

Doc 9971
AN/485



Manual on Collaborative Air Traffic Flow Management

Approved by the Secretary General
and published under his authority

Second Edition – 2014

International Civil Aviation Organization

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FOREWORD

Collaborative decision-making (CDM) is defined as a process focused on how to decide on a course of action articulated between two or more community members. Through this process, ATM community members share information related to that decision and agree on and apply the decision-making approach and principles. The overall objective of the process is to improve the performance of the ATM system as a whole while balancing the needs of individual ATM community members.

The purpose of this manual is to present the CDM concept as a means to reach the performance objectives of the processes the concept supports in a consistent and harmonized manner.

Future developments

Comments on this manual would be appreciated from all parties involved in the development and implementation of CDM. These comments should be addressed to:

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GLOSSARY

ABBREVIATIONS/ACRONYMS

AAR	Airport acceptance rate
ACC	Area control centre
A-CDM	Airport-CDM
ADP	ATFM daily plan
AFTN	Aeronautical fixed telecommunication network
AIM	Aeronautical information management
AIXM	Aeronautical information exchange model
AMAN/DMAN	Arrival/departure management
ANM	ATFM notification message
ANSP	Air navigation services provider
AOBT	Actual off-block time
AOP	Airport operator
AP	Airspace provider
APP	Approach control service
ASM	Airspace management
ASP	ATM service provider
ATC	Air traffic control
ATCO	Air traffic controller
ATFCM	Air traffic flow and capacity management
ATFM	Air traffic flow management
ATM	Air traffic management
ATMC	Air traffic management centre
ATOT	Actual take-off time
ATS	Air traffic services
AU	Airspace user
CDM	Collaborative decision-making
CEF	Capacity enhancement function
CFMU	Central flow management unit
CGNA	Centro de Gerenciamento da Navegação Aérea (air navigation management centre)
CLDT	Calculated landing time
CNS/ATM	Communications, navigation and surveillance/air traffic management
CPDLC	Controller-pilot data link communications
CTOT	Calculated take-off time
DCB	Demand and capacity balancing
DCPC	Direct controller-pilot communications
ECAC	European Civil Aviation Conference
EOBT	Estimated off-block time
ESP	Emergency service provider
ETD	Estimated time of departure
ETOT	Estimated take-off time
FAP	Future ATM profile
FDPS	Flight data processing system
FF-ICE	Flight and flow — information for a collaborative environment

FIR	Flight information region
FIXM	Flight information exchange model
FMP	Flow management position
FMU	Flow management unit
FOIS	Flight operation information system
FUM	Flight update message
GDP	Ground delay programme
GS	Ground stop
IATA	International Air Transport Association
IFR	Instrument flight rules
IMC	Instrument meteorological conditions
IR	Infra-red
KPA	Key performance area
LoA	Letter of agreement
MDI	Minimum departure interval
METAR	Aerodrome routine meteorological report
MINIT	Minutes-in-trail
MIT	Miles-in-trail
NAVAIDs	Aid to air navigation
NOP	Network operations plan
PBN	Performance-based navigation
Prog	Prognosis
R&D	Research and development
RDPS	Radar data processing system
ROI	Return on investment
RTA	Required time of arrival
RWY	Runway
S-CDM	Surface-CDM
SID	Standard instrument departure
STAR	Standard instrument arrival
STATFOR	Statistic 2 forecast service
TAF	Aerodrome forecast
TFM	Traffic flow management
TMA	Terminal control area
TOBT	Target off-block time
TOD	Top of descent
TSAT	Target start-up approval time
TWR	Aerodrome control tower
VMC	Visual meteorological conditions

REFERENCES

ICAO documents

Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM, Doc 4444)

Global Air Traffic Management Operational Concept (Doc 9854)

Manual on Air Traffic Management System Requirements (Doc 9882)

Manual on Global Performance of the Air Navigation System (Doc 9883)

Manual on Flight and Flow — Information for a Collaborative Environment (Doc 9965)

Civil/Military Cooperation in Air Traffic Management (Cir 330)

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PART I

COLLABORATIVE DECISION-MAKING (CDM)

Chapter 1

INTRODUCTION

1.1 NEED FOR COLLABORATION

1.1.1 The Eleventh Air Navigation Conference (AN-Conf/11) was held in Montréal from 22 September to 3 October 2003. At this meeting, Recommendation 1/1 was agreed upon for the “Endorsement of the global ATM operational concept”. This concept was subsequently published as the *Global Air Traffic Management Operational Concept* (ICAO Doc 9854), First Edition, 2005. Central to this concept is the need to evolve towards a more collaborative environment, as noted in the AN-Conf/11 Report (AN-Conf/11 Report, Agenda item 1, 1.2.1.3):

The goal, therefore, was an evolution to a holistic, cooperative and collaborative decision-making environment, where the expectations of the members of the ATM community would be balanced to achieve the best outcome based on equity and access.

1.1.2 The concept further articulates (Doc 9854, Appendix I, 10) a high-level explanation of collaborative decision-making (CDM) including the following attributes:

- a) CDM allows all members of the air traffic management (ATM) community to participate in ATM decisions that affect them (i.e. CDM is not limited to any specific domain such as an airport or en route);
- b) CDM may apply to all layers of decision-making from longer-term planning activities through to real-time operations;
- c) CDM can be applied actively or, through collaboratively agreed procedures, passively;
- d) effective information management and sharing enables each participant to be aware of information of relevance to other participants’ decisions; and
- e) any member being able to propose a solution (this is of greater utility when enhanced with effective information management).

1.1.3 AN-Conf/11 further articulated the need to develop ATM requirements derived from the global ATM operational concept. This was described as Recommendation 1/3 — Development of ATM requirements:

That ICAO as a high priority develop a set of ATM functional and operating requirements for a global ATM system on the basis of the global ATM operational concept.

1.1.4 As a result of the above recommendation, the *Manual on Air Traffic Management System Requirements* (Doc 9882) was developed. These requirements repeatedly express the need for CDM across all time horizons and concept components. Certain requirements focusing on collaboration include:

- a) ensuring that airspace users (AUs) are included in all aspects of airspace management via the CDM process;

- b) managing all airspace, and where necessary, be responsible for amending priorities relating to access and equity that may have been established for particular volumes of airspace. Where such authority is exercised, it shall be subject to rules or procedures established through CDM;
- c) establishing a collaborative process to allow for efficient management of the air traffic flow through the use of information on system-wide air traffic flow, weather, and assets; and
- d) modifying the AU's preferred trajectory: 1) when required to achieve overall ATM system performance requirements; and/or 2) collaboratively with the AU, in a manner that recognizes the AU's need for single-flight efficiencies.

1.1.5 Further to the development of the requirements, guidance material was sought in the application of a performance-based approach to ATM decisions. This material was described in the *Manual on Global Performance of the Air Navigation System* (Doc 9883), and provides guidance and a process towards addressing AN-Conf/11, Recommendation 3/3 — Performance framework:

That ICAO, in consultation with the other members of the ATM community:

- a) formulate the performance objectives and targets for a future global ATM system;*
- b) continue the definition of related performance metrics and elementary characteristics in the context of the overall behaviour of the ATM system; and*
- c) coordinate and harmonize all related contributions within the overall performance framework initiated by the Air Traffic Management Operational Concept Panel, including definitions, standards for reporting requirements, information disclosure and guidance for monitoring.*

1.1.6 It is expected that the performance-based approach would be applied in a collaborative manner to address the most strategic decisions. The rationale for such collaboration is provided in terms of the consequences of insufficient collaboration:

- a) where insufficient coordination between Air Navigation Service Providers (ANSPs), airports, AUs, manufacturers, regulators and ICAO takes place, the result is a fragmented air navigation system;
- b) insufficient coordination at local, regional and global levels lead to less than ideal interoperability and to geographic differences in terms of performance and maturity; and
- c) a fragmented approach from an operational perspective (no gate-to-gate and en-route to en-route) leads to less than optimum flight and airport operations efficiency.

1.1.7 Doc 9883 further states that, collaboration and coordination is needed to:

- a) come to an agreed vision on the expected results;
- b) ensure that everyone delivers their part of (their contribution to) the required performance;
- c) ensure that everyone uses a compatible approach, method and terminology; and
- d) ensure that everyone's data can be integrated and aggregated to calculate overall indicators and assess system performance at a higher aggregation level.

