**Nationaal Lucht- en Ruimtevaartlaboratorium**
National Aerospace Laboratory NLR

NLR-CR-2008-299

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EUROCONTROL CARE Innovative Research III

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## Summary

NLR and Vrije Universiteit Amsterdam collaborate in a Eurocontrol CARE Innovative Research III project. It is the objective of this research project to enhance safety analysis of organizational processes in air traffic by development of formal approaches for modelling, simulation and analysis of organizational relationships and processes. These models should describe the organization at different aggregation levels and should lead to emergent safety issues as result of performance variability and interactions of organizational entities.

The organizational modelling research will focus on strengthening the relations between air traffic organization, safety culture and the development of incidents in air traffic operations. To support development and validation of the model, ANSP safety culture survey data will be used that has been and will be gathered in safety culture research at EUROCONTROL Experimental Centre (EEC). The agent-based organizational model is aimed to describe the emergence of safety culture vulnerabilities in ANSPs' organizational contexts, as well as the development of incidents as a result of ANSPs' safety culture vulnerabilities. Such a model may be used as a tool to select and prioritize policies to improve safety culture, and strengthen the general awareness of the link between safety culture and the development of incidents.

The development of the model will be focused on the reporting of safety occurrences and its role within the Safety Management System as a facilitator for optimization of organizational processes (i.e. organizational learning). Occurrence reporting is an important aspect of safety management in an ANSP and it has a range of connections with safety culture.

The current report describes the identification of requirements and methods for development of an agent-based organizational model with emphasis on safety culture in safety occurrence reporting. This will set a basis for development and validation of enhanced agent-based models.

# Contents

# 1 Introduction

In complex and distributed organizations like the air traffic industry, safe operations are the result of interactions between many entities of various types at multiple locations. The importance of proper organizational processes for the safety of complex operations is currently well realised. It is generally acknowledged that the level of safety achieved in an organization depends on the constraints and resources set by people working at the blunt end (e.g. managers, regulators), which determine the working conditions of practitioners who are directly controlling hazardous processes at the sharp end (e.g. pilots, controllers, maintenance operators).

As a way forward for description of organizational structures and processes and inclusion thereof in air traffic safety assessment methods, NLR and Vrije Universiteit Amsterdam collaborate in a Eurocontrol CARE Innovative Research III project. It is the objective of this research project to enhance safety analysis of organizational processes in air traffic by development of formal approaches for modelling, simulation and analysis of organizational relationships and processes. These models should describe the organization at different aggregation levels and should lead to emergent safety issues as result of performance variability and interactions of organizational entities.

The first phase of this research project in 2007 consisted of (1) a literature survey on safety modelling and analysis of organizational processes, and (2) a first application of identified methods to a safety-relevant organizational process in air traffic. The literature survey is reported in (Stroeve et al., 2007a) and it follows that the organizational modelling framework proposed by Popova and Sharpanskykh (2007e) presents the widest repertoire of multi-agent organizational modelling features of the methods considered. This framework has been chosen to study the possibilities of organizational modelling in an air traffic case on safety occurrence reporting (Stroeve et al., 2007b, 2007c).

The continuation of the agent-based organizational modelling research in 2008/2009 will focus on strengthening the relations between air traffic organization, safety culture and the development of incidents in air traffic operations. To support development and validation of the model, ANSP safety culture survey data will be used that has been and will be gathered in safety culture research at EUROCONTROL Experimental Centre (EEC). The agent-based organizational model is aimed to describe the emergence of safety culture vulnerabilities in ANSPs' organizational contexts, as well as the development of incidents as a result of ANSPs' safety culture vulnerabilities. Such a model may be used as a tool to select and prioritize policies to improve safety culture, and strengthen the general awareness of the link between safety culture and the development of incidents.

The development of the model will be focused on the reporting of safety occurrences and its role within the Safety Management System as a facilitator for optimization of organizational processes (i.e. organizational learning). Occurrence reporting is an important aspect of safety management in an ANSP and it has a range of connections with safety culture.

The aim of the work described in the current report is the identification of requirements and methods for development of an agent-based organizational model with emphasis on safety culture in safety occurrence reporting. This will set a basis for development and validation of enhanced agent-based models.

The report is structured as follows. Section 2 presents the identification of safety culture issues with emphasis on its relation with safety occurrence reporting. Section 3 presents agent-based modelling methods to represent these safety culture issues in relation to safety occurrence reporting. Section 4 presents conclusions.

