provider or actor who is involved in an individual turn-round process. As a consequence, the controller is not always aware who provides the turn-round service. If he requires process related data, he may have to contact several companies in order to identify the assigned actors.
- *System complexity and reliability*: Airport size, technological level, and cultural diversities also contribute to system complexity and monitoring difficulties. Monitoring solutions have to be adapted to local needs.
- *Alarm system design:* some monitoring tools have an automatic pop-up alarm for e.g. delays of flights with proceeding crews on board or delayed ground handling start. However, in all observed cases, the timing of the alarm was too late in order to initiate a corrective action able for avoiding a delay. Again, cognitive workload adjustment is applied by controllers and so far the only solution available to solve such problems.

- *Display and control design*: The standard workplace of the turn-round controllers has five screens with functionalities selectable by controllers. The workplace also includes telephones with short dial-up options to all airport partners involved. However, controllers often have to switch between different scenarios or displays and a view of the overall turn-round process information showing all required data is not available.
- *Sharing of Responsibilities:* different actors have different levels of responsibilities for decision making. This information is not always shared with turn-round controller and therefore he has to contact multiple actors to identify the responsible function.
- *Delay Code assignment:* the turn-round controller assigns delay codes for the function that he considers to be responsible for the delay. However, this practice of delay code assignment challenges the whole ATM network philosophy of the A-CDM approach. Even though the turn-round controller often has to rely on information provided by third parties, this procedure is still seen as a punishment for operators' behaviours and fosters the perception of a blame culture among participating actors. This however is counter to the idea of creating a cooperation building culture with mutual trust among operators.

Some of the challenges in turn-round monitoring mentioned here could be overcome through process reengineering, cultural change or technological progress. As a next step in the research process, focus group discussions between turn-round controllers and other functions will be carried out to identify the potential for such alternative approaches towards turn-round management.

6.3.6 Cognitive Challenges for Turn-round Monitoring

A number of challenges for turn-round monitoring arise due to *cognitive* vulnerabilities while on-task. Examples include:

- Monitoring requires *visual sampling* and *selective attention*: this involves turn-round controllers being vulnerable to missing critical events or information because of breakdowns in the serial scanning process. When scanning turn-round processes, controllers face information overload, time constraints, and may not be able to detect unanticipated events at the time required.

- *Data exchange* between partners *across functions* has to be established throughout distributed locations and also via different modes. Data exchange between turn-round controllers and other actors takes place with external functions often having unknown goals and mindsets. Where competing interests are likely to exist, required communication, e.g. between turn-round controller and flight crews is not always pursued as needed and as a consequence, situational awareness cannot be created.
- During peak hours, *interactions* are initiated *from multiple sides*: telephone, supervisor, colleagues, incoming ACARS messages, or requests via radio. Prioritising and selective problem solving skills are required.
- *Insufficient data* from turn-round service providers or about the aircraft turn-round status are available *for a reliable TOBT decision making*, therefore TOBT has to be assigned without having real data on hand.
- Situational awareness depends on the *ability of the turn-round manager* to use the tools, data and displays given to create a mental strategy. Prior experience and long-term knowledge in turn-round management can greatly contribute to monitoring success. E.g. how to detect events requiring attention and now to find solutions for these events.
- *Information representation on displays* themselves can be the cause of a problem. Is it possible to extrapolate the information required to tackle turn-round problems from the screens or does essential data have to be acquired by initiating interferences with other actors?
- Some *systems* are available which *create alarms* in the form of displayed messages about, e.g. a process that has not started or crew arriving delayed from an inbound flight. Turn-round controllers often ignore these because the mental strategy for solving the problem is different from the solution proposed by the system logic. Moreover, the high amount of false alarms results in controllers tending to disregard them completely.

- *Data overload versus insufficient data*: a major reason for cognitive vulnerabilities reported by turn-round controllers includes the *composition* of provided data. The *large amount* of data available does not represent the information format required for operational decision making as well as *the way* it is made available entails the risk to overlook essential information which is hidden among other data. More importantly, decisions made by other airport partners or the results of such decisions are not automatically available. The reasons for non-data sharing could be cognitive factors, avoidance of blame, or other not yet identified hurdles having the effect that updates of controllers' situational awareness is not always possible as required.
- *Data filtering:* by using the large amount of data available, Remote Turn-round Management controllers have to create a visualisation of the turn-round without being able to inspect the situation with their own eyes. This poses a high risk of missing necessary signs indicating process delays that would be obvious during DTM.
- *Network data or status information* from ramp/terminal processes: data about the status of sub-processes from *all* participating actors during turn-round are not automatically shared, but this is required in order to create a situational awareness especially during the critical path of all sequential turn-round processes. Furthermore, data about participating actors is presented in various formats (e.g. visual, numerical, or interactive). Even through a single source format, visualisation has been proven to be the most effective way to create necessary situational awareness it is not yet available for turn-round management.
- *Proactive versus reactive monitoring*: A major challenge arises from the current practise of *reactive* turn-round controlling behaviour. Tools with predictive capabilities for the turn-round processes during critical path enable controllers to create a situational awareness via *proactive* monitoring of turn-round with determination of current state followed by predicting the trajectory of the future state of the turn-round. However, controllers today have to track turn-round in real-time, react to alarms created by the system, or respond to

interactions created by participating actors. Such monitoring only permits reacting to the problem occurring by following an official process – not assessing the future state of the turn-round. In contrast proactive monitoring would enable prediction and result in increased reliability for the network and passengers.

6.3.7 Strategies Used by Turn-round Controllers for Monitoring

Airline companies provide working strategies and modes for monitoring turn-round flows to the controllers. These strategies differ significantly among airlines observed. The turn-round controllers themselves again adopt their *own* strategies for monitoring the turn-round depending on the given working procedures, situations, knowledge, and tools available. However, it has never been demonstrated which strategy used by the airlines results in the most reliable turn-round processes needed to make TOBT prediction as accurate as possible. Flight crews argue in favour of the traditional mode of turn-round monitoring like the local mode turn-round monitoring, because new modes established are so far not able to replace the benefits that are available during local mode turn-round monitoring. The new remote turn-round monitoring was generally accepted, but many difficulties during turn-round are still attributed to the new mode of monitoring.

The major concepts used by turn-round controllers will now be described:

A. 'Situational Model' Driven Monitoring

One major finding witnessed in the observation was to see that regardless of the mode of turn-round control or the tools available, turn-round controllers were trying to build and maintain their *own* situational model which in turn directed their attention and set their expectations during monitoring activities. This situational model however, is greatly different depending on the mode of turn-round control. For example the turn-round controllers at the aircraft could already anticipate problems arising with de-boarding or loading and consequently initiated required actions proactively. Turn-round controllers at remote positions had to be updated about such situations by the ramp agents or the flight crews in order to establish the required situational awareness.

One key aspect of this observed behaviour is the difference between local turn-round management and remote turn-round management which emerges through the technologies and the cognitive driven approaches used. While during local turn-round management controllers use their eyes to observe events which may require predictive analysis of the situation, turn-round controllers at the operation centres have to rely on the information displayed on their monitors, the incoming calls from actors at the airport terminal or the ramp, and the cameras facing towards the aircraft parking positions. This induces that predictive behaviour required for turn-round control is not possible in the operation centre because of the missing information *visually* perceived by the ramp agent at the aircraft. Situational analysis is therefore only possible based on information received via human-human and human-computer interactions. This simple example shows that the task goals are the same in all modes of turn-round monitoring, but the *situational* manifestations between the of direct and remote monitoring locations shaped the *behavioural* manifestations of turn-round control between proactive at the ramp and reactionary at remote.

B. Rule- And Knowledge Driven Monitoring

It was observed during local mode of turn-round management that turn-round controllers usually engage in rule- and knowledge-driven monitoring of the processes at the ramp for estimation of the TOBT. Rather than merely reacting to stimuli from process failures, turn-round controllers seek out specific information of the current, but often - unfamiliar situation. Examples of this type of behaviour include:

- Already before the aircraft arrives at parking position, turn-round controller re-confirms availability of personnel and required equipment with participating actors.
- Not only normal turn-round processes were coordinated, but also special ground handling issues were prepared with confirmation calls to participating actors. If a problem arose during pre-arrival phase, a possible solution was already analysed to avoid failures during the critical chain.
- Problems forwarded from flight crews after landing were analysed directly after AOBT.

- Actual passenger numbers are used to make estimates of boarding/de-boarding times.

Therefore it is proposed to engage in further analysis about the possibility of also establishing proactive behaviour as it was observed during direct turn-round monitoring at remote operation centre.

It is hypothesized that reliable TOBT prediction also depends on the *number* of turn-rounds which the turn-round controller has to monitor simultaneously. Great differences exist among the observed airlines about the number of turn-rounds being monitored in parallel. In some cases, it was observed that turn-round controllers have to monitor up to 15 turn-rounds at the same time. It is argued that sufficient time is not on hand to proactively prepare each turn-round as observed during local mode turn-round monitoring – particularly if unanticipated events are encountered during the critical path of turn-round processes.

Nonetheless, advantages could also be observed during RTM stemming from tools and information sources available at the operation centre which allow turn-round controllers to use other forms of monitoring using activities they are able to apply or the information sources at the working position.

Turn-round controllers adopted strategies like:

- Proactive telephone calls: As the most frequently observed mode of communication turn-round controllers used the direct-dial functions on their telephones to check with actors at the ramp about the availability of personnel and equipment. Needless to say, the number of proactive calls very much depends on the number of turn-rounds being monitored at the same time. The difference observed in the number of turn-rounds being monitored simultaneously ranged from three and 15 turn-rounds. While during turn-round monitoring of only three turn-rounds at the same time, proactive behaviour was applied as prevailing turn-round strategy of the controllers, larger turn-round numbers allow only to *react* to requests from incoming calls of other actors or to focus on the discrepancies already known by the controller.
- Reducing MTTT: While some operators also use different acronyms for the TOBT, large differences could be observed during current practices of TOBT

assignment. It is in the interest of the airlines to reduce MTTT even further, if AIBT is delayed more than SOBT – MTTT, and as a consequence, a departure delay has to be faced. To prevent delays from becoming too long, turn-round controllers use two different strategies: either they reduce the MTTT by applying a special turn-round procedure (e.g. increase support via additional ground personnel), or they only reduce the MTTT by a certain margin without taking any other information or factors into account. During some observed cases, turn-round controllers used only the MTTT as a core reference for TOBT assignment; if TOBT deviations from original SOBT were greater than a predefined value, the new TOBT had to be approved by the airline dispatch or flight crews.

- Creating indicators or alarms: Quite a number of examples of turn-round controllers exploiting the flexibility and functionalities of the available tools and functions could be observed. For turn-round monitoring, most airline operators provide the controllers with five displays and different tools for flight, turn-round, or process monitoring. Turn-round controllers can choose display scenarios and tools depending on their own preferences. The strategies used here also depend on the knowledge level of controller and the ability to extract information as required.
- Difference in creating an overview of displayed information which turn-round controllers were using for day-to-day monitoring: While some controllers used their displays dedicated to individual turn-round events as a *detailed depiction* of all turn-round processes, others used a more *flight status oriented* tool where all monitored flights are visible at the same time on a time axis. The detailed turn-round depiction allows them to follow up each turn-round process in real-time, while the flight status oriented tool only depicts an overview of all monitored flights. This tool however requires additional information on the turn-round status to allow real-time monitoring of the critical turn-round chain.
- Setting Rules: The adopted strategies used also depend on the rules and policies defined by the individual airline. The most prominent example is the definition of the length of a MTTT: For the same type of aircraft, comparable

type of turn-round and size of airport, the MTTT during one Turn-round Process differed up to 20 minutes.

- Other rules set by the airlines include the amount of turn-rounds monitored in parallel. Here, large differences in turn-round numbers were observed because of the different policies among actors involved. In some cases, turn-round controllers are not permitted to contact the flight crew during turn-round, however during other observations the flight crews were contacted by phone up to thirty times.

- Creating external reminders for monitoring: to reduce the demand on their memory, turn-round controllers frequently create external reminders for monitoring. Several examples of this type of facilitating activity were observed, with differences existing between LTM and RTM. During LTM, controllers used e.g. turn-round cards or written notes to add process information related to the assigned flight. Remote Turn-round controllers however, use scratch pads and lists with all assigned turn-rounds. A common practice during monitoring is to take notes during incoming calls onto notepads. When monitoring turn-round, flight status, or incoming messages via data link, discrepancies arise or particular service requirements become necessary which have to be arranged. Some of them are not time critical and notes were written onto the turn-round lists. This strategy was particularly observed, when the notes taken were used to brief the next shift.

- Shifting turn-rounds: During peak hours, turn-round control does not allow leaving working position because observed work demand is very high. To allow breaks or to react to schedule changes due to weather, turn-round controllers can shift assigned turn-rounds to other controllers who have the capacity to handle additional turn-rounds.

- Employ additional turn-round controllers: some airlines observed have designated personnel available during peak hours allowing controllers to maintain the same amount of turn-rounds for monitoring - even during high traffic demand. These ‘spare’ controllers can either handle excess traffic or turn-rounds with high monitoring demand due to extra service requirements.

6.3.8 Organizing the Results in a Qualitative Cognitive Model

Given the high number of cognitive challenges identified during turn-round monitoring, the findings from airline control room observations were organized in a qualitative cognitive model that allowed making conclusions and giving recommendations. Therefore, a model was applied – analogous to that of Vicente et al (2004) who developed this model specifically for operators monitoring a nuclear power plant under normal operation. The qualitative cognitive model of monitoring can be generalized across other domains, because of the general types of activities and cognitive functions used when monitoring complex dynamic systems (Vicente et al 2004). Similarities of such systems include the vast number of interactions and the fact that time and pace of external events determine the mental workload. While failures during nuclear power plant monitoring may result in threats to public and environment, failures during turn-round monitoring has financial and inconvenience impact only.

The model (**Error! Reference source not found.**) includes four major elements: *initiating events, cognitive activities, facilitating activities*, and *monitoring activities*.

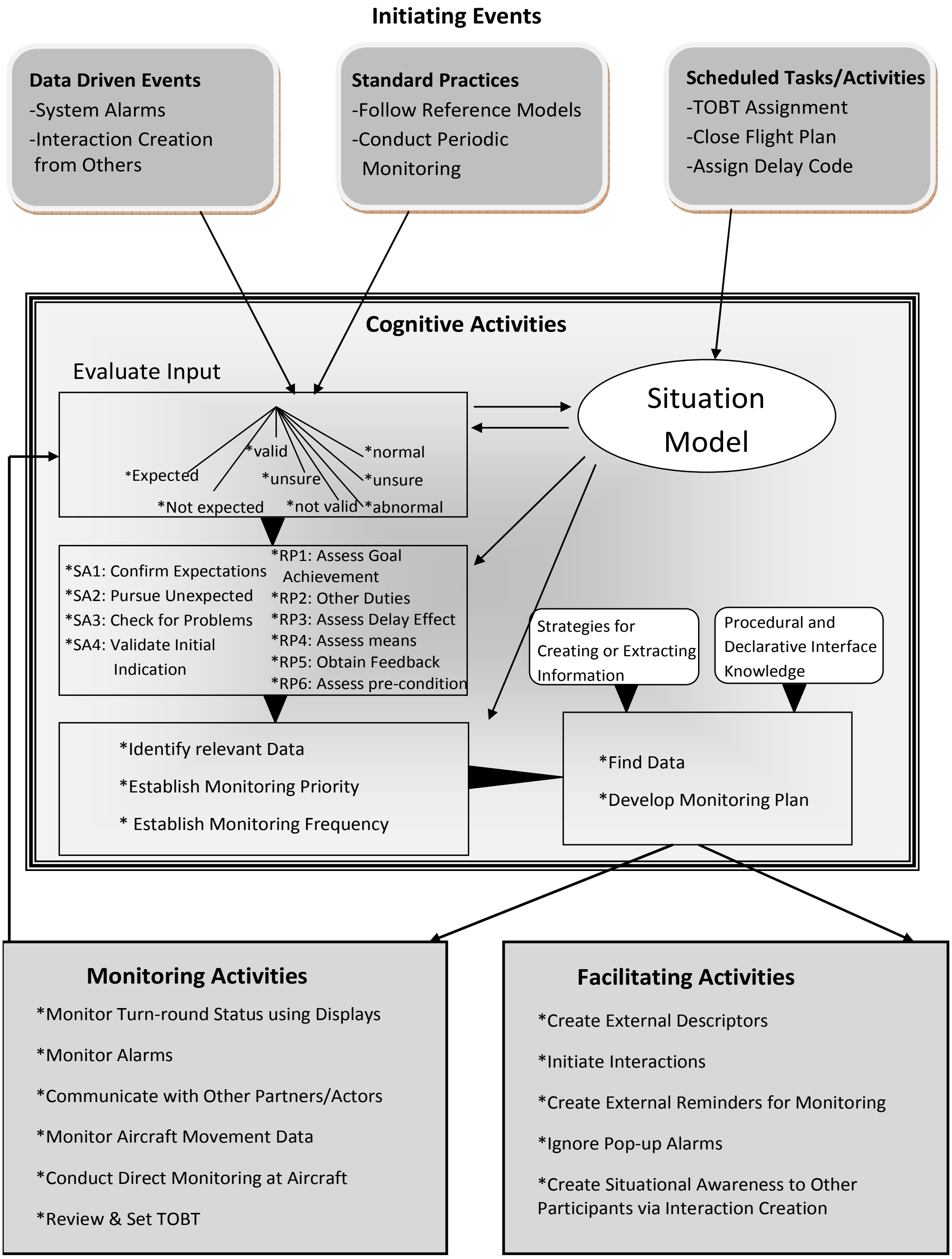


FIGURE 28: MONITORING MODEL ANALOGOUS TO VICENTE (SOURCE: VICENTE, 2004)

First, the events were identified which trigger to *initiate* monitoring. The model identifies three types of triggers that initiate monitoring:

- *Data-driven events:* not actively sought by operators, but rather prompted by changes in the environment, e.g. alarms by the system, interaction creation from system or other partners/ actors.
- *Standard controller practices, policies, or procedures:* events in this category are designed to ensure controllers' periodical and knowledge-driven working practices.
- *Scheduled tasks and activities:* have to be carried out during normal shifts, e.g. close the flights after monitoring is completed.

Most of the triggers result from periodical events, e.g. flight movement messages, but many triggers also relate to specific events, e.g. incoming calls from participating actors. Alarms automatically created through the monitoring system are not usually used as triggers for monitoring events, because the late provision of the alarm requires an action from turn-round controller already much earlier. Once monitoring is initiated, it may result in a specific path of actions and coordination with other airport partners or actors. Also, multiple initiating events may be in effect at the same time, requiring the controller to time-share several activities, especially during time-constrained turn-round situations.

The initiating events result in *cognitive activities* by the turn-round controllers. These are formed and influenced by *interactions* with control room interfaces/ other personnel, or *knowledge* which is held by the respective turn-round controller. The major element that drives cognitive activities however is the situational model developed by the controller as an incomplete mental representation integrating his/her current understanding of functional turn-round aspects, and the automated control system. Applying this situational model to turn-round monitoring, encompasses a number of general cognitive processes:

- Developing turn-round controller's knowledge of the turn-round's physical processes, their characteristics and interfaces;
- supports controller in developing a cause-and-effect relationship for analysing turn-round failures and participating actors' process delays;
- supports controller in integrating separately received or automatically created data to account for all data;

- supports controller in developing a turn-round description that captures a process state at a level higher than individual actor perception;
- it allows the controllers to create a mental simulation of the turn-round to anticipate future states of turn-rounds, or evaluate turn-round performance under various configurations.

According to Vicente (2004), training and experience allows operators to evolve their inherent mental model into a somewhat idealized design and a mirror on the actual operation. The situational model being used for monitoring can so be adjusted.

At a higher level of description, all controllers' cognitive activities can be split into Situation Assessment (SA) and Response Planning (RP). However, situation assessment refers to the process of 'constructing an explanation to account for observations' plus consequences and future system state, and studies show that operators actively develop a coherent understanding of the current state. This in turn emphasizes the need to provide reliable indications for situation assessment. Any failure to provide essential turn-round data from participating actors may stall the assessment process due to missing key indicators. During turn-round, controllers not only monitor, but often proactively retrieve information required for situation assessment via automated systems or interaction creation. However, the often constrained time available during turn-round does not allow controllers to get updates as needed. Different types of situation assessment (SA) were identified:

- *Confirm expectations about the flight/turn-round progress (SA1):* based on the given data, e.g. Flight Update Messages (FUMs) or movement messages, controllers develop expectations about actual in-block or off-block time. Based on these expectations, turn-round controllers develop strategies as a response to the actual situation. During this arrival phase of flight, monitoring the status of the flight serves either to maintain the current strategy or adapt it to the actual situation.

- *Pursue unexpected situations (SA2):* a controller often encounters situations that are not expected, but response is required, e.g. aircraft change, crew change. In these cases, the controller will actively direct monitoring to identify complementary data that might help him better respond to the unexpected situation.

- *Check for problems considered to be likely (SA3):* the controller is best placed to identify problems likely to arise during turn-round. The controller understands that certain processes create the potential for particular problems to be solved, e.g. coordination of sequential processes within the critical chain and needs to be vigilant. Therefore, monitoring is actively directed to indications that can reveal the occurrence of a likely problem.
- *Validate initial indications (SA4):* in general, control room and interface technologies are not perfectly reliable nor do they always provide an appropriate visualisation of the situation. Therefore, controllers often mistrust received information and have to validate it by creating interaction (e.g. phone, ACARS, radio).

After assessment of the actual turn-round situation, a response is usually required. This involves decision making on the necessary course of action. In general, response planning involves identifying goals, generating, evaluating, and selecting response plan that best meets the goals identified (Hoc, 2000). Since there are only a few formal written procedures that guide response, controllers use their *own* assessment of the situation and evaluate whether the actions they are taking can help to achieve their goals. This may include deviation from formal procedures. Five types of actions/monitoring were identified that support response planning (RP).

- *Assess goal achievement (RP1):* controllers' actions are taken in order to achieve their own or airline operators' goals. However, current procedures within A-CDM require weighing operators' interests against ATM network benefits. This becomes necessary since TOBT assigned by turn-round controller can only be updated three times after TSAT has been issued by air traffic control. Otherwise the flight being re-sequenced by air traffic control and departure time may be delayed. Therefore, the controller has to monitor the progress towards achieving the target off-block time and actively monitor indications that can support the assessment of this goal.

- *Other duties while on-task (RP2)*: turn-round control comprises variety of situations: while some turn-rounds require only little attention, others are time-constrained (e.g. if MTTT or even less is available due to arrival delays) and have a high monitoring demand. During these situations, controllers proactively initiate interactions with other airport partners or actors for duties like information forwarding, e.g. inform ramp agents about direct transfer of passengers, follow up late crew arrivals, or identify solutions to resource constraints. Coordination with others is usually required during these situations.
- *Assess potential delay effects of contemplated actions (RP3)*: a key activity of controllers is to ensure that their activities and those of other airport partners and actors do not produce a delay, or if unavoidable, to ensure that the delay remains as short as possible. While airlines have established reference models for standard turn-round flows, controllers are often faced with events resulting from uncontrollable variables in the environment or variables identified late. This requires adapting the reference turn-round flow to the actual situation with necessary assignment of IATA delay codes to actors causing the deviation from standard procedures.
- *Assess means for achieving goals (RP4)*: As a consequence of a turn-round process delay, the controller needs to consider that the process could fail and an alternative process would be required (e.g. aircraft change). Thus, active monitoring is needed to support the evaluation of resource availability. Due to the large number of actors and partners involved, this remains a difficult task.
- *Obtain feedback on actions (RP5)*: after completion of turn-round, controller needs to obtain feedback about how the processes were carried out (departure time or time required for alternate courses of actions). Feedback has usually to be actively sought -although in some cases, actors call.
- *Assess pre-condition for action (RP6):* for all sequential turn-round processes, a certain pre-condition is necessary for the next step of turn-round. This requires that the controller actively monitors status of turn-round and informs partners or actors if problems arise at one stage. Due to the high workload required

therefore, response planning RP6 at some operation centres only marginally takes place so far.

6.4 Concluding Aspects

This step of the research was aimed at focusing more closely into such problems of information sharing and applying focus on information that is beneficial for TOBT prediction and able to avoid a inaccuracy-swing-effect of delay duration as identified during the survey. Therefore, field observations were undertaken to study the emergence of such information deficiencies. The investigation should also identify the different modes of turn-round monitoring and how this monitoring affects TOBT prediction accuracy. Procedural differences between a traditional mode of turn-round management at the aircraft and the increasingly applied approach towards remote turn-round management in a control centre were identified. Moreover, different strategies of the turn-round controller for creating or extracting required information were observed.

Rasmussen's terminology was applied to classify the various strategies of how turn-round controllers monitor the turn-round and predict its outcome via TOBT assignment as it could be observed at various airline operators' turn-round operations. Differences between rule-, data-, and knowledge driven turn-round monitoring were found as well as their effect on TOBT predictability.

It was concluded that turn-round *management* is largely influenced by the *strategies of turn-round controllers* that they apply for coordinating turn-round processes and the *availability of resources* necessary for predicting the TOBT. Turn-round *strategies* are not only determined by individual controllers' knowledge-, rule-, or skill-based behaviour, but also by the *mode* of turn-round monitoring that airlines have established based on their requirements. Hereby, reference models are used to define the milestones of the turn-round and process times required for the overall CDM turn-round process.

Based on the results of a cockpit survey and the observations in various airline operators' control rooms, it is argued that available data for the controller are insufficient to make reliable TOBT predictions: missing inputs from participating actors, poor monitoring capabilities, and unavailability of predictive turn-round information results in TOBT estimates which allow only assessment of a TOBT rather than reliable TOBT decision making based on facts.

It was found that little attention is placed on supporting turn-round processes with the effect that critical path of turn-round events are not sufficiently monitored and necessary data required for updates to TOBT is not available when required. For the benefit of the network however, exact TOBT assignment should be done as early as possible with minimum updates required.

Finally, certain pieces of information available from participating actors like flight crews or ramp agents are not sufficiently taken into consideration for TOBT assignment - consequently making TOBT updates necessary.

6.5 Discussion

It is questionable whether the mutual trust required for the exchange of all information in order to make reliable TOBT predictions is possible with the current practice of *delay code handling*. Since the turn-round controller has to assign the delay via a code to the function, which *she*/*he* estimates as causing the delay, actors or operators involved at action level will not be keen on sharing data revealing their failures. This delay code assignment procedure is usually combined with bonus-mal practices where actors identified as being responsible for the delay have to expect financial penalties (Groppe et al., 2008). Therefore, problems with service delivery will not automatically be communicated to the turn-round controller with a negative effect on his ability to make reliable TOBT predictions (Tempelaar, 2009).

7 TOBT PREDICTION ACCURACY EXPERIMENTS

The A-CDM concept requires that operational information is shared between all participating partners in order to establish sufficient situational awareness for operational decision making. It has been shown earlier that as a part of this decision making the Target Off-block Time TOBT is an important trigger for all ATM decision makers and CFMU for the status of the flight.

This Chapter describes the experimental design and analysis of human-in-the-loop simulations where the TOBT assignments for turn-rounds were compared under different information sharing conditions. The experiments targeted turn-round operation situations under adverse conditions and were aimed at evaluating the influence of cooperative information sharing on TOBT prediction accuracy. During three simulated turn-round scenarios the participants were asked to monitor the progress of 15 aircraft in parallel and determine the Target-Off Block Time (TOBT) ten minutes prior to Estimated Aircraft In-block Time (EIBT) and five minutes after Actual In-block Time (AIBT). While for a number of turn-rounds the turn-round controllers received simulated information from flight crews or ramp agent *automatically* which was required for TOBT updates (cooperative information sharing); for other turn-rounds the turn-round controllers had to call an interlocutor representing the flight crew/ramp agent *by themselves* in order to get the required information for TOBT updates (non-cooperative information sharing).

7.1 Introduction

Throughout the course of daily operations, an airline is often faced with unexpected situations developing from adverse conditions like weather patterns or industrial actions that may result in substantial deviations in its planned operations. As a result, decisions often have to be made few hours before the actual schedule. These decisions can have significant impact on the overall operation of the airline for the rest of the day affecting all aspects of the airline’s operation, but most detrimental to the hub-and spoke schedules for basic resources such as aircraft, flight crews, and turn-round equipment.

As a consequence, turn-round controllers are constantly faced with operational problems that emerge from adverse conditions like flight cancellations or changing aircraft equipment. Turn-round times are so becoming increasingly constrained with aircraft arriving delayed from outstation. Often not even the minimum turn-round time is available for the turn-round.

Because each individual turn-round can have up to 35 supporting processes, early coordination of these turn-round processes with TOBT updates is required. Such updates need to be accurate enough to provide the ATM network and CFMU with reliable TOBT predictions. Therefore, all participating actors have to share their information because a single turn-round process failure that is not communicated can have dramatic impact on TOBT reliability and thus affect the entire network.

Failures to update the TOBT correctly can often be traced back to information that is not automatically available for TOBT decision making. Since such information is usually obtained by distributed actors like flight crews or ramp agents, a more standardised form of situational awareness has to be created that encourages cooperative information sharing by participating actors.

During three experimental conditions the influence of various information availabilities and information dispositional factors on TOBT prediction accuracy was analysed.

7.2 Aims, Objectives and Hypotheses of the Study

The over-arching objective of this research phase was derived from the previous phases. After describing the influences on TOBT accuracy, the aim is now to capture these influences and whether they can be measured or quantified in controlled laboratory scenarios. A number of variables were included that might be relevant for TOBT accuracy and which were assumed to have influence on TOBT. As a result of this study, a concept for the design and analysis of decision support functionalities for TOBT decisions should be produced. Such concept is so based on the results of a comparison between standardised and cooperative information sharing between turn-round controllers and distributed functions like flight crews or ramp agents via ACARS/HMI, with the currently used baseline data and functionalities available to the turn-round controller today. The experimental setting was designed to obtain quantitative measures of the influence of information that is cooperatively shared between turn-round controllers and flight crews/ramp agents on the TOBT assignments at two measurement points. Such a set-up should allow sharing information in a more standardised form that creates situational awareness and encourages information forwarding. Therefore, the focus applied for the turn-round laboratory scenarios was set to factors related to information disposition and information accuracy that have not been investigated before.

Hypothesis I: Information required for TOBT updates (independent variable) which is cooperatively shared between flight crews and turn-round controller before |EIBT - 10 Minutes| increases the accuracy of TOBT, i.e. reduces |TOBT - AOBT| (Dependent Variable).

Hypothesis II: Information required for TOBT updates (independent variable) which is cooperatively shared between flight crew, ramp agent and turn-round controller before |AIBT + 5 Minutes| increases the accuracy of TOBT, i.e. reduces |TOBT - AOBT| (Dependent Variable).

Constraints that were considered included:

- How does the level of workload influence the interactions that are created between turn-round controllers and flight crews/ramp agents?
- Can lack of trust between turn-round controller and flight crews/ramp agents resulting from past experience influence TOBT decision making?
- How does established working procedures of turn-round controllers influence TOBT decision making (See also Chapter 6)?

7.3 The Participants

The participants (N = 6) were recruited from the very small group of turn-round controllers with operational A-CDM experience at Lufthansa Hub Control Centre at Munich Airport. All turn-round controllers at Munich airport have been performing turn-round control for a minimum of three years. The age of the turn-round controllers ranged between 35 to 52 with 2 females and 4 males in each condition. Munich Airport is the first airport in Europe that has emerged as an operational CDM airport from prior trials, while other European airports either still have trial status only or handle only smaller amounts of traffic. Due to the local environment, Munich airport is a representative example of adverse weather conditions and therefore has experience with such operational restrictions. Participants are trained in handling more than 15 turn-rounds in parallel.