1.1.8 While the above establishes the need for collaboration across multiple stakeholders, objectives and time horizons, an additional attribute to collaboration is the degree to which the collaborative processes are harmonized. While this document seeks to not be overly prescriptive in specifying collaborative mechanisms and processes, there are clear consequences resulting from a lack of harmonization, some examples include:

- a) Data requirements: CDM processes operate in a future information-enriched environment, with exchange of data as the primary facilitator of collaboration. Divergence in data requirements to support disparate CDM processes leads to additional required investments on the part of AUs in information infrastructure and data collection mechanisms.
- b) Automation: Increased automation is expected, particularly in the faster response time CDM processes. In addition to divergent data requirements, differing CDM processes will require AU automation with tailored algorithms. Furthermore, CDM processes that are constantly changing require evolving automation.
- c) Airborne scope of CDM: An extension of the collaborative process to the flight deck for the most tactical CDM processes invites greater harmonization of the required data and processes as the aircraft will operate in multiple environments.
- d) Training: Similar to the need to develop new algorithms for disparate or changing CDM processes, AUs operating across boundaries require additional training to handle the variation in these processes.
- e) Seamlessness: Flights will cross through boundaries which differing CDM processes may be applied. Disparate CDM processes and data affect performance for various reasons such as inconsistent objectives, obtaining optima piece-wise, different decision times, and lack of visibility into each other's processes.
- f) Consistency across decisions: The different layers of decision-making can lead to inconsistencies. For example, agreement can be reached on broad performance objectives through CDM for strategic decisions. Operational decisions reached collaboratively may seek different operational performance objectives based upon circumstances, effectively working at odds to the strategic decisions. Processes should consider potential inconsistencies and guidelines for mitigating these inconsistencies.
- g) Verification and robustness for gaining an advantage or "gaming": Since the CDM processes are based upon information provided by multiple participants with differing objectives, the provision of false information to "game" the system in their favour is a potential concern. Lack of harmonization may make it difficult to detect, or be too robust against, the impact of these behaviours across disparate processes with the end result being a less equitable system.

1.2 DOCUMENT OBJECTIVES AND SCOPE

1.2.1 As the prior section indicated, Doc 9854 and derived documents call for increased levels of collaboration across the spectrum of decision-making. While these documents indicate a need for and a description of the applicable areas of collaboration, the guidance on implementing CDM is not complete; this manual provides that additional guidance.

1.2.2 It is recognized that CDM is applicable to long-term planning activities such as infrastructure investments and procedural changes. For those types of activities, the performance-based approach, as described in Doc 9883, provides guidance on the methods for attaining collaborative, performance-focused solutions. Furthermore, given the

long time horizons available for collaboration, rules, methods and roles of individual collaborating participants can be customized to the situation. Some types of decisions are out of the scope of this manual and will be covered by Doc 9883, Part I — *Global Performance* and Part II — *Performance-based Transition Guidelines*, First Edition, 2009.

1.2.3 For other types of CDM requiring additional guidance beyond the performance-based approach (e.g. agreement on day-of-operations configurations, flight-specific trajectory changes as required for queue or traffic flow management), this manual provides guidance material in the following areas:

- a) CDM description in addition to overarching collaboration principles and processes, which include:
 - 1) a description of the ATM areas suitable for collaboration;
 - 2) a classification and description of the types of collaboration, and conditions under which they apply;
 - 3) a description of complementary decision-making, and conditions under which it may apply; and
 - 4) issues to be addressed when implementing collaborative processes, including the use of rules managing behaviour;
- b) the role of information exchange — information-sharing is central to collaborative processes; important considerations in this area are described below:
 - 1) data standards — why standards at a syntactic and semantic level are necessary;
 - 2) information quality — types of approaches for mitigating impacts, where applicable; and
 - 3) role of the collaborative environment — how the information for a collaborative environment supports collaboration;
- c) articulating a CDM process — identifying what is necessary to describe a CDM process given an objective for collaboration, including:
 - 1) participants — who is participating in the collaboration;
 - 2) roles and responsibilities — what functions do the participants perform and how do they interact;
 - 3) information requirements — description of requirements and standards imposed on information exchanged as part of the above interactions;
 - 4) making the decision — how is a decision made; and
 - 5) rules — what are some rules constraining the behaviour;
- d) examples of present-day CDM processes, which include:
 - 1) airport and surface CDM;
 - 2) network operations planning;
 - 3) coordination of airspace use;

- 4) CDM under adverse weather;
- 5) special traffic management programmes and security; and
- 6) use of collaborative working groups and tools.

1.3 RELEVANT ICAO DOCUMENTS

The following documents provide additional background on CDM including its role in the concept, areas requiring collaboration, guidelines for collaboration on strategic planning decisions and an information-sharing approach to support it:

- a) *Global Air Traffic Management Operational Concept* (Doc 9854), First Edition, 2005;
- b) *Manual on Air Traffic Management System Requirements* (Doc 9882), First Edition, 2007;
- c) *Manual on Global Performance of the Air Navigation System, Part I — Global Performance and Part II- Performance-based Transition Guidelines* (Doc 9883), First Edition, 2008; and
- d) *Manual on Flight and Flow — Information for a Collaborative Environment (FF-ICE)* (Doc 9965).

Chapter 2

DESCRIPTION OF COLLABORATIVE DECISION-MAKING (CDM)

2.1 GENERAL APPROACH AND PRINCIPLES

2.1.1 CDM is a process applied to support other activities such as demand/capacity balancing. CDM can be applied across the timeline of activities from strategic planning (e.g. infrastructure investments) to real-time operations. CDM is not an objective but a way to reach the performance objectives of the processes it supports. These performance objectives are expected to be agreed upon collaboratively. Since implementing CDM likely will require investments, these will need to be justified in accordance with the performance-based approach.

2.1.2 Although information-sharing is an important enabler for CDM, the sharing of information is not sufficient to realize CDM and the objectives of CDM.

2.1.3 CDM also requires pre-defined and agreed upon procedures and rules to ensure that collaborative decisions are made expeditiously and equitably.

2.1.4 CDM ensures decisions are taken transparently based on the best information available as provided by the participants in a timely and accurate manner.

2.1.5 The development and operation of a CDM process follows these typical phases:

- a) identification of the need for CDM;
- b) CDM analysis;
- c) CDM specification and verification;
- d) CDM performance case;
- e) CDM validation and implementation; and
- f) CDM operation, maintenance and improvement (continuous).

It is important that the results of all these phases are shared between the involved community members.

2.1.6 The first phase is the identification of the need to apply CDM to realize a performance improvement. This can relate to current processes/operations or to future processes. A “need statement” should refer to the process(es) to which CDM should be applied and specify the current situation, involved community members and current (or projected) performance shortfall(s). It should include a first assessment (often based on expert judgement) describing how and through which means CDM can mitigate a shortfall. Shortfalls should be identified in areas related to all eleven key performance areas (KPAs) identified in Doc 9854. While CDM has the ability to influence performance in all eleven KPAs, CDM provides a mechanism specifically well-suited to addressing the following performance areas, which are frequently difficult to quantify:

- a) **Access and equity** — A global ATM system should provide an operating environment that ensures that all AUs have right-of-access to the ATM resources needed to meet their specific operational requirements and that the shared use of airspace by different users can be achieved safely. The global ATM system should ensure equity for all users that have access to a given airspace or service. Generally, the first aircraft ready to use the ATM resources will receive priority, except where significant overall safety or system operational efficiency would significantly improve or national defence considerations or interests dictate that priority be determined on a different basis.
- b) **Participation by the ATM community** — The ATM community should have continuous involvement in the planning, implementation and operation of the system to ensure that the evolution of the global ATM system meets the expectations of the community.

2.1.7 In the second phase, the CDM analysis, the process is further analysed from a decision-making perspective. The analysis should make clear what decisions are to be made, which community members are involved (or affected), which information is used in support of the decision(s), which process(es) are followed, how and through which means the decision-making process can be improved and how such an improvement could contribute to better performance.

2.1.8 The third phase, which builds on the CDM analysis, results in a shared and verified specification of the CDM process. It will address:

- a) the decisions to be taken, how they are reached and finalized;
- b) the community members involved and their roles/responsibilities in the decision(s);
- c) agreement on objectives; there may be a shared objective with individual sub-objectives (e.g. resolve congestion while minimizing impact to my operation);
- d) decision-making rules, processes and principles including specification of timeline/milestones, interactions, roles and responsibilities;
- e) information requirements including data standards, quality, frequency and deadlines; and
- f) the CDM maintenance process: review, monitoring/verification, etc.

The above is further detailed in these guidelines and illustrated through examples.

2.1.9 The objective of the performance case, developed through the fourth phase, is to justify the decision to implement the CDM process and to make the necessary investments. It should clearly specify what the costs are and the benefits (using the relevant KPAs) that will result from the operation of CDM. It is important that the results of the performance case are shared between all relevant community members. In case the CDM process is an integral part of a new process, it should be integrated in the performance case.

2.1.10 The fifth phase, CDM validation and implementation, includes all steps to bring CDM into operation. It includes training and informing staff, implementation/adaptation of systems, information networks, etc.