# 2 Identification of safety culture issues in organizational structure

It is the aim of this section to identify safety culture issues in relation to safety occurrence reporting and to relate these safety culture issues to the structure of the organization of safety occurrence reporting. This is done in three steps:

1. Identify the relevant aggregation levels for the organization of safety occurrence reporting;
2. Identify safety culture issues;
3. Form composite safety culture issues and relate them to the aggregation levels in the organizational structure.

Details of these steps are presented next.

**Step 1: Identify aggregation levels**

This study uses the organizational modelling method developed by Popova and Sharpanskykh (2007e), which has been applied for air traffic by Stroeve et al. (2007b,c). In this approach the structure of an organization is considered at various aggregation levels, which describe roles and sub-roles in the organization.

Based on the description of the safety occurrence reporting procedure (cf. Stroeve et al., 2007b) and on the general organization modelling practices (Scott et al., 1981; Popova and Sharpanskykh, 2007e) four aggregation levels have been distinguished for the organization of safety occurrence reporting at an ANSP:

1. The level of an individual in the organization (e.g. a controller, a supervisor, a manager);
2. The level of a team (in particular, a team of air traffic controllers is considered for this study);
3. The level of an organization (i.e. intra-organizational structures, as departments in an ANSP);
4. The level of inter-organizational interaction (i.e. influences from other organizations on an ANSP).

**Step 2: Identify safety culture issues**

As a basis for the identification of safety culture issues we used the sources shown in Table 1. In particular, using safety culture literature we gained general insights into a variety of different types of safety culture issues that may occur in an ANSP. Further, safety culture research by the EUROCONTROL Experimental Centre provided us useful insight in the degrees of importance and significance of particular safety culture issues related to safety occurrence reporting, recognized by different organizational individuals (controllers, maintenance personnel, management). These sources provide a large number of different types of safety culture issues; some examples are provided as part of Step 3.

*Table 1: Sources used for identification of safety culture issues.*

| Source | Details |
|---|---|
| Safety culture survey research by EEC | Safety culture insights for 2 ANSP's: ANSP-1, ANSP-2 |
| Interview sessions | • Safety occurrence reporting expert at EUROCONTROL Headquarters<br>• Safety occurrence reporting expert at ANSP-3<br>• Safety management expert at ANSP-3 |
| Safety culture literature | Ek et al. (2007), Gordon et al. (2006), Montijn and De Jong (2007) |

**Step 3: Form composite safety culture issues and relate them to aggregation levels**

Similar safety culture issues as identified in Step 2 are grouped in composite issues that define a level of abstraction for the grouped issues. Abstraction is performed for example by aggregation of specific types of information and role names, and by omitting insignificant details. Then, these composite issues are related to the aggregation levels distinguished in the organization of ANSP safety occurrence reporting. This step can be done naturally, as the identified aggregation levels encompass all important aspects of the organization of ANSP safety occurrence reporting and each safety culture issue can be classified easily.

Examples of the composition of safety culture issues from the source documents are provided in Table 2.

As part of the mapping of the composite safety culture issues to the aggregation levels of the organization, groups of issues are identified at each aggregation level of the organization. The identification of the groups has been performed along the dimensions, which are also recognized as important in organization modelling (Scott et al., 1981; Popova and Sharpanskykh, 2007e). Furthermore, the identified groups have similarities with safety culture modelling dimensions considered in the literature (Ek et al., 2007; Gordon et al., 2006; Montijn and De Jong, 2007). Table 3 shows the result of the mapping of the composite safety culture issues to the groups in the four aggregation levels considered for the organization of safety occurrence reporting. A composite safety culture issue is attributed to a group depending on the organizational or individual aspect that it concerns. Such a mapping is performed first by identifying the organizational or individual aspect(s) that the issue concerns, and then, by attributing this issue to the group(s) that encompass(es) this (these) aspects. For example, all issues that concern intentional aspects of individuals are combined in the group "Individual safety-related goals, needs and motivation".