Problems realized with the selection of such participant group include:

- Established working procedures may interfere with new turn-round functionalities like the proposed experimental design.
- Inherent refusal to use or mistrust of new functionalities perceived as a threat to existing working practices.
- Inherent mistrust towards other participating actors like ramp agents or flight crews based on prior experience.

The method used was a within-participant experimental design that offered advantages like:

- Intra-operator comparisons increase statistical strength by eliminating between-subject variability.
- The rare existence of the participating group requires fewer subjects to be recruited.

7.4 Experimental Design

A. <u>Concept of the Experiments:</u>

The TOBT prediction accuracy experiments built on the design requirements as identified during the Cognitive Work Analysis. With the starting point Turn-round Control Centre, representing the A-CDM workspace today, a concept for an information sharing concept was created that provides a prototype of a cooperative environment. It should be able to deliver more accurate and earlier TOBT predictions and so avoid CTOTs being made, that cannot be used because the flight is not ready for dispatch (see Chapter 1.3). While the Turn-Round Control Mock-up (TRCM) provides decision support for TOBT decisions, the improvements for A-CDM as pursued by the experiments should result from the increased cooperation that emerges from the *way* of working together. This means that information that is available by stakeholders, is *proactively* shared with A-CDM decision makers compared to information that is shared via request or by accident only. As this is a significant change of cooperating during daily working practices, such approach might be able to change existing working practices via creation of an awareness where information is available or needed and can so used to improve decision making.

B. <u>The Turn-round Scenarios:</u>

The scenarios used for the experiment incorporated real flight data as recorded from actual operation at Munich airport. First, an extract was chosen from a daily flight schedule of Lufthansa CityLine flights where a peak was observed and all flights arrived delayed from outstation due to adverse weather condition (Table 10). During the consecutive turn-rounds of these flights, various events were encountered that resulted in additional delays of the following outbound flights. The delay causes of these turn-round events were then given to experts from other airports who were asked to estimate the delay duration of various turn-round events *independent* from the real time duration of the turn-round data from Munich in order to get mean values of the turn-round delay events that should be used for building the scenarios. The expert assessment was needed to avoid variations of the delay events that should be used for the experiments being too large or too small.

TABLE 10: DATA SET AS RECORDED FROM ACTUAL OPERATION (SOURCE: LUFTHANSA, 2009)

	FLIGHT	DEP	EIBT	ARR	A/C	REGT	STTT		FLIGHT	DES	EOBT
LH	5590	ZAG	11:30:00	MUC	AR8	DAVRF	00:35:00	LH	3744	BCN	12:05:00
LH	7200	GOT	11:35:00	MUC	CR9	DACKG	00:35:00	LH	3402	BEG	12:10:00
LH	4100	BRU	11:50:00	MUC	CR9	DACKE	00:35:00	LH	4364	MRS	12:25:00
LH	5432	BRE	11:50:00	MUC	CR7	DACPN	00:35:00	LH	3084	CPH	12:25:00
LH	4549	BIO	11:55:00	MUC	CR7	DACPO	00:35:00	LH	4700	AMS	12:30:00
LH	5610	FMO	11:55:00	MUC	CR2	DACJD	00:30:00	LH	3828	BSL	12:25:00
LH	4861	MAN	12:00:00	MUC	AR8	DAVRB	00:35:00	LH	3314	WAW	12:35:00
LH	4153	NCE	12:05:00	MUC	CR9	DACKA	00:35:00	LH	3334	KRK	12:40:00
LH	3313	WAW	12:05:00	MUC	AR8	DAVRK	00:35:00	LH	4250	CDG	12:40:00
LH	3083	CPH	12:10:00	MUC	CR7	DACPT	00:35:00	LH	4916	BHX	12:45:00
LH	3685	GVA	12:15:00	MUC	AR8	DAVRQ	00:35:00	LH	1072	DRS	12:50:00
LH	3333	KRK	12:15:00	MUC	AR8	DAVRL	00:35:00	LH	3558	TIA	12:50:00
LH	4345	BUD	12:20:00	MUC	CR2	DACJE	00:35:00	LH	5448	VIE	12:55:00
LH	7564	LHR	12:20:00	MUC	CR7	DACPA	00:35:00	LH	3698	DUS	12:55:00
LH	8342	BEG	12:20:00	MUC	AR8	DAVRE	00:35:00	LH	6678	BIO	12:55:00

As a next step, only the turn-round events with inherent delays were chosen that are highly likely to be known to the pilot or ramp agent before the flight arrives at the parking position. Therefore, the flight crew or ramp agents are able to estimate the amount of delay caused by this event that has to be reckoned with. The assumption was that if this information had been cooperatively shared with the turn-round controller either on flight crews' or ramp agents' initiative (cooperative information sharing), a more accurate TOBT prediction could have been made. All turn-round events chosen could be allocated to a specific IATA delay code event.

Table 11 shows measured operational delay data together with the delay range in minutes that actually occurred on from Lufthansa CityLine flights between March and September 2009. The event types were used for building the experimental scenarios. Thereby it was assumed that all these turn-round events were known to the *flight crew* and such knowledge could be used to cooperatively share it with the turn-round controller. Today however, the information about these events and the expected duration of delay is not shared in a standardised way. While some flight crews are using the ACARS or some ramp agents are using their mobile phone to update the turn-round controller about such turn-round events, other flight crews/ ramp agents do *not* forward this information.

TABLE 11: MEASURED OPERATIONAL DELAY DATA I (SOURCE: LUFTHANSA, 2009)

DELAY CODE	**9**	**15**	**15**	**32**
Δt in Minutes	**[3-15]**	**[3-29]**	**[3-29]**	**[3-45]**
EVENT TYPE	**ADD FUEL**	**ADD PAX**	**ADD DEBOARDING**	**ADD BULK**
Event No	**1**	**2**	**3**	**4**
Description	High Fuel Load	Heavy Carry on Luggage increases deboarding time/ Other related PAX	Additional WCH or UM have to be picked up	Cello or other cabin bulk
DELAY CODE	**15**	**41**	**18**	**15**
Δt in Minutes	**[3-29]**	**[2-70]**	**[4-15]**	**[3-29]**
EVENT TYPE	**ADD BOARDING**	**ADD TEC**	**ADD LOAD**	**ADD DEPU**
Event No	**5**	**6**	**7**	**8**
Description	Pre-boarding of WCH, UM	Technical Repair	Large Amount of DAA Baggage	DEPU on Board

Keys	
Delay Code	Number according to IATA Delay Coding
Δt in Minutes	Delay range in minutes from CLH flights between March and September 2009
CLH	Lufthansa CityLine
Event Type	Nature of the delay
ADD	Indicates that the problem was additional to normal
UPDD	Deviation from MTTT due to Updates from Ramp
PAX	Passenger
WCH	Wheel Chair
UM	Unaccompanied Minor
TEC	Technical Issues
DAA	Delivery at Aircraft
DEPU	Deported Passenger

Table 12 shows measured operational delay data together with the delay range in minutes that also occurred on these flights with events that were assumed to be known to the *ramp agent*. These event types were additionally used for building the experimental scenarios and could be used for cooperative information sharing initiated by the ramp agent:

TABLE 12: MEASURED OPERATIONAL DELAY DATA II (SOURCE: LUFTHANSA, 2009)

DELAY CODE	**39**	**35,36,37**	**32**	**33,34**
Δt in Minutes	**[5-34]**	**[3-41]**	**[3-45]**	**[3-21]**
EVENT TYPE	**UPDD TEC**	**UPDD SERVICES**	**UPDD LOAD**	**UPDD PERSONNEL**
Event No	**10**	**11**	**12**	**13**
Description	Ground Crew updates about changes of unavailable services (Parking, Air Starter, Bridge…)	Service needs longer/shorter than expected	Loading takes longer/shorter than scheduled	Missing personnel results in delayed turn-round services

Thereafter, the turn-round events were distributed within the turn-rounds of table 10 and used for the different experimental scenarios.

B. The Independent Variables: Different Information Sharing Conditions

Three different information sharing conditions C0, C1, and C2, used as independent variables were embedded within three experimental scenarios A, B, and C. In this way, different information was available to the turn-round controller during each monitored turn-round:

- **Condition C0** or *Baseline Information* as the way of information sharing today:

  During condition 0 turn-round scenarios, the turn-round controller was able to use information required for TOBT updates which was provided via incoming telephone calls and/or by making self-initiated telephone calls with the ramp agent or flight crew in order to get the required information.
- **Condition C I** included *Cooperative Information from Flight crew* shared with the Turn-round Controller via ACARS:

  During condition C I turn-round scenarios, the effect on TOBT prediction accuracy was identified which resulted from flight crew-induced information sharing between aircrews and turn-round controller before the first TOBT assignment. The turn-round controller was therefore additionally provided with information from cockpit via simulated ACARS messages containing information required for TOBT updates.
- **Condition C II** included Cooperative Information from flight crew *and* ramp agent shared with the turn-round controller via ACARS and HMI:

  During condition C II turn-round scenarios, the effect on TOBT prediction accuracy was identified which resulted from flight crew and ramp agent induced information sharing between aircrews/ramp agent and turn-round controller before second TOBT assignment. The turn-round controller was therefore provided with information from cockpit via simulated ACARS messages and information from ramp agent via simulated HMI messages containing information required for TOBT updates.

C. The Experimental Scenarios A, B and C:

The sample group included six turn-round controllers that participated in all three experimental scenarios A, B, and C. Each setting included 15 turn-rounds with different information sharing conditions (15 turn-rounds represent one experimental scenario A, B, or C). All scenarios included a similar amount of such information inputs that had an effect on the duration of the turn-round (5- 6 inputs per turn-round).All scenarios included also a similar amount of information that did not have an effect on the duration of the turn-round (1-2 inputs per turn-round). Randomisation between scenarios was done with a Latin-square design.Additionally, each of the experimental scenarios included 100 incoming pre-recorded telephone calls from participating actors like flight crews, ramp agents, or airport.

A one-factorial design type of experiment with three information conditions as independent variables and TOBT prediction accuracy as dependent variable (Two dependent variables as timely scheduled TOBT predictions).

The three information sharing conditions (C0/CI/CII) were embedded in the three experimental scenarios (A/B/C) with sharing the conditions between the turn-round scenarios as equally distributed as possible. Thereby, the experimental scenarios A/B/C had a similar structure. A total of 15 different turn-rounds based on the conditions C0, CI, and CII were used from actual recorded operations of the Lufthansa CityLine flights. They were randomly distributed within the experimental scenarios A, B, and C in order to minimise the order effect.

A total of 15 turn-round delay sets were built from Table 11 and Table 12, each represented by a number. The delay sets were randomly distributed within the turn-rounds in order to minimize the order effect.

The following tables (Table 13- 15) show detailed information about the experimental scenarios A, B, and C:

While the first column shows the turn-round number and the second number (in brackets) indicates the turn-round delay event number that was used for the turn-round, the second column shows the different information sharing conditions that were used in the turn-round.

The third column has the flight number that was not changed during the different experimental scenarios and the last three columns show the information that is available to the flight crew or ramp agent. If the cell is highlighted in yellow, this information was cooperatively shared between flight crew and turn-round controller, respectively between flight crew, ramp agent and turn-round controller. The white cells indicate that only baseline information was available to the turn-round controller and represents the information sharing as it is established today.

The content of these cells gives the cause of delay analogous the measured operational data in Tables 11 and 12. The time indicates the duration of the average delay in minutes that has been validated by the SMEs from other airports, independent from the measured operational data.

The cells highlighted in yellow indicate cooperative information sharing conditions (C1/C2), while the white cells indicate that only baseline information (C0) was available to the turn-round controller:

TABLE 13: TURN-ROUND EXPERIMENTAL SCENARIO A: DELAY EVENTS

TR/ SET	CONDT.	INBOUND FLIGHT	INFORMATION AVAILABLE FROM FLIGHT CREW (ACARS)			OUTBOUND FLIGHT	INFORMATION AVAILABLE FROM RAMP AGENT (HMI)		
1 (14)	C2	LH 5590 ZAG	UM De-boarding +4 Minutes	Musical Instrument	DAA De-loading	LH 3744 BCN	Late Fuelling +3 Minutes	WCH De-boarding	Late Loading Personnel
2 (10)	C2	LH 7200 GOT	Crew Change +5 Minutes	Carry-on Lug +3 Minutes	Cabin Baggage +3 Minutes	LH 3402 BEG	Security +1 Minutes	WCH Pick up Delay	React. Fuelling +7 Minutes
3	C0	LH 4100 BRU	De-boarding WCH	High Fuelling +3 (No ADD)	Tec (Oven) +12 Minutes	LH 4364 MRS	De-boarding delay	Amount Luggage	Spec. Cleaning +5 Minutes
4 (2)	C2	LH 5432 BRE	De-boarding WCH	De-loading +4 Minutes	---	LH 3084 CPH	Loading Personnel	Heavy Luggage +3 Minutes	Air Starter Delay
5	C0	LH 4549 BIO	De-boarding +5 (NO ADD)	Tec (TIRE) +49	------	LH 4700 AMS	Reactionary Ramp Agent	De-boarding +3 (NO ADD)	Loading +2 (NO ADD)
6 (4)	C1	LH 5610 FMO	Flight crew Request	De-boarding WCH	-----	LH 3828 BSL	Cleaning Delay +1 Minutes	Conveyor INOP +26 Minutes	Late Loading Personnel
7 (13)	C1	LH 4861 MAN	DAA De-loading +5 Minutes	De-boarding WCH	Musical Instrument	LH 3314 WAW	Late WCH Pickup	Late Crew +6 Minutes	No Loading Person
8	C0	LH 4153 NCE	Crew Change +5 Minutes	DAA De-Loading +4 Minutes	De- De-boarding	LH 3334 KRK	No Loading Personnel	No Pick up for DEPU	No Push-Back +2 Minutes
9	C0	LH 3313 WAW	Extra Fuelling +3 (NO ADD)	De-boarding +5 (NO ADD)	Tec (NAV) +12 Minutes	LH 4250 CDG	Late Fuelling +5 (NO ADD)	De-boarding WCH	Late Loading Personnel
10 (7)	C2	LH 3083 CPH	De-boarding UM +2 Minutes	Musical Instrument	DAA De-loading	LH 4916 BHX	Loading Time +2 Minutes	Late Catering +9 Minutes	No Cleaning Personnel
11	C0	LH 3685 GVA	De-boarding WCH	Tec (COMP.) +39 Minutes	-----	LH 1072 DRS	Late Technician +7 Minutes	Tec Repair +3 Minutes	React PAX Bus +2 Minutes
12 (6)	C1	LH 3333 KRK	Cabin Luggage +5 Minutes	De-boarding DEPU	Refuelling +3 Minutes	LH 3558 TIA	Late Crew +23 Minutes	Fuelling Block +2 (NO ADD)	WCH Pick-up Delay
13 (12)	C2	LH 4345 BUD	Carry-on Baggage +3 Minutes	De-boarding DEPU	Refuelling +3 Minutes	LH 5448 VIE	No Air Starter +23 Minutes	Crew Change +2 Minutes	Reaction Push B
14 (1)	C1	LH 7564 LHR	De-boarding WCH	Tec. (TIRE) +38 Minutes	----	LH 3698 DUS	No Loading Personnel	No DEPU Pick up	No Push back +2 Minutes
15 (15)	C2	LH 8342 BEG	Carry On Luggage +3 Minutes	De-boarding DEPU	Refuelling +3 Minutes	LH 6678 BIO	Late Cleaning +4 Minutes	Conveyor INOP +6 Minutes	No Loading Person

TABLE 14: TURN-ROUND EXPERIMENTAL SCENARIO B: DELAY EVENTS

TR/ SET	CONDT.	INBOUND FLIGHT	INFORMATION AVAILABLE FROM FLIGHT CREW (ACARS)			OUBOUND FLIGHT	INFORMATION AVAILABLE FROM RAMP AGENT (HMI)		
1	C0	LH 5590 ZAG	De-boarding WCH +6 (NO ADD)	Tec. (TIRE) +38 Minutes	----	LH 3744 BCN	No Loading P +4 Minutes	No DEPU BGS +3 Minutes	No Push back +2 Minutes
2	C0	LH 7200 GOT	De-boarding WCH +7 Minutes	De-loading +4 Minutes	---	LH 3402 BEG	Loading Personnel	Heavy Luggage +3 Minutes	Air Starter Delay +2 Minutes
3 (11)	C1	LH 4100 BRU	De-boarding WCH +12 (NO ADD)	Tec (COMP.) +39 Minutes	-----	LH 4364 MRS	Late Technician +7 Minutes	Tec Repair +3 Minutes	React PAX Bus +2 Minutes
4 (9)	C1	LH 5432 BRE	Extra Fuelling +3 (NO ADD)	De-boarding +5 (NO ADD)	Tec (NAV) +12 Minutes	LH 3084 CPH	Late Fuelling +5 (NO ADD)	De-boarding WCH	Late Load Personnel
5 (3)	C2	LH 4549 BIO	De-boarding WCH +5 Minutes	High Fuelling +3 (No ADD)	Tec (Oven) +12 Minutes	LH 4700 AMS	De-boarding delay	Amount Luggage	Spec. Cleaning +5 Minutes
6	C0	LH 5610 FMO	Cabin Luggage +5 Minutes	De-boarding DEPU	Refuelling +3 Minutes	LH 3828 BSL	Late Crew +23 Minutes	Fuelling Block +2 (NO ADD)	WCH Pick-up Delay
7 (7)	C1	LH 4861 MAN	De-boarding UM +2 Minutes	Musical Instrument	DAA De-loading +4 Minutes	LH 3314 WAW	Loading Time +2 Minutes	No Flight Documents	No Cleaning Personnel
8 (10)	C1	LH 4153 NCE	Crew Change +5 Minutes	Carry-on Lug +3 Minutes	Cabin Bag +3 Minutes	LH 3334 KRK	Security Check +1 Minutes	WCH Pick up Delay	React. Fuelling +7 Minutes
9 (4)	C2	LH 3313 WAW	Flight crew Request	De-boarding WCH	-----	LH 4250 CDG	Cleaning Del +1 Minutes	Conveyor INOP +26 Minutes	Late Loading Personnel
10 (5)	C1	LH 3083 CPH	De-boarding +5 (NO ADD)	Tec (TIRE) +49 Minutes	------	LH 4916 BHX	Reactionary Ramp Agent	De-boarding +3 (NO ADD)	Loading +2 (NO ADD)
11 (13)	C2	LH 3685 GVA	DAA De-loading +5 Minutes	De-boarding WCH	Musical Instrument	LH 1072 DRS	Late WCH Pick-up	Late Crew +6 Minutes	No Loading Personnel
12	C0	LH 3333 KRK	Carry on +3 Minutes	De-boarding DEPU	Refuelling +3 Minutes	LH 3558 TIA	No Air Starter +23 Minutes	Reactionary Ramp Agent	Reaction Push B +5 Minutes
13 (8)	C1	LH 4345 BUD	Crew Change +5 Minutes	DAA De-Loading	De-boarding DEPU	LH 5448 VIE	No Load. Person	No BGS DEPU +3 Minutes	No Push-Back +2 Minutes
14	C0	LH 7564 LHR	UM De-boarding +4 Minutes	Musical Instrument	DAA De-loading +4 Minutes	LH 3698 DUS	Late Fuelling +3 Minutes	WCH De-boarding	Late Loading Personnel
15	C0	LH 8342 BEG	Carry On Luggage +3 Minutes	De-boarding DEPU	Refuelling +3 Minutes	LH 6678 BIO	Late Cleaning +4 Minutes	Conveyor INOP +6 Minutes	No Loading Person

TABLE 15: TURN-ROUND EXPERIMENTAL SCENARIO C: DELAY EVENTS

TR/ SET	CONDT.	INBOUND FLIGHT	INFORMATION AVAILABLE FROM FLIGHT CREW (ACARS)			OUBOUND FLIGHT	INFORMATION AVAILABLE FROM RAMP AGENT (HMI)		
1 (15)	C1	LH 5590 ZAG	Heavy Carry On Luggage	De boarding of DEPU	Refuelling +3 Minutes	LH 3744 BCN	Late Cleaning +4 Minutes	Conveyor INOP +6 Minutes	No Loading Person +3 Minutes
2 (3)	C1	LH 7200 GOT	De-boarding WCH +5 Minutes	High Fuelling +3 (No ADD)	Tec (Oven) +12 Minutes	LH 3402 BEG	De-boarding delay	Amount Loading	Spec. Cleaning +5 Minutes
3 (8)	C2	LH 4100 BRU	Crew Change +5 Minutes	DAA De-Loading	De-boarding DEPU	LH 4364 MRS	No Load. Person	No Pick up for DEPU	No Push-Back +2 Minutes
4	C0	LH 5432 BRE	Flight crew Request	De-boarding WCH	-----	LH 3084 CPH	Cleaning Del +1 Minutes	Conveyor INOP +26 Minutes	Late Loading Personnel
5 (12)	C1	LH 4549 BIO	Carry on +3 Minutes	De-boarding DEPU	Refuelling +3 Minutes	LH 4700 AMS	No Air Starter +23 Minutes	Crew Change +2 Minutes	Reaction Push B +5 Minutes
6 (5)	C2	LH 5610 FMO	De-boarding +5 (NO ADD)	Tec (TIRE) +49	------	LH 3828 BSL	Reactionary Ramp Agent	De-boarding +3 (NO ADD)	Loading +2 (NO ADD)
7	C0	LH 4861 MAN	De-boarding UM +2 Minutes	Musical Instrument	DAA De-loading +4 Minutes	LH 3314 WAW	Loading Time +2 Minutes	No Catering +9 Minutes	No Cleaning Personnel
8 (11)	C2	LH 4153 NCE	De-boarding WCH +12 (NO ADD)	Tec (COMP.) +39 Minutes	-----	LH 3334 KRK	Late Technician +7 Minutes	Tec Repair +3 Minutes	React PAX Bus +2 Minutes
9 (2)	C1	LH 3313 WAW	De-boarding (WCH)	De-loading +4 Minutes	---	LH 4250 CDG	Loading Personnel	Heavy Luggage +3 Minutes	Air Starter Delay +2 Minutes
10	C0	LH 3083 CPH	Crew Change +5 Minutes	Carry-on Lug +3 Minutes	Cabin Bag +3 Minutes	LH 4916 BHX	Security Check +1 Minutes	WCH Pick up Delay	React. Fuelling +7 Minutes
11 (6)	C2	LH 3685 GVA	Cabin Luggage +5 Minutes	De-boarding DEPU	Refuelling +3 Minutes	LH 1072 DRS	Late Crew +23 Minutes	Fuelling Block +2 (NO ADD)	WCH Pick-up Delay +5 (NO ADD)
12 (9)	C2	LH 3333 KRK	Extra Fuelling +3 (NO ADD)	De-boarding +5 (NO ADD)	Technical (NAV)	LH 3558 TIA	Late Fuelling +5 (NO ADD)	De boarding WCH	Late Load Personnel +2 Minutes
13	C0	LH 4345 BUD	DAA De-Loading +5 Minutes	De-boarding WCH	Musical Instrument	LH 5448 VIE	Late WCH Pick up	Late Crew +6 Minutes	No Loading Personnel
14 (1)	C2	LH 7564 LHR	De-boarding WCH +6 (NO ADD)	Tec. (TIRE) +38 Minutes	----	LH 3698 DUS	No Loading P +4 Minutes	No DEPU BGS +3 Minutes	No Push back +2 Minutes
15 (14)	C1	LH 8342 BEG	UM De-boarding +4 Minutes	Musical Instrument	DAA De-loading +4 Minutes	LH 6678 BIO	Late Fuelling +3 Minutes	WCH De boarding	Late Loading Personnel

D. Experimental Setting Overview

Experimental Design: Figure 29 illustrates the factorial structure of the experiments. Aircraft pilots were participating as interlocutors for the turn-round controllers and were placed in a separate room. They were advised to take either the role of the flight crew or ramp agent, depending on the kind of contact that the turn-round controller requested from the interlocutor.

Counterbalancing: Figure 29 also illustrates how the experimental scenarios were counterbalanced. A Latin-square design was used to control this effect as well as a switch between the different conditions throughout the experiments. The design was counterbalanced for 3 pairs of scenarios with a total of 18 pairs of scenarios.

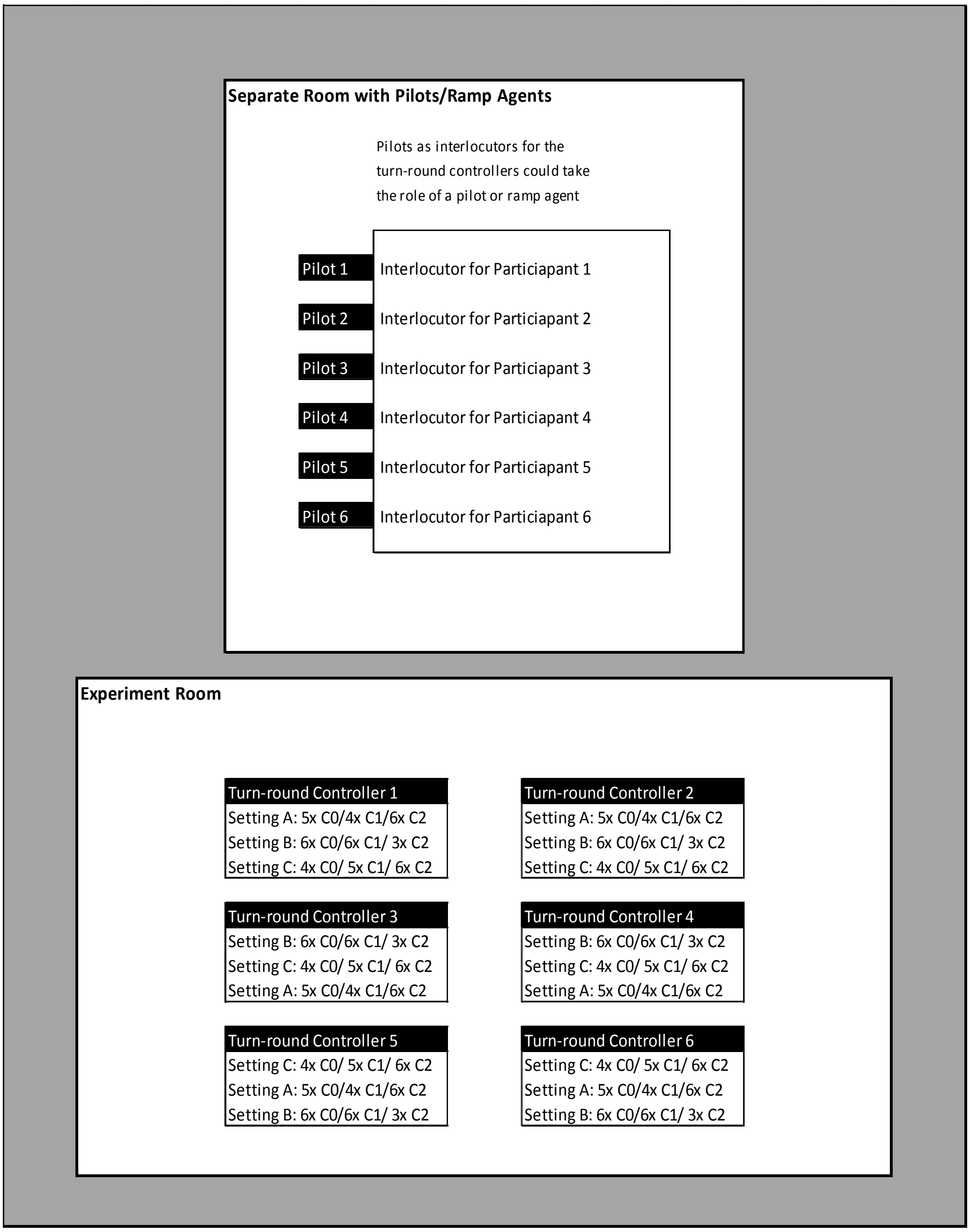


FIGURE 29: FACTORIAL STRUCTURE AND LATIN SQUARE DESIGN

E. Measurement Points

Measurement Point I:

As part of the underlying aim of getting earlier and more accurate TOBT predictions, the first measurement point was recorded at a time representing Milestone 5 of the A-CDM information-sharing concept. This point represents the inbound aircraft at the final approach and TOBT predictions are currently only available via automated calculation of the remaining flight time plus EXIT and MTTT. On average, this milestone is ten minutes prior to AOBT and time deviations between Milestone 5 and Milestone 7 (AIBT) are relatively infrequent. This does not apply at airports with parallel runways because waiting times may have to be expected on the second runway due to arriving aircraft. However, for the experiments, an adherence to the predefined variable taxi time was assumed. Therefore, Milestone 5 is proposed as a first predictable TOBT to be assigned by the turn-round controller and also used as the first measurement point during the experiments.

Measurement Point II:

The second measurement point was also determined using the underlying assumption that the majority of unpredictable events during turn-round can be captured by the ramp agent during the phase between AIBT and five minutes after AIBT. This presumes that all turn-round service providers cooperatively share updates to their estimated service delivery time with the turn-round controller between Milestone 5 and Milestone 8. Upon arrival of the flight at the parking position, the ramp agent captures the remaining irregularities and forwards these to the turn-round controller. During the experiments, this procedure was simulated via a HMI message sent by the ramp agent. The second measurement point for TOBT updates was therefore chosen at AIBT plus five minutes.

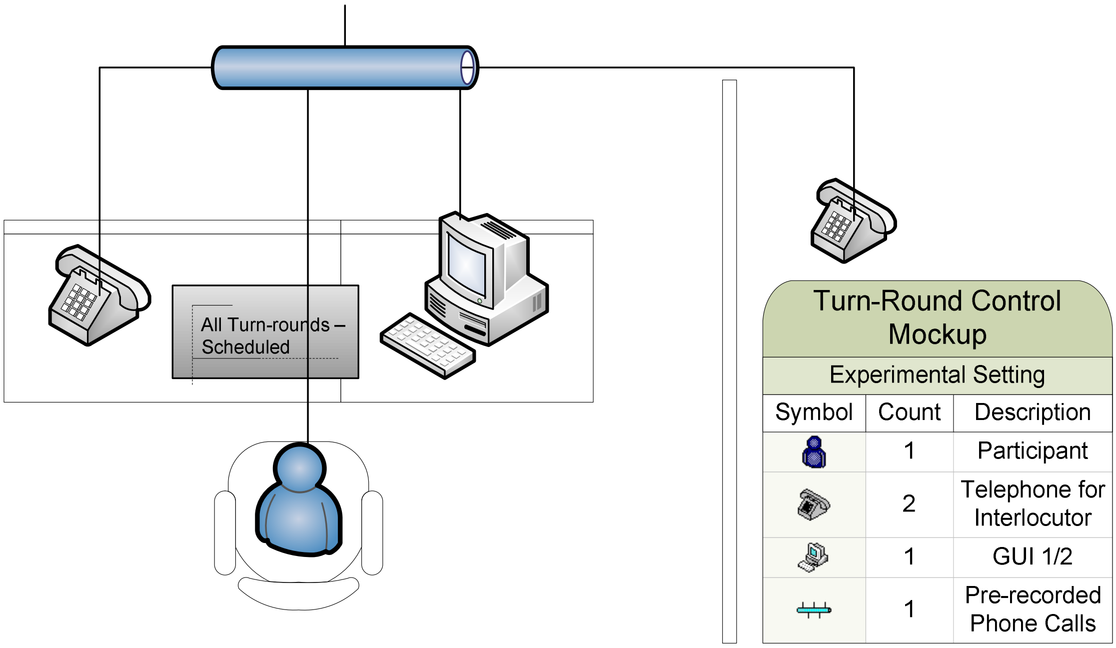
At both Measurement Points, the turn-round controllers had to insert their predicted TOBT into a spread sheet. These TOBTs had to be determined by (1) using their prior experience with turn-round control, (2) the possible support from the proposed TOBT of the TRCM and (3) the information received via telephone. It would have been possible that the turn-round controller uses only the TOBTs that are proposed by the TRCM, because GUI II and TOBT on GUI I were automatically updated with information inserted by the controller. In this case the results of the experiments would have been compromised by the fact that in one condition the controller accepts a machine-generated proposal that would have been available to him, hence the experiments would have reproduced the accuracy of the machine generated predictions. However, it has been shown that in only in 12% of all turn-rounds the turn-round controller inserted exactly the time [-1; +1 minute] as proposed by the TRCM.