2.1.11 Once the CDM process is operational it should be subject to a continuous and shared review, maintenance and improvement process. In this way, performance can be continually improved.

2.2 GOVERNANCE

2.2.1 Much of the approach described in the prior section falls under a broader classification of “governance”. It is essential that a CDM process have well-articulated governance.

2.2.2 Governance is described in the 1994 World Bank report, *Governance: The World Bank’s Experience*, as follows:

“Good governance is epitomized by predictable, open and enlightened policy making; a bureaucracy imbued with a professional ethos; an executive arm of government accountable for its actions; and a strong civil society participating in public affairs; and all behaving under the rule of law.”

2.2.3 While the above document clearly is aimed at governance of a different scope, the characteristics of good governance are applicable to the governance of any CDM process.

2.3 AREAS OF APPLICATION

2.3.1 Doc 9965 provides a concept for flight information-sharing of relevance to CDM. Figure I-2-1 defines a timeline for information-provision that can be used to describe areas to which these CDM guidelines may be applied. Together with the timeline, there are other ways in which areas of application may be described, as identified below:

- a) position in timeline;
- b) ATM process/concept component reference; and
- c) CDM objective and type of decisions it supports.

2.3.2 As already defined in 1.2, this manual does not address CDM in the context of performance-based strategic planning. More guidance on this can be found in Doc 9883. Examples of areas of collaboration not addressed by this manual, but addressed through the performance-based approach include:

- a) collaboration on long-term performance outcomes and targets;
- b) collaboration on implementation of operational improvements, including changes to procedures, airspace organization, and infrastructure; and
- c) collaboration on forecasts and post-event analyses used for long-term strategic planning.

2.3.3 Collaboration while applying the performance-based approach applies to longer time horizon activities. Given these long lead times, collaboration can be individually tailored to the circumstances.

2.3.4 Toward the end of the timeline, tactical decision-making during flight operations or just before departure may not provide sufficient time for collaboration to be accomplished effectively. This can have two distinct effects on:

- a) decisions on events or new information that provide insufficient time for collaboration between the time of the event and the deadline for a decision; and
- b) decisions for which collaboration has occurred at an earlier point in the timeline and as time progresses, there is insufficient time remaining to continue collaborating.

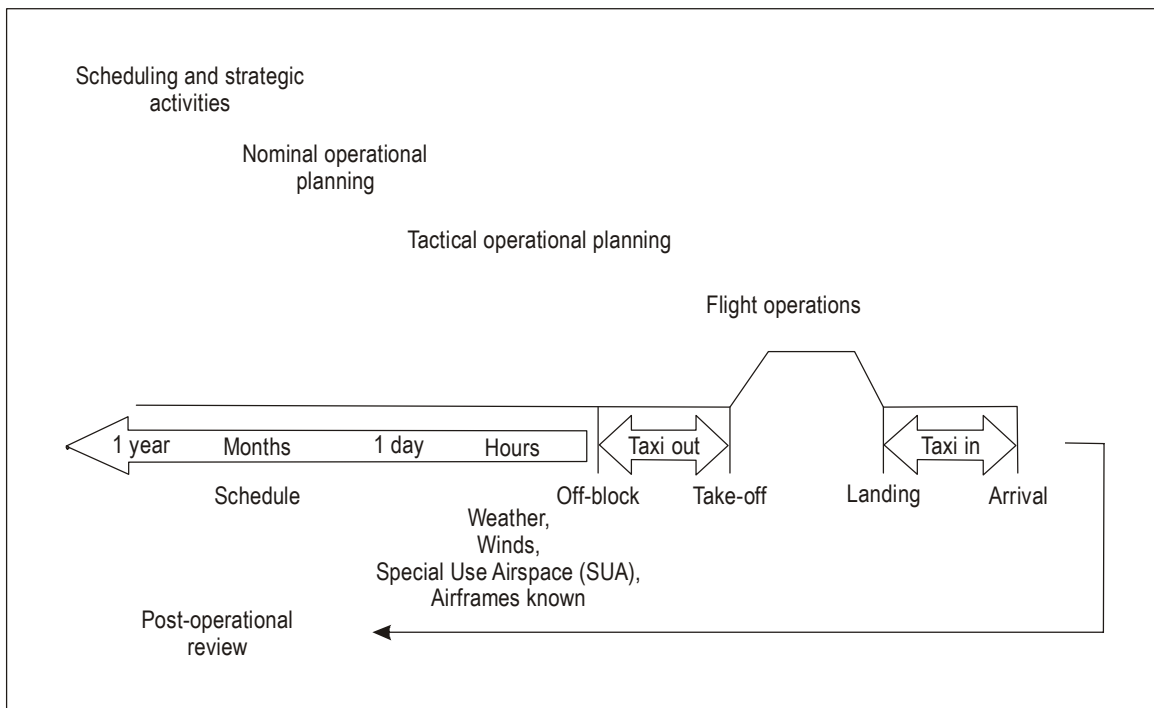


Figure I-2-1. Timeline of information provision (extracted from FF-ICE concept)

2.3.5 In both of the above cases, collaboration is applied to agree upon the processes and rules by which these time-critical decisions are made. As a result of these agreements, combined with an anticipated information-rich environment, the second of the above cases is expected to evolve into CDM.

2.3.6 CDM may also be applied to various concept components as they are executed across the timeline. Doc 9882 identifies requirements for collaboration and CDM across multiple concept components including:

- a) airspace organization and management;
- b) aerodrome operations;
- c) demand and capacity balancing;
- d) traffic synchronization; and
- e) ATM service delivery management.

2.3.7 Looking at the requirements for the components across the timeline, some collaboration requirements fall under the purview of the performance-based approach (e.g. definition of airspace structures and procedures under Doc 9882, AOM – R04). Other requirements indicate the need to apply CDM to establish rules or procedures.

2.3.8 Beyond the requirements for collaboration, it is clear that decisions on strategic conflict management may also benefit from CDM. However, as it is achieved through other concept components (see the extract below from Doc 9854), CDM as it applies to conflict management is covered through other components.

Strategic conflict management is the first layer of conflict management and is achieved through the airspace organization and management, demand and capacity balancing and traffic synchronization components.

2.3.9 Good practices indicate that any decision in ATM is based on the best available information and according to predefined, transparent and agreed criteria and processes. CDM becomes especially relevant when:

- a) one or more decisions are required;
- b) more than one stakeholder is impacted by the outcome of the decision(s);
- c) one or more stakeholders are best suited to evaluating the impact of the decision(s) on their own interests; and
- d) time is available prior to the decision(s) deadline to accommodate collaboration.

2.3.10 Decisions may be competitive between stakeholders (e.g. allocation of resources) or may benefit multiple stakeholders (e.g. relaxation of restrictions in airspace redesign).

2.3.11 The above criteria are all applicable to the areas of collaboration specifically identified in Doc 9882. For example, collaboration:

- a) prior to departure (pre-departure) to manage the turn-around process and departure queue;
- b) to manage flows through the control and synchronization of individual flights;
- c) on agreed weather forecasts to implement airspace/airport flow restrictions;
- d) on timing and selection of dynamic airspace configurations;
- e) to determine the relevant performance criteria to be applicable to a given period; and
- f) to determine equitable unilateral responses to event(s) when time does not permit further collaboration in response to the event(s).

2.3.12 Collaboration is an integral part of the ATM system. However, this document provides guidance on a subset of CDM as defined below:

- a) CDM applied to any concept component;
- b) time is not available to tailor the CDM process for every decision. When time is available to tailor the process to the specific situation, one would expect the performance-based approach to provide sufficient guidance;
- c) time is available to collaborate before a decision deadline; there must be enough time available to do so; and
- d) when time is not available to collaborate on the decision itself, a collaborative process is applied to define the decision-making rules, and to identify the decision-maker that will apply the agreed-upon rules.

2.3.13 Figure I-2-2 illustrates the cases when CDM guidance is applicable and the situation that occurs when time is expiring to a decision deadline. Some deadlines may result in a decision having to be made for planning purposes, but still subject to refinement through a collaborative process. It is noted that CDM can revert to complementary decision-making when actions at a deadline can be anticipated by all participants because sufficient information is available to determine the outcome of a looming deadline.