*Table 2: Examples of the relation between composite safety culture issues and underlying safety culture issues as reported in the sources shown in Table 1.*

| | |
|---|---|
| **Composite SC issue** | • S1.2: Actors are not motivated to report their safety concerns because of the lack of feedback and interest experienced in the organization (attributed to the individual aggregation level) |
| **Source SC issues** | • Little confidence in the response on "little things"<br>• Have not seen any results of reporting e.g. change in methods/rules<br>• We need feedback on our actions<br>• Feedback from incidents comes months or years later with few recommendations<br>• Have not seen any results of reporting e.g. change in methods/rules<br>• We use the system, but we don't always get the feedback<br>• Feedback is put on the intranet – what was recommended. Can you see if the solution has had any effect? The recommendation is normally to discuss it, or change, but there is no follow up.<br>• Appropriate responses are not made after an incident to address the reasons why the incident occurred<br>• I do not get feedback on the status and results of the investigation when I report an incident<br>• We are not consulted about changes to the system and our opinions and input into areas such as safety assessments is not actively sought after<br>• The organization would not always support me if I had a safety concern<br>• People do not get involved in safety because they feel their opinions are not listened to<br>• We do not receive feedback on the results of safety initiatives that we have participated in<br>• Controllers are less willing to speak up (about improvements to systems) as they are not listened to |
| **Composite SC issue** | • S2.3: Willingness of actors to cooperate with an actor may decrease after s/he has been involved in a (serious) incident (attributed to the team aggregation level) |
| **Source SC issues** | • I would not like to work with someone who has been involved in a near miss |
| **Composite SC issue** | • S3.11: Meetings to discuss safety-related issues often are difficult to plan and are not productive (one way information transfer: from managers – to controllers) (attributed to the organizational aggregation level) |
| **Source SC issues** | • Lack of participants from admin<br>• Admin spend them informing. One way monologue.<br>• Too few meetings – not enough time to express yourself<br>• Lack of team 'feeling' – people are in groups – feel they are in a big team (e.g. here).<br>• Big organization – therefore it is more difficult to organise team meetings<br>• Controller briefing by management is there to cover management's backs – controllers are just told to read the notices |
| **Composite SC issue** | • S3.35: Insufficient number of safety experts and support staff for tasks such as processing of occurrence reports (attributed to the organizational aggregation level) |
| **Source SC issues** | • If everyone was going to report everything, it would not be possible to manage all the reports, we would have to triple our administration for it.<br>• Staffing insufficient to get involved in analysis (3 votes)<br>• 2005 introduced electronic reporting but had no staff to process/handle reports. They had to throw away a lot of reports. |

| | |
|---|---|
| | • Too small capacity in handling reports (1 vote)<br>• We don't have enough people here – they are centralised<br>• Focus today is having just enough to make things go around – no extra resources for admin, people being sick. Politically driven targets. Minimum target<br>• No extra resources for admin<br>• We have insufficient safety experts and support staff in the house<br>• There is no separate safety department |
| **Composite SC issue** | • S4.2: Regulator is considered not helpful and understanding (attributed to the inter-organizational interaction aggregation level) |
| **Source SC issues** | • The Regulator makes life difficult for us<br>• The Regulator is not helpful and understanding in their dealings with us |

In Table 3 for each aggregation level of the organization of safety occurrence reporting at an ANSP a number of groups addressing particular aspects within the level are specified. The identified composite safety culture issues are classified along these groups.

*Table 3: Overview of composite safety culture issues.*

| Item | Description |
|---|---|
| ***Group 1: Individuals*** | |
| Group 1A: Individual safety-related goals, needs and motivation | |
| S1.1 | Occurrence reporting may lead to 'naming and blaming' and therefore it may not be in the personal interest of an actor. |
| S1.2 | Actors are not motivated to report their safety concerns because of the lack of feedback and interest experienced in the organization. |
| S1.3 | During analysis of more severe occurrences, the license of involved controller(s) may be temporarily retracted. |
| S1.4 | Fear of prosecution may lead to some reservation to formal (written) occurrence reporting and a preference for informal (oral) reporting. |
| S1.5 | In some exceptional cases, it may be that shame and peer pressure is a reason for not reporting. |
| Group 1B: Individual safety-related beliefs and attitudes | |
| S1.6 | The influence of occurrence reporting on the improvement of safety is not clear to individual human operators. |
| S1.7 | The role of the safety department is not clear to individuals in the organization. |
| S1.8 | Actors do not report some minor occurrences because they consider that there is no enough staff to process these reports. |
| S1.9 | The confidentiality of reporting is not trusted. |
| S1.10 | Actors do not recognize minor occurrences as important to report. |
| S1.11 | Actors consider that they are not supposed to report minor occurrences. |
| S1.12 | Actors prefer verbal communication about occurrences to written/electronic occurrence reporting. |