7.5 Experimental Apparatus

A. The Turn-round Control Work Station and the Turn-round Control Mock-up TRCM:

The experimental apparatus as well as the simulation software were specifically developed for these experiments. The aim thereby was to reduce the functionality of the turn-round control system that is used during day-to-day operation as far as possible down to the basic functions that are required to allow a control of the variables relevant for the study. The equipment provided included:

- A Turn-round Control Mock-up TRCM as a basic functional station of the turn-rounds' controllers working position having two dynamical Graphical User Interfaces (GUI). The first GUI showed all flights represented by rectangular symbols during the period of an experimental setting. The flights were moving horizontally from the inbound phase of the flight until reaching the turn-round phase and the outbound phase of the flight. The simulation started 15 minutes prior to Estimated In-block Time EIBT and lasted until the last flight reaches its' outbound phase (AIBT + 10 minutes). The second GUI could be accessed by clicking on each flight symbol, showing the critical path of turn-round events of the flight together with the related turn-round process times and process completion times including the turn-round completion time in form of a TOBT. Only one screen was available to display both GUIs. Turn-round updates to each of the turn-round processes could be inserted into a defined column resulting in an automated calculation of a TOBT update.
- A telephone with short-dial function to reach the interlocutor.
- A headset for receiving the incoming pre-recorded telephone calls.
- A spreadsheet with the turn-round experimental setting having two columns to insert the TOBT updates at the pre-defined times (EIBT – 10 minutes; AIBT + 5 Minutes).



Turn-Round Control Mockup

Experimental Setting

Symbol	Count	Description
👤	1	Participant
☎	2	Telephone for Interlocutor
🖥	1	GUI 1/2
╪	1	Pre-recorded Phone Calls

FIGURE 30: THE EXPERIMENTAL TURN-ROUND CONTROL MOCK-UP

B. Requirements for the Simulation Software:

The software used was also specially developed for the experiments, because the following conditions should be met:

- The experimental environment should be comprehensible for an experienced turn-round controller.
- It should not duplicate turn-round controllers working environment exactly, but have the functionalities required for analysing the variables of concern. Therefore, the environment should not be too realistic in order to alleviate turn-round controllers' resistance to something they perceive as competing with their current working environment.
- The experimental environment should allow for making TOBT predictions based on available data.

Since no other system exists that provides these requirements, a Turn-round Control Mock-up (TRCM) was specially developed for this purpose with a set of design criteria for the software.

C. Development of a Software Application for the Turn-round Control Mock-up:

Before the experiments, a project was initiated aimed at developing a software tool that is able to support the experimental TRCM with TOBT predictions based on information or data provided to the system. BeOne Hamburg GmbH, a company with more than ten years experience in airport management and process design was asked to develop the required software application for the TRCM. The required specifications were outlined as follows:

Software Specifications:

- The software consists of two GUIs.
- The first GUI application looks like the picture just below (Figure 31).

FIGURE 31: GUI I SPECIFICATION FOR THE TRCM

Depicted aircraft can be divided in four different categories:

- approaching aircraft *(orange);*
- delayed aircraft during approach or turn-round *(flashing red);*
- aircraft during turn-round process *(mint); and*

- departed aircraft *(blue).*

Any aircraft encountering a EIBT deviation greater or equal 3 minutes starts flashing. The turn-round controller can confirm flashing aircraft by mouse click; thereafter the flashing stops.The maximum number of aircraft that can be depicted is 15. Aircraft are depicted as moving bars with following information directly available:

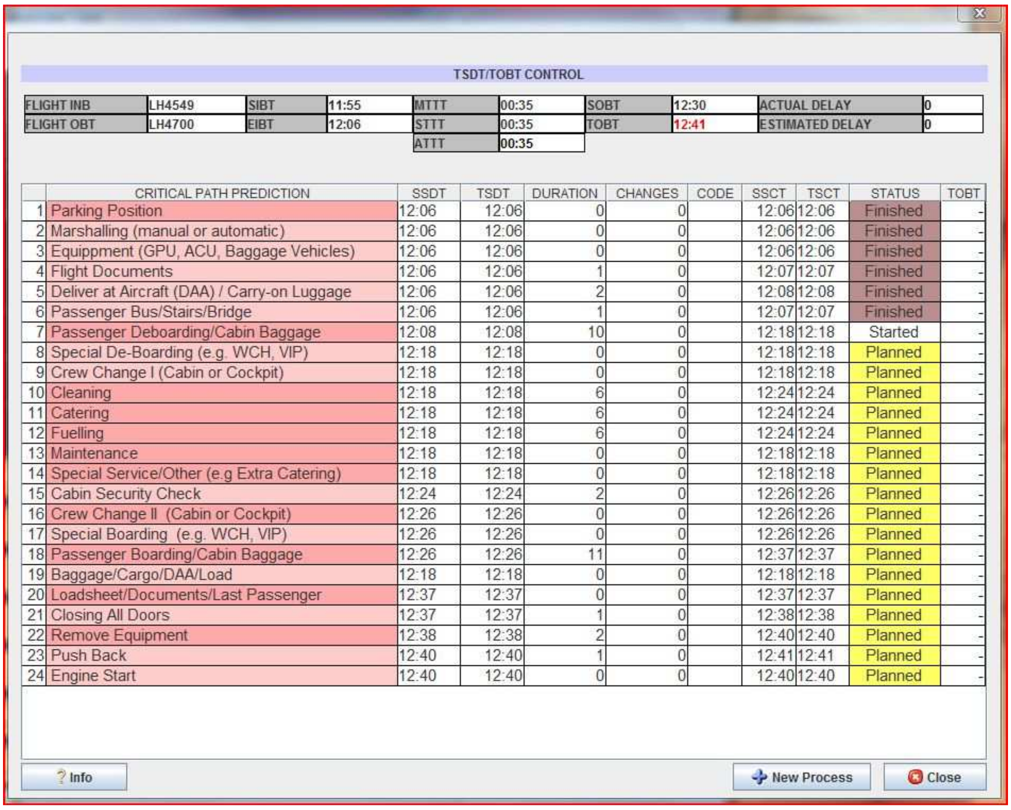
- flight number;
- departure and arrival airports according to IATA codes;
- SIBT (Scheduled In-block time);
- MTTT (Minimum Turn-round Time).
- TOBT (Target Off-Block Time); and
- EIBT (Estimated In-Block Time).

Arriving aircraft automatically appear on the screen approximately 15 minutes before EIBT according to the flight plan or actual flight status. When the aircraft has completed the turn-round, the turn-round controller can shade the aircraft after sending a movement message.

The TOBT is calculated automatically using MTTT, but can be updated at any time by inserting relevant values into GUI 2. The middle line (the thick red dashed line in Figure 31) describes the time of the beginning of the turnaround process and is named AIBT (Actual In-Block Time).

To support the experiments, two time stamps were defined and depicted in the GUI application: EIBT-10; AIBT; AIBT +5. The left line (left red line in Figure 31) describes the time stamp used as Measurement Point I (MP I) 10 minutes before the beginning of the turnaround process and is labelled EIBT -10 (Estimated In-block Time -10). The right line (right red line in Figure 31) describes the time stamp used as Measurement Point II (MP II) 5 minutes after the beginning of the turnaround process and is labelled AIBT +5 Min (Actual In-block Time + 5 Minutes). Each aircraft are inserted into the simulation 15 minutes before EIBT and stay until the simulation ends, but TOBT updates are only possible until AIBT + 5 Min.

The second GUI application can be activated by clicking on an aircraft being in the 1st main GUI as depicted in Figure 32. It shows all turnaround processes that the aircraft is passing through. The 2nd GUI application looks like the picture below (Figure 32):



TSDT/TOBT CONTROL

FLIGHT INB	LH4549	SIBT	11:55	MTTT	00:35	SOBT	12:30	ACTUAL DELAY	0
FLIGHT OBT	LH4700	EIBT	12:06	STTT	00:35	TOBT	12:41	ESTIMATED DELAY	0
				ATTT	00:35				

	CRITICAL PATH PREDICTION	SSDT	TSDT	DURATION	CHANGES	CODE	SSCT	TSCT	STATUS	TOBT
1	Parking Position	12:06	12:06	0	0		12:06	12:06	Finished	-
2	Marshalling (manual or automatic)	12:06	12:06	0	0		12:06	12:06	Finished	-
3	Equippment (GPU, ACU, Baggage Vehicles)	12:06	12:06	0	0		12:06	12:06	Finished	-
4	Flight Documents	12:06	12:06	1	0		12:07	12:07	Finished	-
5	Deliver at Aircraft (DAA) / Carry-on Luggage	12:06	12:06	2	0		12:08	12:08	Finished	-
6	Passenger Bus/Stairs/Bridge	12:06	12:06	1	0		12:07	12:07	Finished	-
7	Passenger Deboarding/Cabin Baggage	12:08	12:08	10	0		12:18	12:18	Started	-
8	Special De-Boarding (e.g. WCH, VIP)	12:18	12:18	0	0		12:18	12:18	Planned	-
9	Crew Change I (Cabin or Cockpit)	12:18	12:18	0	0		12:18	12:18	Planned	-
10	Cleaning	12:18	12:18	6	0		12:24	12:24	Planned	-
11	Catering	12:18	12:18	6	0		12:24	12:24	Planned	-
12	Fuelling	12:18	12:18	6	0		12:24	12:24	Planned	-
13	Maintenance	12:18	12:18	0	0		12:18	12:18	Planned	-
14	Special Service/Other (e.g Extra Catering)	12:18	12:18	0	0		12:18	12:18	Planned	-
15	Cabin Security Check	12:24	12:24	2	0		12:26	12:26	Planned	-
16	Crew Change II (Cabin or Cockpit)	12:26	12:26	0	0		12:26	12:26	Planned	-
17	Special Boarding (e.g. WCH, VIP)	12:26	12:26	0	0		12:26	12:26	Planned	-
18	Passenger Boarding/Cabin Baggage	12:26	12:26	11	0		12:37	12:37	Planned	-
19	Baggage/Cargo/DAA/Load	12:18	12:18	0	0		12:18	12:18	Planned	-
20	Loadsheet/Documents/Last Passenger	12:37	12:37	0	0		12:37	12:37	Planned	-
21	Closing All Doors	12:37	12:37	1	0		12:38	12:38	Planned	-
22	Remove Equipment	12:38	12:38	2	0		12:40	12:40	Planned	-
23	Push Back	12:40	12:40	1	0		12:41	12:41	Planned	-
24	Engine Start	12:40	12:40	0	0		12:40	12:40	Planned	-

FIGURE 32: GUI II SPECIFICATION FOR THE TRCM

Each aircraft runs through different turnaround processes (see the left column). The alternating solid and light pink colour indicates the next step in the critical path of turn-round processes while all processes either in solid or light pink that are in the same sequence can take place at the same time. For each turnaround process, the following information is depicted in a separate column:

- Scheduled starting and finishing times normal duration with regard to MTTT;
- Process Deviation time (Changes), Scheduled Service Delivery Time (SSDT) and Scheduled Service Completion Time (SSCT);
- Time elapsed with defined TOBT + predicted deviation from SSDT;

  Target Service Delivery Times (TSDT) that can be inserted by turn-round controller and automatically updates the TOBT in GUI 1; the Target Service Completion Time (TSCT) will be calculated automatically by using the Duration Time in column 1.

STATUS: Each turn-round process is coloured depending on process status. There are four turn-round process states (see status column in Figure 32):

- Planned;
- Confirmed;
- Started; and
- Finished.

TSDT updates by turn-round controller automatically shift the start and completion times of the other turn-round processes within the critical path with the ‘end- result’ being an updated TOBT on GUI 1.Appropriately adjusted TOBT is calculated automatically and GUI 1 is updated automatically as well by showing the new TOBT.

The number of processes are defined analogous to the critical path of turn-round events (see Chapter 4.4), but can be adjusted by the operator. If a delay arises within the critical path, a TOBT deviation is predicted as indicated in red and the subsequent critical processes within the chain change their colour in order to indicate that an additional confirmation by the service provider about the TSDT/TSCT is required.

The last column TOBT gives an indication *how* the entries under ‘Changes’ affect the TOBT, e.g. processes which take place in parallel to the critical path do not necessarily change the TOBT. This is seen as an essential part of the decision support functionality of the TRCM.

7.6 Method

A. Pre-Trials

Experimental trials were executed three weeks before the main experiments as a dry-run for the experimental set-up and scenarios. The aim was also to evaluate the following factors:

- To simulate the day-to-day workload of the turn-round controller as closely as possible.
- The number of incoming telephone calls represents the average number of calls during peak hours (approximately 100 incoming calls per hour).
- The number of turn-rounds represents an average number of turn-rounds during peak hours (approximately 15 turn-rounds in parallel).
- Any specific information from ramp agent or flight crew that is not included in the experiments but should be added, because it is essential for TOBT prediction.
- The experimental set-up can be used and understood after a 40 minute introduction, followed by 20-minute individual testing of the TRCM by the participants.

After the trials with two turn-round controllers, some fundamental changes had to be made that reflected turn-round controllers' perception of the TRCM. Major resistance to the TRCM from turn-round controllers was observed against the TRCM because they viewed this tool as a replacement for their established working procedures rather than as a mock-up designed for the sake of the experiments alone. To counteract this resistance, statements and power point slides were used during the introduction of the main experiments to stress the TRCM's function as an aid to TOBT decision making.

Some minor refinements to the wording in the ACARS/HMI messages were also made. The content was adapted to the wording on the GUI based on trial participants' input in order to better identify the cell where the change has to be inserted. Other minor changes also included changes to the GUIs (i.e. the letters were too small).

B. Distribution of Instructions and Experiment Run

The duration of the experiments was settled for one working day and took place in a room having all backup functionalities of the standard turn-round control room. After the participants took their seats in one of the three rows with the workstation/TRCM, the instructions for the experiment were given that had already been made available to the participants for home study. A 40-minutes introduction was given to the participants on how to use the workstation/TRCM and how to perform turn-round control using the telephone, pre-recorded messages, and the TRCM. The instructions were also available in printed form. However, the real objectives of the study were undisclosed to the participants. This introduction was followed by a 20-minute individual testing of the TRCM functionalities.

Airline pilots, employed as interlocutors for the participants, had also received the instructions of their tasks two weeks before the experiments in order to have time available for home study. A separate 20-minute briefing before the start of the experiments was provided to the flight crews as well as a printed form of the instructions.

Instructions for the participants:

The following list (Figure 33) shows the instructions and guidelines that were available to the participants before the study:

INSTRUCTIONS FOR THE PARTICIPANTS

- Three experimental scenarios, each lasting for 55 minutes are proposed that consist of 15 incoming flights with subsequent turn-rounds.
- All flights arrive delayed from outstation due to adverse weather in Munich.
- During each turn-round a number of events occur that have an effect on the length of the turn-round. A number of events arrive via simulated ACARS/HMI messages on the turn-round control Mock-up, other event information arrive via telephone calls or have to be asked from the flight crew/ramp agent.
- Each of the event information that arrives via ACARS/HMI requires a TOBT update by the participant, if ADD TIME is indicated; no update if NO ADD TIME is shown.
- The turn-round control Mock-up as well as the information given does not replace the day-to-day environment by 1:1. Therefore, the incoming information has to be evaluated by using own experience with turn-round control.
- Two times during each turn-round you will be asked to determine the TOBT for a subsequent departure. Please directly insert this TOBT in the spreadsheet on your Table.
- Additionally you will receive a number of telephone calls and ACARS messages that do not require a TOBT update. You can either take the call directly or delay it. The call will then be repeated one minute later. Information from telephone calls or other arriving information should support getting the required situational awareness about the turn-round status.
- After the experimental setting is completed you will receive a message: ‘End of Experimental Setting - Many thanks for your participation’

FIGURE 33: INSTRUCTIONS FOR THE PARTICIPANTS

Instructions for the interlocutors:

The following list (Figure 34) shows the instructions and guidelines that were available to the interlocutors before the study. Only airline flight crews were used as interlocutors because they are familiar with the turn-round procedures of airlines. All flight crews had a minimum experience of three years as airline flight crew:

INSTRUCTIONS FOR THE INTERLOCUTORS

General

- The participants (turn-round controllers) receive three experimental scenarios, each having the duration of 55 minutes.
- Each experimental setting consists of 15 incoming flights with subsequent turn-rounds.
- All flights arrive delayed so that the participants may want to keep the turn-round time short.
- During each turn-round a number of events occur that have an effect on the duration of the turn-round.
- While some events are shared with the participants via simulated ACARS/HMI messages from cockpit/ramp agent (cooperative information sharing), other events are only available to the participant, if he calls the flight crew/ramp agent for the flight/turn-round of concern (baseline information sharing).
- Each of the event information that arrives via a simulated ACARS/HMI requires a TOBT update by the participant, if ADD TIME is indicated; no update if NO ADD TIME is shown.

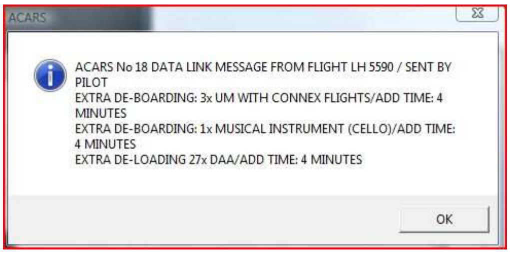
Confidential

- The baseline information that is handed over to the flight crews before the start of the experiments also includes TOBT update proposals which are only given to the interlocutors/flight crews.
- These update proposals are necessary to make TOBT predictions that are required for the TOBT accuracy pursued.
- The flight crews should play the role of the flight crew/ramp agent and forward the event information to the participant, only if he participant calls and asks for turn-round status.
- Each of the information given to the participants has to be noted in the adjacent column.

FIGURE 34: INSTRUCTIONS FOR THE FLIGHT CREWS

Examples of Cooperative Information:

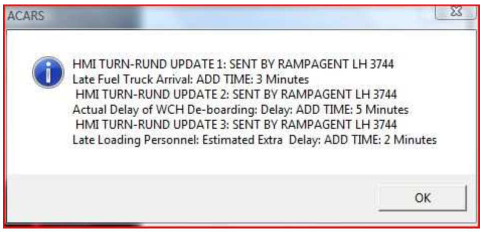
Figure 35 shows an example of an ACARS message that was provided to the participants for condition C1 and required TOBT updates to be inserted into GUI 2:



```
ACARS No 18 DATA LINK MESSAGE FROM FLIGHT LH 5590 / SENT BY
PILOT
EXTRA DE-BOARDING: 3x UM WITH CONNEX FLIGHTS/ADD TIME: 4
MINUTES
EXTRA DE-BOARDING: 1x MUSICAL INSTRUMENT (CELLO)/ADD TIME:
4 MINUTES
EXTRA DE-LOADING 27x DAA/ADD TIME: 4 MINUTES
```

FIGURE 35: COOPERATIVE INFORMATION SHARED FROM FLIGHT CREWS

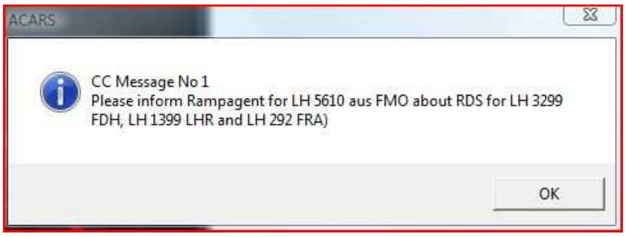
Figure 36 shows an example of an HMI message that was provided to the participants during condition C2 and required TOBT updates to be inserted into the GUI2:



```
HMI TURN-RUND UPDATE 1: SENT BY RAMPAGENT LH 3744
Late Fuel Truck Arrival: ADD TIME: 3 Minutes
 HMI TURN-RUND UPDATE 2: SENT BY RAMPAGENT LH 3744
Actual Delay of WCH De-boarding: Delay: ADD TIME: 5 Minutes
 HMI TURN-RUND UPDATE 3: SENT BY RAMPAGENT LH 3744
Late Loading Personnel: Estimated Extra  Delay: ADD TIME: 2 Minutes
```

FIGURE 36: COOPERATIVE INFORMATION SHARED FROM RAMP AGENTS

Figure 37 shows an example of additional information that was provided to the participants during condition C0/C1/C2 and did not require a TOBT update. This message represents information from the working position of a *Connex Controller* who is in charge of managing transfer passengers, if the inbound or the connecting flight has a delay:



```
CC Message No 1
Please inform Rampagent for LH 5610 aus FMO about RDS for LH 3299
FDH, LH 1399 LHR and LH 292 FRA)
```

FIGURE 37: TURN-ROUND INFORMATION FROM OTHER PARTICIPATING ACTOR

Figure 38 shows an example of additional information that was provided to the participants during condition C0/C1/C2 and did not require a TOBT update. This message represents an update received from CFMU about a CTOT for the affected flight:

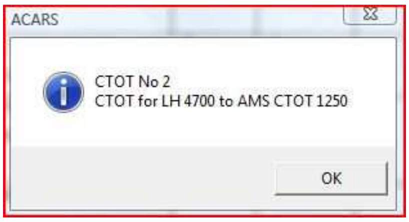

CTOT No 2
CTOT for LH 4700 to AMS CTOT 1250

FIGURE 38: TURN-ROUND INFORMATION FROM OTHER PARTICIPATING ACTOR

Figure 39 shows an example of an incoming pre-recorded telephone call. The participant could either take the call directly (ja) or delay it by one minute (nein):

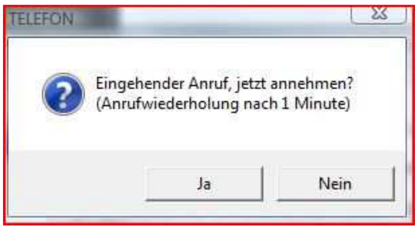

Eingehender Anruf, jetzt annehmen?
(Anrufwiederholung nach 1 Minute)

FIGURE 39: MESSAGE FOR INCOMING PRE-RECORDED TELEFON CALL

Training phase:

After the instructions were given, the participants had 20 minutes to familiarise themselves with the TRCM functionalities they were required to use.
No questions remained open after this training phase, which included a demonstration of all interactions used during the course of the experiments.

Experimental Conditions:

Each experimental setting lasted for 55 minutes. After each experimental scenario, the participants were allowed to take breaks as necessary. A feedback sheet was handed out with questions on the experiments in order to assure that the workload perceived by the participants did not exceed day-to-day demand and that the participants felt well treated during the day.

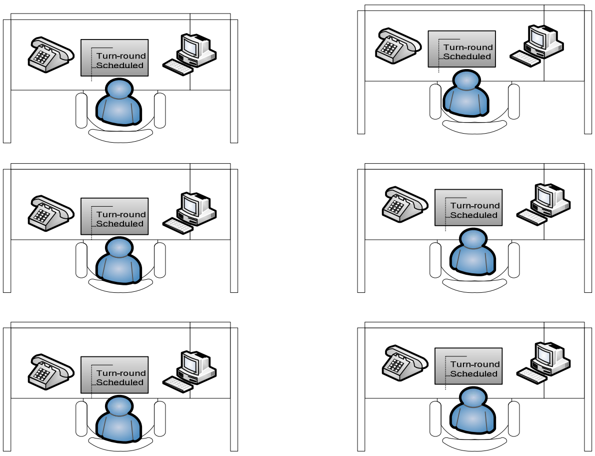


FIGURE 40: THE PARTICIPANTS & THE EXPERIMENTAL SET-UP

7.7 Data Analysis and Results

A. Analysis Software

The collected data was depicted in Excel Tables and SPSS Statistics Version 18.0 was used to analyse the results using descriptive statistics and inferential statistics via Kolmogorov-Smirnov test, Friedman test, Wilcoxon Signed-Rank Tests, Bonferroni adjustments, and Games-Howell test on the results.

B.Selection of Statistical Method

The nature of the experimental design relies heavily upon non-parametric statistics, since a pre-test with Kolmogorov-Smirnov showed that the DV is not normally distributed (see Table 17).

Box plot diagrams were used to analyse and visualize the data. The main statistical analysis was done via a Friedman test as such is able for non-parametric testing of differences between variables with the dependent variable that is measured being ordinal. It is based on the following assumptions:

- One group is measured on three or more different occasions.
- The group is a random sample from the population.
- One dependent variable is either ordinal, interval or ratio and
- The sample does not need to be normally distributed.

A post-hoc test was required in order to identify where the differences between the different information sharing conditions exactly occurs. A Wilcoxon-Signed Rank test was chosen for this purpose. As a second post-hoc test, the Games-Howell test was used to test for the homogeneity of the variance between the participants. The Games-Howell test is able to identify single differences between the heterogeneity of variances and does not rely on homogeneity of variance.

C. Inducing Statistical Significance:

The following difficulties were assessed before conducting the analysis on the data obtained by the experiments:

- Carry-over Effect: the participants transfer something from one scenario to another. Due to the small amount of participants, the carry-over effect could be assessed from each participant individually. No major changes in behaviour during the course of the experiments could be observed from all participating.
- Order Effect: the order of the conditions has an effect on the dependent variable. This effect was avoided by counterbalancing the information sharing condition within the three experimental scenarios using Latin-Square tables for experimental scenarios A/B/C.
- Imparity Effect: Some turn-round scenarios may be more difficult to handle than others. This effect was reduced by maintaining the amount of information almost constant for each turn-round condition and scenario.

D.Data Analysis

All TOBTs received by the participants in the spreadsheet were organized as follows:

Based on the EIBT of each flight, the turn-round time estimated by the participant was calculated via |TOBT I - EIBT| and |TOBT II - EIBT|. This was used to compare the deviations from MTTT and get an understanding about the different ways of participants' TOBT assignment behaviour. A significance level of $P = 0.05$ was chosen.

Then, |TOBT I - AOBT| and |TOBT II - AOBT| were calculated and used in order to perform the Friedman test. The Friedman test is able to handle non-parametric data distribution as it is received for the values of the DV ‘expected deviation from MTTT’ at the two test points (measurement points) under the three information sharing conditions C0/C1/C2. The DV were labelled as (Table 16):

TABLE 16: LABELING CONVENTION OF TEST VARIABLES

Mode of Test Variables	**Label of Test Variables**
No cooperative Information Sharing C0/ Measurement Point I	C0 MPI
Cooperative Information Sharing C1/ Measurement Point I	C1 MPI
Cooperative Information Sharing C2/ Measurement Point I	C2 MPI
No cooperative Information Sharing C0/ Measurement Point II	C0 MPII
Cooperative Information Sharing C1/ Measurement Point II	C1 MPII
Cooperative Information Sharing C2/ Measurement Point II	C2 MPII

Table 17 shows the results of the Kolmogorov-Smirnov (KS) Test:

TABLE 17: KOLMOGOROV-SMIRNOV TEST

Turn-round Time		Actual at MP I	Actual at MP II	Predicted at MP I	Predicted at MP II	Predicted at MP I	Predicted at MP II	Predicted at MP I	Predicted at MP II
Condition		C0	C0	C0	C0	C1	C1	C2	C2
N		90	90	90	90	90	90	90	90
Parameter of the standard distribution	Mean	48,66	57,73	38,50	41,30	45,19	45,48	44,88	52,98
	Standard Deviation	11,20	13,03	10,82	12,68	10,61	11,63	10,43	12,38
Most extreme differences	Absolute	,359	,213	,316	,269	,252	,228	,251	,140
	Positive	,359	,213	,316	,269	,252	,228	,251	,140
	Negative	-,153	-,179	-,229	-,188	-,168	-,162	-,172	-,102
Kolmogorov-Smirnov-Z		3,407	2,018	2,995	2,555	2,386	2,166	2,380	1,330
Asymptotic Significance (2-tailed)		,000	,001	,000	,000	,000	,000	,000	,058

The KS-Test reports that the relative distribution of the data from the DV is non-parametric.

E. Descriptive Statistics

Table 18 shows the deviations of the predicted TOBT from actual off-block time at the different measurement points while applying the different conditions C0, C1, and C2 in minutes:

TABLE 18: DESCRIPTIVE STATISTICS FROM EXPERIMENTS

Measure/ Test Point*	Measurement Point 1/C0	Measurement Point 2/C0	Measurement Point 1/C1	Measurement Point 2/C1	Measurement Point 1/C2	Measurement Point 2/C2
Mean |TOBT- AOBT|	21,21*	20,39	12,74	14,59	12,86	5,00
Max |TOBT- AOBT|	59	47	38	44	38	26
Min |TOBT- AOBT|	1	2	0	0	0	0
Median |TOBT- AOBT|	18,00	18,00	10,00	12,00	11,00	3,00
Standard Deviation	14,01	12,41	10,95	11,62	10,42	5,27

***All units in minutes**

Figure 41 shows a box-and-whisker diagram with the deviation of the predicted TOBT from the actual turn-round time at measurement point I and II during conditions C0, C1, and C2 in minutes. While the middle of the box represents the median assigned TOBT, the bottom and the top of the box represent the 25th percentile (bottom) and the 75th percentile (top) of all assigned TOBTs. While the upper end of whisker at C0MPII and the lower end of the whisker at C1MPI, C2MPI, and C2MPII represent the maximum, respectively the minimum value of all assigned TOBTs, the lowest/ highest ends of the other values are still within 1.5 Inter-Quartile Range (IQR) of the lower/upper quartile, but as indicated by the dots/stars there are some weak outliers (dots) and some strong outliers (stars).

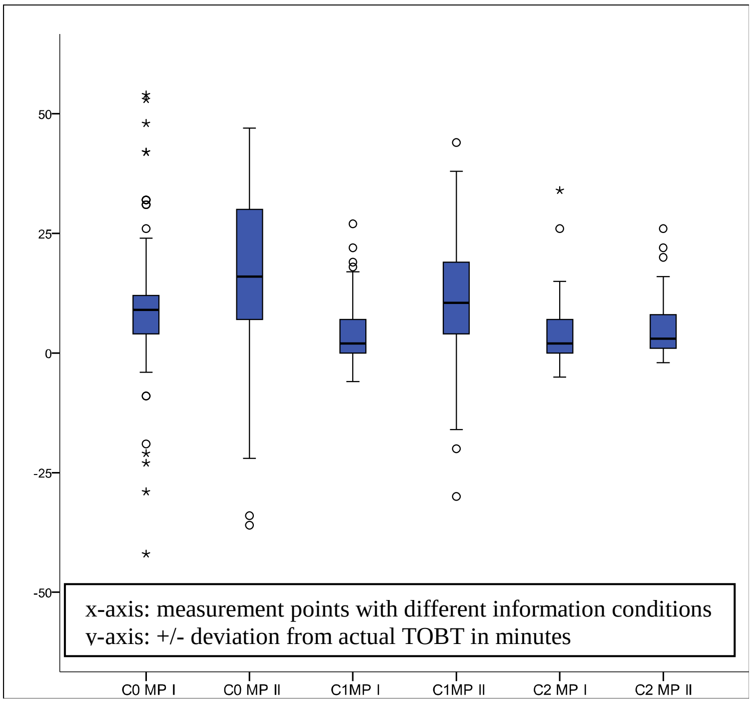


FIGURE 41: PLOT OF THE DIFFERENCES BETWEEN ACTUAL AND PREDICTED TOBT

Table 19 shows the descriptive statistics of the Friedman Test at Measurement Point I:

TABLE 19: DESCRIPTIVE STATISTICS AT MEASUREMENT POINT I

Descriptive Statistics

		Percentiles		
	N	25.	50. (Median)	75.
C0 MPI	90	10.00	18.00	35.25
C1 MPI	90	4.00	10.00	17.00
C2 MPI	90	4.75	11.00	19.00

There was a statistically significant difference in TOBT assignment accuracy depending on which information was provided to the participants whilst assigning the *first* TOBT update for the turn-rounds, $\chi^2(2) = 71,514$, $P = 0.003$.