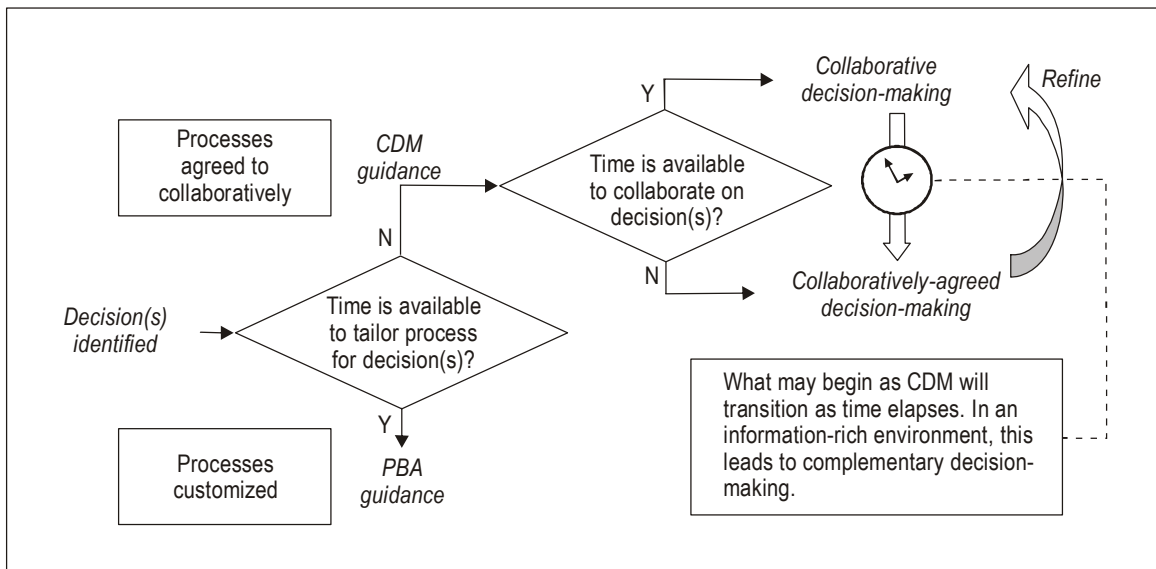


Figure I-2-2. Selection of applicable guidance material

2.3.14 It is the dynamic nature of the ATM environment which necessitates decision-making at various time-horizons. This dynamism refers to an environment in which the future is both uncertain and subject to changing objectives and decisions as a consequence. The impact of weather is an example of how uncertainty can require decision-making at several time-horizons. Early decisions (such as planning operations assuming an arrival delay due to forecast snow) can be made taking into consideration the uncertainty and the ability to respond closer to the time of interest. As the situation unfolds and becomes more certain, decisions respond to this more certain information, with changing decisions contributing to the dynamism.

2.4 TYPES OF CDM

2.4.1 Several situations may occur when making decisions affecting a collection of disparate stakeholders. Figure I-2-3 illustrates these situations along two principal dimensions:

Decision-making — Specifies whether decisions are made by one participant (unilateral) or if decisions are made multilaterally across multiple stakeholders. As applied to ATM, many individual decisions (e.g. across many flights) can be taken to affect an outcome.

Alignment — Identifies whether the interests of the multiple stakeholders are driven by a single common objective, or whether each stakeholder has individual objectives. In the latter case, these can be further decomposed:

Complementary — The pursuit of a stakeholder's individual goals either does not affect or is in alignment with other stakeholders' goals.

Adversarial — The pursuit of a stakeholder's individual goals is in conflict with another stakeholders' goal. This is frequently the case when faced with resource contention.

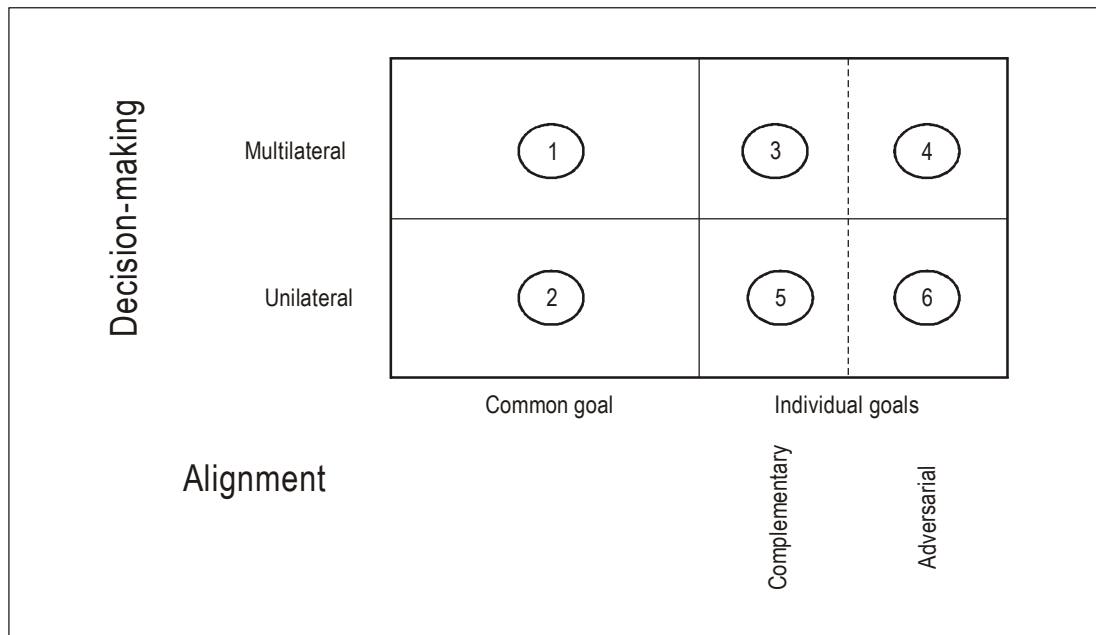


Figure I-2-3. Classification of types of CDM

2.4.2 As has already been mentioned in the prior section, decisions which are multilateral at one point may eventually require a unilateral solution as time progresses.

2.4.3 The objective behind this classification is to provide guidance on some important considerations within each type as described below:

Multilateral decision-making with a common goal — All participants are in agreement on a common, socialized goal driving their decisions (e.g. minimize environmental noise impact given a fixed number of operations). Multilateral decision-making can be preferable in this situation when multiple stakeholders hold the best information necessary to make decisions and it may be difficult or undesirable to share the information. In this case, it is necessary to ensure the following:

- the relationship between the decision and the desired outcome must be known to decision-makers. This can prove to be difficult when the outcome is the result of many combined decisions, some of which may not be announced yet by other stakeholders;
- appropriate levels of information-sharing must be maintained to ensure that each stakeholder has enough information to make decisions that, combined with other stakeholders' decisions, achieve the common goal; and

- c) since the common goal may be insufficient to close the problem, additional goals, including individual goals, may be applied to close the problem. If these are adversarial, these need to be considered.

Unilateral decision-making with a common goal — As in the case above, all participants are in agreement on a common, socialized goal. In this case, a single decision-maker is provided the authority to make decisions towards this goal. It is necessary to ensure:

- a) rules governing the decisions are collaboratively agreed-to prior to engaging in this form of decision-making. These rules must be known to all participants;
- b) adequate information must be provided to the decision-maker by all participants to ensure that the common goal can be attained by the decision-maker given the information. Adequate information requires both that the appropriate information items are provided and that the information be of sufficient quality, stability and timeliness to support the required action by the decision-maker;
- c) secondary objectives may be addressed through the provision of preferences by other participants to the decision-maker, with rules governing their application; and
- d) the relationship between the decision being taken, the goal being pursued and the information supporting the decision must be understood. When this relationship is poorly understood, decision rules will not necessarily be capable of attaining the stipulated goal.

Multilateral decision-making with complementary individual goals — Similar to the situation with a common goal, all participants make their own decisions towards individual complementary or non-competing goals. Considerations are the same as the common goal case; with the added complexity that it may be difficult to ascertain that goals are in fact complementary. Given that CDM is frequently applied to the allocation of constrained resources, this is not likely a common situation between competing participants. However, certain situations may lead to this case, for example:

- a) decisions may have geographically separate impact;
- b) as is frequently the case today, different ATM service providers (ASPs) make decisions affecting flights operating across multiple ASPs. Through the sharing of appropriate information and tailoring of processes to accommodate this information, more globally optimal solutions can be reached, even with different objectives;
- c) individual objectives may align with a common goal (e.g. maximize capacity at some location, potentially for differing purposes); and
- d) once constrained resources have been allocated to participants, decisions may occur within those constraints (e.g. substitutions) to achieve a secondary objective.

Multilateral decision-making with adversarial individual goals — The case of multiple participants making individual decisions with competing objectives is frequent in a capacity-constrained environment. The objective of collaboration is to seek a solution which is considered acceptable (including equitable) to all participants. Several approaches and considerations to this case are:

- a) a set of rules governing the process should be agreed-to prior to initiating collaboration;
- b) rules should include specified deadlines for decision-making. The consequence of missing the deadline should be known to all participants. One such consequence may be reversion to a single decision-maker acting in accordance with known rules;

- c) rules may include a mechanism for constraining the decisions of individual participants. These constraints seek to transform the problem from an adversarial one into a non-competing one. For example, capacity-constrained resources may be allocated to individual participants. Each participant may make decisions within the specified constraints in accordance with individual goals; and
- d) with rules implemented through the use of information provided by participants, a verification function may be required to ensure that information is not provided specifically for the purposes of “gaming” the rules.