| Item | Description |
|---|---|
| S1.13 | Older controllers are less disposed towards safety occurrence reporting than younger ones. |
| | Group 1C: Individual commitment to safety |
| S1.14 | Not all organizational actors recognize their responsibility for safety. |
| S1.15 | Organizational actors may question the safety commitment or safety improvement strategy of managers (not known, outward appearance of the commitment). |
| | Group 1D: Individual capabilities |
| S1.16 | Actors find it difficult to keep up with numerous changes in procedures/the system. |
| | ***Group 2: Team*** |
| | Group 2A: Team composition |
| S2.1 | Learning of a new way of working in a different team may be difficult for some controllers (especially if a team is not relaxed). |
| S2.2 | Fixed teams may have a negative effect on reporting (peer loyalty). |
| | Group 2B: Team collaboration |
| S2.3 | Willingness of actors to cooperate with an actor may decrease after s/he has been involved in a (serious) incident |
| S2.4 | Actors avoid informal discussion of problems with their peers, since it may lead to (unfavourable) consequences. |
| S2.5 | A negative approach to safety of colleagues may impact team collaboration. |
| | Group 2C: Safety-related values/attitudes of a team |
| S2.6 | Problems are not raised as actors do not want to be seen as trouble-makers. |
| S2.7 | Safe behaviour does not influence the level of respect by colleagues. |
| S2.8 | Safe behaviour is not encouraged (e.g., neutral attitude) by a team. |
| | Group 2D: Leadership |
| S2.9 | Supervisors may not effectively reinforce safety culture |
| | ***Group 3: Intra-organizational structures, relations, goals and processes*** |
| | Group 3A: Organizational safety-related goals |
| S3.1 | Importance of safety-related goals may be threatened by performance-related goals. |
| S3.2 | Safety issues are addressed only to ensure compliance with the requirements of the Regulator. |
| | Group 3B: Organizational procedures, regulations and working practices |
| S3.3 | Formal procedures do not always sufficiently describe the required work processes and sometimes need to be worked around. |
| S3.4 | It takes too long to create an occurrence report. |
| S3.5 | Different requirements to a controller position in different countries. |
| S3.6 | Minor safety occurrences are not defined precisely. |
| S3.7 | Controllers partially fulfilling staff functions have lack of time to do their primary work. |
| S3.8 | Formal procedures may be forgotten or neglected (e.g. computer-based briefing). |

| Item | Description |
|---|---|
| Group 3C: Intra-organizational interaction (communication) | |
| S3.9 | A gap exists between the development team and management |
| S3.10 | Lack of interaction between controllers and people designing and assessing new systems |
| S3.11 | Meetings to discuss safety-related issues often are difficult to plan and are not productive (one way information transfer: from managers – to controllers) |
| S3.12 | Information exchange between controllers and maintenance personnel about the status of technical systems may not be complete |
| S3.13 | Information about changes in procedures and in the system is not provided on time to (some) actors that require this information |
| S3.14 | Lack of support from Incident Analysis Office (Safety department) during reporting |
| S3.15 | No open door policy for (safety-related) complaints |
| S3.16 | No feedback on reporting is received |
| S3.17 | Feedback / lessons learned from incidents comes too late or not at all |
| Group 3D: Authority | |
| S3.18 | Controllers have little influence on scheduling and processes in the organization. |
| Group 3E: Reward/blame system | |
| S3.19 | Lack of consistency about disciplinary measures for incidents. |
| S3.20 | In some countries controllers may get a financial penalty if they are involved in a safety occurrence. |
| S3.21 | Controllers do not receive acknowledgement for reporting. |
| Group 3F: Organizational support of safety | |
| S3.22 | Not sufficient financial investments in safety. |
| S3.23 | Safety-related concerns / proactive proposals of actors are not always addressed/supported by the organization. |
| S3.24 | Controllers experience lack of consultation or information about development of systems or services (e.g. no effective involvement in safety assessment). |
| S3.25 | New procedures are not sufficiently tested in simulations before going into operation. |
| S3.26 | Formal organizational structure does not support implemented SMS. |
| Group 3G: Organizational learning | |
| S3.27 | Organizational knowledge related to safety is not maintained. |
| S3.28 | The organization does not use feedback from occurrences to improve the way of working / technical systems. |
| Group 3H: Interaction with technical systems | |
| S3.29 | Technical systems may sometimes be unreliable. |
| S3.30 | Maintenance of technical systems is not performed optimally. |
| Group 3I: Training | |