Table 20 shows the descriptive statistics of the Friedman Test at Measurement Point II:

TABLE 20: DESCRIPTIVE STATISTICS AT MEASUREMENT POINT II

Descriptive Statistics

		Percentiles		
	N	25.	50. (Median)	75.
C0 MPII	90	10.00	18.00	30.00
C1 MPII	90	5.00	12.00	19.25
C2 MPII	90	1.00	3.00	8.00

There was a statistically significant difference in TOBT assignment accuracy depending on which information was provided to the participant whilst assigning the *second* TOBT update for the turn-rounds, $\chi^2(2) = 90,875$, $P = 0.003$.

F.Post-hoc Tests

In order to examine the differences of |AIBT - TOBT| between the related information sharing conditions C0/C1/C2 that actually occur, a Wilcoxon Signed-Rank Test was used that is able to identify the differences without making assumptions about their distribution and the participants or repeated measurements can be from the same sample group.

Table 21, 22 and 23 show the Rank Scores at Measurement Point I:

TABLE 21: TEST 1 RANK SCORES BETWEEN C0 AND C 1 AT MEASUREMENT POINT I

Ranks

		N	Mean Rank	Sum of Ranks
C1 MPI - C0 MPI	Negative Ranks	73[a]	43.45	3171.50
	Positive Ranks	11[b]	36.23	398.50
	Ties	6[c]		
	Total	90		

a. C1 MPI < C0 MPI

b. C1 MPI > C0 MPI

c. C1 MPI = C0 MPI

TABLE 22: TEST 2 RANK SCORES BETWEEN C0 AND C 2 AT MEASUREMENT POINT I

Ranks

		N	Mean Rank	Sum of Ranks
C2 MPI - C0 MPI	Negative Ranks	72[a]	40.79	2937.00
	Positive Ranks	8[b]	37.88	303.00
	Ties	10[c]		
	Total	90		

a. C2 MPI < C0 MPI

b. C2 MPI > C0 MPI

c. C2 MPI = C0 MPI

TABLE 23: TEST 3 RANK SCORES BETWEEN C1 AND C 2 AT MEASUREMENT POINT I

Ranks

		N	Mean Rank	Sum of Ranks
C2 MPI – C1 MPI	Negative Ranks	40[a]	40.01	1600.50
	Positive Ranks	41[b]	41.96	1720.50
	Ties	9[c]		
	Total	90		

a. C2 MPI < C1 MPI

b. C2 MPI > C1 MPI

c. C2 MPI = C1 MPI

Table 24, 25 and 26 show the Rank Scores at Measurement Point II:

TABLE 24: TEST 4 RANK SCORES BETWEEN C0 AND C 1 AT MEASUREMENT POINT II

Ranks

		N	Mean Rank	Sum of Ranks
C1 MPII - C0 MPII	Negative Ranks	60[a]	45.28	2717.00
	Positive Ranks	23[b]	33.43	769.00
	Ties	7[c]		
	Total	90		

a. C1 MPII < C0 MPII

b. C1 MPII > C0 MPII

c. C1 MPII = C0 MPII

TABLE 25:TEST 5 RANK SCORES BETWEEN C0 AND C 2 AT MEASUREMENT POINT II

Ranks

		N	Mean Rank	Sum of Ranks
C2 MPII - C0 MPII	Negative Ranks	80[a]	43.33	3466.00
	Positive Ranks	3[b]	6.67	20.00
	Ties	7[c]		
	Total	90		

a. C2 MPII < C0 MPII

b. C2 MPII > C0 MPII

c. C2 MPII = C0 MPII

TABLE 26: TEST 6 RANK SCORES BETWEEN C1 AND C 2 AT MEASUREMENT POINT II

Ranks

		N	Mean Rank	Sum of Ranks
C2 MPII – C1 MPII	Negative Ranks	73[a]	49.35	3602.50
	Positive Ranks	16[b]	25.16	402.50
	Ties	1[c]		
	Total	90		

a. C2 MPII < C1 MPII

b. C2 MPII > C1MPII

c. C2 MPII = C1 MPII

Test 7: The Games-Howell-Test identified only two significant differences among all data sets of the turn-round controllers (see Appendix VII).

G.Test Statistics of Post Hoc Tests 1 – 7

Post-hoc analysis with Wilcoxon Signed-Rank Tests and Bonferroni correction applied resulted in a significance level set at $P < 0.017$. Median (IQR) assigned differences in TOBT prediction accuracy for the C0, C1, and C2 information sharing condition were 18.0 minutes (10 to 35.25), 10.0 minutes (4 to 17) and 11.0 minutes (4.75 to 19), respectively.

Test 1 (significant): At measurement point I, there were significant differences between C0 information sharing and C1 information sharing condition, if information was cooperatively shared between flight crews and turn-round controller. The Wilcoxon Signed Ranks Test showed that cooperative information shared between flight crews and turn-round controllers elicited a statistically significant change in TOBT prediction ten minutes prior estimated aircraft in-block time (Z = -6,188; P = 0.003). The median between the different TOBT prediction scores was 8.00.

Test 2 (significant): At measurement point I, there were significant differences between C0 information sharing and C1 information sharing condition, if information was additionally provided by ramp agent. The Wilcoxon Signed Ranks Test showed that cooperative information shared between flight crews/ramp agents and turn-round controllers elicited a statistically significant change in TOBT prediction ten minutes prior estimated aircraft in-block time (Z = -6,320; P = 0.003). The median between the different TOBT prediction scores was 7.00.

Test 3 (not significant): At measurement point I, there was no significant difference between C1 and C2 information sharing condition despite the overall deviation from AOBT, if information is cooperatively shared between flight crews, ramp agents, and turn-round controllers. The Wilcoxon Signed Ranks Test showed that cooperative information shared only between flight crews and turn-round controllers compared to cooperative information sharing between flight crews/ramp agents and turn-round controllers did *not* elicit a statistically significant change in TOBT prediction ten minutes prior estimated aircraft in-block time (Z = -2,83; P = 0.777). The median between the different TOBT prediction scores was 1.00.

Test 4 (significant): At measurement point II, there were also significant differences between C0 information sharing and C1 information sharing condition, if information were cooperatively shared between flight crews and turn-round controllers. The Wilcoxon Signed Ranks Test showed that cooperative information shared between flight crews and turn-round controllers elicited a statistically significant change in TOBT prediction five minutes actual aircraft in-block time (*Z* = -4,426; *P* = 0.000). The median between the different TOBT prediction scores was 6.00.

Test 5 (significant): At measurement point II, there were also significant differences between C0 information sharing and C1 information sharing condition, if information were additionally provided by the ramp agent. The Wilcoxon Signed Ranks Test showed that cooperative information shared between flight crews/ramp agents and turn-round controllers elicited a statistically significant change in TOBT prediction five minutes actual aircraft in-block time (*Z* = -7,825; *P* = 0.000). The median between the different TOBT prediction scores was 15.00.

Test 6 (significant): Comparing measurement point I and II, there were also significant differences, when comparing cooperative information sharing between flight crews and turn-round controllers or additional information provided by the ramp agent. The Wilcoxon Signed Ranks Test showed that cooperative information shared only between flight crews and turn-round controllers compared to flight crews/ramp agents and turn-round controllers elicited a statistically significant change in TOBT prediction five minutes actual aircraft in-block time (*Z* = -6,551; *P* = 0.000). The median between the different TOBT prediction scores was 9.00.

Test 7 (significant): The Games-Howell Test showed that there was no significant difference between the turn-round controllers throughout all experimental conditions C0, C1, and C2; $p < .05$. Therefore it is statistically significant that the results of the controllers' assessment are valid.

H. Distinctive Features of the Experiment Results

- A total of 540 TOBT assignments were noted during the experiments (90 per participant)
- Out of all 540 TOBTs which were assigned during the experiments, only 34 TOBTs were assigned with Estimated TOBT (+/- 1 minute) > AOBT (6.30 %).
- Out of all 540 TOBTs, only 65 TOBTs (12.0%) were assigned using the TOBT that was proposed by the Turn-round Control Mock-up [-1; +1 minute].
- Out of all 180 Scenarios where no cooperative information was provided, 25 TOBT assignments were based on turn-round times short than MTTT (13.9%)
- The second column of Table 26 shows the number of TOBT updates that participants inserted into the 'change' column on the TRCM in GUI 2. This was part of the experiment instructions; however, only one participant occasionally (12.0%) used the TOBT proposal from the TRCM, but denoted the information from the ACARS/HMI messages and calculated the TOBTs on the spreadsheet. Table 27 also shows the number of outgoing telephone calls, where the participants contacted the interlocutor during the experiments. Column three are the number of calls that were used by the participants to actively acquire information; whereas column four are the number of telephone calls without any specific information request by the controller.

TABLE 27: DESCRIPTIVE STATISTICS FROM EXPERIMENTS

Participant	No of TOBT Updates during Experiment No I/II/III	Telephone Call with Information Request	Telephone Call without Information Request
1	41/46/42	21	20
2	57/56/59	9	11
3	36/31/40	18	23
4	56/48/52	6	12
5	31/32/42	5	20
6	4/5/4	3	11

- Two Participants used the spreadsheet to calculate TOBT predictions.

- Three participants denoted the CTOT time that was provided for a number of flights next to the TOBT column. Then they used the CTOT to determine TOBT estimates.
- All participants denoted the known major delays from technical aircraft status or crew delay next to the TOBT column.
- Table 18/ Figure 41 show a significant decrease in TOBT deviation and decreasing range from actual turn-round time, when comparing the TOBT that was assigned at *measurement point I* with the different information sharing conditions C0, C1, and C2.
- Table 18/ Figure 41 show also a significant decrease in TOBT deviation and decreasing range from actual turn-round time, when comparing the TOBT that was assigned at *measurement point II* with the different information sharing conditions C0, C1, and C2.

I. Distinctive Features from the Participants Feedback

TABLE 28: QUALITATIVE DATA FROM EXPERIMENTS

Statements	Fully Agree	Rather Agree	Rather Disagree	Fully Disagree
Content of the experiments was relevant to my day-to-day work	4*	2		
The workload during experiments was comparable to my day-to-day work	2	4		
The cooperative information received was useful to increase Situational Awareness for the turn-round control		4	2	
Generally I was satisfied with operation of the Turn-round Control Mock-up		4	2	
The cooperative information from cockpit were useful for TOBT prediction		5	1	
The cooperative information from ramp agent was useful for TOBT prediction		5	1	
Too much information was depicted	2	4		
Additional information is required		4	2	
If additional information is required, please give examples	Crew Delays, Technical Info, TSAT, Transit Passengers (RDS), Ready for Boarding Messages			

***All units are No of participants**

7.8 Limitations, Control and Validity of the Experiments

Two issues concerning the TRCM, in particular, require further discussion. First, there was a concern whether the TOBT assignment was based on the TRCM proposal or personal experience with turn-round control. It would have been possible that the participants adopted a strategy of just ‘playing the game’ or devoted cognitive resources from their own experiences for turn-round monitoring. The high workload condition could be an indication that the participants had to prioritise tasks and therefore used a lower-level-effort strategy. Thus, it would not be surprising that the participants were too busy using their telephones to get required information from the ramp or flight crew directly. However, a strong indication that the participants used their own strategy based on experience is the small number of TOBT predictions that were based on the TOBT proposed by the TRCM (See also Chapter 7.8).

Second, a methodological limitation could have resulted from the design of the study: information provided via pre-recorded telephone calls or ACARS messages included also generic information related to Munich airport operation. Although participants were instructed to not use such information for TOBT updates, feedback after the study revealed that participants were somehow confused by some of this information. It is therefore not possible to assess the extent that such information influenced overall turn-round control.

The scenarios included also a greater number of delayed and hence critical turn-rounds than in reality. Therefore, the benefits of information sharing will not be quantitatively the same in reality.

Control and Validity

Control of experiments with human participants is difficult to achieve because of the different personalities, intelligence and experience level of the participants. The control for this study was therefore maximised by the nature of its design. Measures taken included avoiding non-equivalent control groups by using the participants as control group and counterbalancing the experimental scenarios. Effects resulting from history, maturation, instrumentation, mortality, and diffusion of treatment were neglected due to the design of the experiments. While a testing effect could not be observed, a possible experimenter effect was avoided by predefined instructions given to the participants before the experiments as well as a single –blind experimental design where the participants were not informed of the manipulation of the provided variable. The participant effect was avoided by signalising a different aim of the experiments than the manipulation. The participants thought that the focus of the experiments was on cooperation between interlocutors and participants rather than on TOBT accuracy. Only one participant could be observed using such imagined demand characteristics during the experiments: the participant used his telephone in order to share the information that *he* received via ACARS with the interlocutor instead of using the information *from* the interlocutor.

A number of measures was undertaken to keep the external validity high. This includes the selection of turn-round controllers as participants (See Chapter 7.3) and the design of the Turn-round control Mock-up (See Chapter 7.5). Therefore, the *external* validity of the experiments that allows a generalisation of the results is seen as very high. Despite the artificiality of the situation, the experiments can be applied to other A-CDM airports, assuming that the workload of the turn-round controllers, as well as their workplace scenarios remain comparable. A systematic replication of the experimental setting at other CDM airports is therefore recommended to further elaborate the findings of this study.

7.9 Concluding Aspects

By using non-parametric statistics it could be demonstrated that there was a statistically significant difference in TOBT assignment accuracy depending on which information was provided to the participant. Interpretation of these results indicates that there is a strong indication (Test 1/2/4/5/6) that cooperative information provided from cockpit and ramp can significantly improve TOBT predictions. As indicated by measurement point I, not only can predictions be more accurate, they can also be available at an earlier stage of the flight/turn-round than today.

Results from Test 3 are not surprising, because before measurement point I no cooperative information was provided from ramp agent that may have influenced the TOBT assignment.

Even though the participants stated that the workload level was realistic compared to day-to-day business, they complained of information overload during the experiments. This could be an indication that the workload during adverse conditions exceeds the level acceptable to the participants. In these cases, there is an inherent risk of losing situational awareness at a level that is required for monitoring turn-rounds.

The controllers almost always underestimated the duration of the turn-round (See Chapter 7.8). This indicates also the intentions of the controllers to keep the turn-round delay short.

Overall, during experimental studies with turn-round controllers as participants and airline flight crews as interlocutors, it was possible to influence TOBT decision making positively to achieve more accurate predictions of the estimated turn-round end. As postulated in Hypothesis I and II, the cooperative information from the cockpit and ramp not only improved turn-round completion predictability, the cooperative aspect of the experimental setting also seemed to have influenced the cooperative attitude of the participants. As indicated in the questionnaire directly following the experiments, the participants welcomed the opportunity to *cooperatively* share information among the distributed participants of the turn-round and their workplace.

Therefore Hypothesis I, *Information required for TOBT updates which is cooperatively shared between flight crews and turn-round controller before |EIBT - 10 Minutes| increases the accuracy of TOBT*, and Hypothesis II *Information required for TOBT updates (independent variable) which is cooperatively shared between flight crew, ramp agent and turn-round controller before |AIBT + 5 Minutes| increases the accuracy of TOBT, i.e. reduces |TOBT - AOBT|*, could be validated.

However, while the participants appreciated the cooperative attitude of the participating flight crews, they had to cope with an information overload condition comparable to their day-to-day working environment. All participants agreed that the information overload and workload in general during the experiments was similar to their actual working situations.

7.10 Discussion

The approach chosen requires asking about the validity of a laboratory approach for complementing field observations. The underlying question here was how the laboratory setting could be used to gain insights into or contribute to the design of field studies that would further increase the credibility of the field observations. Implicit in this approach is the assumption that more control can be gained in the laboratory than in the field studies. This approach also includes the assumption that the laboratory cannot substitute field investigations.

It is argued however that a discussion about comparability of lab and field scenarios is not relevant for this research for several reasons. Firstly, all phases of the project were seeking practical significance and are therefore applied type research questions. Secondly, the first, second, and third phases of the research highlights the constraints to TOBT assignment, while the last phase sought potential solutions. The research setting in this final phase was designed as closely as possible to reality which is, according to Skraaning (2003), the only possibility for combining laboratory and field studies. Such an approach entails conducting simulator studies in complex operational environments as they can be found during turn-round management. Thirdly, all phases of the research had their own objectives that were addressed at the relevant stages. Different aspects were centred in each study approach to grasp the specific aspects that were identified for the TOBT assignment problem, starting from a broad ecological perspective to a view focused on individual cognitive aspects towards TOBT prediction. As an analogy, this approach can be compared with the task of building the shortest, most suitable road from A to B in a fairly unknown terrain. This will not be possible, if the topological or surface factors remain unknown. As for the TOBT, it can only be determined successfully, if the factors influencing the adherence are known and then regarded.

A key message for the still inherent constraints on cooperation revealed during the feedback from turn-round controllers after the experiments is the little amount of awareness that the airline company itself places on the need for reliable TOBT predictions: Instead of increasing mutual trust and understanding of other participating CDM partner's operation, the reality is shaped by increasing pressure and high workload levels, also affecting available options for successful turn-round control and so also TOBT accuracy. One major issue here is the uncertainty about other partners' behaviour, e.g. '*what happens exactly if the CTOT or TSAT is lost?*' 'I*sn't it better to first give the earlier departure a try?*' Such continuing mistrust among partners fosters the focus on the advantages of the airlines' own operation instead of establishing a broader view onto the network benefits. Additionally, given the high work load, adherent to turn-round controllers' jobs, emphasis can barely be placed on establishing cooperation with other participants or information gathering for TOBT predictions, when focus has to be placed on minimising delay or keeping pace with the other duties on task. Such pressure also explains the reduction of turn-round time below MTTT that was surprisingly often applied by turn-round controllers instead of getting a realistic picture of the required turn-round duration. E.g. hardly any TOBT prediction *exceeded* the actual turn-round time (see Chapter 7.7).

An example was provided by the participants and the flight crews, which revealed to be useful in illustrating this chain of constraints during daily routine operations: Starting situation is any turn-round event with a confirmed duration of the estimated delay by a SME: either the still existing possibility that the delay could actually be also shorter than predicted or the option to compensate the delay by accelerating other turn-round processes, together with the underlying pressure to keep delays short, causes the turn-round controller to predict a TOBT that does not incorporate the full process duration of all turn-round processes. Experiences with such situations in the past have confirmed that for a certain amount of turn-rounds this strategy was successful and TOBT could be maintained. At the same time, the number of flight crews expressing dissatisfaction or declining to accelerated turn-round has to be put up with the advantage having minimised the delay at least for a certain number of turn-rounds. In the majority, however, this strategy doesn't work when comparing the cost of missing a CTOT versus cost of reassigning a later CTOT, thus resulting in network benefits from improved TOBT prediction accuracy.

8 SUMMARIES, CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusion on the Methodological Framework Chosen

The framework chosen as well as the methods used for the analyses revealed being able to account for the environmental constraints affecting TOBT prediction *and* the cognitive factors influencing the human-information interactions of the participants. A *Cognitive Work Analysis (CWA)* was used which was aimed at identifying the constraints shaping these interactions during turn-round, grasping the information behaviour of the actors at the various distributed locations, and also the reason for their actions. Tools proposed by the CWA and conceptual constructs provided the structure for the design of this human-information interaction analysis. The results were then applied to specific turn-round situations, and used as a guide for designing the experiments that simultaneously included facets from social, technological, and organisational aspects of the contemplated situations.

A set of research activities was proposed to answer the research questions presented as outlined in Chapter 1. The Chapter here summarizes these methods and discusses the advantages and disadvantages of the applied research procedures. Generally, three research methods were used to investigate the problems of TOBT inaccuracy. First, a *formative* analysis was chosen based on document analysis, stakeholder discussions, and SME interviews. In contrast to a normative approach, this form provided a structure for analysing how things *could* rather than *should* be done. Second, a *descriptive* form of analysis was chosen with data collection via survey and field studies. Even though this form has reduced controllability, it offers high external and ecological validity. Finally, an *explanatory* method was used via experimental studies in a controlled setting with human-in-the-loop, allowing for a full control of the influencing variables and keeping the internal validity high.

To control the advantages and disadvantages of each method, a combination of all approaches was chosen to arrive at a comprehensive description of the influencing factors and possible strategies to mitigate the current problem with TOBT prediction. This combination of methods not only allowed a logical and iterative zoom-in from the turn-round environment to the specific problem of TOBT assignment, but is also seen as a complementary approach to the problem.

8.2 Data Organization, Hypothesis Testing, and Statistical Analysis

The first two phases of the project were aimed at identifying descriptive information. The qualitative data that was gained from these phases was organized in class interval frequency distributions. *Descriptive data analysis* was applied to obtain measures of central tendency via a Likert scale, e.g. from various critical turn-round situations or the dispersion of possible delay avoidance. Even with the restriction in mind that the survey with flight crews acquired qualitative data only, correlation analysis was carried out, e.g. between the turn-round process delay and the departure delay of the consecutive flight by using Spearman's rho as a coefficient to measure two variables on an ordinal scale. As an alternate-forms reliability test, moderate to strong relationship could be demonstrated by using equivalent questions. Equivalency was assured by using the same difficulty level, instructions and format of test.

The data gained during the third phase via field observations was organized in a qualitative cognitive model that could be used to analyse the mental models of the turn-round controllers and their data requirements.

The basic issues from the final phase of the research are related to the specific experimental setting of a correlated groups design: originated from the rare existence of the participants, an experimental condition showed advantageous which allows serving the experimental as well as the control condition. Since all participants served all conditions, randomisation was not necessary. The greatest benefit however was gained from statistical power, because individual differences could be minimised under the applied conditions. Variability between the three conditions under analysis came from the manipulation of the independent variable 'information sharing' and according to Jackson (2008) has the potential to provide a purer measure of the true effects of this variable.

The focus of the analysis was to validate the specific information *distribution* in the contemplated environment, but not the *specific* details of the information. Therefore, only a small number of hypotheses was used that account for the problems related to information distribution between the turn-round controllers and the flight crews/ramp agents. Inferential statistics were used to draw the conclusions about the participants under analysis based on the data collected through the experiments. The hypotheses testing chosen was valid for the proposed one-tailed hypotheses with an alpha level of .05 statistical significance. Such a 5% risk of Type I error is common in social and behavioural scenarios and is so seen as also acceptable for the proposed experiments.

Since the characteristics (µ) or deviation (σ) of the analysed population revealed to be non-standard distributed, a non-parametric test was used that does not require m and s parameters. The Friedman Test, also called a two-way analysis on ranks, was suitable because it did not require a standard distribution of the analysed data. It was used to detect differences in treatments (condition 0, I, and II) across multiple test attempts (scenarios) by modelling the ratings of *n* rows representing the different turn-rounds on *k* columns as the different turn-round sets under analysis.

The repeated measures ANOVA test however could not be used because it requires a normal distribution of the data and compared to the Quade Test, Friedman showed stronger significance with given sample size. As a post-hoc test, the Wilcoxon Signed-Ranks Test with Boferroni adjustments on the chosen alpha level was applied.

8.3 Conclusion from Cognitive Work Analysis

The Cognitive Work Analysis as the overall framework chosen for the project revealed to be useful for the analysis of the A-CDM work system. It aimed at identifying the constraints from environmental factors that have an influence on TOBT prediction accuracy. The large number of turn-round participants being at distributed locations and therefore inherent constraints on decision making called for an analysis with an ecological perspective that can handle both the intentional and physical constraints on the actions of all participating. Since this form of analysis is not based on quantitative measures, an early validation of the results from such form of analysis was pursued to verify that the analysis was on track. Results from the survey were used to provide an independent source of information for the validation of the Abstraction-Decomposition Space (ADS) of the A-CDM work system.

While the ADS could be validated using results from the flight crew survey, neither the decision ladder as the proposed tool for the control task analysis nor the strategies, social worker and cooperation analysis could usefully be applied to the A-CDM work system because of their inherent limitations of these tools. Thus, they were perceived as being detrimental to the aim pursued by this project. Further details on identified limitations can be found in Appendix VI.

However, the largest benefit gained with the CWA resulted from the information requirement analysis and the application of the contextual activity templates. These forms of investigation were able to provide the basis for the subsequent studies. By analysing all of the turn-round processes, the turn-round constraints resulting from the parallel turn-round events could be depicted in form of a *critical path*. This critical path analysis could also identify the responsibilities for decision making and the control tasks at the various stages of the turn-round. Additionally, the critical path could be used to unveil information requirements for the various processes that may influence TOBT prediction accuracy. Furthermore, the critical path provided the foundation for selecting the critical events that were used for the scenarios that made up the experiments on TOBT prediction accuracy. It was therefore concluded that the CWA was able to provide a valuable framework for modelling the A-CDM work domain, even though some of the proposed tools could not be used. It was able to identify a number of fundamental constraints that are imposed on TOBT decision making and to show the specific environmental factors that influence TOBT decision making.

8.4 Summary and Conclusion from the Flight Crew Survey

The Participants

The second step of this project was a survey with airline flight crews aimed at identifying and describing critical situations for TOBT adherence. This measure was applied in order to identify how frequently the turn-round problems occur, seen from the perspective of the user. Airline flight crews were chosen as participants for the survey, because although they are initially not regarded as A-CDM partners and normally do not assign the TOBT, but they *use* the Target Start-up Approval Time (TSAT) which depends on accurate TOBT predictions and hence influences the time available for their turn-round tasks. The second major reason for using flight crews as participants was because they are the only users who can compare A-CDM at *various airports* and usually do not have to expect negative consequences from delayed turn-rounds; while other participants have to expect pay actions from delayed services.

Therefore, they are seen as the group with the lowest bias possible and the descriptions obtained from them were used to prioritise the most critical turn-round processes. This survey complements the CWA and provides a means of investigating the distinctive characteristics of the A-CDM turn-round process.

Critical Situations for TOBT Adherence

The most important result from the survey was captured by the high agreement among flight crews that information sharing is a root cause for failures during turn-round as well as their remarkable consensus on the frequency of the reported events. Statistically noticeable results from the survey could be gained by comparing process delays and departure delays with the limitation that the data was acquired via qualitative assessment only: a significant relation was identified between the delay from a service or information provision failure and its’ effect on the departure punctuality of the following flight for all contemplated situations.

Strikingly high results were reported from delays caused by failures to provide operational information to and from the cockpit. Such findings give an idea about the flight crew’s view of the problem of how the *airlines* manage operational turn-round processes. Contemplated operational problems included e.g. changes of equipment, parking position, or crew, re-booking or direct transfer of connecting passengers. Operational reliability for such events requires pre-planning with other airport partners in order not to jeopardise TOBT adherence. However, the initiative for such pre-planning has usually to be taken by the airline company or their representatives.

No correlation could be observed between the effect of providing information to the flight crew and therefore subsequently preventing ground handling delay. Several reasons are possible for this result: either the flight crews are not aware of the possibility of avoiding an arising problem by using the information provided in order to allow the flight crew to take appropriate actions (e.g. arranging alternative ways of ground handling). Alternatively, a real lack of resources, capabilities, aims, or other reasons yet to be identified can be responsible for service delays.

The TOBT Inaccuracy-Swing-Effect: Failing to Share Information during Turn-Round

Additionally, it could be observed in almost all reported events that the departure delay after turn-round following the information provision failure shows higher values than the delay values caused by the service provision failure. A possible reason is the so-called phenomenon of a inaccuracy-swing-effect where the network of service providers can oscillate in very large swings as each organisation in the supply chain (critical path of turn-round events) seeks to solve the problem from its own perspective and so raising the outcome of the problem (here the outcome is the departure delay after passing the critical path of ground handling services). This is a very common problem in the supply chain management of production lines where many partners are involved and a typical phenomenon within complex systems. Although, the turn-round has characteristics of a supply chain, such a conclusion has to be validated via additional information because the delay following a service/ information provision failure could also be caused by other reasons not yet identified.

Decision Making during Turn-Round

In the context of the survey it was also analysed how the current approach to operational decision making is *perceived* by the flight crew, because it is unlikely that flight crews will forward operational information or accept operational decisions, if current approach to decision making is not satisfactory for flight crews. While the majority of flight crews is asking for *more* involvement in decision making (69,9%), because they see situational awareness for decision making is at higher level at the aircraft, the majority of flight crews who are *against* additional involvement by flight crews in operational decision making (30,1%) see situational awareness better established at places other than the aircraft cockpit. The high percentage of flight crews favouring increased involvement and the high number of reported delays can be seen as an indication of the high importance that flight crews attribute to the need of operational reliability. This was also recognized in the high number of free text answers where dissatisfaction with the current approach to ground handling was stated. Namely it was mentioned that ramp agents do not have the same training as they once did and only react to flight crew requests. Moreover, they are usually in charge of several turn-rounds at the same time and are not always directly accessible to the cockpit crew. In cases of emerging problems, the flight crew has to forward the problem themselves or wait until the ramp agent comes back. Under these circumstances, discontent with the current approach is not surprising since it is often the air crew who has to manage turn-round problems directly. However, different approaches to ground handling are pursued at different airports and it was concluded that inside knowledge of the affected airport is required to identify best-practice solutions individually for each airport.

Information Sharing and Cooperation

In order to analyse cooperation during turn-round, the possible failure causes of turn-round processes were proposed to the flight crews analogous to Ferber (1995) who divides cooperation in the three components, competing aims, insufficient resources, or insufficient abilities. Ferber (1995) integrates these components in a cooperation model and argues that cooperative situations can be grouped either in indifferent, cooperative, or non-cooperative situations depending on the combination of these three components. Attention is required if a situation reveals itself to be structurally non-cooperative as it is the case, when actors have competing aims *and* either resources or abilities are not sufficient. Following Ferber's theory, only *one* situation was reported by flight crews to be non-cooperative if following his theory: the assignment of parking stands. All other situations were reported to be cooperative and failure can be traced back to resource problems or inabilities of responsible function.

In order to capture possible further causes responsible for turn-round problems also other reasons than outlined before were proposed as well as free text answers. In this context, 52,5 % of the flight crews view the short turn-round time, information overload (43,6 %) and sharing of responsibilities (45,5 %) as possible failure causes. Divergent aims, lack of competencies and resources were also seen as failure causes. Free text answers mentioned competency, motivation, and the decreasing availability of ground personnel as key issues for turn-round problems.

Finally, it was concluded that the results of the survey could identify a number of situations that are critical for TOBT adherence and could so be used for the subsequent studies. Additionally, the perspective of aircrews regarding cooperation of actors during turn-round could be captured.

8.5 Summary and Conclusion from the Study via Field Observations

After the survey, a qualitative study with field observations during turn-rounds at CDM airports was conducted which aimed at identifying the constraints to operational turn-round *monitoring* and the resulting influence on *TOBT assignment*. The critical situations identified in the first step of the analysis were also to be further investigated. The initial concept was to observe solely *one* operators' approach to TOBT assignment. During this field research however the study concept changed from observing a single operators' TOBT assignment to a comparison of five different operator's approaches towards TOBT assignment because a comparison of different TOBT assignment processes would reveal a broader view of approaches currently applied to turn-round monitoring and TOBT assignment.