Unilateral decision-making with complementary individual goals — Pre-collaboration is applied to identify the decision-maker and the rules by which decisions are made. Considerations for unilateral decision-making under common goals all apply. Rules may consider the differences in goals between participants through information (e.g. preferences) provided by participants.

Unilateral decision-making with adversarial individual goals — As for the case with complementary individual goals, pre-collaboration is applied. In this case, the pre-collaboration must clearly establish rules of behaviour and information-provision on the part of participants to ensure that rules are not being “gamed” through the provision of false information or through otherwise undesirable actions seeking to trigger an outcome.

2.5 HARMONIZING CDM PROCESSES

2.5.1 The prior section described different types of decision-making circumstances and considerations for collaborating under the types of decision-making. In order to collaborate successfully, each type of decision-making requires a process for collaborating; that is, a CDM process. The description of a CDM process requires specification of interactions to a sufficient level of detail to ensure:

- a) the process will allow decisions to be reached; and
- b) compatibility exists when multiple decision-makers (across the ATM community) are participating and potentially applying different internal processes.

2.5.2 The phased approach described in 2.1 results in the definition of a CDM process. The analysis phase of this approach must ensure that compatibility exists when differing internal processes may be interacting. For example, it is not expected that CDM processes will be defined in a manner that are identical across all regions of the globe or across all borders. While CDM processes may not be globally identical, with AUs operating globally, investments in automation supporting CDM would suggest that a counter-balancing performance benefit should exist to continue to justify these disparities. For tactical decision-making, some harmonization is required to ensure that processes enhance rather than degrade system performance and that the exchange of information in support of CDM can be accomplished with adequate data standards. Below are some examples of the consequences of not harmonizing CDM processes, including a lack of cross-border CDM processes:

- a) as part of airspace organization and management, constraints may be provided to a flight across multiple ASPs. Multiple CDM processes may even define these in each locality. Lack of harmonization and collaboration across these multiple ASPs and other participating ATM community members of these constraints may lead to inefficient flight profiles (and potentially infeasible profiles in an extreme case);

- b) having different objectives across locations applying CDM processes may lead to both objectives not being met. For example, a focus on environment versus AU economic performance would not be aligned when time is the driver of economic performance. Collaboration could enable an end-to-end solution that is more acceptable to both than a fragmented solution; and
- c) rationing of capacity constrained resources may be accomplished through different means in different locations. Examples include first-come-first-served, ration-by-schedule, or market-based approaches. Priorities may change for flights as they enter into different airspace regions potentially resulting in flights hurrying to be first in line, only to have to wait longer (a “hurry-up-and-wait” situation).

2.5.3 Dealing with the above examples requires that CDM processes essentially “make sense” across boundaries. This necessitates: a) the definition of a CDM process in each location; and b) the harmonization of those processes across locations so they are not working at odds.

2.5.4 Specific areas for which CDM processes should be standardized include:

- a) agreement on processes or interacting processes;
- b) data/information standards; and
- c) rules and compliance monitoring.

2.6 CDM PROCESS DETAILS

2.6.1 Whether one is considering the application of CDM within a single location, or one is considering the harmonization of CDM processes across multiple locations (i.e. cross-border CDM), there are some detail-oriented considerations that must be taken into account. This section highlights some of these considerations without providing a recipe for doing so, as CDM is expected to be flexible in its implementation.

2.6.2 As one develops a CDM process or attempts to harmonize potentially disparate processes, a detailed end-to-end analysis of the process and interactions will likely be required. This is described in 2.1.7 as the second phase. At a minimum, these analyses will entail the following:

Understand objectives (shared and individual) — Identify the overall shared objective(s) of collaboration. Individual objectives may be at odds, difficult to establish, and will affect behaviour. Understanding objectives is critical to developing likely interactions so that the proper information exchange and control mechanism can be put in place. Together, these seek to achieve shared objectives, and mitigate potentially adverse behaviour. For example, control mechanisms may need to be in place to allow the overall objective to be achieved (e.g. constrain flight changes to ensure an equitable process). These control mechanisms are described as rules governing a CDM process in 2.8.

Understand decisions being made by various participants — Once objectives are understood, the next step is to understand the decision(s) that can be made by whom to reach that objective. As one investigates these decisions, the following questions should be considered:

What are the decisions to be made? Whatever CDM process is being investigated, there is a set of decision variables that can be affected by certain CDM participants. For example: a decision can be to impose a constraint on a flight or a defined group of flights (e.g. a participant may be allowed to have two flights use a resource within a time frame), or a flight itself can be changed (e.g. re-route, change departure time, altitude constraints).

Who makes the decision? The allocation of responsibilities for decision-making is central to defining a CDM process. In the examples provided previously, an ASP might alter the flight in accordance with CDM rules and provided information, or might allocate resources to a participant that then alters the flights to meet the resource allocation. The resulting performance may be very different depending on who has access to what information. Who decides is critical to understanding the outcome since the decision-maker will seek to meet their individual objectives within required constraints. If system-performance improvement (across all KPAs including access and equity) is the overall goal, then the process may have to define constraints on select groups of participants to ensure that the pursuit of individual objectives leads to system-performance improvements.

What does the decision affect? The relationship among the decisions being made, the goals of the participant making the decisions (subject to constraints) and the performance outcome of those decisions should be understood. These enable an analysis of candidate processes to define a CDM process that will be feasible and best meet performance objectives.

How does one achieve convergence? When a CDM process is defined to make decisions across multiple participants, decisions may need to be collaboratively reconciled. It is important to define a process that enables this reconciliation to occur in a manner that does not lead to stalemates. One approach is to pre-collaborate to define a process to be applied when a deadlock has been reached (e.g. an algorithmic approach, or guidelines for a single unilateral decision-maker to end a deadlock).

Determine the compatibility of interacting processes of various types — When multiple CDM processes interact, or when the decision discussion requires an evolving process, it is necessary to ensure that these processes are compatible. This includes:

Time evolution — When the process changes type across the decision-time horizon, decisions made at an earlier point in time may conflict with later decisions if the processes are incompatible. For example, evolution from multilateral to unilateral decision-making should make sure that decisions do not get compromised by the unilateral decision-maker thereby creating deleterious performance effects.

Differences across ASPs — A single flight or flow may operate through multiple areas of jurisdiction each with CDM processes of different types. It is important to ensure that the overall end-to-end solution can be achieved at acceptable levels of performance. For example, when multiple ASPs encounter capacity constraints affecting a shared flow, the modification of trajectories to deal with each constraint independently is not a desirable situation. It is preferable that an end-to-end solution be developed for each flight, yet this is difficult to accomplish unless the processes have methods to prioritize constraints, to allow trading between flights, or are flexible in the timing of constraints.

Ensure compatibility of interaction between various participants — CDM occurs through a continuous process of information-provision and individual decision-making by various interacting participants. The process must be analysed to ensure compatibility of these interactions across boundaries. This includes:

Timing of events — Decisions made by various participants may have to be synchronized, as may the sharing of information. For example, all constraint information would ideally be provided prior to decision altering a trajectory in order to meet constraints one at a time. Poor timing of decisions in one area can affect the decision in another area which could lead to sub-optimal trajectory choices.

Information exchange — Information that is exchanged should be subject to standards to ensure interoperability and to minimize data translation. The link between local airport processes and broader ATM network processes is ensured through execution of the CDM phases as described in 2.1. This is especially valid as described in the second phase for those ATM community members who are affected by the outcome of decisions and the need for supporting information made available through defined exchanges.

Consistency of rules — CDM processes may allow individual participants to make individualized decisions within the confines of rules (e.g. substitutions within a resource allocation). These rules are frequently defined to ensure that system performance is not adversely affected by individual participants optimizing their own performance. When multiple CDM processes interact, the rules must be investigated to ensure that the overall system performance is still not adversely impacted.

2.7 HARMONIZING DATA

2.7.1 Data exchange is critical to CDM as participants in the decision-making process must have the information necessary to make decisions consistent with sought objectives. However, in order for information exchange to be effective, information standards must be defined to ensure compatibility and common understanding among participants and decision-makers. These standards should address the following:

- a) Syntactic interoperability — data formats, communications protocols, etc., and so on must be defined to ensure the successful exchange of data between systems. Units must be considered. Formats should apply to complex data structures, not just the simplest data item;
- b) Data definition — data items should be defined in a consistent manner across CDM processes that use the data. Ambiguous or duplicative data elements should be avoided;
- c) Update requirements — requirements on frequency of cyclical information updates, and definition of events triggering information updates should be established. This includes requirements on the update of data whose content is derived from other updated data elements; and
- d) Information quality — there are many dimensions to information quality, these include: accuracy of provided data, precision with which it is provided, stability of the data in a changing environment, and latency of information provision.

