Introduction

- Many projects have contributed to the CDM concept
  - DAVINCI
  - LEONARDO
  - Gate to Gate
  - C-ATM
  - Nordic SWIM
  - ...
- Eurocontrol CDM Project
  - Airport CDM Implementation Manual
  - Airport CDM Applications – Operational Concept Document
  - Airport CDM Applications – Level 1, Functional Requirements
  - The European CDM Portal on the Internet: http://www.euro-cdm.org
Conclusion
Read these documents carefully and you will know everything about CDM !!!

..., but

... there are still some questions that need further consideration, like

- How to use existing/future decision support systems for collaborative decision making?
- How to incorporate preferences of other partners in the decision making process?
- How to evaluate an improved predictability of operations, events, necessary resources, etc.?
Intention and Content of Presentation

Intention of the Presentation

- Provide an insight in the coordination of XMAN decision support tools and the resulting contribution to CDM
- **XMAN: Decision Support Tools based on planning algorithms**
  - AMAN (Arrival Manager)
  - DMAN (Departure Manager)
  - SMAN (Surface Manager)
  - TMAN (Turn-around Manager)
  - EMAN (En-route Manager)
  - ADCO (Arrival Departure Coordination Layer)

Content

- Brief overview about the CDM-A objectives, partners and elements
- Brief overview about the XMAN approach, its objectives and status
- **AMAN – TMAN – DMAN coordination and its contribution to Information Sharing and Collaborative Decision Making**
- Incorporation of Aircraft Priorities of the Airline/Airport
- Conclusions
CDM-A: Objectives, Partners and Elements

Objectives

- Increase punctuality (TOBT!)
- Increase predictability
- Increase efficiency
  - Airport resources
  - Network capacity

Partners

- Airport Operators
- Aircraft Operators
- Ground Handlers
- Air Navigation Service Provider (ATC)
- The CFMU
- Support services

Elements

- Airport CDM Information Sharing
- Airport CDM Turn-round Process (Milestones Approach)
- Variable Taxi Time Calculation
- Collaborative Management of Flight Updates
  - CDM-A and CFMU Message Exchange
    - FUM Flight Update Message
    - DPI Message
- Collaborative Pre-departure Sequence
- CDM in Adverse Conditions
  - Anticipate delay situation
  - Recovery strategies to facilitate a quick return to normal operations
XMAN Approach

- **XMAN Approach**
  - Use of automated tools to assist controllers in planning and tactical decision making
  - Part of Eurocontrol’s ASA programme (Automated Support to ATS)

- **Objectives**
  - Increase of efficiency
  - Increase throughput (utilization of capacity)
  - Increase predictability
  - Reduce environmental impacts

- **Status of system development, implementation and coordination**
  - AMAN (fully developed; implemented)
  - DMAN (fully developed; implemented)
  - SMAN (partly developed)
  - TMAN (fully developed; implemented)
  - AMAN – DMAN (under development)
  - AMAN – TMAN – DMAN (first considerations)
XMAN Approach

- Need for coordination is caused
  - Share of common resource(s)
    - AMAN-DMAN
      - Resource: Runway System
    - AMAN – TMAN; TMAN – DMAN
      - Resource: Stands & Gates
    - TMAN I (Hub-Control)
      - Various resources of means and personnel
  - Persistence of physical objects (aircraft)
    - Arrivals turn into departures in the turn-around process
- AMAN & SMAN:
  - only minimal functionality required
    - aman: prediction of landing times
    - sman: prediction of taxi time
- Optional Systems:
  - SMAN
  - ADCO (Arrival Departure Coordination)
AMAN-TMAN-DMAN Coordination and its Contribution to Information Sharing and Collaborative Decision Making