The most important findings from observations of today's turn-round management could be localized to two factors: (1) procedural differences between traditional *local turn-round management* monitoring and current approach towards *remote turn-round management*, and (2) the strategies of turn-round controllers for creating or extracting information.

Procedural differences between traditional local turn-round monitoring and today's remote turn-round monitoring are relatively straightforward: During traditional local turn-round monitoring, the turn-round controller identifies required information via a *knowledge-driven* form of monitoring turn-round events. Data is directly identified at the action level and used for developing a proactive strategy. Reliable TOBT prediction is based on the experience of the controller and only possible after the aircraft has arrived at the parking position and doors are opened. The turn-round controller enters the aircraft, visually assesses the time required for turn-round with confirmation from the flight crew and then initiates appropriate actions for coordinating the required turn-round processes. He continuously monitors current turn-round status and considers that updates are required to all actors involved. This was done by taking the given situation into account, e.g. number of passengers, baggage or specials. This approach is *knowledge-driven* because TOBT accuracy depends on ability of turn-round controller to estimate process time required for all processes along the critical chain. It is also the most appreciated form of turn-round control for flight crew members, because all operational requirements are handled by the controller and crew members can focus on their own duties.

During remote turn-round monitoring however, monitoring is more *data-driven* and depends on the information available via tools and telephone. Turn-round controllers have to rely on displayed information or updates via voice contacts in order to create situational awareness. The difficulty for the controller here is that he has to monitor several turn-round simultaneously and often the time available does not allow him to capture all information necessary to estimate a TOBT based on *all* given situational constraints. As a result, simplified strategies were used for TOBT assignment instead of taking *all* available information into account. Updates to TOBT require interaction creation from participating actors with the turn-round controller or data received by actors. Therefore, this approach is *data-driven*, because it depends on data made available to the turn-round controller; any proactive strategy depends on this information. It is recommended to analyse how information available at the aircraft can be forwarded via automated procedures. During observations, only one operator of a major European airline was using a designated ramp person who precisely monitors turn-round process start/end of all processes during critical chain of turn-round and then transmits the data to the control room. All other airlines observed rely on automated systems or interactions received via phone, ACARS, or two-way radio communication.

Overall it was concluded that an understanding could be captured of how the major European airlines actually assign the TOBT today and also how they deal with unexpected situations.

8.6 Summary and Conclusion from the Experiments

Since the previous phases of analysis allowed identifying the constraints imposed by the environment and cognition of all participating actors and operators, this step was now aimed at identifying countermeasures to those constraints. Therefore, small-scale human-in-the-loop experiments were conducted to validate issues related to the specific constraints resulting from information sharing and cooperation. A within-participant experimental design was chosen and adapted to different turn-round situations having different information sharing conditions. The study design depicted situations experienced during turn-round operations under adverse conditions where a more standardised approach to information sharing was investigated. Order effects were counterbalanced with Latin squares and the extent of a possible carryover effects as well as demand characteristics were assessed by the analysis of the results.

During the experimental studies with human-in-the-loop, the influence of cooperative information sharing from flight crews and ramp agents with the turn-round controllers on TOBT prediction accuracy was analysed. Within three experimental scenarios in a Turn-round Control Mock-up, three different information sharing conditions were used to investigate the prediction of the turn-round controller on the duration of the turn-round. Starting point of the analysis was the assumption that cooperative information from cockpit and airport ramp could influence the turn-round controllers’ TOBT decision making. Simulation with the TRCM allowed establishing such information sharing conditions.

Hypotheses I and II could be validated via the statistical method of a *Friedman Test* together with post-hoc test of *Wilcoxon Signed-Rank Test* and application of *Bonferroni Adjustments*. The Friedman test was able to show that differences between groups of data exist because the dependent variable having been measured was ordinal. The median values for measurement point I and II were also provided at this stage. The Friedman test was only able to show that differences exist *somewhere* between the influence of the three information sharing categories C0, C1, and C2. However, in order to know *exactly* where those differences are, a post-hoc test was required. The Wilcoxon Signed Rank test could then show where the differences between information sharing condition C0 and C1, C0 and C2, and C1 and C2 actually occurred. Subsequent Bonferroni adjustments were required, because multiple comparisons were made and Type I error should be avoided where results are falsely declared to be significant.

It could be concluded that there was a statistically significant difference in TOBT assignment accuracy depending on which information was provided to the participant whilst assigning the *first* TOBT update for the turn-rounds. Thereby, TOBT prediction accuracy increased by a mean value of more than 8 minutes (See also Table 17). Applying *post-hoc* analysis with Wilcoxon Signed-Rank Tests and Bonferroni correction resulted in significant results: There were significant differences between C0 information sharing and C1 information sharing conditions, and between C1 and C2 information sharing conditions.

There was no significant difference between C0 and C2 information sharing conditions despite the overall deviation from AOBT, but there was a statistically significant difference in TOBT assignment accuracy depending on which information was provided to the participant whilst assigning the *second* TOBT update for the turn-rounds. Thereby, TOBT prediction accuracy increased by a mean value of more than 15 minutes (see Table 17).

It was concluded that the experiments were able to define countermeasures for dealing with unexpected situations and strategies for decision support that are able to increase TOBT prediction accuracy. The countermeasures and further recommendations for A-CMD turn-round management are lined out in Chapter 8.7.

8.7 Recommendations Resulting from this Project

A number of measures were identified that are able to increase TOBT prediction accuracy. Recommendations and possible measures resulting from the *descriptive* analysis of this project include:

1. Before changing established ways of turn-round monitoring, e.g. from direct turn-round monitoring to remote turn-round monitoring, airline policy and decision makers should *recognize the facilitating activities* with the inherent predictive capabilities that are used by direct monitoring turn-round controllers. It is necessary to anticipate turn-round controllers' monitoring needs comprehensively and create interfaces that systematically support such monitoring with reliable TOBT prediction rather than simply expecting controllers to adapt to a situation with poor data available.
2. As a step towards designing monitoring and communication tools with functionalities required by controllers, valuable information can be collected by *observing the facilitating activities* that turn-round controllers are currently

engaged in during direct turn-round monitoring and remote turn-round monitoring under consideration of aspects from *cognitive* perspective.

3. As a further step in this direction, the *available tools* for remote turn-round monitoring *need to be better understood* in order to allow facilitating activities with *predictive* behaviour being used for the design of new computer-based systems able to support decision making in such a complex and dynamic environment.
4. This not only entails the need to *analyse all information required* to estimate process time during all processes within the critical path, but also to establish functionalities allowing a *mandatory assessment of Target Service Delivery Times* (TSDT) for all partners and actors involved in service delivery during the critical path. As a result, the TOBT can be created based on *predictive* information from service providers, combined with the reference model, and the required adjustments to the reference model based on information provided by the crew.
5. This also entails the need to *take information from the flight crew* emerging during flight *into account* or depending on flight progress *and* the information provided *by actors on the ramp or terminal building.* This recommendation could later be confirmed during an experimental study of turn-round situations.
6. More attention should also be paid to *basic human factors issues* in the design of such supporting tools since control issues and responsibility sharing are involved, e.g. turn-round times shorter than MTTT should be in agreement with the flight crew; if flight crew does not favour using MTTT, not only may flight safety be affected, it is questionable whether MTTT can be performed without his or her consent.
7. Examples for facilitating strategies of turn-round management should be compiled by innovative ATM network approaches to delay code management - namely away from assignment of the delay code onto a *real-time* situational analysis (reactive analysis) towards a delay code assignment based on non-adherent service *prediction* (proactive analysis). This gives a more realistic estimation of the responsible function without creating a blame culture.

Some further recommendations and measures resulting from the experimental results of this project are outlined next.

1. Establishing *realistic turn-round time predictions* that are able not only to increase TOBT adherence, but also to improve pre-departure sequencing at the airport and thus allowing for reduced the buffer times for taxi.
2. Increasing attention to *accurate turn-round time planning is required*, because service providers can so abide by the reference models established by the airlines. This allows them to execute their services within a coordinated chain of turn-round events, while reducing the pressure to omit necessary safety precautions due to time constraints.
3. Further investigation is required for the ‘critical path’ processes of parallel turn-round events. The critical path used during the experiments reflects the specific turn-round situation of the hub-and-spoke operation at Munich airport. The TRCM that was developed for the experiments includes therefore additional functionalities that permit adding and removing processes depending on the specific turn-round situation of other airports. This functionality should be used to insert additional required processes and to investigate the given turn-round situation at other airports.

8.8 Limitations of the Research Undertaken

The work presented in this thesis is limited and cannot be generalised without considerations of its assumptions and shortcomings.

With the introduction of the conceptual framework, there are assumptions underlying the analysis, and also a number of simplifications that had to be applied when compared to the real world. This allowed an investigation of the research objectives in a greater level of detail and so a greater contribution to knowledge. However, the limitations which should be kept in mind before applying the knowledge to the real world include:

The survey undertaken only delivers the opinion and experience of one group among the numerous other participants. The advantage of using this group specifically was outlined before; however a generalisation of the results is not possible.

The data that produced the TOBT inaccuracy-swing effect originates from qualitative data. Using qualitative data with a correlational analysis method to describe behaviour is often questioned within the literature for not being able to deliver rigorous results.

The number of airports using A-CDM is still rather small and also size of airport varies. Comparison of turn-round monitoring in highly congested airports may differ significantly from airport to airport and also from turn-round duration that is used for planning. The presented results therefore only apply for turn-round operation at congested airports. The relevance increases, if a short turn-round time is a factor.

8.9 Contributions to Knowledge

Despite of its limitations the thesis aims to have contributed to the body of knowledge as follows:

The relevance of this project for A-CDM could be recognized by the attention it received from both the industry and the A-CDM Coordination Team from EUROCONTROL Headquarters via repeated presentations and publications on this topic. (See also Chapter 9). An increased attention towards the importance of TOBT was realized by several stakeholders and industry partners based on paper presentations at EUROCONTROL Headquarters and various conferences (see Chapter 9.1) because it was realized that reliable TOBT predictions are crucial to successful airport operation.

This is the first time that a CWA as an approach to Cognitive Engineering has been applied to turn-round management. It revealed some distinct characteristics and constraints in a work domain with characteristics of distributed decision making environment that have neither been identified nor investigated before.

While within the framework of Cognitive Work Analysis, respectively during the phase II ‘Control Task Analysis’ and phase III ‘Social Organisation and Cooperation Analysis’, existing tools could not be used, other approaches to cooperation that have not been applied in such context so far were integrated into the CWA framework.

Finally, employing human-in-the-loop experiments to analyse cooperative information sharing is a novel approach to operational information sharing in the domain of turn-round management that has not been taken to date. Seeing the increasing complexity of turn-round management, such an approach revealed to be a viable option that can be used for analyses in environments or work domains with similar constraints.

A concluding remark from the author referring to knowledge identified from the analysis that should be seen as a warning sign:

Accurate turn-round time predictions also encompass concerns about flight safety: *'Caused by shortening of turn-round times below minimum process times as a procedure identified during field studies and experiments, flight safety could be at risk, if the time available especially for safety relevant procedures is getting increasingly constrained. This comprises the preparation of the flight crews for the next flight segment including document study, fuelling, de-icing, walk-around, cabin security checks, and loading'. If not sufficient time is available to thoroughly execute these duties because a pressure is placed from airline operation or inappropriate TOBT predictions, the risk of missing or neglecting relevant information can rise significantly.*

8.10 Areas for Future Research

This thesis could address only a few aspects of cognitive engineering and design criteria within the domain of turn-round management. The high relevance to operational day-to-day problems reveals opportunities for future research especially in:

- Field studies about the practicability of the identified cooperative information sharing for operational application.
- Investigations on how non-punitive elements during turn-round operation can enhance cooperative information sharing between partners without the mutual blaming which often stems from the current IATA Delay Code Assignment procedure.
- Research on how additional measurement points for ground handling services can be introduced and monitored for more accurate service delivery time predictions.
- Study on the accurate process times required for the turn-round services with focus on processes relevant to flight safety.

Generally, the portion of research projects in turn-round management is relatively low compared to other ATM domains. A majority of research projects aimed at increasing airport throughput relate to investigations for the terminal side of the operation, although a number of problems can be attributed to the land-side operations.

9 PUBLICATIONS AND REFERENCES

9.1 Publications Resulting from this Project

ACHI 08, *Study of Cockpit's Perspective on Human-Human Interactions to Guide Collaborative Decision Making Decision in ATM*, International Conference in Advances in Computer Human Interactions ACHI 2008, Conference Proceedings, Saint Luce/ Martinique, 10-15 February, 2008.

ICRAT 08, *Applying Cooperation Analysis to Study the Airline Flight crew's Perspective on Human-Human Interactions during Flight Operation* in International Conference in Research on Air Transport ICRAT 2008, Conference Proceedings, Fairfax/ Virginia (USA), 1-4 June, 2008

ATRS 08, *Influence of Cooperation between Airport Partners During Aircraft Turn-round Operation,* in World Meeting of the Air Transport Research Society ATRS 2008, Conference Proceedings, Athens/ Greece, 6-10 July, 2008.

ENRI 09, Paper acceptance at Electronic Navigation Research Institute International Workshop *Applying Cognitive Work Analysis to Study Airport-Collaborative Decision Making,* 7-8th May 2009 in Tokyo, Japan

HFES 09, Paper acceptance at Annual Conference of Human Factors and Ergonomics Society HFES Europe, *Applying Work Domain Analysis to Study Airport Collaborative Decision Making,* 14th -16th October in Linkoeping, Sweden

Journal of Air Transport Science(2009), *Applying Functional Analysis to Study the Airline Flight crew's Perspective on Human-Human Interactions During Flight Operation*, Journal of Air Transport Studies, Vol. 1(1), January 2010, p 62-81, Hellenic Aviation Society, Greece.

INO 2009, *Monitoring the Airport-CDM Turn-Round Process: Applying a Qualitative Cognitive Model Based on Field Observations,* Innovative Workshop INO 2009 in Brétigny/ France, 1-3 December, 2009.

EUROCONTROL DOC., 2010, *Field Observations during Airport-CDM Turn-Round Process: Study on Airline's Approach to TOBT Assignment*, available at www.euro-cdm.org, EUROCONTROL Documentation, Brussels

ATRS 10, *Monitoring the Airport-CDM Turn-Round Process: Applying a Qualitative Cognitive Model Based on Field Observations*, 14th ATRS Conference, Porto, Portugal

EAAP 2010, *Aviation Safety During Aircraft Turn-Round Process: Applying a Qualitative Cognitive Model Based on Field Observations*, The 29th Conference on Performance, Safety and Well-being in Aviation, Conference Proceedings, Budapest/ Hungary, 20-24 September, 2010

EICWAC 2010, *Field Observations During Aircraft Turn-Round: Applying a Qualitative Cognitive Model* , The second ENRI International Workshop on ATM/CNS(*EIWAC 2010*), Conference Proceedings, Tokyo/Japan, 10-12 November 2010

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APPENDICES

APPENDIX I: Description of the A-CDM Milestones

Milestone 1	ATC Flight Plan Activated
Definition	The ICAO flight plan is submitted to ATC. The Airport CDM Platform is initiated for this flight, and all available information is processed
Origin and priority	The ATC Flight Plan is submitted by the Aircraft Operator and distributed by the IFPS. All involved ATC units receive the flight plan, including departure and destination aerodromes.
Timing	Normally this takes place 3 hours before EOBT, however it may be later. In some cases a repetitive flight plan (RFPL) has been submitted, covering daily or weekly flights.
Data Quality	The ATC Flight Plan corresponds to the airport slot programme.
Effect	One aircraft turn-round normally includes an arriving and a departing flight, meaning that it will have two related flight plans. For coordinated airports, the outbound flight is already known. The flight plan may be used to update certain information such as type of aircraft. For long distance flights, the ELDT may differ from the airport slot. For non coordinated airports, the flight plan is used to initiate the outbound flight. The flight is ready not later than 15 minutes after the planned EOBT. The DPI process commences the correct messaging with CFMU (if implemented - see attachment 2 for details).
Procedures	To check consistency between ATC Flight Plan, Airport Slot and Airport flight data and then confirm the flight to the CFMU and allow further local processing of the flight. This check shall be performed to verify the consistency between the ATC Flight Plan, Airport Slot and Airport flight data before the first E-DPI is sent. The AO must provide correct information before this first E-DPI message, in order to feed CFMU with consistent SOBT, aircraft registration, and first destination data, as early in time as possible. The E-DPI message should not be sent if no or inconsistent information is provided. This process is triggered by: • The first activation of the ATC Flight Plan (earliest EOBT-3 hr), or • New or late submissions of the ATC Flight Plan, after cancellation or revised EOBT
Operational Status	SCHEDULED
Action on CDM Operation (ACISP)	ELDT and EIBT updated for an arrival EOBT and ETOT updated for a departure The DPI process commences (if implemented - see section 3.7.3 for details).

Milestone 2	EOBT – 2h
Definition	At EOBT-2 hr most flights will be known in the Airport CDM Platform including if they are regulated or not. All regulated flights receive a CTOT from CFMU.
Origin and priority	The CTOT is issued by the CFMU and is sent to relevant ATS units as well as the departure aerodrome. CTOT flights usually have a priority over unregulated flights.
Timing	If the flight is regulated, a CTOT is issued at EOBT-2h.
Data Quality	Not applicable.
Effect	For inbound flights, ELDT is updated based on information provided by the FUM messages, taking into account the actual progress of the flight.
Procedures	To check (before or after takeoff from outstation) whether AO/GH flight estimates are consistent with the ATC Flight Plan and to inform CFMU about the updated take off time estimate, using a T-DPI Message. This check shall be performed to verify feasibility of the ATC Flight Plan estimated off block time at EOBT-2 hrs. At EOBT-2 hrs CFMU is informed through the first T-DPI message. Calculation basis for the TTOT shall take into account EIBT+MTTT+EXOT, if later than EOBT+EXOT. In the case of manual input of TOBT, this estimate will override the E1BT+MTTT estimate, hence TTOT equals TOBT+EXOT. This procedure is triggered by • A time stamp, at EOBT - 2h.
Operational Status **(changes to)**	N.A.
Action on CDM Operation (ACISP)	ETOT/TTOT/CTOT Mark appropriate fields as REGULATED

Milestone 3	**Take Off from Outstation**
Definition	The ATOT from the outstation (ADEP)
Origin and priority	The outstation provides ATOT to the CFMU and Aircraft Operator.
Timing	The information is directly available after occurrence of the milestone.
Data Quality	The accuracy of ATOT is +/- 1 minute.
Effect	If the departure airport is more than 3hrs flying time from the destination airport the ATOT is received from either the CFMU FUM or via the Aircraft Operator / Ground Handler. Using the ATOT an ELDT can be calculated by using the Estimated Elapsed Time on the FPL. If the flight is within 3hrs flying time of the destination airport the CFMU monitors progress of the flight using the ETFMS and send a Flight Update Message (FUM) that provides updates of the flight's progress.
Procedures	To check whether the AO/GH estimated landing time after take off from outstation are consistent with the outbound ATC Flight Plan, and when needed inform the CFMU about the updated take off time estimates using a T-DPI-c Message. This check shall be performed to verify feasibility of the ATC Flight Plan at take off from outstation. A TTOT tolerance of 5 minutes is respected before CFMU is informed of the updated TTOT. Calculation basis for the TTOT shall take into account EIBT+MTTT+EXOT. In case EOBT is later than EIBT+MTTT, TTOT equals EOBT+EXOT. In the case where TOBT is available this prediction will overrule the EIBT+MTTT estimate, hence TTOT equals TOBT+EXOT. This process is triggered by • the take off from outstation.
Operational Status (changes to)	AIRBORNE
Action on CDM Operation (ACISP)	ELDT, EIBT, TOBT and TTOT updated

Milestone 4	**Local Radar Update**
Definition	The flight enters the FIR (Flight Information Region) or the local airspace of the destination airport.
Origin and priority	This information is normally available from the Area Control Centre (ACC) or Approach Control Unit that is associated with an airport. The radar system is able to detect a flight based upon the assigned SSR code when the flight crosses a defined FIR/ATC boundary.
Timing	Dependent upon the position of the airport in relation to the FIR boundary.
Data Quality	Must be equal to the accuracy of the ATC system.
Effect	Update of the ELDT can trigger a new TOBT to be entered by the AO/GH, or calculated automatically by the Airport CDM Platform. The accuracy of ELDT is particularly important at this stage since downstream decisions are taken, such as stand /gate / aircraft changes, preparation of arrival sequence, preparation of ground handling operations, decisions for connecting passengers. Uncertainty and ELDT non-accuracy at this stage significantly increase risks for bad and last minute decisions and internal disruptions. The objective to decrease the number of stand and gate changes in the last 30 minutes requires high accuracy regarding departure and arrival times. Therefore, taking into account the taxi-in time (EXIT), any change to a stand or gate is not preferred after ELDT-30'. The update of TOBT for the related departing flight takes place following this milestone. Decisions such as the turn-round period, connecting passengers etc are taken and need to be sTable at this event. An estimated in-block time (EIBT) is computed using the ELDT and the estimated taxi-in time.
Procedures	To commence the TOBT process and check whether the AO/GH TOBT is consistent with the ATC Flight Plan. CFMU is informed when the TTOT changes by more than the agreed TTOT tolerance. This check shall be performed to verify feasibility of the ATC Flight Plan given the updated TOBT. The TTOT tolerance is respected before CFMU is informed of updated TTOT. This process is triggered by • the detection of the flight by radar in either FIR, TMA, or on Final Approach.
Operational Status (changes to)	FIR
Action on CDM Operation (ACISP)	ELDT, EIBT, TOBT and TTOT updated

Milestone 5	Final Approach
Definition	The flight enters the Final Approach phase at the destination airport.
Origin and priority	This information is normally available from ATC. The radar system detects a flight based upon the assigned SSR code and identifies when the flight crosses either a defined range / position or passes/leaves a predetermined level.
Timing	Dependent upon local parameters that are defined by ATC.
Data Quality	Must be equal to the accuracy of the ATC system.
Effect	Update of the ELDT to determine a new TOBT. When a flight reaches this stage it is usually between 2 and 5 minutes from landing (depending on the parameter set by ATC). This is often the prompt for many partners to start moving resources connected with the flight, such as positioning a parking marshal and ground handling services.
Procedures	To commence the TOBT process and check whether the AO/GH TOBT is consistent with the ATC Flight Plan. CFMU is informed when the TTOT changes by more than the agreed TTOT tolerance. This check shall be performed to verify feasibility of the ATC Flight Plan given the updated TOBT. The TTOT tolerance is respected before CFMU is informed of updated TTOT. This process is triggered by • The detection of the flight by radar in either FIR, TMA, or on Final Approach.
Operational Status **(changes to)**	FINAL
Action on CDM Operation (ACISP)	ELDT, EIBT, TOBT and TTOT updated EOBT and ETOT updated for a departure The DPI process commences (if implemented - see section 3.7.3 for details).

Milestone 6	**Landed**
Definition	ALDT - Actual Landing Time. This is the time that an aircraft touches down on a runway. (Equivalent to ATC ATA - Actual Time of Arrival landing, ACARS=ON).
Origin and priority	Provided by ATC system or by ACARS from equipped aircraft.
Timing	The information is directly available after occurrence of the milestone.
Data Quality	Data is available with an accuracy of +/-1 minute.
Effect	The occurrence of ALDT triggers an update of downstream estimates: TOBT and TTOT are updated automatically or inserted manually by the Aircraft Operator / Ground Handler, calculated on the basis of the defined turn-round period for the departing flight. The EIBT can be updated according to the ALDT +EXIT.
Procedures	To check whether the AO/GH TOBT is consistent with the ATC Flight Plan. CFMU is informed when the TTOT changes by more than the agreed TTOT tolerance. This check shall be performed to verify feasibility of the ATC Flight Plan given the updated TOBT or ATC Flight Plan. A TTOT tolerance is respected before CFMU is informed on updated TTOT. This process is triggered by • Actual Landing Time: ALDT
Operational Status **(changes to)**	LANDED
Action on CDM Operation (ACISP)	ELDT changes to ALDT, EIBT, TOBT and TTOT updated

Milestone 7	**In-Block**
Definition	AIBT - Actual In-Block Time. This is the time that an aircraft arrives in-blocks. (Equivalent to Airline/Handler ATA - Actual Time of Arrival, ACARS = IN) *Note: ACGT is considered to commence at AIBT*
Origin and priority	ACARS equipped aircraft or automated docking systems or ATC systems (e.g. A-SMGCS) or by manual input.
Timing	The information is directly available after occurrence of the milestone.
Data Quality	Data is available with an accuracy of +/-1 minute.
Effect	The occurrence of AIBT should trigger an update of downstream estimates: TOBT and TTOT are updated automatically or inserted manually by the Aircraft Operator / Ground Handler, calculated on the basis of the estimated turn-round period for the departing flight.
Procedures	To check whether the AO/GH TOBT is consistent with the ATC Flight Plan. CFMU is informed when the TTOT changes by more than the agreed TTOT tolerance. This check shall be performed to verify feasibility of the ATC Flight Plan given the updated TOBT or ATC Flight Plan. A TTOT tolerance is respected before CFMU is informed on updated TTOT. This process is triggered by • Actual In Blocks Time: AIBT
Operational Status **(changes to)**	IN-BLOCK
Action on CDM Operation (ACISP)	EIBT changes to AIBT TOBT and TTOT updated

Milestone 8	**Ground Handling Started**
Definition	Commence of Ground Handling Operations (ACGT). Note: this milestone is specific to flights that are the first operation of the day or that have been long term parked. For flights that are on a normal turn-round ACGT is considered to commence at AIBT.
Origin and priority	Aircraft Operator / Ground Handler will provide the information.
Timing	The information is directly available after occurrence of the milestone.
Data Quality	Data is available with an accuracy of +/-1 minute.
Effect	The occurrence of ACGT triggers an update of downstream estimates: TOBT is updated automatically or inserted manually by the Aircraft Operator / Ground Handler, calculated on the basis of the estimated turn-round period for the departing flight.
Procedures	To check whether the AO/GH TOBT is consistent with the ATC Flight Plan. CFMU is informed when the TTOT changes by more than the agreed TTOT tolerance. This check shall be performed to verify feasibility of the ATC Flight Plan given the updated TOBT or ATC Flight Plan. A TTOT tolerance is respected before CFMU is informed on updated TTOT. This process is triggered by • Actual Commence of Ground Handling: ACGT
Operational Status **(changes to)**	IN-BLOCK
Action on CDM Operation (ACISP)	ETTT/ TTOBT, TTOT updated

Milestone 9	Final Confirmation of the TOBT
Definition	The time at which the Aircraft Operator or Ground Handler provide their most accurate TOBT taking into account the operational situation.
Origin and priority	The Aircraft Operator / Ground Handler provides the information.
Timing	The information is provided t minutes before EOBT (t is a parameter time agreed locally).
Data Quality	Accuracy is agreed locally.
Effect	The aim of the final TOBT is to give a timely, accurate and reliable assessment of the off-block time. It is recognised that main benefits of sharing the TOBT are expected in case of disruptions (internal or external). In such cases, the difference between EOBT (shared by ATC, CFMU and Stand / Gate Management) and TOBT may be important. An accurate TOBT at [EOBT-t minutes] is a pre-requisite for ATC to establish a push back / pre-departure sequence. Emphasis is put on the need for the Aircraft Operator to integrate his own strategy to compute a TOBT related to the flight. Following the receipt of the TOBT, the ATC system will calculate and provide the Estimated Taxi-Out Time (EXOT) based on the predicted traffic load, gate / stand location, runway in use, and waiting period at the Holding Position, etc. The flight is introduced into the pre-departure sequence. The Aircraft Operator / Ground Handler, in coordination with the aircrew, can manage the turn-round process according toly.
Procedures	To check whether the AO/GH TOBT is consistent with the ATC Flight Plan. CFMU is informed when the TTOT changes by more than the agreed TTOT tolerance. This check should be performed at a predefined time (local parameter) to confirm TOBT prior to TSAT issue and verify feasibility of the ATC Flight Plan estimates given the updated TOBT. A TTOT tolerance is respected before CFMU is informed on updated TTOT. This Milestone Process is actually constantly applicable in the CDM Platform, as soon as a TOBT is available. However the confirmed TOBT prior to TSAT has special status, where AO/GH check the quality of TOBT before TSAT issue. This process is triggered by a new TOBT or TTOT update. No need to confirm an existing TOBT if it has been manually modified before.
Operational Status	SEQUENCED
Action on CDM Operation	TTOT updated.

Milestone 10	**TSAT Issued**
Definition	The time ATC issues the Target Start Up Approval Time.
Origin and priority	ATC
Timing	The information is provided t-minutes before EOBT, where t is a parameter agreed locally.
Data Quality	Accuracy is agreed locally.
Effect	The flight is stabilised into the pre-departure sequence. The Aircraft Operator/ Ground Handler, in coordination with the aircrew, can manage the turn-round process according toly.
Procedures	First step: To inform all relevant partners of the TSAT that has been allocated to the flight. The CFMU is informed by a T-DPI-s for non regulated flights. Second step: To check whether the number of TOBT updates exceeds a tolerance defined locally, after TSAT has been issued. First: The TSAT will indicate to the partners the time when the start up approval can be expected. CFMU will be informed with a T-DPI-s for non regulated flights. No check is performed. Second: A check shall be performed to see the number of TOBT updates after TSAT has been issued. In case the number of TOBT updates exceeds a threshold, then the TOBT input should be processed according to local procedure. This process is triggered by • A defined time (local parameter) before TOBT • TOBT update after TSAT issue
Operational Status **(changes to)**	N.A.
Action on CDM Operation (ACISP)	TTOT updated

Milestone 11	Boarding Starts
Definition	The gate is open for passengers to physically start boarding (independent of whether boarding takes place via an air-bridge/pier, aircraft steps or coaching to a stand). This is not to be confused with the time passengers are pre-called to the gate via flight information display systems (FIDS) or public address systems.
Origin and priority	Automatic from airport system or manual input by Aircraft Operator/ Ground Handler.
Timing	The information is directly available after occurrence of the milestone.
Data Quality	Data is available with an accuracy of +/-1 minute.
Effect	When boarding commences it gives the Airport CDM Partners a good indication of whether the TOBT/TSAT will be respected.
Procedures	First step: To inform all relevant Airport CDM Partners of Actual Start Boarding Time (ASBT). . Second step: To check whether boarding starts in time to respect TOBT and inform the AO/GH in case TOBT needs to be updated. Inform of Actual Start Boarding Time (ASBT) when it occurs. At a certain time before TOBT (local variable e.g. corresponding to aircraft type) a check shall be performed to check the boarding status. This process is triggered by • a time variable <value> minutes before TOBT.
Operational Status (changes to)	BOARDING
Action on CDM Operation (ACISP)	N.A.

Milestone 12	Aircraft Ready
Definition	The time when all doors are closed, boarding bridge removed, push back vehicle connected, ready to taxi immediately upon reception of TWR instructions (ARDT).
Origin and priority	Provided by the Aircraft Operator/ Ground Handler.
Timing	The information is directly available after occurrence of the milestone.
Data Quality	Data is directly available with an accuracy of +/-1 minute.
Effect	ATC refines the pre-departure sequence. The flight crew requests start up just before TSAT, following coordination with the Ground Handler. (Dispatcher / Supervisor / Redcap).
Procedures	First step: To inform all relevant Airport CDM Partners of Actual Ready Time (ARDT) in the Airport CDM Platform and that the aircraft is ready for start up / pushback. Second step: To inform the AO/GH that TOBT has passed and the Airport CDM Platform has not yet received ARDT or Ready Status (RDY). Inform of ARDT or RDY confirming that the flight follows the indicated TOBT. At TOBT + tolerance the AO/GH are informed that TOBT has passed and there has not been a ready status message yet. This procedure is triggered by • An input to the Airport CDM Platform.
Operational Status (changes to)	READY
Action on CDM Operation (ACISP)	N.A.