2.7.2 The application of data standards not only helps to reduce incompatibilities in decisions due to conflicting interpretation of information, but reduces development costs for automation systems interacting across disparate locations (i.e. cross-border CDM). An analysis of CDM processes to ensure that data update requirements are sufficient for successful decision-making may also be required when interacting CDM processes have disparate information and timing requirements.

2.8 HARMONIZATION OF RULES AND COMPLIANCE MONITORING

2.8.1 As the time horizon for decision-making shortens into the more tactical decision-making, there is less time available for negotiation, and collaboration is expected to be more structured. This structure consists of rules of behaviour during collaboration including:

- a) description of information to be provided by participants;
- b) indication of deadlines for provision of information;
- c) identification of quality of information to be provided, including accuracy;
- d) allowable use of provided information and requirements on protection of provided information; and

e) identification of decision-makers and constraints on decisions, these constraints can include:

- 1) parameters for user-responses to resource allocation (e.g. bounds on departure times, treatment of substitutions);
- 2) algorithms or rules for unilateral decision-making (e.g. use of information for prioritization of resource use); and
- 3) deadlines for decision-making and potentially switching between types of decisions (e.g. from multilateral to unilateral decision-making).

2.8.2 This structure is expected to be defined through pre-collaboration between the expected participants of the CDM process. With a structure comes the expectation that participants will abide by it; however, it may not always be in their interest to do so. As a result, a compliance monitoring function may be required to ensure that rules are followed. For example, this can include the verification of the accuracy of information when that information is used for allocation of constrained resources.

2.8.3 The rules that are agreed to for a CDM process will likely have a strong effect on the behaviour of the participants in response. In particular, the process for prioritization can be based upon:

- a) observation of actual behaviour such as a first-come-first-served approach;
- b) information provided reflecting intent, such as a ration-by-schedule. Observations must be consistent with the intent; and
- c) global performance considerations, such as a best-equipped-best-served approach when equipage is deemed to provide system-level performance gains.

2.8.4 In each of the above, individual stakeholder performance will be affected by their behaviour in response to the prioritization approach. For example, scheduling decisions will reflect a desire to be prioritized highly. First-come-first-served will suggest that a “hurry-up and wait” strategy will be preferable. This indicates the need to ensure that participants in the definition of the CDM process consider the impact on individual behaviours when developing the process.

2.8.5 When dealing with the interaction between different locations, potentially with differing CDM processes, an agreed upon CDM process should be considered by the union of participants in each individual CDM process. The interaction of different constraints and rules may adversely impact the performance of the overall ATM system. As a specific example, the allocation of priorities (for assignment of access to capacity-controlled resources) across different ASPs may lead to airborne delays if a flight is considered high priority in one constrained airspace only to fly into airspace where it is considered low priority.

2.9 COMPLEMENTARY DECISION-MAKING

2.9.1 With time elapsing, a multilateral decision-making approach may not be reaching a solution that solves known capacity imbalances because individual participants seek their individual objectives in lieu of a collective one. An example includes decisions on routes required to deal with airspace congestion prior to a deadline such as a flight's planned departure time. AUs may be unwilling to re-route their own flights if other users may do so.

2.9.2 At some point a unilateral decision might be reached by the ASP assigning re-routes to the various impacted flights. This can be accomplished in an equitable manner by pre-collaborating on the precise method by which flights will be re-routed in such a situation, or by specifying an allocation of flights to each participant to be re-routed.

2.9.3 Complementary decision-making occurs when the outcome of the unilateral decision-making is known to all participants because the information and methods for deciding are also known to all participants. Another approach may be for the unilateral decision-maker to pre-emptively broadcast the action before it is taken. The consequence of such a situation is that decisions made multilaterally will only be taken if they provide an improvement over the expected unilateral outcome. As a result, the performance for each individual is improved over the unilateral situation. However, it is important that the CDM process be defined in such a manner that all such decisions taken by an individual participant are “Pareto” optimal; that is, they cannot harm the performance of other participants.

Chapter 3

ROLE OF INFORMATION EXCHANGE

3.1 INTRODUCTION

Without information exchange, it is difficult to imagine collaboration. This exchange can occur with various degrees of structure. At one end, an unstructured approach to information exchange might involve teleconferences between collaborating parties affording an opportunity to ask for clarification. As more structure is incorporated, information exchange could be at a system-to-system level with algorithms on both ends exchanging information to reach individual decisions. When time is at a premium, many parties are involved, automation requires data and more structure is required for information exchange. This chapter focuses on the information exchange in this more structured environment, as follows:

- a) a future collaborative environment envisaged to support the Global ATM Operational Concept;
- b) what is meant by data standardization in such an environment; and
- c) defining quality of information.

3.2 THE COLLABORATIVE ENVIRONMENT

3.2.1 Doc 9965 describes the flight and flow — information for a collaborative environment concept. The future vision of this collaborative environment follows from the vision provided through Doc 9854, which states:

Information management will assemble the best possible integrated picture of the historical, real-time and planned or foreseen future state of the ATM situation. Information management will provide the basis for improved decision-making by all ATM community members. Key to the concept will be the management of an information-rich environment.

3.2.2 Figure I-3-1, extracted from Doc 9965, describes participants, at a high level, collaborating by providing and consuming information across various information domains. The high-level categories of participants that may be included in the collaboration are the:

- a) ATM service provider (ASP);
- b) airport operator (AOP);
- c) AU;
- d) airspace provider (AP); and
- e) emergency service provider (ESP).

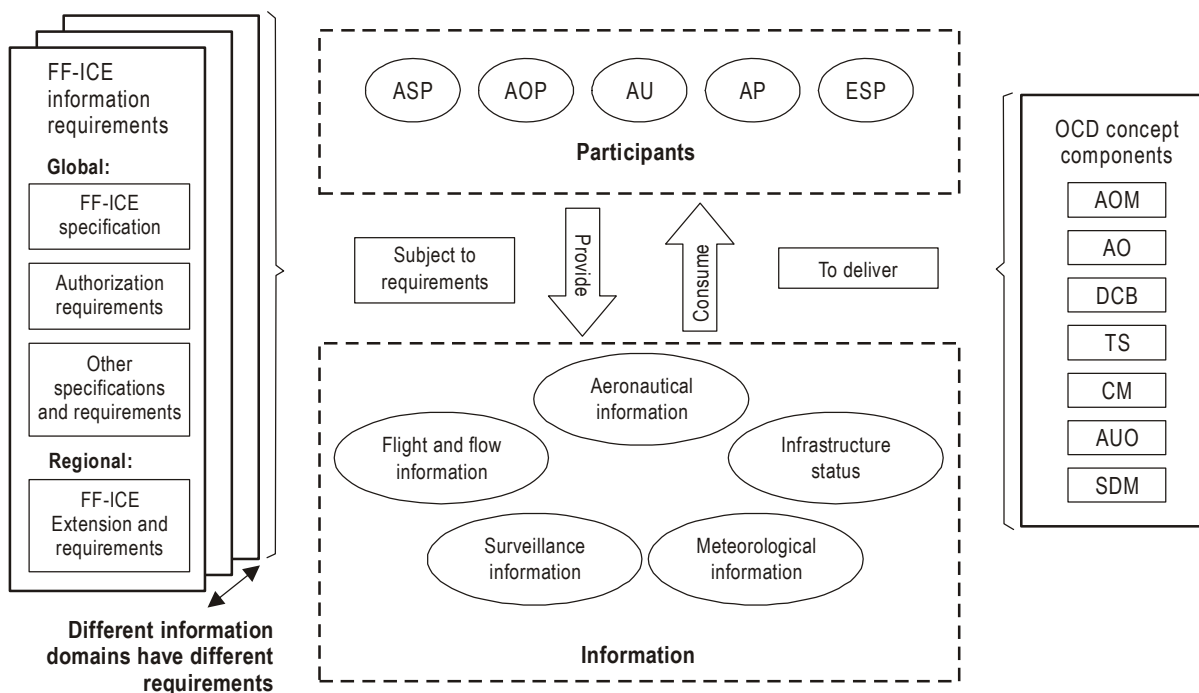


Figure I-3-1. Example information in a collaborative environment

3.2.3 One purpose of the collaboration is to deliver the concept component functionality. Each information domain would be subject to specific information requirements at a global level and potentially at a regional level as well. These requirements on information are expected to consist of:

Data specification — Successful data exchange requires specific standards for data items including the definition and the structure with which they will be exchanged. In a performance-based environment, data are also subject to requirements on quality enabling the delivery of the concept components within a target level of performance. These two aspects: data standards and information quality are discussed in more detail in subsequent sections.