Principles / facts to be taken into account

- Planning and/or forecast information are functions of time
  - continuously varying (sliding / shifting)
  - discontinuously changing
    - events
    - sequence changes
- In principle, accuracy/predictability can be estimated with the help of statistical analysis based on normalized times (actual times)
  - accuracy/predictability itself is time-dependent
  - can be used in off-line analysis
    - e.g.: “10 minutes before landing, i.e. ELDT=NOW+10
      the 90% confidence interval for ELDT is [NOW+9 NOW+12], i.e. NOW+9<= ELDT<= NOW+12
      (95% confidence interval: [NOW+8 NOW+14])”
  - might be used in on-line quality assessments
    - e.g.: “When TTOT is NOW+10min, with a 90% confidence then ATOT will be in the range of [NOW+9 NOW+12].”
AMAN-TMAN-DMAN Coordination and its Contribution to Information Sharing and Collaborative Decision Making

Principles / facts to be taken into account

- Use of the latest information
  - requires either
    - broadcast of information (subscribing mechanism) and / or
    - persistence of information (DBMS)

- Substitution of information
  (more precise information replaces less precise information)
  - information is generated by a sequence of information sources
  - as a consequence thereof the accuracy of information is increasing steadily
  - e.g. TTOT
    - flight plan
    - pre-tactical departure planning
    - tactical departure planning
  - tendentious increase of accuracy
  - discontinuous changes of level of accuracy

Planning / Forecast Information provided by source A (e.g. ETOT according filed Flight Plan, CDM)
Planning / Forecast Information provided by source B (e.g. TTOT according DMAN)
Time determination of events

- **In-Block; EIBT; AIBT**
  - \( EIBT = SLDT \text{ (CDM)} + EXIT \text{ (CDM)} \)
  - \( EIBT = SIBT \text{ (CDM)} \)
  - \( EIBT = ELDT \text{ (AMAN)} + EXIT \text{ (SMAN)} \)
  - \( EIBT = ALDT \text{ (CDM)} + EXIT \text{ (SMAN)} \)

- **Estimated / First Off-Block; (EOBT, SOBT)**
  - \( EOBT = SIBT \text{ (CDM)} + ETTT \text{ (CDM)} \)
  - \( EOBT = SOBT \text{ (CDM)} \)
  - \( EOBT = EIBT \text{ (CDM)} + ETTT \text{ (TMAN)} \)
  - \( EOBT \geq SOBT \text{ (by definition)} \)
  - \( TOBT: \) The time that an aircraft operator / handling agent estimates that an aircraft will be ready, all doors closed, ...

- **Target Off-Block Time (TOBT)**
  - \( TOBT = TTOT \text{ (DMAN)} - EXOT \text{ (DMAN/SMAN)} \)
  - \( TTOT \geq EOBT \text{ (TMAN)} + EXOT \text{ (DMAN/SMAN)} \)
  - \( \Rightarrow \)
  - \( TOBT \geq EOBT \)

Remarks

- **General principle for planning of consecutive operations**
  - Backward propagation of target times
  - Forward estimation of first (earliest) times of events
  - Every planned Target Time shall be never smaller (earlier) than the corresponding predicted Earliest Time!

- **Use of TOBT \( \geq \) EOBT information**
  - Will cause savings for airlines!
    - Avoidance of the use of additional resources
    - May allow the boarding of late passengers
    - May improve connectivity
    - May shorten the ETTT of other flights!
  - More appropriate usage of resources according to actual needs and acuteness
Incorporation of Aircraft Priorities of the Airline/Airport

- Airline/airport preferences for departure service are often unknown to ATC
- The preferences reflect specific interests, objectives and problems of these CDM partners, e.g.
  - to assure a high extend of punctuality and passenger connectivity for their customers
  - to avoid resource conflicts (stands, personnel, ...)
- Preferences might be expressed
  a) through a preferred departure sequence (respectively sub-sequence of their own flights), i.e. technically expressed by “sequence constraints” (e.g. “aircraft A should depart before aircraft B” (A < B))
  b) through aircraft importance factors w (e.g. aircraft A is twice as important as aircraft B” w_A=2w_B)
- Both methods require “rules”/regulations
  - expressing the conditions for “Who can induce constraints and when?”
  - in order to assure fairness between competitive airlines operating at this airport
Incorporation of Aircraft Priorities of the Airline/Airport