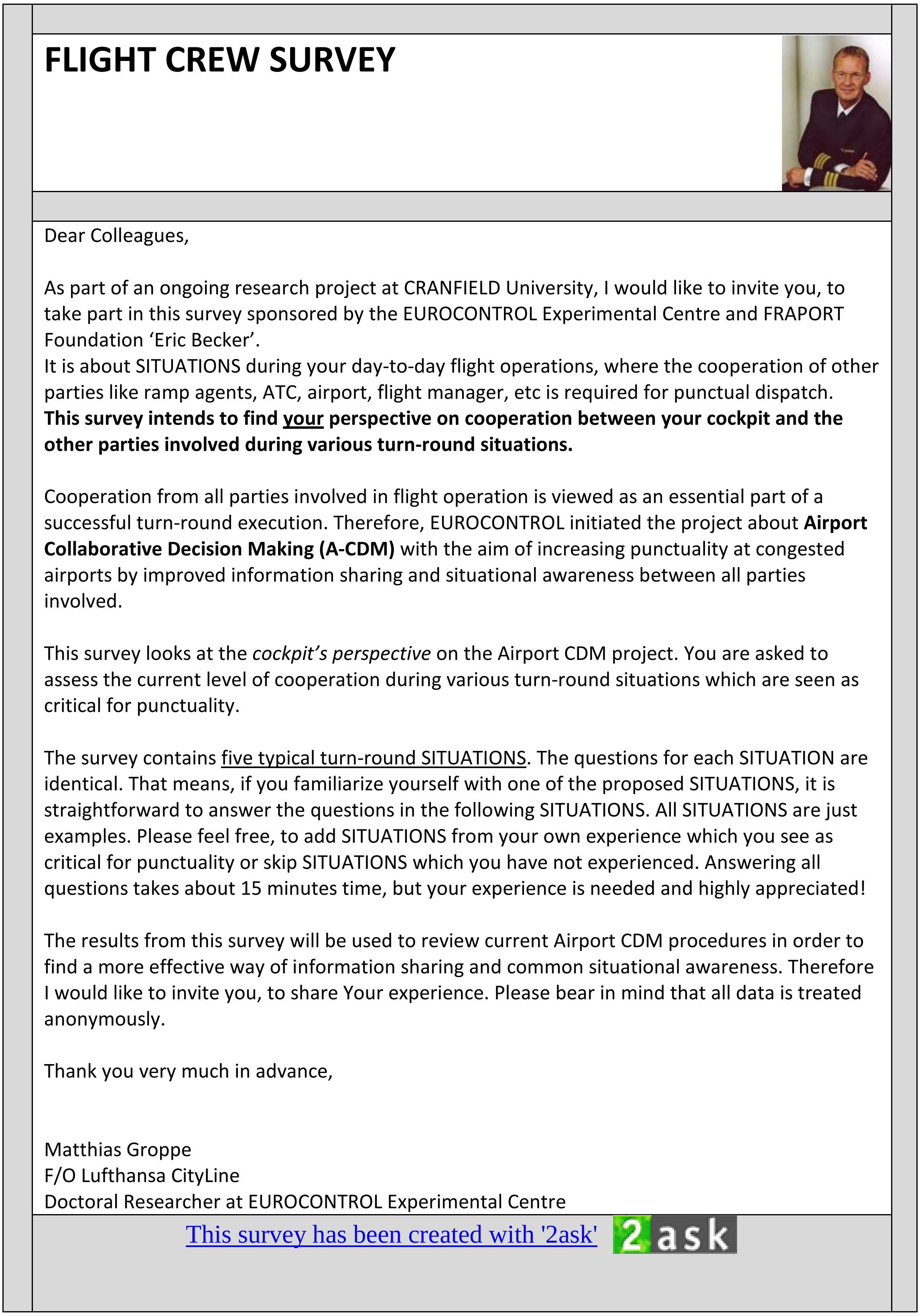
Milestone 13	**Start Up Requested**
Definition	The time that start up is requested (ASRT).
Origin and priority	ATC (based on flight crew request).
Timing	The information is directly available after occurrence of the milestone.
Data Quality	Data is available with an accuracy of +/-1 minute.
Effect	ATC confirms TSAT to the flight crew in order to maintain the aircraft in the pro-departure sequence. Provided the aircraft was ready on time (ARDT), it is now up to ATC to assure that a regulated flight can respect its CTOT.
Procedures	First step: To inform all relevant Airport CDM Partners of Actual Start up Request Time (ASRT) in the Airport CDM Platform. Second step: to alert all relevant Airport CDM Partners when no start up has been requested inside the locally agreed TSAT tolerance window. Inform of ASRT when it occurs. If the start up request is not made by TSAT + tolerance, the AO/GH is informed that no start up has been requested, and should update TOBT. Timestamp when the tolerance window has passed at TSAT.
Operational Status (changes to)	N.A.
Action on CDM Operation (ACISP)	N.A.

Milestone 14	**Start Up Approved**
Definition	ASAT - Actual start up Approval Time. This is the time that an aircraft receives its start up approval.
Origin and priority	ATC
Timing	The information is directly available after occurrence of the milestone.
Data Quality	Data is available with an accuracy of +/-1 minute.
Effect	On receipt of ATC approval, the aircraft will start up, push back and start to taxi.
Procedures	First Step: All relevant Airport CDM Partners are informed of Actual start up approval Time (ASAT) in the Airport CDM Platform and that the aircraft has received start up approval / pushback clearance. Second step: To check if ASAT is in accordance to TSAT and to alert all relevant Airport CDM Partners when no start up has been granted. Inform of ASAT when it occurs. In case the start up approval is not granted at TSAT + tolerance, all relevant partners should be informed. The flight will be re-sequenced. Start up request by flight crew (voice or DCL) or a locally defined time around TSAT if Milestone Process 13 is omitted.
Operational Status (changes to)	N.A.
Action on CDM Operation (ACISP)	N.A.

Milestone 15	Off-Block
Definition	AOBT - Actual Off-Block Time. The time the aircraft pushes back/vacates the parking position (Equivalent to Airline/Handler ATD - Actual Time of Departure ACARS=OUT).
Origin and priority	ACARS equipped aircraft or automated docking systems or ATC systems (e.g. A-SMGCS) or by manual input.
Timing	The information is directly available after occurrence of the milestone.
Data Quality	Data is available with an accuracy of +/-1 minute.
Effect	TTOT updated considering the EXOT.
Procedures	First step: To inform all relevant Airport CDM Partners of Actual Off-Block Time (AOBT) in the Airport CDM Platform and that the aircraft has commenced pushback / taxi from parking position. Second step: To check if TTOT changes by more than the agreed tolerance and inform CFMU. Inform of AOBT when it occurs. AOBT always triggers an A-DPI message to CFMU or in the case of remote holding at a defined time prior to TTOT. After a first A-DPI is sent this check shall be performed to check TTOT updates against the TTOT tolerance before CFMU is informed, with a new A-DPI, of the updated TTOT. This process is triggered by AOBT detection.
Operational Status (changes to)	OFF-BLOCK
Action on CDM Operation (ACISP)	AOBT recorded

Milestone 16	ATC Flight Plan Activated
Definition	ATOT - Actual Take Off Time. This is the time that an aircraft takes off from the runway. (Equivalent to ATC ATD-Actual Time of Departure, ACARS = OFF).
Origin and priority	Provided by ATC system or from ACARS equipped aircraft.
Timing	The information is directly available as soon as possible after occurrence of the milestone.
Data Quality	Data is available with an accuracy of +/-1 minute.
Effect	FSA and MVT messages are sent.
Procedures	To inform all relevant Airport CDM Partners about the actual take off. An airborne message is generated and the flight is removed from the departure sequence. This process is triggered by Tower FDPS, A-SMGCS / Radar detection or ACARS.
Operational Status (changes to)	DEPARTED / TAKE OFF
Action on CDM Operation (ACISP)	ATOT recorded

APPENDIX II: Flight Crew Survey



FLIGHT CREW SURVEY

Dear Colleagues,

As part of an ongoing research project at CRANFIELD University, I would like to invite you, to take part in this survey sponsored by the EUROCONTROL Experimental Centre and FRAPORT Foundation 'Eric Becker'.
It is about SITUATIONS during your day-to-day flight operations, where the cooperation of other parties like ramp agents, ATC, airport, flight manager, etc is required for punctual dispatch.
This survey intends to find your perspective on cooperation between your cockpit and the other parties involved during various turn-round situations.

Cooperation from all parties involved in flight operation is viewed as an essential part of a successful turn-round execution. Therefore, EUROCONTROL initiated the project about **Airport Collaborative Decision Making (A-CDM)** with the aim of increasing punctuality at congested airports by improved information sharing and situational awareness between all parties involved.

This survey looks at the *cockpit's perspective* on the Airport CDM project. You are asked to assess the current level of cooperation during various turn-round situations which are seen as critical for punctuality.

The survey contains five typical turn-round SITUATIONS. The questions for each SITUATION are identical. That means, if you familiarize yourself with one of the proposed SITUATIONS, it is straightforward to answer the questions in the following SITUATIONS. All SITUATIONS are just examples. Please feel free, to add SITUATIONS from your own experience which you see as critical for punctuality or skip SITUATIONS which you have not experienced. Answering all questions takes about 15 minutes time, but your experience is needed and highly appreciated!

The results from this survey will be used to review current Airport CDM procedures in order to find a more effective way of information sharing and common situational awareness. Therefore I would like to invite you, to share Your experience. Please bear in mind that all data is treated anonymously.

Thank you very much in advance,

Matthias Groppe
F/O Lufthansa CityLine
Doctoral Researcher at EUROCONTROL Experimental Centre

This survey has been created with '2ask'

FLIGHT CREW SURVEY

SITUATION I: You have just landed at your destination and your parking stand is still occupied. Please recall any of your more recent flights:

When were you notified of that your parking stand is not yet available?		○	After landing
		○	During flight
		○	I did not encounter a situation like this
How long did you have to wait for your parking stand?		○	1-5 minutes
		○	6- 10 minutes
		○	11 - 15 minutes
		○	16- 20 minutes
		○	More than 20
What was the impact on departure delay for the flight after the turn-round		○	1-5 minutes
		○	6- 10 minutes
		○	11 - 15 minutes
		○	16- 20 minutes
		○	More than 20
Do you think this delay would be avoidable through timely notification of *'parking stand problems'*? (e.g. because it allows you to take an appropriate initiative)		○	Very unlikely
		○	Unlikely
		○	Likely
		○	Very Likely
How often does this happen		○	Daily
		○	Weekly
		○	Monthly
		○	Irregularly
What could be the reason(s) for this waiting time/ delay?	Competing Interests among functions responsible for the allocation of the parking stand such as airport, airline, or ground handling	○	Very unlikely
		○	Unlikely
		○	Likely
		○	Very likely
	Not enough parking stands available	○	Very unlikely
		○	Unlikely
		○	Likely
		○	Very likely
	Competence of responsible function/ individual	○	Very unlikely
		○	Unlikely
		○	Likely
		○	Very likely
Any Comments?			

SITUATION II: Delay of a Ground Handling Process: Please recall your last turn-round where you encountered such a delay:	
Please choose one event which you would like to refer to:	
○ Baggage loading/ unloading	○ Airport Facilities
○ Ramp transfer bus (Crew or Passengers)	○ Wheelchair Boarding
○ Catering	○ UM Boarding
○ Cleaning	○ Special Loading (e.g. musical instrument)
○ Fuelling	○ VIP Boarding
○ Check-in	○ I cannot recall encountering a situation like this (please
○ Security	○ Other Ground Handling event (please name)
○ Boarding	

How were you notified of the delay?		○	You were duly informed about the problem
		○	You learned about it yourself, having observed that the process was not executed or you received information too late
How much delay resulted from this lack of information?		○	1-5 minutes
		○	6- 10 minutes
		○	11 - 15 minutes
		○	16- 20 minutes
		○	More than 20 minutes
What was the impact on departure delay for the flight after the turn-round		○	1-5 minutes
		○	6- 10 minutes
		○	11 - 15 minutes
		○	16- 20 minutes
		○	More than 20 minutes
Do you think this delay would be avoidable through timely notification of *'ground handling problems'* (e.g. through taking appropriate initiatives)?		○	Very unlikely
		○	Unlikely
		○	Likely
		○	Very Likely
How often does this happen		○	Daily
		○	Weekly
		○	Monthly
		○	Irregularly
What could be the reason(s) for this waiting time/ delay?	Competing interests among responsible functions like airport, airline, or handling service provider	○	Very unlikely
		○	Unlikely
		○	Likely
		○	Very likely
	Not enough resources available (e.g.personnel, vehicles, check-in desk...)	○	Very unlikely
		○	Unlikely
		○	Likely
		○	Very likely
	Competence of responsible function/ individual	○	Very unlikely
		○	Unlikely
		○	Likely
		○	Very likely
Any Comments?			

SITUATION III: You got operational changes at your destination (e.g. aircraft change, technical repair, crew duty changes….) Please consider your last turn-round where you encountered such situation:	
Please choose one event which you would like to refer to:	
○ Aircraft Change	○ I cannot recall encountering a situation like this (please
○ Technical Repair	○ Other Ground Handling event (please name)
○ Crew Duty Change (new duty roster)	
○ Crew Change (new crew member)	

How were you notified of the delay?		○	Before Departure
		○	During Flight
		○	After Arrival at Destination
How much additional time did you need because of this?		○	1-5 minutes
		○	6- 10 minutes
		○	11 - 15 minutes
		○	16- 20 minutes
		○	More than 20 minutes
Because of this, was there an impact on departure delay for the flight after the turn-round?		○	1-5 minutes
		○	6- 10 minutes
		○	11 - 15 minutes
		○	16- 20 minutes
		○	More than 20 minutes
Do you think this delay would be avoidable through timely notification of 'operational changes? (e.g. because it allows you to take an appropriate initiative)		○	Very unlikely
		○	Unlikely
		○	Likely
		○	Very Likely
How often does this happen		○	Daily
		○	Weekly
		○	Monthly
		○	Irregularly
What could be the reason(s) for this waiting time/ delay?	Competing interests among responsible functions like airport, airline, or handling service provider	○	Very unlikely
		○	Unlikely
		○	Likely
		○	Very likely
	Not enough resources available (e.g.personnel, vehicles, check-in desk...)	○	Very unlikely
		○	Unlikely
		○	Likely
		○	Very likely
	Competence of responsible function/ individual	○	Very unlikely
		○	Unlikely
		○	Likely
		○	Very likely
Any Comments?			

SITUATION IV: You have yourself proposed operational changes (e.g. via ACARS, telephone, radio…). Please recall your last flight or turn-round where you encountered such a situation			
Your proposal was about: (please choose one situation)			
○ Necessary technical repair during turnaround			○ I cannot recall encountering a situation like this (Please
○ Connecting passenger			○ Other Ground Handling event (please name)
○ Avoidance of an unnecessary Aircraft Change			
Consequences from your proposal:		○	Your proposal was considered (you got an answer on your proposal)
		○	Your proposal was not considered (no reaction on your proposal)
How much extra time did you spend because your proposal was not considered?		○	1-5 minutes
		○	6- 10 minutes
		○	11 - 15 minutes
		○	16- 20 minutes
		○	More than 20 minutes
Because of this, was there an impact on departure delay for the flight after the turn-round?		○	1-5 minutes
		○	6- 10 minutes
		○	11 - 15 minutes
		○	16- 20 minutes
		○	More than 20 minutes
Do you think this delay (if relevant) would be avoidable through *‘timely reaction on your proposal’*? (e.g. because it allows you to take an appropriate initiative)		○	Very unlikely
		○	Unlikely
		○	Likely
		○	Very Likely
How often does this happen		○	Daily
		○	Weekly
		○	Monthly
		○	Irregularly
What could be the reason(s) for this waiting time/ delay?	Competing interests among responsible functions like airport, airline, or handling service provider	○	Very unlikely
		○	Unlikely
		○	Likely
		○	Very likely
	Not enough resources available (e.g.personnel, vehicles, check-in desk...)	○	Very unlikely
		○	Unlikely
		○	Likely
		○	Very likely
	Competence of responsible function/ individual	○	Very unlikely
		○	Unlikely
		○	Likely
		○	Very likely
Any Comments?			

GENERAL: DECISION MAKING	
Do you think it would be an advantage if the flight crew is more involved in decision making for operational issues in flight or during the turn-round?	
○ Yes, please give reason	
○ No, please give reason	

GENERAL: PROBLEMS DURING TURN-ROUND		
If problems arise during turn-round: what do you think could be the reasons? (please rate):		
Turn-Round Time too short?	○	Very unlikely
	○	Unlikely
	○	Likely
	○	Very Likely
Delays result from information overload: more important information is hidden among less important information?	○	Very unlikely
	○	Unlikely
	○	Likely
	○	Very Likely
Inappropriate distribution of responsibilities (e.g. decision making…)?	○	Very unlikely
	○	Unlikely
	○	Likely
	○	Very Likely
Inappropriate or insufficient communication facilities (radio, intercom…)?	○	Very unlikely
	○	Unlikely
	○	Likely
Other Reason? **(please name)**		

GENERAL INFORMATION		
Please name the company you are working for:		
How many years of experience do you have as	Captain	First Officer
I would like to remind you that all information is treated completely anonymously. Many thanks for your participation!		

APPENDIX III: IATA Commonly Used Airline Delay and Diversion Codes

Numeric	Alphabetic	Description
Airline Internal Codes		
00		IATA has recommended that these codes are used by individual airline to develop code definition that meet their specific requirements: e.g. 03 ‘Three-class-System’ moving curtain Note: At time of writing the IATA Recommendation AHM 730 does NOT suggest any Alphabetic Equivalents fro these codes
01		
02		
03		
04		
05		
Others		
06	OA	NO STAND/GATE AVAILABILITY DUE TO OWN AIRLINE ACTIVITY
Schedules		
09	SG	SCHEDULED GROUND TIME LESS THAN DECLARED MINIMUM
Passenger and Baggage		
11	PD	LATE CHECK-IN; acceptance after deadline
12	PL	LATE CHECK-IN; congestion in check-in area
13	PE	CHECK-IN ERROR; passenger and baggage
14	PO	OVERSALES; booking errors
15	PH	BOARDING; discrepancies and paging, missing checked-in passenger
16	PS	COMMERCIAL PUBLICITY; PASSENGER CONVENIENCE, VIP, press,
17	PC	CATERING ORDER; late or incorrect order given to supplier
18	PB	BAGGAGE PROCESSING; sorting, etc.
Cargo and Mail		
If delays caused by Mail handling can be identified use the Mail specific codes in the next section (27-29), otherwise use the codes detailed below (21-26)		
21	CD	DOCUMENTATION; errors, etc.
22	CP	LATEPOSITIONING
23	CC	LATE ACCEPTANCE
24	CI	INADEQUATE PACKING
25	CO	OVERSALES; booking errors
26	CU	LATE PREPARATION IN WAREHOUSE
Mail Only		
27	CE	DOCUMENTATION; PACKING; etc.
28	CL	LATE POSITIONING
29	CA	LATE ACCEPTANCE
Aircraft and Ramp Handling		
31	GD	AIRCRAFT DOCUMENTATION/INACCURATE; weight and balance, general declaration, pax manifest, etc.
32	GL	LOADING/UNLOADING; bulky, special load, lack of loading staff
33	GE	LODADING EQUIPMENT; lack of or breakdown, e.g. container pallet loader, lack of staff
34	GS	SERVICING EQUIPMENT; lack or breakdown, lack of staff, e.g.steps

35	GC	AIRCRAFT CLEANING
36	GF	FUELLING/ DEFUELLING; fuel supplier
37	GB	CATERING; late delivery or loading
38	GU	ULD, lack or serviceability
39	GT	TECHNICAL EQUIPMENT; lack or breakdown, lack of staff, e.g. push-back

Numeric	Alphabetic	Description
Technical and Aircraft Equipment		
41	TD	AIRCRAFT DEFECTS
42	TM	SCHEDULED MAINTENANCE; late release
43	TN	NON-SCHEDULED MAINENTANCE, special checks and/or additional works beyond normal maintenance schedule
44	TS	SPARES AND MAINTENANCE EQUIPMENT; lack of or breakdown
45	TA	AOG SPARES, to be carried to another station
46	TC	AIRCRAFT CHANGE, for technical reasons
47	TL	STANDBY AIRCRAFT, lack of planned standby aircraft for technical reasons
48	TV	SCHEDULED CABIN CONFIGURATION VERSION ADJUSTMENTS
Damage to Aircraft		
51	DF	DAMAGE DURING FLIGHT OPERATIONS, bird or lightning strike, turbulence, heavy or overweight landing, collision during taxing
52	DG	DAMAGE DURING GROUND OPERATIONS, collisions (other than during taxiing), loading/off-loading damage, contamination, towing, extreme weather conditions
Automated Equipment Failure/ EDP (Computer System)		
55	ED	DEPARTURE CONTROL
56	EC	CARGO PREPARATION/ DOCUMENTATION
57	EF	FLIGHTPLANS
Flight Operations and Crewing		
61	FP	FLIGHT PLAN, late completion or change of flight documentation
62	FF	OPERATIONAL REQUIREMENTS, fuel, load alteration
63	FT	LATE CREW BOARDING OR DEPARTURE PROCEDURES, other than connection and standby (flight deck or entire crew)
64	FS	FLIGHT DECK CREW SHORTAGE; sickness, awaiting standby, flight time limitations, crew meals, valid visa, health documentations, etc.
65	FR	FLIGHT DECK CREW SPECIAL REQUEST, not within operational requirements
66	FL	LATE CABIN CREW BOARDING OR DEPARTURE PROCEDURES, other than connection and standby
67	FC	CABIN CREW SHORTAGE, sickness, awaiting standby, flighttime limitations, crew meals, valid visa, health documents, etc.
68	FA	CABIN CREW ERROR OR SPECIAL REQUEST, not within operational requirements
69	FB	CAPTAINS REQUEST FOR SECURITY CHECK, extraordinary
Weather		
71	WO	WEATHER AT DEPARTURE STATION

72	WT	WEATHER AT DESTINATION STATION
73	WR	WEATHER EN ROUTE OR ALTERNATE
75	WI	DE-ICING OF AIRCRAFT, removal of ice and/or snow, frost prevention excluding unserviceable equipment
76	WS	REMOVAL OF SNOW, ICE, WATER AND SAND FROM AIRPORT
77	WG	GROUND HANDLING IMPARED BY ADVERSE WEATHER CONDITIONS

Numeric	Alphabetic	Description
Air Traffic Flow Management Restrictions		
81	AT	ATFM DUE TO ATC EN-ROUTE DEMAND/CAPACITY, standard demand/capacity problems
82	AX	ATFM DUE TO ATC STAFF/EQUIPMENT EN-ROUTE, reduced capacity caused by industrial action or staff shortage or equipment failure, extraordinary demand due to capacity reduction in neighbouring area
83	AE	ATFM DUE TO RESTRICTION AIRPORT, airport and/or runway closed due to obstruction, industrial action, staff shortage, political unrest, noise abatement, night curfew, special flights
84	AW	ATFM DUE TO WEATHER AT DESTINATION
Airport and Governmental Authorities		
85	AS	MANDATORY SECURITY
86	AG	IMMIGRATION, CUSTOMS, HEALTH
87	AF	AIRPORT FACILITIES, parking stands, ramp congestion, lighting, buildings, gate limitations, etc.
88	AD	RESTRICTIONS AT AIRPORT OF DESTINATION, airport and/or runway closed due to obstruction, industrial action, staff shortage, political unrest, noise abatement, night curfew, special flights
89	AM	RESTRICTIONS AT AIRPORT OF DEPARTURE WITH OR WITHOUT ATFM FESTRICTIONS; including Air Traffic Services, start-up and push-back, airport and/or runway closed due to obstruction or weather (restriction due to weather in case of AFTM regulation only, else refer to code 71)
Reactionary		
91	RL	LOAD CONNECTION, awaiting load from another flight
92	RT	THROUGH CHECK-IN-ERROR, passenger and baggage
93	RA	AIRCRAFT ROTATION, late arrival from another flight or previous sector
94	RS	CABIN CREW ROTATION, awaiting cabin crew from another flight
95	RC	CREW ROTATION, awaiting crew from another flight (flight deck or entire crew)
96	RO	OPERATIONS CONTROL, rerouting, diversion, consolidation, aircraft change for reasons other than technical
Miscellaneous		
97	MI	INDUSTRIAL ACTION WITHIN OWN AIRLINE
98	MO	INDUSTRIAL ACTION OUTSIDE OWN AIRLINE, excluding ATS
99	MX	NOT COVERED BY ANY OTH OTHER DEFINED CODES

APPENDIX IV: Currently Used Turn-round Monitoring Tools

A number of tools with real-time turn-round process monitoring capabilities are currently available. However, none of the tools have predictive functionalities allowing TOBT predictions.

1 GroundStar HubControl as process monitoring tool by INFORM GmbH, Aachen

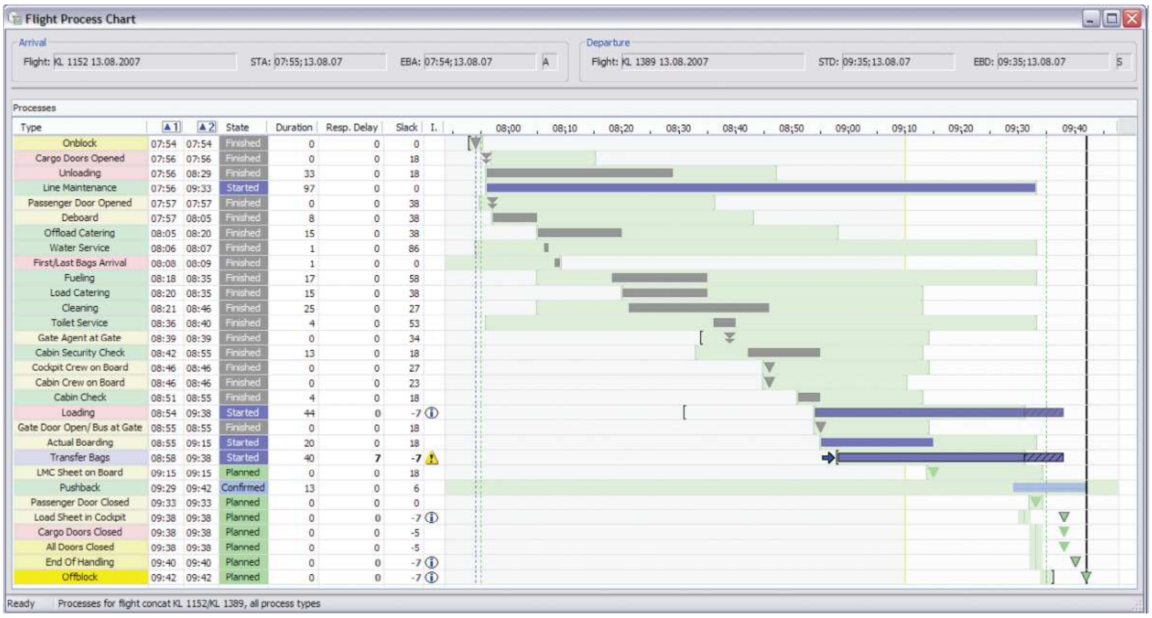
GroundStar HubControl claims itself as a process-monitoring tool able to identify factors that may negatively affect a seamless turn-round and to evaluate their impact on the turn-round operation. Characteristics of HubControl are:

- provision of operational transparency via significant pre-warning times;
- identification and prevention of bottlenecks for aircraft, passenger, and baggage handling.

According to company information, between 100 million and 170 million Euro of cost is attributed to delay with one fourth that can be attributed to ground handling. HubStar describes itself as a generic product able to adapt to any turn-round operation.

GroundStar HubControl also claims being able to monitor the concatenation of correlated handling tasks for turn-round flights, arrivals and departures, to identify the critical path and in doing so, supplying all decision-support information required. It detects actual delays and their reasons; delay durations are calculated automatically. It is able to produce warnings for predictable irregularities in handling processes and to offer various resolution options at the same time.

Figure 42 shows a possible depiction of HubControl where all processes during turn-round are displayed with a colour-code indicating the allocation of the process according to airlines’ requirements. The right half of the display shows the timeline indicating the temporal sequence and duration of the ground handling processes. Processes can be added or removed analogous the requirements of the airline. Real-time tracking as well as process start/completion are colour-coded.



Flight: KL 1152 13.08.2007 STA: 07:55;13.08.07 EBA: 07:54;13.08.07 A

Flight: KL 1389 13.08.2007 STD: 09:35;13.08.07 EBD: 09:35;13.08.07 S

Type	▲1	▲2	State	Duration	Resp. Delay	Slack	I.
Onblock	07:54	07:54	Finished	0	0	0	
Cargo Doors Opened	07:56	07:56	Finished	0	0	18	
Unloading	07:56	08:29	Finished	33	0	18	
Line Maintenance	07:56	09:33	Started	97	0	0	
Passenger Door Opened	07:57	07:57	Finished	0	0	38	
Deboard	07:57	08:05	Finished	8	0	38	
Offload Catering	08:05	08:20	Finished	15	0	38	
Water Service	08:06	08:07	Finished	1	0	86	
First/Last Bags Arrival	08:08	08:09	Finished	1	0	0	
Fueling	08:18	08:35	Finished	17	0	58	
Load Catering	08:20	08:35	Finished	15	0	38	
Cleaning	08:21	08:46	Finished	25	0	27	
Toilet Service	08:36	08:40	Finished	4	0	53	
Gate Agent at Gate	08:39	08:39	Finished	0	0	34	
Cabin Security Check	08:42	08:55	Finished	13	0	18	
Cockpit Crew on Board	08:46	08:46	Finished	0	0	27	
Cabin Crew on Board	08:46	08:46	Finished	0	0	23	
Cabin Check	08:51	08:55	Finished	4	0	18	
Loading	08:54	09:38	Started	44	0	-7	ⓘ
Gate Door Open/ Bus at Gate	08:55	08:55	Finished	0	0	18	
Actual Boarding	08:55	09:15	Started	20	0	18	
Transfer Bags	08:58	09:38	Started	40	**7**	**-7**	⚠
LMC Sheet on Board	09:15	09:15	Planned	0	0	18	
Pushback	09:29	09:42	Confirmed	13	0	6	
Passenger Door Closed	09:33	09:33	Planned	0	0	0	
Load Sheet in Cockpit	09:38	09:38	Planned	0	0	-7	ⓘ
Cargo Doors Closed	09:38	09:38	Planned	0	0	-5	
All Doors Closed	09:38	09:38	Planned	0	0	-5	
End Of Handling	09:40	09:40	Planned	0	0	-7	ⓘ
Offblock	09:42	09:42	Planned	0	0	-7	ⓘ

Processes for flight concat KL 1152/KL 1389, all process types

FIGURE 42: GUI FOR TURN-ROUND PROCESSES (SOURCE: INFORM, 2009)

2 ALLEGRO as a process monitoring tool by Lufthansa German Airlines

Until launch of this tool, no time-oriented information was available for ground handling processes. The target of ALLEGRO was to gather information with focus on timeliness of turn-round processes between in-block and off-block time. Landside and airside processes were analysed in order to identify required measurement points where timestamps can be set (Figure 43). The measurement points are indicated by the little triangles.