Authorization requirements — The provision and consumption of information will be subject to context-sensitive authorization requirements. Participants will be able to provide, modify and obtain data only when certain conditions are met. These conditions will depend on the circumstance and the participant requesting authorization. For example, one AU will not be capable of modifying information on other AUs' flights. As a flight transitions through multiple ASPs, authorization requirements will change.

Operational requirements — In addition to requirements on the data and the access to the data, there may be operational requirements. An example would be the requirement to provide data in order to qualify for a procedure or access to some constrained resource (e.g. level of RNP to access airspace with criteria, permission information for access to certain airspace, equipage and crew qualifications for advanced procedures). Another example involves the need for information to comply with specified constraints (e.g. trajectory complies with airspace constraints). These requirements are not expected to be static (temporally or geographically) as service delivery management will modify these as necessary to achieve performance levels in accordance with anticipated demand.

3.2.4 Given the collection of requirements that information exchange in this collaborative environment is expected to comply with, a system of checks should be in place to ensure compliance. Some checks, such as whether the document is valid and well-formed (in XML parlance), can be accomplished through the availability of an appropriate standards document (e.g. schemas). Other forms of compliance verification will require definition during the establishment of the requirements.

3.2.5 With appropriate information management, a CDM environment is created through the following:

- a) the information infrastructure supports the sharing of information across a wider, extensible set of participants, thereby allowing greater participation by the ATM community and reaching shared situational awareness. Decisions can be made in a more collaborative manner with greater knowledge to determine their consequences;
- b) an extensible information infrastructure supports the addition of new information items, such as preferences to enable all participants to extend their information needs as decision-making processes evolve; and
- c) international data standards and information requirements enable decision-automation to be developed once without customization across multiple regions. Through lower participation costs, collaboration is increased.

3.3 DATA STANDARDIZATION

3.3.1 Paragraph 2.7 indicates the need for data harmonization. Furthermore, Doc 9854 indicates that “information management will use globally harmonized information attributes”. One stage of data harmonization is the development of globally applicable data standards.

3.3.2 As it pertains to CDM, data standardization is pertinent to several areas within which we would expect decisions to be made through collaboration, such as:

- a) areas (e.g. agreement on performance outcomes, operational improvement deployment, airspace redesign, projections and post-operational analysis) falling under the purview of the performance-based approach. For these areas, decisions are expected to be supported with the necessary standardized data to enable performance evaluation. These considerations are described in Doc 9883, Appendix D, First Edition, 2009; and
- b) areas involving more tactical CDM for which information is expected, in many regions, to be exchanged system-to-system. These areas include:
 - 1) tactical airspace organization (e.g. collaborating on defining airspace configurations for capacity);
 - 2) tactical capacity management (e.g. collaborating on airport/airspace configurations potentially trading capacity for efficiency); and
 - 3) trajectory management (including management of priority, sequences, and access);

these areas are expected to require information as illustrated by the five information domains as shown in Figure I-3-1. These domains are:

- 1) aeronautical information — standards for aeronautical information would be described through the aeronautical information exchange model (AIXM);
- 2) flight and flow information — Doc 9965 provides initial material to define standards for the flight information exchange model (FIXM);
- 3) surveillance information — current standards for the ground-to-ground exchange of surveillance information;
- 4) meteorological information — current standards for the global dissemination of weather products. Further standards development work may be required for new aviation weather products and to make these applicable to aviation CDM (e.g. see the weather information exchange model (WXXM)); and
- 5) infrastructure status — standards for infrastructure status could largely be expressed using modified AIXM standards.

3.3.3 Data standardization in each of the above domains seeks to address the following:

- a) data item identification — defines the universal name for the data item;
- b) definition — an unambiguous definition of the data item is required. This refers to a plain-language definition of the data item;
- c) syntax — this describes how the data are expressed. Descriptions of syntax should, to the extent possible, apply repeatable data types (e.g. integer, decimal, string, data) as defined in existing standards (e.g. FAQ Markup Language (FML) per ISO 19136 for standards defined in XML):
 - 1) the syntax of one data element may be defined as a collection of nested data elements. For example, a data element may be a list comprised of multiple data elements each with their own definitions and syntax. A trajectory would likely be composed of many other nested data elements; and
 - 2) valid lexical representations of the data should be identified (e.g. 10e3 and 1000 represent the same numbers);
- d) constraints on syntax — these limit the set of possible data elements that can be defined within the given syntax:
 - 1) default values for the data type, if applicable;
 - 2) range and domain of the data item. This may include an enumeration of valid categorical data such as wake categories or aircraft types;
 - 3) maximum and minimum level of precision of the data (e.g. decimal places);
 - 4) restrictions on the order of appearance of data; and
 - 5) repeatability — how many of these data elements are allowed (e.g. multiple equipment codes, but only one aircraft type); and
- e) additional information about data items:

- 1) approved units — what are valid units and how they will be expressed. Constraints on syntax will vary depending on the selected unit; and
- 2) accuracy and information quality — if information quality is required, how is this expressed.

3.4 QUALITY OF INFORMATION

3.4.1 Decision-making is improved with accurate information; where such data are not available, good decision-making is then based upon expected outcomes. There are many reasons why information may be of lower quality. The reasons for this determine the manner in which the information is treated. Examples include:

- a) accuracy of forecast or predicted information is affected by the foreseeable horizon. It is useful to have metrics indicating the prediction accuracy together with the information. The most basic approach to dealing with such inaccuracies is to seek improvements in forecast ability, but this may be prohibitive or infeasible. Alternatively, decision-making may consider the expectation of error in a variety of manners:
 - 1) expectation-based decision-making;
 - 2) allocation of decisions between strategic and tactical decisions are based upon uncertainty; and
 - 3) exemption from decision-making;
- b) information quality is expected to vary as a function of location, in part due to differences in available infrastructure. Any CDM process spanning localities with disparities in information quality must be able to accommodate these. It is expected that a performance-based approach would be applied to ameliorating the infrastructure where necessary;
- c) when information is provided by participants for the purpose of informing of decisions pertaining to the information providers, and where interests are competitive, the possibility exists that misleading information will be provided, essential information will be omitted, or information may not be provided in the timeliest manner. These would be guided by the desire of an individual participant to obtain a beneficial outcome. In particular, the provision-of-intent information could be subject to interpretation. Paragraph 2.8 discussed the need for rules in this area;
- d) ATM is dealt with in a dynamic environment. As a result, information may change frequently and significantly. Highly unstable information may prove of little use. Knowledge of the stability of the information is important when making decisions. For example, knowing that a user may significantly change their desired trajectory provides information to be used in determining demand/capacity imbalance likelihoods. The stability of the information can be managed through: a) providing indications of stability of the information; and/or b) requiring that decisions be stabilized by certain deadlines. These would be defined collaboratively when identifying the CDM processes; and
- e) additional technical quality details. These include the accuracy of measured data, the fidelity or resolution of reported data, the frequency of events leading to updates, and the basis for reporting the data (such as a specific grid). For these details, one would expect requirements to be in place to define the level of quality required from information providers.

3.4.2 As part of the definition of CDM processes, one would expect the specification of data-sharing agreements between collaborating participants to be documented through Memoranda of Understanding, data specifications, and data quality documents. Reporting measures on data quality may also be explicitly articulated and reported on a regular basis.

Chapter 4

ARTICULATING A CDM PROCESS

4.1 INTRODUCTION

In a collaborative process, the goal is not only to achieve a desired outcome, but to achieve that desired outcome in the most efficient and effective way possible for the organization(s) and for all collaborating parties involved. This can only be achieved if the collaborating parties give as much attention to how they work together throughout the process as they do to the process itself. Without one or the other, true cooperation, synergy and teamwork cannot occur.

The description of a CDM process requires the identification of:

- a) What is the objective of the collaboration? This includes identifying the end-product of the collaboration. CDM leads to decisions, including agreements;
- b) Who are the collaborating participants?
- c) How are they collaborating? This includes addressing:
 - 1) What are the roles and responsibilities of the individual participants towards reaching the objective?
 - 2) What is the exchange of information required? This includes addressing how the CDM process interacts with the overall collaborative environment.
 - 3) What are the rules? How are they enforced?
 - 4) How is a decision reached/finalized?
 - 5) Disagreements:
 - i) What process is used to handle disagreements within the group?
 - ii) How will disagreements that seem irresolvable be handled?
 - 6) If a decision has a deadline, how are deadlocks arbitrated?