Pros and Cons of these methods

a) preferences expressed by sequence constraints
   + appropriate method for hard constraint conditions (“A must be pushed before B)
   + may end in a pre-departure sequence $A < B < C \Rightarrow A-B-C$
   - may become inconsistent especially when several partners/instances induce such constraints
     (e.g. $A < B$ and $B < C$ and $C < A$)
   - $A < B$ does not express the relations to other flights
     ($A < B \Rightarrow A-B-C-D$ or $C-D-A-B$ or $A-C-D-B$)
   - may be unacceptable/disadvantageous for ATC with respect to throughput, control effort etc.
   - number of constraints could become greater than number of departures

b) preferences expressed by priority importance factors $w_A, w_B, ...$
   + this method never causes inconsistency
   + does express the relations to other flights (standard: $w=1$)
   + might not have negative impact on ATC (further investigations needed)
   + priorities can be treated easily as additional flight plan information (TMAN)
   + different priorities of airline, airport and ATC can be combined through mathematical functions
     (e.g.: $w_A = w_{A,Airline} + w_{A,Airport}$)
   - does not guarantee that $A$ departs before $B$ when $w_A > w_B$
   - may have unexpected impacts on other flights
Aircraft Priorities of Airlines and DMAN (ATC) Departure Scheduling

Rules of the “Game”

Basic

- Airline (participating in CDM) owns a number of “weight points” proportional to the number of owned flights (e.g. 10 points per flight \( w=1 \))
- Standard is \( w=1 \) (if no other information given)
- For every flight the number of assigned points can be changed by the airline according to its preference
- The total sum of assigned points remains constant, i.e. an increase of the importance of one flight necessarily requires a decrease of other importance weights

Additional rules to avoid instability and outwitting

- Changes of weights not later than ...
- Re-changes of weights cause a decrease of the total sum of weight points owned

Example (from RTS1 traffic scenario)

- Scandinavian Airlines induce: \( w_{SAS589} = 2.5; w_{SAS172} = w_{SAS637} = w_{SAS555} = 0.5 \)
Conclusions

- CDM and XMAN are not competitive but mutual supporting concepts, i.e.
  - “better” plans based on more reliable, consistent and complete information
  - more reliable information replacing the estimates (what a partner can do) by optimal targets/plans (what the partner should do)

- The XMAN planning tools can provide quantitative measures for accuracy (predictability, reliability) as on-time information based on
  - recorded data
    (planning and estimates as functions of time, in dependence on events / milestones)
  - built-in statistical analysis methods

- More reliable, more actual planning information provided in combination with quantitative measures for accuracy will support both
  - Intra Airport CDM
  - Inter Airport CDM
    - CFMU (DPI messages)
    - peer-to-peer CDM-A coordination
Conclusions

- Coordinated Planning Tools, have the potential to provide techniques, with whose help airline/airport preferences can be taken into account softly without disadvantageous side-effects such as
  - the need of additional communication
  - the risk of inconsistent constraints
  - the risk of a substantial loss of overall efficiency
  - disturbances and complication of the management tasks of ATC

What needs to be done?

- XMAN: Extension of tactical planning horizon (pre-tactical planning) in order to
  - increase the effectuality of plan based (time based) operations
  - allow tool supported what-if-considerations by human decision makers
- TOP: Extended CDM at major airports (i.e. several CDM partners, competitive airlines) may need Total Operations Planning and an Airport Control Centre
- CDM: Extend and adapt the CDM concept with thorough consideration of the incorporation of XMAN

BECAUSE THESE TOOLS ALREADY EXIST!