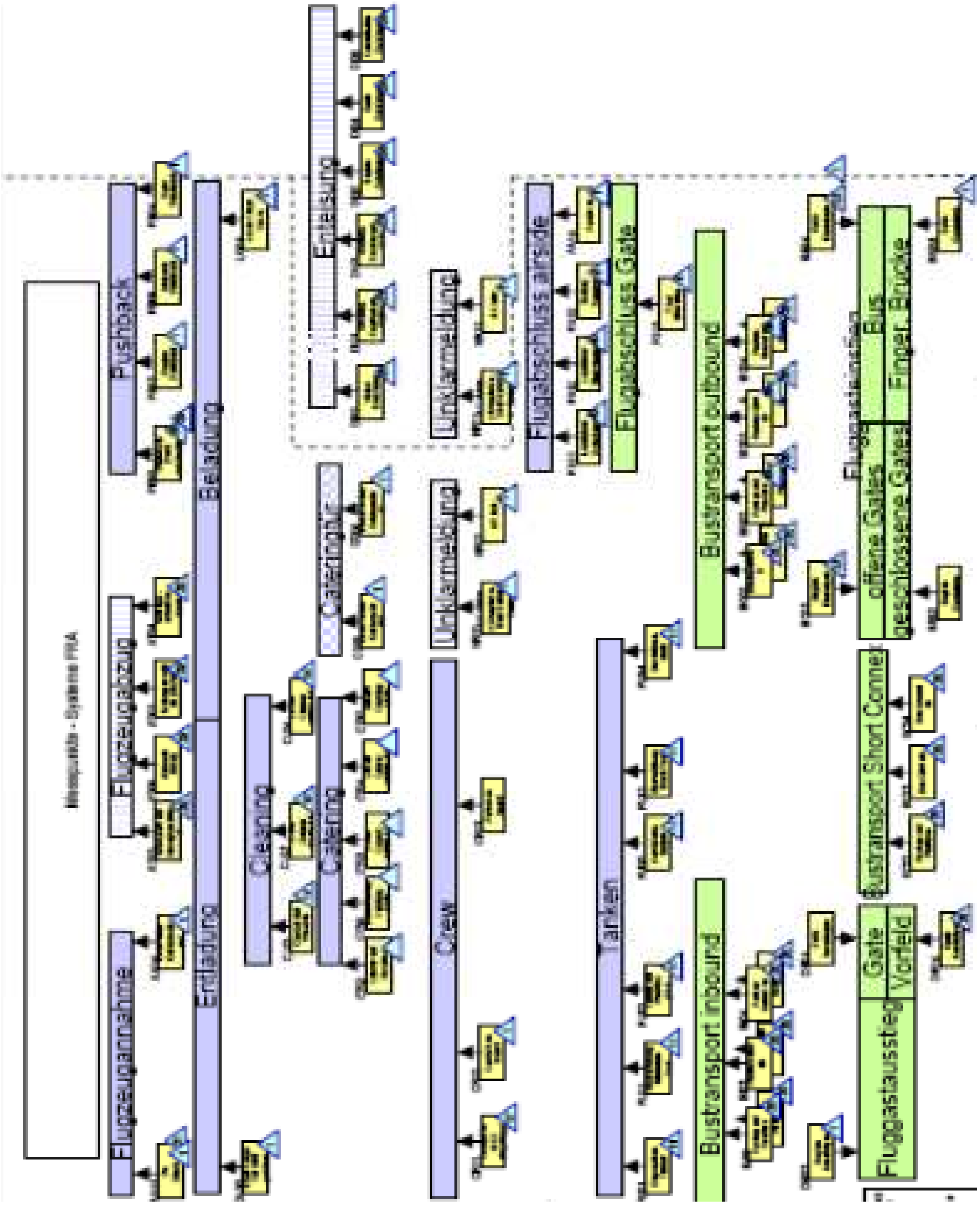


FIGURE 43: DEFINED TURN-ROUND MEASUREMENT POINTS (SOURCE: LUFTHANSA, 2004)

Defined target times are flexible and include buffer times in order to incorporate delays of preceding processes. The underlying objective for development of this tool was to identify the root causes of delays.

The tool should also provide:

- a better ground handling transparency;
- the base for debriefings with operational staff;

- the base for performance agreements with internal and external service partners;
- the base for analyses by A/C type, by gate, by A/C position, by day of week, etc;
- the reduction of spot checks and thereby cost of surveys;
- the validation of target times; and
- the base for inductive definition of minimum ground times.

APPENDIX V: Further Results from Literature Study

1 Factors influencing Cooperation

1.1 Organisational Structure

Artman (1999) describes cooperative situations as ‘team-think’ and analyses cooperation and situation awareness within different teams. He demonstrated that serial teams engage more in cooperating activities than parallel teams which can result in problems for coordination. This is in line with findings from Brehmer and Svenmarck (1995) who claim that a hierarchical organisation of information distribution results in a better performance than an organisation where all participants can talk to everybody else. As a possible reason for this differences in performance levels he identifies that a central unit does not only collect and organize information, but understands the overall situation and plans for appropriate actions.

1.2 Information Sharing and Conceptual Design

Within the Computer Supported Cooperative Work (CSCW) research initiative, Davis (2000) studied *information flows* as the basis for creating shared information spaces on a web-based repository system that can be used to support asynchronous distributed collaborative work. He claims that a systematic approach uses a global perspective of information flows in the organisation with continuous participation of the end users. This allows him to uncover the complex technical and organisational requirements for effective acceptance and use of IT tools.

Shouqian et al (2003) studied models and techniques of computer supported cooperative *conceptual design* for motorcycles. Hoc et al (2002) analysed the demands of task and function’ allocation on human-machine cooperation design from a psychological perspective; Rogalski (1996) analysed the cooperation process and how cooperation can evolve during training.

1.3 Generative Models for Cooperation among Operators

When conflict resolution in terms of operators' preferences and values is not possible during face-to-face or synchronous communication, a representation of operators' proposition in form of a *generative model* was introduced by Jameson et al (2003). The underlying idea thereby is that, during asynchronous communication, operators have a poor awareness of how *other* operators' tackle the problems that they jointly face because of the inherent difficulties of the media typically available during asynchronous communication. During such situations, a computational model of operators' relevant beliefs, preferences, motivations, and other relevant properties as *operators' representative* should be used (Figure 44).

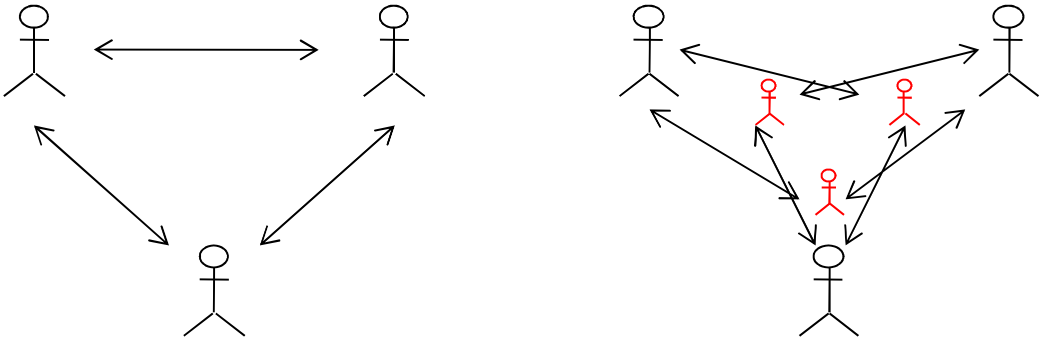


FIGURE 44: GENERATIVE PREFERENCES MODEL (SOURCE: JAMESON ET AL, 2003)

1.4 Influence of Explanation on Cooperation

Karsenty et al (1995) emphasized the role of *explanation* for the study of cooperation where little consideration has been placed so far and studied explanation in cooperation via human-human cooperative dialogues. Gregor (2000) catches up with explanations for the analysis of the *role* of explanation when knowledge-based systems are used for cooperative problem solving. Both argue in favour of an increased need for explanation.

1.5 Human-Computer Interaction and Cooperation

Focus of the Computer Supported Cooperative Work (CSCW) research has been placed on the interaction design and decision support. It was recognized that *cooperation theories and models* are an important aid for CSCW systems. Most central there are the *Activity Theory*, *Action/Interaction Theory, Coordination Theory,* the *Task Manager Model*, and the *Object-Oriented Activity Support Model* (De Farias et al, 1999). De Farias denotes that these different models and theories have a set of common concepts and uses these commonalities for developing a new model based on these similarities and strengths. The identified generic concepts among all models include activities, actors, services, and information which should be used to develop cooperative systems.

1.6. The Role of Performance Metrics for Cooperation

Performance metrics can be useful for favouring cooperation and driving operators' behaviour. E.g., during turn-round management, the IATA delay codes are used as performance metrics. These however, do not show appropriate characteristics to foster cooperation across participating functions. For ROI (2004) it is crucial that performance measures should be *horizontally* and not *vertically* integrated and be linked with the company's mission, vision, and value proposition. They should also be actionable and within that manager's span of control. Hence, if vertical integration of metrics prevails, all the measures of success for a supplier are only aligned along *traditional* functional lines. However, if horizontal integration of metrics is present the measures of success for an area look *across* functional boundaries to search for the effect on a process as a whole. Usage of horizontally integrated metrics can prevent sub-optimization by seeking to measure the success of a function by its impact on the process as a whole. But this raises the question of what to measure during process management. E.g. how can suppliers be aware what *their* contribution is to accomplishing the objectives of the company?

1.7 Cooperation via Cascading Key Performance Indicators

ROI (2004) propose the implementation of a technique called ‘KPI cascade’. This should ensure that measures which are required to accomplish the mission, vision, and value proposition of the organisation, are in place at all levels allowing a company to eliminate metrics that no longer have value. ROI identifies a number of advantages resulting from suitable performance metrics:

- avoidance of sub-optimization;

- alignment within and between functional areas;
- understanding of what is and what is *not* important to achieve the company objectives;
- a "holographic" set of measures describing the health of a process; and
- measures that are actionable and assigned at the appropriate level.

Cascading KPIs have been proposed by ROI (2004) that are able to link the performance management strategies of the company to these KPIs. In such way, they create a process that is suitable for the *overall* outcome and not just the outcome of a single supporting process. E.g. the A-CDM key performance indicators could be cascaded into particularized KPIs, thus set the latter KPIs and target them to the processes and procedures that contribute to the overall success. Such form of cultural change with KPIs primarily for the whole company will require compensation processes for the supplying companies and also requires performance levels allowing the supplying companies to meet their own objectives. Miller (1996) proposes to use causal relationships in order to make supplying companies comprehend the overall goal and the meaning behind the importance of the key performance indicators.

1.8 Influence of the Goal Structure on Cooperation

Nezamirad et al. (2005) proposed a model that includes all individual actors’ and operators’ goals, tasks, and resources towards the establishment of group goals and group tasks. Figure 46 shows a possible application of this model to A-CDM and TOBT prediction. This representation allows an analysis of goal structures as an iterative refinement process: first, all participating operators’ local goals towards the collaborative goal have to be identified (Figure 45). The results should then be used to analyse how these local goals influence the overall goals and the global goal. The local goals should be continuously re-defined using the underlying sub-goals of each participating operator. This allows getting a more realistic view on the individual operators’ goals which in turn influence the group goals. Using this form of analysis helps to identify the sub-goals which have negative or positive impact on the global goal or group goals.

Furthermore, this approach combined with the cascading performance indicators as proposed in Sub-Chapter 1.7 may allow identifying how the local operators' goals can look like and how the global goal can be achieved:

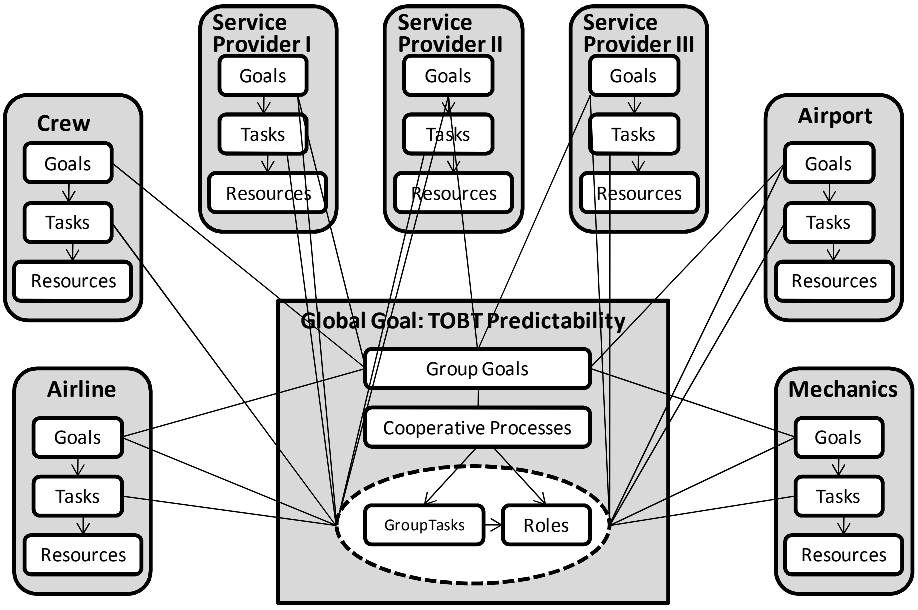


FIGURE 45: COOPERATION MODEL ANALOGOUS NEZAMIRAD (2005) APPLIED TO A-CDM

As cooperation continues, operators identify group goals based on their individual goals and group knowledge. As the management of a process is dynamically entwined with the elaboration and maintenance of group knowledge, the goal structures are dynamic, e.g. focus of sub-goal C1 shifts the importance of sub-goal C2 which again may change the outcome of the global goal. Also the relationship between the group and individual goal structures is a recursive and cooperative process, e.g. as global goal changes, the individual goals may be amended or revised.

Operators work together at different levels and forms of work. When looking at different levels of abstraction towards a process, goal structures and therefore cooperative activities are different for each situation which again has consequences on the overall global goal. Nezamirad et al (2005) emphasizes the importance that operators are aware of goals of other participants in order to allow them to anticipate events or to plan resources.

1.9 The Different Levels of Cooperation

Ferber (1995) discusses cooperation as only *one* possible category of human-human interaction situation (micro-level analysis). However, focus can also be applied on the social-organisational and cross-functional organisational aspects during interaction situations (macro-level analysis). Typical characteristics here are e.g. the cognitive factors related to common goals, influencing operators' goals by other operators, control issues, types- and models of communication, influence of knowledge based behaviour on other operators, or the role of incentives. A macro-level situation results from combinations of micro-level situations with emergent characteristics (Figure 46) where again the macro-situation imposes social constraints on the micro-level situation (Ferber, 1995).

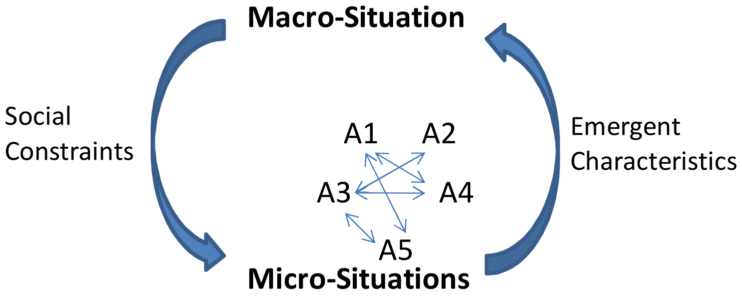


FIGURE 46: RELATION BETWEEN COOPERATION SITUATIONS (SOURCE: FERBER, 1995)

1.10 Further Aspects on Cooperation

Most theories about cooperation have looked at the interest of actors to cooperate with other actors (e.g. Axelrod, 1984) or communication in groups or teams (Stoetzel, 1978; Hoc, 2004). Research within multi-agent systems however looks to cognitive aspects and behavioural aspects required for implementation of cooperative acting (Demazeau and Mueller, 1991; Durfee et al, 1987; Galliers, 1991; Castelfranchi and Conte, 1991; Bouron, 1992).

The notion of cross-organisational cooperation emphasizes a holistic aspect of cooperation. While at task execution or human-human interaction level cooperation emerges from goal, motive, and the instrumental condition (Leontyev, 1959), the holistic perspective of cross-organisational cooperation includes also other influences. According to ROI (2004), three components are required for successful management across functions and organisations, including appropriate management performance metrics, periodic cross-functional management meetings, and inter-organisational communication channels. Thereby, a cross-functional system is defined as *a 'coalitional structure whose member groups maintain their separate identities and, if relevant, different goals, yet employ either some formal organisation or informal collaboration for joint decision making or problem solving'* (Cummings, 1984). Such a coalitional structure can be found during turn-round management decision making.

Studies by Winograd and Flores (1986), and Suchman (1987) started to provide radically different orientations for HCI with the introduction of new ideas of how to think about the design of computer systems. Frameworks like the activity theory, originating in Soviet psychology, have also been applied for interface design. With the emergence of the Computer Supported Cooperative Work (CSCW) as a new field in the mid 80's, the HCI community realized the need to support groups of people communicating and working together, but did not take cognitive perspectives into account. Inspired by Suchman's work, scientists started to conduct ethnographic studies of technology-mediated collaborative work (e.g. studies of Suchman and Trigg, 1991). The main findings of these studies showed how important informal working practices can be for the coordinating work and managing of unanticipated events.

Piaget (1965) distinguishes between cooperation seen from a structural (e.g. network organisation) and functional point of view and 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 of the actors strives towards goals and can interfere with other actors on goals, resources, and procedures. (2) Each actor tries to manage interferences to facilitate individual activities or common tasks. Both conditions are not necessarily symmetric, because goal orientation or interference management depend on individual behaviour or time constraints.

In the context of Air Traffic Management (ATM) Hoc (2001) argues that current ATM is more concerned with operators' plans, goals, or role allocation than with common situational awareness. Lee (2005) determines situational awareness, responsibilities and control, time, workload, and safety constraints as key factors driving collaborative behaviour in air traffic control operation: *To have proper awareness of the situation, a controller and/or flight crew needs to initiate or be informed of actions taken by other operators*. Nevertheless, time pressure and safety issues have negative effect on communication behaviour and therefore also on cooperation or common situational awareness.

Collaborative Decision Making means *applying principles of individual decision making on groups, whereby groups are established with the aim to show collectively a specific behaviour (Jennings et al, 2001)*. This implies that cooperation of participating individuals should be beneficial for CDM operation, also in air transport management. How does a cooperative working environment look like on a day-to-day basis? Cooperation has *a wide variety of connotations in everyday usage (Schmidt, 1994)*. Do people only cooperate, if they are mutually dependant in their work? Is mutual dependency sufficient for cooperation to emerge? In context of CDM operation, confrontation and the combination of different perspectives of cooperation is an issue: how is the flight crew's perspective embedded in the current CDM approach? For Schmidt (1994), the multifarious nature of a task can be matched by the application of multiple perspectives on a given problem via articulation of these perspectives and transforming/ translating information from different domains.

2 Aspects of Distributed Cognition and Distributed Decision Making

2.1 Introduction

The Distributed Cognition theory was used to model the A-CDM work system (See Chapter 4). This approach showed potential not only to analyse, how coordination and cooperation of the various subsystems during interdependent work practices are established or how information is currently shared within the system, but also allowed to include the *environment* as a factor influencing the individuals when executing their tasks.

Another prevailing advantage of *distributed cognition* is that the theory can accommodate the rich variety of systems and media inherent in organisations' or groups' cognitive processes like within A-CDM. Since the unit of analysis is not committed to a fixed value, the entire system can be decomposed into the smaller, functional groups. However, Nardi (2002) and Rogers (2000) argue that analysis towards distributed cognition approach cannot generally be used: a low-level distributed cognition analysis will not enhance engineering practices for building design applications. Also the theoretical perspective is committed to ethnographical data collection: a substantial investment is required to actually apply the theory to any specific issue (Hutchins, 1994; Hollan et al, 2000).

2.2 The Distributed Cognition Theory

Distributed Cognition is a hybrid approach to studying all aspects of cognition, from a cognitive, social, *and* organisational perspective. It attempts to understand how cognitive phenomena are distributed across individuals and artefacts (e.g. how tools like computers can be used for solving problems). It emphasizes the fact that cognition does not lie strictly within the individual, but instead is an emergent, distributed activity, performed by people with tools, within the context of a team or organisation, in an evolved cultural context. Because of its focus on the *whole* environment, it gives the theory a special role in understanding interactions between people and technology. This includes *what* people do and *how* they coordinate activities in their environment, and so provides a radical reorientation about the design and support of human-computer interactions.

2.3 Background of Distributed Cognition

Distributed cognition was developed in the mid 1980s by Edwin Hutchins at the University of California, San Diego as a *theoretical and methodological framework*. While the traditional view saw cognition as a *localized* phenomenon that is best explained in terms of information processing at the level of the individual interacting with applications derived from decomposition of work activities into individual tasks, Hutchins argues that cognition does not strictly lie within the individual. Distributed cognition tends to reach of what is considered cognitive *beyond* the individual to encompass interactions between people with resources and materials in the environment.

The theoretical and methodological approaches to distributed cognition derive from cognitive sciences, cognitive anthropology, and the social sciences. Traditional frameworks however were developed separately from respective disciplines (cognitive, social, and organisational). Therefore, they do not provide an adequate means of studying dynamics of collaborative activities in situ. As a consequence, distributed cognition emerged from this need to better understand the dynamics of human-computer interaction within a complex networked world of information and computer-mediated interactions (Hollan et al, 2000).

After the theory was established, the challenge was to integrate concepts from social and organisational sciences with the cognitive analysis of micro-level descriptions from individuals' interactions. Even with the distributed cognition approach has been able to provide analysis for problems experienced by individual users of awkward-to-use interfaces, the lack of consideration on those problems has led to a HCI design that is unable to support people using computer-based interaction systems. For Hollan et al (2000) this new approach is a radical reorientation of how to think about designing and supporting HCIs during complex tasks, and how to ensure human-centred focus. Such support should be achieved by extending the scope of the cognitive perspective beyond the individual to comprise human-human interactions with resources in such an environment in which people pursue their goals in collaboration with elements of the social and material world.

The distributed cognition approach can also be distinguished from others by its commitment to two principles: it looks for cognitive processes on the basis of the *functional* relationships of elements (e.g. a process is not cognitive simply because it happens in a brain, nor is a process non-cognitive simply because it happens in the interaction among many brains). Second principle concerns the *range*: distributed cognition does not limit cognitive events to reside at an individual only, but also the physical environment of thinking or material world can reorganize the distributed cognitive system.

Hollan et al (2000) describe three kinds of distribution of the cognitive process:

- Cognitive processes may be distributed across the members of a social group.
- Cognitive processes may involve coordination between internal and external (material or environmental) structure.
- Processes may be distributed through time in such a way that the products of earlier events can transform the nature of later events.

The first tenet of *socially distributed* cognition was already determined in the 1970s by Roberts (Hollan et al, 2000) and studied by anthropologists, sociologists, and artificial intelligence researchers. This approach studied a social organisation itself as a cognitive architecture with the consequence that cognition of an individual is also distributed. According to Hollan et al (2000), the new approach to distributed cognition however integrates phenomena that emerge in social interactions with interactions of people and structure in their environment. He highlights three fundamental questions in this context: (1) how are the cognitive processes that we normally associate with an individual mind implemented in a group of individuals, and (2) how are the cognitive properties of groups differing from the cognitive properties of the people who act in those groups, and (3) how are the cognitive properties of individuals minds affected by participation in group activities.

The second tenet is the approach that cognition is an *embodied* phenomenon and not an incidental matter. This approach is increasingly supported by Brooks (1991), Kirsh (1991), and Lakoff (1999) who emphasize the relations between internal and external processes. Such relations involve coordination at many different time scales between internal resources like memory, attention, and external resources like objects or artefacts.

The third tenet is that *studies of culture cannot be separated* from studies of cognition. While on one hand culture emerges out of human activities in their historical context, on the other hand culture shapes cognitive processes through the history of material artefacts and social practices (Hutchins, 1994). As a result, culture cannot be isolated or separated from cognition and so shapes the cognitive processes of systems that transcend the boundaries of individuals (Hutchins, 1994). This includes the notion that the environment constitutes as a reservoir of resources for learning, problem solving, and reasoning.

2.4 Distributed Cognition as Integrated Framework for Research

For the research in cognitive science and the design of new forms of human-computer interactions, Hollan et al (2000) proposes an integrated research framework which puts together the core principles of the theory with classes of phenomena that serve the relations with these principles as an assemble of an completed integrated research system (Figure 47).

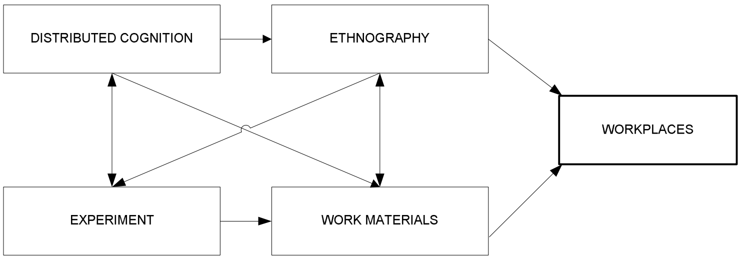


FIGURE 47: INTEGRATED RESEARCH ACTIVITY MAP (SOURCE: HOLLAN ET AL, 2000)

Core principles of an integrated framework include e.g.:

- people which establish and coordinate different types of structure in their environment;
- maintaining coordination requires an effort; and
- social organisations hold improved dynamics of cognitive load-balancing available.

These principles are used to identify classes of phenomena via cognitive ethnography e.g. (1) information flow or cognitive properties, to make experiments, or

(2) for demonstrating the impact of changes, where the distributed cognition principles, the ethnographic data, and the experiments mutually constrain each other.

2.5 Methods used by the Framework of Distributed Cognition

An analysis using the Distributed Cognition Framework comprises a number of different methods ranging from detailed analysis via video or audio recordings of real life events to neural network simulations and laboratory experiments. The method used for analysis depends on the unit of analysis and the level at which a cognitive system is being explained.

A proper analysis requires focus on the relations and interactions between the individual and the artefacts, and a profound knowledge of analysed system domain. This entails going to the workplace and spending time determining and analysing the problems with the existing technology and work practices (Rogers, 1994). The central unit of analysis is the *functional system* which essentially is a collection of individuals and artefacts as well as their relations to each other in a particular work practice (Rogers et al, 1994). However, it is possible to adopt different units of analysis to describe a range of cognitive systems; whereby some subsume others (Hutchins, 1995). Focus is on the nature of distributed activities: how is information propagated through and across artefacts, and how is knowledge transmitted between individual members of a team or group.

A distributed cognition analysis requires also an increased attention on the *abstract* functional relations in order to develop a framework for modelling and design (Rasmussen et al, 1994). Traditionally work systems are analysed by using a structural perspective which focuses on a causal interaction among parts. That means elements of analysis are arranged in cause-and-effect chains and the characteristics are determined by their output. This way may be true for machines, however human actors do not have such stable input-output characteristics because humans may change their characteristics or behaviour, and modelling human-machine systems cannot be accomplished in isolation. This means, in order to understand system behaviour where humans are involved, the *entire system* has to be contemplated and structural elements of the system have to be abstracted at a purely *functional level* in order to identify functional relations. Additionally, in order to make the functional relation more effective, the actor should not be assigned to specific behaviour, but a space bounded by the goal and resource constraints (Rasmussen et al, 1994).

Other issues which constitute important properties of distributed cognition are the access to information and dynamic aspects of activities: shared access together with shared knowledge is the basis for coordinated actions. Thereby the means of knowledge propagation is focusing on dynamic aspects of the activities rather than static entities. Rogers (1994) emphasizes the need to describe in increasing detail the seemingly trivial and usually taken for granted aspects of interactions (micro-level analysis) since they often play a crucial role in coordination of work activities. Additionally there are always situations emerging during day-to-day working activities where the members of the group are required to carry out additional tasks. This results in new coordination procedures giving additional aspects on the carried out interactions.

2.6 Related Research Using the Distributed Cognition Framework

A wide spectrum of approaches to apply distributed cognition can be found having analysed cognitive phenomena. Most of the attention has focused on cognitive systems of work practices, e.g. engineering, cockpits, ship navigation, software development in order to design interfaces between humans and/or humans and computers (e.g. Burns, 2000; Burns, Bryant and Chalmers, 2000; Dinadis and Vicente, 1999; Gualtieri, Elm, Potter and Roth, 2001).

2.7 Summary and Discussion

A general advantage of the distributed cognition approach is that it provides a framework and analytic method for examining the interactions between people and artefacts which is not possible with traditional approaches to cognitive task analyses (Roger, 1994). Prevailing thereby is the advantage that the theory can accommodate the rich variety of systems and media inherent in an organisation’s or groups cognitive processes. Complex interdependencies between people and people and artefacts in their collaborative activities can be highlighted, and since the unit of analysis is not committed to a fixed value, the entire system can be decomposed into the smaller, functional groups that make it up. As a result, seemingly trivial communication failures or interaction problems can be detected having significant and sometimes dramatic consequences for the operation of a system.

APPENDIX VI: The CWA and Critical Aspects for Application to A-CDM

1 Characteristics of the CWA

Cognitive Work Analysis has a number of characteristics which distinguish CWA from other forms of analysis. These include:

- *Formative Approach:* a formative analysis intends to identify the technological and organisational requirements that need to be satisfied, in order to create interfaces able to support work effectively. It focuses on modelling work constraints instead of design of devices. This means, it looks on the way thinks could be done, rather than should be done like the normative approach, or on the way how things are like the descriptive approach. *"Understanding the structure of work leads to supporting work at the level of structure, which rarely changes, and suggests structural changes that radically improve the work"* (Vicente, 1999). A formative approach is also model based which means it allows for flexibility and continuing evolution of work practices, rather than building in a fixed and narrow work flow. As a consequence, interface device structure supports worker's natural movement through his work and is flexible enough to allow the invention of new ways of working (Beyer and Holtzblatt, 1998 in Vicente).
- *Flexible Adaptive Action*: Due to the demands of a complex socio-technical system, unexpected situations occur, where workers must respond with adaptive, problem solving behaviour tailored to the local context. E.g. during turn-round management, actors are faced with such situations and do not have appropriate support from computer-based information systems. CWA emphasizes an interface design which is able to support actors during such unpredictable contingencies.
- *Ecological Perspective:* CWA is based on an ecological approach which gives primary importance to the constraints imposed by the environment on workers' actions. This is in contrast to the more popular approach where focus is applied on the constraints of the human cognitive system. Even those constraints are relevant as well, the design process for CWA starts with consideration of the ecological constraints (Flach, 1990; Hancock et.a., 1988).

- *Activity independent:* The first phase of the CWA is the Work Domain Analysis as an activity independent form of analysis which focuses on the functional structure of the work domain rather than the activities within the domain. This is achieved by mapping out the functional, but activity independent properties of the work domain at five levels of abstraction and multiple levels of decomposition.
- *Revolutionary Design:* Since evolutionary design is based on the analysis of current practices leading to a design that supports that practice, revolutionary design however creates opportunities for the development of new and more efficient work practices.
- *Practicality for unanticipated situations:* CWA incorporates an analysis approach which is able to handle unpredictable events, because it is able to reveal the intentional as well as the physical constraints on actions.

2 The CWA – Control Task Analysis and Decision Ladder

A. Description of the Decision Ladder

Rasmussen et al (1994) proposes the decision ladder (Figure 48) as a modelling template for control tasks. He has developed the decision ladder based on his field studies on operators from nuclear industry.