It is important that the CDM process be defined considering the aspects described herein, but also be detailed in unambiguous governing documents that are agreed-to by all participants.

4.2 COLLABORATING PARTICIPANTS AND OBJECTIVE SETTING

4.2.1 One of the first steps in articulating a CDM process is to first understand what the objective is of the collaboration. An initial objective can be high-level, such as improving the allocation of delays when resource constraints

require delays. With an initial objective identified, a set of participants can be defined. Participants may include both humans and automation systems.

4.2.2 The phases described in 2.1 can be classified into two stages of collaboration: 1) the setting up of the CDM process (phases 1-5); and 2) the execution of the agreed-upon CDM process (phase 6). During the initial stage, identified participants collaborate on refining the objective of collaboration as illustrated in Figure I-4-1. This may lead to changes in the required participants as well. Examples of objectives include:

- a) agreement on flight-specific trajectory information (e.g. pushback times, departure times, routing) in order to mitigate demand/capacity imbalances;
- b) agreement on collaborated forecast products as input to capacity estimates; or
- c) agreement on airspace configuration changes including timing.

4.2.3 As previously described in 3.2, Figure I-4-1 illustrates the high-level categories of participants that may be included in collaboration, these are:

- a) ASP;
- b) AOP;
- c) AU;
- d) AP; and
- e) ESP.

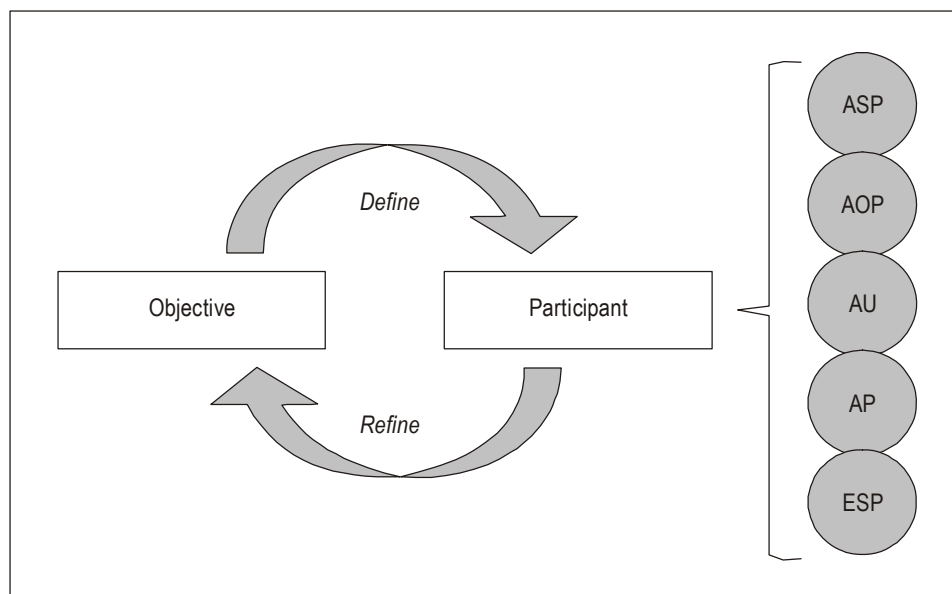


Figure I-4-1. Iterative process identifying participants and objective(s)

4.2.4 In addition to the collaborating participants listed above, depending on the specifics of a collaborative process, additional participants may include:

- a) information provider — for example, a weather provider may be included for decisions impacted by weather forecasts;
- b) flying public — information may be provided to the flying public to enable improved decision-making on their part; and
- c) regulators — particularly during the definition of the CDM process, regulators in all areas, including economic, environment, and safety may need to be involved.

4.2.5 The identification of collaborating participants will require some iteration as well. When the purpose of the collaboration is defined, the impact of the types of decisions that are anticipated should be understood. An initial list of collaborating participants would be those participants that are expected to be impacted by the decisions, and those that are required to provide information or make related decisions. In this manner, one can feel confident that the right people are part of the process.

4.2.6 With participants and objectives established, roles and responsibilities for each stakeholder may be identified as per 4.3. These will establish the manner in which the CDM process will be executed during the second stage of collaboration.

4.3 ROLES AND RESPONSIBILITIES

4.3.1 In a CDM process, participants typically have the following overall types of roles and responsibilities:

- a) consume and interpret information;
- b) provide information, including the updating and sharing of data triggered by received information;
- c) making a decision and sharing the result of that decision;
- d) executing on a decision that has been made. The executing participant may or may not be the participant that made the decision; and
- e) providing a service consistent with decisions that have been made.

4.3.2 Prior to describing a collaborative process, the set of specific circumstances under which the described situation may occur should be defined. There may be several sets of circumstances with different roles and responsibilities (e.g. with a limited amount of time, decision-making may be more unilateral). This effectively defines how and when collaboration is expected to begin. This may involve the specification of a participant that has the authority to determine, through a set of established rules or guidelines, when collaboration is initiated for a specific objective.

4.3.3 In an effort to better understand the collaborative process roles and responsibilities, it is frequently useful to express the process through interaction diagrams (e.g. sequence diagrams, activity diagrams) that allow an unambiguous representation of the interactions between participants. These can be used to describe:

- a) which participants are providing and receiving what information and when. Information may be provided based upon identified events, an update cycle or at the discretion of the provider. It is useful to identify compulsory versus optional interactions. Deadlines on the provision of information should be specified. Standards for quality of information provision and requirements on information are expected to be in place in accordance with Chapter 3; and
- b) participants expecting to react to provided information should be identified, together with what the information is used for (e.g. re-compute flight-specific pushback times, determine flights impacted by congestion). This may lead to the provision of additional information to be used by other participants, or may lead to a decision to act, such as:
 - 1) in some cases, the use of information may be constrained by a set of rules governing the application of the information. For example, operators may be constrained to modify flight times such that only a certain number of flights use a resource. Unilateral decision-makers may be constrained to assign resources or modify departure times subject to precise algorithms based on provided information; and
 - 2) different participants may be assigned the responsibility to decide on different portions of the problem space (e.g. AUs may decide on individual flights and ASP on the allocation of capacity to AUs);
- c) once decisions have been taken, it is expected that execution of those decisions will follow by the responsible parties.

4.3.4 The above applies to a more structured collaborative process with emphasis on information-exchange. Some less structured collaborative processes may involve participants in a teleconference to discuss information however the roles and responsibilities would be defined in a similar manner as described above.

4.4 INFORMATION REQUIREMENTS

Requirements for information, as detailed in Chapter 3, must be defined in detail (e.g. through interface requirements where automation may be involved) when describing a CDM process.

4.5 MAKING DECISIONS

4.5.1 The collaborative process must indicate which participants are responsible for making which decisions as part of the definition of roles and responsibilities (see 2.4). When the CDM process is first defined, the allocation of decisions into sub-problems with the best decision-maker responsible for their own decisions is critical. One example for distributed decision-making is to let a unilateral decision-maker assign a portion of constrained resources to participants, in accordance with pre-collaborated rules ensuring an equitable process. Participants are then able to make decisions within the allocation as suitable for their own operations.

4.5.2 The process for making decisions is not expected to be static in all cases. As a deadline approaches, collaboration may not be quick enough to ensure convergence to a solution. In these cases, pre-collaboration may establish a process for timelier decision-making. This includes identifying a unilateral decision-maker, defining roles and responsibilities in accordance with 4.3, and unambiguously specifying a deadline for switching to unilateral decision-making. In the example provided in 4.5.1, a unilateral decision-maker may only get involved at a specified time prior to planned arrival time. Prior to that, other participants may propose their own changes. In an environment with shared situational awareness, complementary decision-making would follow as per 2.9.

4.5.3 Once a decision is made, the mechanism for communicating these decisions to participants must be defined. Typically, this will be through the provision of some information (e.g. flight pushback time, desired route of flight) subject to information standards as defined in Chapter 3.

4.6 RULES AND ACCOUNTABILITY

4.6.1 Rules and the mechanisms for accountability must be described as part of a CDM process (see Chapter 3).

4.6.2 The CDM process is governed by rules defining the participants, provision and consumption of information, quality of that information, expected decisions and times/events for those decisions, requirements as part of the collaborative process (see 3.2) and constraints which must be followed for decision-making. These rules and requirements are expected to be set during the CDM process definition stage and may use a collaborative performance-based approach to do so.

4.6.3 In addition to describing the rules, the consequences of not following the rules should be established a priori through the collaborative process. These may include pre-collaborated penalties (e.g. less allocation of resources in the future) when a participating member is not demonstrating accountability. This may require the need for participants to provide additional information and to have an arbitrator acting as an independent party to enforce the rules. Where possible, real-time monitoring would be preferable, but this may be prohibitive.