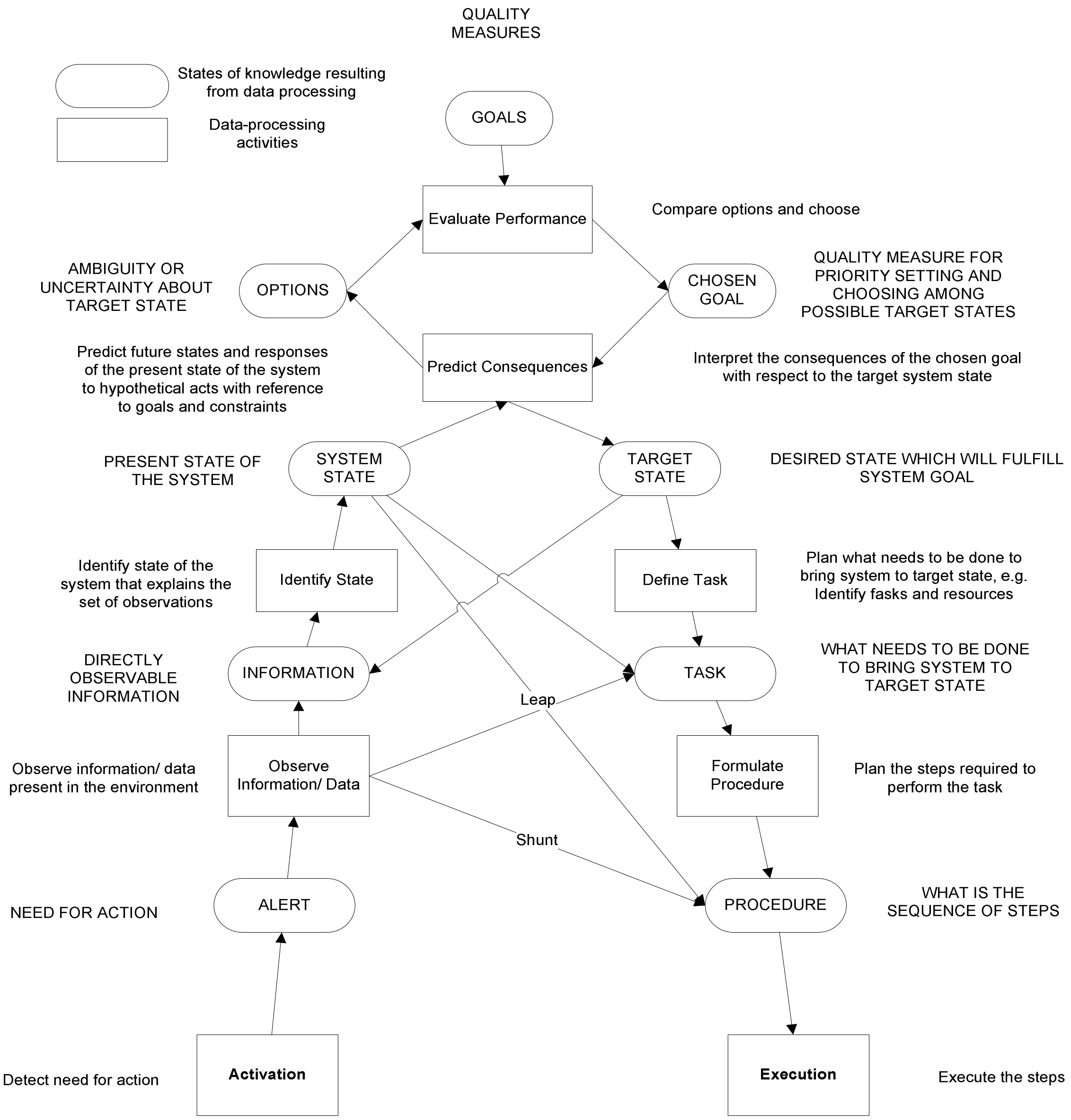


FIGURE 48: RASSMUSSEN'S DECISION LADDER (SOURCE: NAIKAR, 2006)

The decision ladder is able to identify the control tasks. The boxes represent information-processing activities; the ovals represent the states of knowledge that are the results or outputs of these activities. The arrows in the centre of the decision ladder allow shortcuts from one part of the decision ladder to another. While shunts connect an information-processing activity to a state of knowledge, leaps connect two states of knowledge. This indicates that two states of knowledge can be directly associated with each other. Rasmussen (1994) and Vicente (1999) describe a variety of other shortcuts. The decision ladder can be divided in three parts: Understanding the system state with related control tasks (left side), goal evaluation with related control tasks (top), and achieving the goals with related control tasks (right side). Observations of the information or data present in the environment are necessary in order to achieve the required knowledge about the system state. While some system states may allow to shortcut to directly execute procedures or tasks, other occasions require evaluation of the target state against the different options available.

The advantages of the decision ladder compared to traditional information processing for decision support include:

- Shortcuts which allow following the decision ladder directly to the knowledge states which are suitable to the specific situation instead of fixed decision nodes.
- The decision ladder accommodates various start and end points, and
- The decision ladder allows choosing the sequence of following the ladder where information processing paths can be established in all directions.

Traditional approaches however require following all steps in a linear sequence, but the order is not always necessary to be followed in the particular situation. E.g. experts are able to recognize situations and as a consequence, take efficient shortcuts or even move from right to left *after* task definition is completed.*“Expertise is the ability to compose a process needed for a specific task as a sequence of familiar subroutines that are useful in different contexts”* (Rasmussen, 1976). This means by using their ‘subroutines’ as a ‘collection of tricks’, experts actively generate a contextually tailored sequence of cognitive activities which is appropriate for the present situation (Dreyfus and Dreyfus, 1988).

The decision ladder can then be used for each work function in order to find the associated control task. As applied to the contextual activity template (Figure 49), it shows the qualitatively different sets of cognitive demands on actors which are imposed during the different situations:

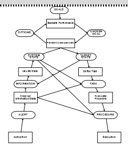
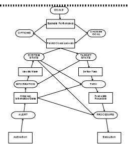
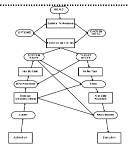
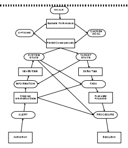
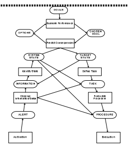
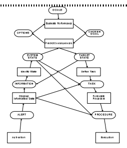
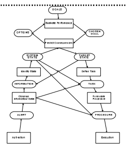
WORK SYSTEM	Work Situation 1	Work Situation 2	Work Situation 3	Work Situation 4
Work Function A				
Work Function B				
Work Function C				
Work Function D				
Work Function E				
Work Function F				

FIGURE 49: CONTEXTUAL ACTIVITY TEMPLATE WITH CONTROL TASKS

B. Critical Aspects of the Decision Ladder when applied to Turn-round Control

Even with all steps identified where decisions are required during turn-round it still has to be questioned whether the decision ladder is useful for decisions as they have to be made during turn-round control. Initially the model was developed for describing problem solving of operators in nuclear power plant control rooms (Rasmussen, 1985). It has now to be demonstrated that the model can be applied as a formal tool for the specification of control structures prevailing during turn-round decision making. E.g. Lind (1986) argues that Rasmussen's decision model can also be used for decision support when designing Advanced Knowledge Based System architectures. He shows how the decision model integrates rule-based problem solving support for planning and decision making, as well as knowledge-based support corresponding to the deeper knowledge corresponding to Rasmussen’s theory of how to make distinctions among human performance. This makes the model useful for planning the use of different types of knowledge in problem solving. He argues that the model can also be used either in a normative way via specifying the tasks involved and the relation between tasks, or in a formalized way via representing knowledge to be used for control of the system. However, the strategy used for decision making depends on the knowledge owned by the decision maker. This in turn defines the information requirements for analysis of the situation.

However, Lind (1986) also argues that the decision ladder does not specify all aspects required in order to use it as a formalized decision aid: Instead of fully describing the information flow during decision making, the model only describes the flow of control from task to task. This is also true for the diagnostic process: if the overall target state is not known, it is not possible to determine the proper level of system state that would allow taking the proposed shunt or leap. Another problem is that the knowledge as the basis for decision making changes over time and so the decisions made. Therefore a formalized way of decision making where each decision task corresponds to an information process which applies for the knowledge presently available should be considered. Furthermore, the decision making based on rules or knowledge is not entirely represented in the model: different decisions require different level of knowledge that must be represented in the flow of data to support decision making. But what if the decision cannot be made due to lack of sufficient information?

Since turn-round management has characteristics of decision making as described by Lind with often unknown target states, changing knowledge, and lack of information, the decision ladder was not used to model the control task as they were identified in the critical path of turn-round events.

3 The CWA - Strategies Analysis

A. Introduction

The third stage of the CWA identifies how the different tasks can be conducted involving the identification of strategies that workers might employ when performing the control tasks. During this phase of analysis, the focus is applied on *the ways* of performing the control tasks. The analysis can be done, e.g. by using information flow maps to identify different cognitive procedures that are possible during control tasks execution.

The strategies adopted by actors under a specific situation may vary significantly depending on the actor's work demand level. This means that different agents may perform work in different ways depending on the situation and strategies depend on variables like knowledge level, experience, training, work load, and familiarity with the given situation. As a consequence, actors might even use different strategies at different occasions.

While during CTA it has been identified what decisions have to be made, it is the scope of the Strategies Analysis to describe how these decisions can be made and what alternatives courses of actions are available. Luce (1995) describes the difference between these two phases of analysis (Figure 50):

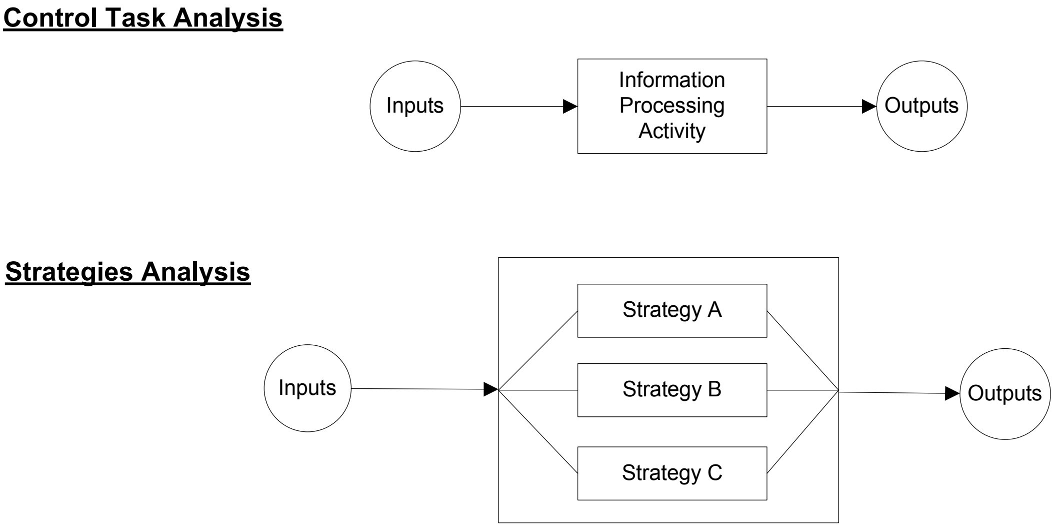


FIGURE 50: COMPARISON OF CONTROL TASK AND STRATEGIES ANALYSES (SOURCE: LUCE, 1995)

If the decision ladder is applied to the CTA, it represents the information processing activities which result in the outputs by using the different strategies, because there are often multiple ways of solving a task. The strategies analysis tries now to identify each of the possible strategies that can be used to provide tailored support to each strategy (Vicente, 1999).

B. Methods of Strategy Analysis

Vicente (1999) compares two contrasting approaches to define strategy. While Payne et al (1993) defines strategy as application of knowledge transformation onto a particular decision problem, Rasmussen (1981) views the knowledge transformation as a category of cognitive task procedures. The fundamental difference with Rasmussen's approach is that he sees strategy as a category of procedures (Rasmussen), compared to an instance of a procedure (Payne et al). The underlying reason for Rasmussen's definition is the inherent variability across different situations and therefore the idiosyncratic characteristics of cognitive procedures and behaviours used by actors. Therefore, a detailed strategy description may result in a normative way of work analysis only with the limitations of the 'one right way' rather than context-conditioned variability required during complex and unexpected decision making situations. The definition of 'categories' of cognitive procedures with action sequences as instantiation of a category should help to solve such problems, because a detailed level of description is not very useful for design. The definition of categories however offer a bounded, but infinite number of action sequences.

Rasmussen (1981) proposes information flow maps to describe such categories of cognitive task procedures. Vicente (1999) distinguishes topographic and symptomatic search strategies, where topographic strategies are idealized process representations from which particular instances of action sequences can be generated. Symptomatic problem solving strategies can be 'pattern recognition' driven where actor recognizes a pattern of familiar data, 'decision table' driven where actor relies on a number of state models that are used to associate a particular data pattern with a particular state, or 'hypothesis-and-test' driven where actor uses a hypothesis about the particular state derived from earlier applications or other search strategies.

Vicente (1999) points out that information flow maps are not yet exist as a modelling tool like the decision ladder, but as a generic and context-specific tool to model strategies. Information required to conduct a strategy analysis should be derived from descriptive field studies, an a priori analysis of actions required by study of the work domain, and then identify the degree of freedom associated with particular classes of situations using a control task analysis. Finally, Vicente (1999, p.234) proposes also operational research models for identification of strategies.

C. Critical Review of the Strategies Analysis for Application to Turn-Round Managment

A review of the degree of freedom as proposed by Vicente (1999) reveals that each decision of one function within the critical turn-round path can have significant influence on other functions within the sequential turn-round processes. As a result, the outcome of an individual decision from one function propagates to other functions and so influences decision makers who have to build on the outcomes of other decisions. However, performing a Strategies Analysis does not incorporate interdependencies between strategies as they are applied during turn-round management. Even if a strategy analysis shows how activities may be executed by using the various options, it does not automatically link the neighbouring tasks or strategies from other participating decision makers to a global activity of an overall optimum turn-round management strategy. Therefore, seen from such an overall turn-round operation perspective, the advantage of a service delivery for one service provider could be a disadvantage for another service provider. For example, the catering trolleys can block the working space for cleaning personnel when moved through aircraft cabin and vice versa. As a consequence, only local optimum strategies can be identified, if the strategies analysis is conducted separately for an individual participating decision maker using the decision ladder.

Also, even consistently taking into account the constraints from other participants does not automatically result in a global optimum turn-round strategy. Since actors have the tendency to switch strategies depending on their cognitive load it is also difficult to predict shifts in their strategies (Vicente, 1999). As a consequence, coordination of a very large number of possible strategies is necessary to provide an intelligent decision support for such situations. This suggests that a strategy analysis for the purpose here should first identify the information requirements associated with each of the strategies so that a conceptualized support of information can be offered allowing a centralized decision making of turn-round operation and TOBT predictions. Such approach is able to provide formalized information support in a tailored manner for all participating decision makers.

D. Possible Application of a Strategies Analysis to the A-CDM work system

As outlined before, a number of decision makers are involved in TOBT decision making with each participant having its own strategy for tackling problems as they arise within their local environment. As a consequence, even with information flow maps as proposed by Vicente (1999), participating actors only receive support for possible local strategies. It is therefore proposed to use an approach where a single turn-round manager is responsible for the overall turn-round strategy and communicates this strategy to all actors involved. As a consequence, actors' task definitions are based on the turn-round managers' strategy. However, it has also to be considered that actors may switch their individual strategies for task execution based on their cognitive load, performance levels, conflicting interests, or sudden shifts in the environment.

For achieving the specific task goals, tailored information support should be provided to all involved. Therefore the primary aim of a step towards an application to the A-CDM system should be to develop a systematic approach of the information requirements of each participating actors which allows him to execute his task, but also allows the decision maker to chose and pursue a strategy based on the given situation and existing constraints. This goes along with the design implications identified by Vicente (1999) that strategies can in principle be actor-independent and can be distributed across workers and automation.

Such a significant prerequisite for decision making should be achieved via information sharing by providing synchronous information support to all participating actors for turn-round tasks execution or required negotiation between actors and turn-round controller. The research in Computer Supported Collaborative Work (CSCW) has already drawn attention to developing comprehensive understanding of such complexities in collaborative working environments. The CSCW approach builds on a search for an in-depth understanding of the practical contingencies of today’s work practices including social and organisational context (Davis et.al, 2000). Divergent perspectives have emerged as ‘shared information spaces that provide contextual guidance and support’ and ‘automated work flow systems with the ability to deal with contingencies’ (Schmidt, 1997). Davis et al (2000) proposes a structure of information sharing using a personal and group perspective. As a novel aspect he also proposes that the participants are organized as a cooperative ensemble whether derived from a project or functional structure, but operating with own coordination and interaction patterns among the participants. Such study should be able not only to identify the different modes of coordination and information exchange required, but also information sharing breakdowns and functional system design specifications. As a method of data collection for such information flow analysis David (2000) uses a questionnaire with questions like:

- Which tasks do you perform in relation to the product development process?
- For each of the tasks: which documents or other information do you need/ use? (e.g. specifications, contracts, orders, invoices, procedures, standards, etc.)
- For each of the above: where /who do you get this information from (Customers, colleagues, other departments, databases, archives etc….)?
- What format is the information in? (Text/letters, spreadsheets, drawings, photos. Database-data, sound recording, video, etc.)
- How is the information transferred to you? (Collected, post, fax, mail, oral, phone, fileserver etc.)
- How do you sort and store this information?
- What kind of results do you produce? (Different kinds of documents, approvals, controls, physical products etc…)
- Who uses the results of your work? (customer, subcontractor, supplier, colleagues, archives, etc.)
- How are the results passed on? (automatically or on request)
- Who checks the results/ what kind of feedback do you get?
- Which tools do you use for your tasks?(computer assisted or /and manual ones)
- Which of your tasks seem most time-consuming or in-efficient?

4 The CWA - Organisation and Co-operation Analysis

During this stage of the CWA, the distribution of activities and associated strategies amongst the workers and artefacts within the system should be identified. The CWA uses the modelling tools from previous phases of the framework in order to identify how the actors may be organized in groups or teams, how they communicate, and how the authority relationships govern their cooperation. However, modelling tools from the CWA do not reflect how the individual goal structures have influence on the cooperative activities towards a global goal. As the CWA constitutes using modelling tools building on the constraints identified from previous phases of analysis with conclusions of how cooperative interactions should be designed, the CWA was not applied for this project.

E.g. during turn-round, the operators from the different domains not necessarily work together cooperatively, increasing the need for identification of the group goals, the cooperative processes supporting the group goals and the underlying group tasks. The overall aim should be pursued in a way that all work is coordinated towards the common goals and establishing a global goal, while each operator attempts to satisfy its' own organisational sub-goal. Goal complexity even further increases with dynamic aspects of operators' goal scenarios: for goal achievement, subordinate goals are identified during task execution and operators act on their immediate goals in order to achieve the higher level goal (Hacker, 1994). Goal creation can also follow the other direction, where operators first become aware of the problem, then make the highest level of their own goal structure and construct lower level subordinate goals during action in order to achieve the higher level goal (see Figure 51).

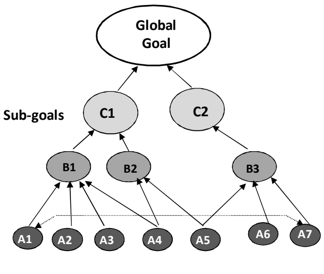


FIGURE 51: THE OPERATORS' GOAL STRUCTURE (SOURCE: HACKER, 1994)

APPENDIX VII: The Results from Games-Howell Test

The data presented in this appendix results from a Games-Howell test that was used to demonstrate the homogeneity among the experiment participants.

Dependent Variable	(I) Control	(J) Control	Mean Difference (I-J)	Std Error	Significance	95%-Confidence Interval	
						Lower Bound	Upper Bound
D_T01	1	2	-13,20000	7,01739	,435	-34,7239	8,3239
		3	-7,33333	5,83117	,803	-25,9359	11,2693
		4	-6,33333	6,94829	,940	-27,6631	14,9965
		5	-5,46667	7,02287	,969	-27,0060	16,0727
		6	-8,26667	5,93654	,731	-27,0799	10,5466
	2	1	13,20000	7,01739	,435	-8,3239	34,7239
		3	5,86667	4,76422	,816	-9,1625	20,8958
		4	6,86667	6,08062	,865	-11,7159	25,4492
		5	7,73333	6,16570	,806	-11,1083	26,5750
		6	4,93333	4,89262	,910	-10,3827	20,2494
	3	1	7,33333	5,83117	,803	-11,2693	25,9359
		2	-5,86667	4,76422	,816	-20,8958	9,1625
		4	1,00000	4,66183	1,000	-13,6860	15,6860
		5	1,86667	4,77227	,999	-13,1895	16,9228
		6	-,93333	2,94898	1,000	-9,9580	8,0913
	4	1	6,33333	6,94829	,940	-14,9965	27,6631
		2	-6,86667	6,08062	,865	-25,4492	11,7159
		3	-1,00000	4,66183	1,000	-15,6860	13,6860
		5	,86667	6,08694	1,000	-17,7353	19,4686
		6	-1,93333	4,79298	,998	-16,9162	13,0495
	5	1	5,46667	7,02287	,969	-16,0727	27,0060
		2	-7,73333	6,16570	,806	-26,5750	11,1083
		3	-1,86667	4,77227	,999	-16,9228	13,1895
		4	-,86667	6,08694	1,000	-19,4686	17,7353
		6	-2,80000	4,90047	,992	-18,1423	12,5423
	6	1	8,26667	5,93654	,731	-10,5466	27,0799
		2	-4,93333	4,89262	,910	-20,2494	10,3827
		3	,93333	2,94898	1,000	-8,0913	9,9580
		4	1,93333	4,79298	,998	-13,0495	16,9162
		5	2,80000	4,90047	,992	-12,5423	18,1423

D_T02	1	2	-15,46667	7,29092	,309	-37,9166	6,9833
		3	-13,93333	6,54978	,314	-34,5466	6,6799
		4	-15,73333	7,38755	,304	-38,4465	6,9798
		5	-11,93333	7,78733	,647	-35,7758	11,9092
		6	-13,53333	6,73079	,369	-34,5593	7,4927
	2	1	15,46667	7,29092	,309	-6,9833	37,9166
		3	1,53333	5,04330	1,000	-14,0558	17,1225
		4	-,26667	6,09189	1,000	-18,8846	18,3513
		5	3,53333	6,57098	,994	-16,5892	23,6559
		6	1,93333	5,27624	,999	-14,2807	18,1474
	3	1	13,93333	6,54978	,314	-6,6799	34,5466
		2	-1,53333	5,04330	1,000	-17,1225	14,0558
		4	-1,80000	5,18202	,999	-17,8478	14,2478
		5	2,00000	5,73760	,999	-15,8958	19,8958
		6	,40000	4,19296	1,000	-12,4300	13,2300
	4	1	15,73333	7,38755	,304	-6,9798	38,4465
		2	,26667	6,09189	1,000	-18,3513	18,8846
		3	1,80000	5,18202	,999	-14,2478	17,8478
		5	3,80000	6,67804	,992	-16,6338	24,2338
		6	2,20000	5,40899	,998	-14,4464	18,8464
	5	1	11,93333	7,78733	,647	-11,9092	35,7758
		2	-3,53333	6,57098	,994	-23,6559	16,5892
		3	-2,00000	5,73760	,999	-19,8958	15,8958
		4	-3,80000	6,67804	,992	-24,2338	16,6338
		6	-1,60000	5,94338	1,000	-20,0049	16,8049
	6	1	13,53333	6,73079	,369	-7,4927	34,5593
		2	-1,93333	5,27624	,999	-18,1474	14,2807
		3	-,40000	4,19296	1,000	-13,2300	12,4300
		4	-2,20000	5,40899	,998	-18,8464	14,4464
		5	1,60000	5,94338	1,000	-16,8049	20,0049

D_T11	1	2	-4,00000	2,28397	,515	-11,1168	3,1168
		3	-3,66667	1,82244	,363	-9,2614	1,9280
		4	-3,80000	1,96719	,408	-9,8668	2,2668
		5	-,06667	1,90171	1,000	-5,9190	5,7857
		6	-,53333	1,49560	,999	-5,1073	4,0406
	2	1	4,00000	2,28397	,515	-3,1168	11,1168
		3	,33333	2,46254	1,000	-7,2438	7,9105
		4	,20000	2,57152	1,000	-7,6812	8,0812
		5	3,93333	2,52178	,631	-3,8073	11,6740
		6	3,46667	2,23152	,636	-3,5268	10,4601
	3	1	3,66667	1,82244	,363	-1,9280	9,2614
		2	-,33333	2,46254	1,000	-7,9105	7,2438
		4	-,13333	2,17197	1,000	-6,7769	6,5103
		5	3,60000	2,11285	,541	-2,8586	10,0586
		6	3,13333	1,75626	,493	-2,2805	8,5471
	4	1	3,80000	1,96719	,408	-2,2668	9,8668
		2	-,20000	2,57152	1,000	-8,0812	7,6812
		3	,13333	2,17197	1,000	-6,5103	6,7769
		5	3,73333	2,23891	,563	-3,1097	10,5764
		6	3,26667	1,90605	,537	-2,6414	9,1747
	5	1	,06667	1,90171	1,000	-5,7857	5,9190
		2	-3,93333	2,52178	,631	-11,6740	3,8073
		3	-3,60000	2,11285	,541	-10,0586	2,8586
		4	-3,73333	2,23891	,563	-10,5764	3,1097
		6	-,46667	1,83839	1,000	-6,1508	5,2175
	6	1	,53333	1,49560	,999	-4,0406	5,1073
		2	-3,46667	2,23152	,636	-10,4601	3,5268
		3	-3,13333	1,75626	,493	-8,5471	2,2805
		4	-3,26667	1,90605	,537	-9,1747	2,6414
		5	,46667	1,83839	1,000	-5,2175	6,1508

D_T12	1	2	-3,26667	5,70185	,992	-20,6958	14,1625
		3	-7,06667	4,99759	,719	-22,4984	8,3651
		4	-11,53333	5,23116	,269	-27,5975	4,5308
		5	-5,53333	6,18318	,945	-24,4405	13,3738
		6	-4,53333	4,97741	,940	-19,9123	10,8456
	2	1	3,26667	5,70185	,992	-14,1625	20,6958
		3	-3,80000	4,78609	,966	-18,5375	10,9375
		4	-8,26667	5,02950	,578	-23,6810	7,1477
		5	-2,26667	6,01353	,999	-20,6756	16,1423
		6	-1,26667	4,76502	1,000	-15,9474	13,4141
	3	1	7,06667	4,99759	,719	-8,3651	22,4984
		2	3,80000	4,78609	,966	-10,9375	18,5375
		4	-4,46667	4,21434	,893	-17,3616	8,4282
		5	1,53333	5,35045	1,000	-15,0656	18,1323
		6	2,53333	3,89489	,986	-9,3691	14,4358
	4	1	11,53333	5,23116	,269	-4,5308	27,5975
		2	8,26667	5,02950	,578	-7,1477	23,6810
		3	4,46667	4,21434	,893	-8,4282	17,3616
		5	6,00000	5,56925	,886	-11,1665	23,1665
		6	7,00000	4,19039	,562	-5,8249	19,8249
	5	1	5,53333	6,18318	,945	-13,3738	24,4405
		2	2,26667	6,01353	,999	-16,1423	20,6756
		3	-1,53333	5,35045	1,000	-18,1323	15,0656
		4	-6,00000	5,56925	,886	-23,1665	11,1665
		6	1,00000	5,33161	1,000	-15,5518	17,5518
	6	1	4,53333	4,97741	,940	-10,8456	19,9123
		2	1,26667	4,76502	1,000	-13,4141	15,9474
		3	-2,53333	3,89489	,986	-14,4358	9,3691
		4	-7,00000	4,19039	,562	-19,8249	5,8249
		5	-1,00000	5,33161	1,000	-17,5518	15,5518

D_T21	1	2	-4,60000	2,95361	,634	-13,8952	4,6952
		3	-,06667	1,58284	1,000	-4,9222	4,7888
		4	1,00000	1,61068	,988	-3,9347	5,9347
		5	3,26667	1,33832	,193	-,9775	7,5109
		6	,46667	1,54262	1,000	-4,2770	5,2103
	2	1	4,60000	2,95361	,634	-4,6952	13,8952
		3	4,53333	2,85301	,616	-4,5517	13,6184
		4	5,60000	2,86855	,405	-3,5159	14,7159
		5	7,86667	2,72496	,096	-,9898	16,7231
		6	5,06667	2,83090	,497	-3,9755	14,1088
	3	1	,06667	1,58284	1,000	-4,7888	4,9222
		2	-4,53333	2,85301	,616	-13,6184	4,5517
		4	1,06667	1,41780	,973	-3,2666	5,3999
		5	3,33333	1,09863	,061	-,1078	6,7745
		6	,53333	1,33998	,999	-3,5629	4,6296
	4	1	-1,00000	1,61068	,988	-5,9347	3,9347
		2	-5,60000	2,86855	,405	-14,7159	3,5159
		3	-1,06667	1,41780	,973	-5,3999	3,2666
		5	2,26667	1,13836	,381	-1,3075	5,8408
		6	-,53333	1,37275	,999	-4,7321	3,6655
	5	1	-3,26667	1,33832	,193	-7,5109	,9775
		2	-7,86667	2,72496	,096	-16,7231	,9898
		3	-3,33333	1,09863	,061	-6,7745	,1078
		4	-2,26667	1,13836	,381	-5,8408	1,3075
		6	-2,80000	1,03984	,118	-6,0446	,4446
	6	1	-,46667	1,54262	1,000	-5,2103	4,2770
		2	-5,06667	2,83090	,497	-14,1088	3,9755
		3	-,53333	1,33998	,999	-4,6296	3,5629
		4	,53333	1,37275	,999	-3,6655	4,7321
		5	2,80000	1,03984	,118	-,4446	6,0446

D_T22	1	2	-1,80000	2,34866	,970	-9,1266	5,5266
		3	1,00000	1,45406	,982	-3,4557	5,4557
		4	-3,26667	2,08958	,629	-9,7319	3,1985
		5	3,40000	1,22202	,105	-,4643	7,2643
		6	2,13333	1,47637	,700	-2,3866	6,6533
	2	1	1,80000	2,34866	,970	-5,5266	9,1266
		3	2,80000	2,25769	,812	-4,3193	9,9193
		4	-1,46667	2,71094	,994	-9,7652	6,8319
		5	5,20000	2,11570	,196	-1,6451	12,0451
		6	3,93333	2,27212	,529	-3,2175	11,0841
	3	1	-1,00000	1,45406	,982	-5,4557	3,4557
		2	-2,80000	2,25769	,812	-9,9193	4,3193
		4	-4,26667	1,98678	,302	-10,4789	1,9455
		5	2,40000	1,03648	,232	-,8428	5,6428
		6	1,13333	1,32689	,954	-2,9219	5,1885
	4	1	3,26667	2,08958	,629	-3,1985	9,7319
		2	1,46667	2,71094	,994	-6,8319	9,7652
		3	4,26667	1,98678	,302	-1,9455	10,4789
		5	6,66667*	1,82383	,022	,7917	12,5416
		6	5,40000	2,00317	,117	-,8508	11,6508
	5	1	-3,40000	1,22202	,105	-7,2643	,4643
		2	-5,20000	2,11570	,196	-12,0451	1,6451
		3	-2,40000	1,03648	,232	-5,6428	,8428
		4	-6,66667*	1,82383	,022	-12,5416	-,7917
		6	-1,26667	1,06756	,838	-4,6134	2,0801
	6	1	-2,13333	1,47637	,700	-6,6533	2,3866
		2	-3,93333	2,27212	,529	-11,0841	3,2175
		3	-1,13333	1,32689	,954	-5,1885	2,9219
		4	-5,40000	2,00317	,117	-11,6508	,8508
		5	1,26667	1,06756	,838	-2,0801	4,6134

*. The difference of the means is on the level 0.05 significant