| Item | Description |
|---|---|
| S3.31 | Actors are not trained properly for major changes in procedures/system. |
| S3.32 | Delays in training without explanations. |
| S3.33 | Training is costly. |
| S3.34 | Handling of technical faults may not be properly trained. |
| | Group 3J: Staffing |
| S3.35 | Insufficient number of safety experts and support staff for tasks such as processing of occurrence reports. |
| S3.36 | Availability of controllers may be a problem. |
| | ***Group 4: Inter-organizational interaction*** |
| | Group 4A: Interaction with regulator |
| S4.1 | Information about occurrences in other ANSP's is not provided by the Regulator. |
| S4.2 | Regulator is considered not helpful and understanding. |
| S4.3 | Lack of open communication between ANSP and Regulator. |
| S4.4 | Existence of differences in the reporting systems/regulations of different countries. |
| S4.5 | An inexperienced regulator may base his decision to initiate an investigation on formal details (e.g., classification of an event) only, whereas a more experienced regulator takes into account also other aspects (from his own experience with this type of events, with the involved ANSP). |
| S4.6 | Regulator may put too many irrelevant requirements and norms on ANSP's that are hard to fulfil and that decrease the freedom of ANSP's significantly. |
| S4.7 | Regulator may accept proposals by ANSP's without properly checking them. |
| S4.8 | High trust relations between an ANSP and a Regulator may result into insufficient number of checks and overlooking important safety issues. |
| S4.9 | The boundary between a major and a minor change is not always completely clear and may be a point of discussion between ANSP and regulator. |
| | Group 4B: Interaction with pilots / airlines |
| S4.10 | Knowing that pilots intend to report an occurrence is a stimulus for the involved controller(s) to report the occurrence (and vice versa). |
| | Group 4C: Interaction with Ministry of Justice |
| S4.11 | The Ministry of Justice may decide to investigate (severe) occurrences and decide to prosecute involved organizations or human operators. In investigation and prosecution, occurrence reports may be used. |
| | Group 4D: Interaction with others |
| S4.12 | The impact of media attention for (severe) safety occurrences can be very large. Media descriptions may well grossly neglect the context of an occurrence. |
| S4.13 | Union has information about incidents, but does not want to share. |

# 3 Methods for modelling of ANSP safety culture issues in relation to safety occurrence reporting

## 3.1 Approach for selection of modelling aspects

In Section 2 safety culture issues have been identified and related to organizational aggregation levels of an ANSP. The aim of this section is to select and describe the aspects that should be included in the development of an organizational model that addresses safety culture issues in relation to safety occurrence reporting.

To this end, the following selection approach is followed:

1. Identification of a wide set of potentially suitable modelling aspects;
2. Identification of selection criteria;
3. Evaluation and selection of modelling aspects.

These steps are discussed next.

**Step 1: Identification of a wide set of potentially suitable modelling aspects**

Based on the set of safety culture issues identified in Section 2 and expertise on organizational modelling possessed by the project team, a wide set of potentially suitable modelling aspects has been identified. These aspects have been identified for each group of issues described previously by considering roles, relations between roles, processes, and (common) characteristics of individuals covered by the group that are also of relevance for safety occurrence reporting. These modelling aspects are described in Appendix A. They are structured along the adopted four organizational aggregation levels. For these aspects, specific modelling techniques are specified and data requirements are specified.

**Step 2: Identification of selection criteria**

For the selection of the most suitable aspects that should be included in the model, the following criteria have been chosen:

(a) Level of importance of the aspect for safety occurrence reporting;
(b) Availability of data on the aspect;
(c) Level of maturity of the modelling techniques for the aspect.

**Step 3: Evaluation and selection of modelling aspects**

For all modelling aspects identified in Step 1, the criteria identified in Step 2 are evaluated along three-stepped scales. The results of this evaluation are presented in Appendix B. The aspects that rank sufficiently high on all three criteria (i.e., at least 2 on each scale) will be chosen for inclusion in the organizational model. The chosen aspects are clustered in the groups

presented in Figure 1 within the aggregation levels identified in Section 2. The arrows in Figure 1 indicate influence relations.

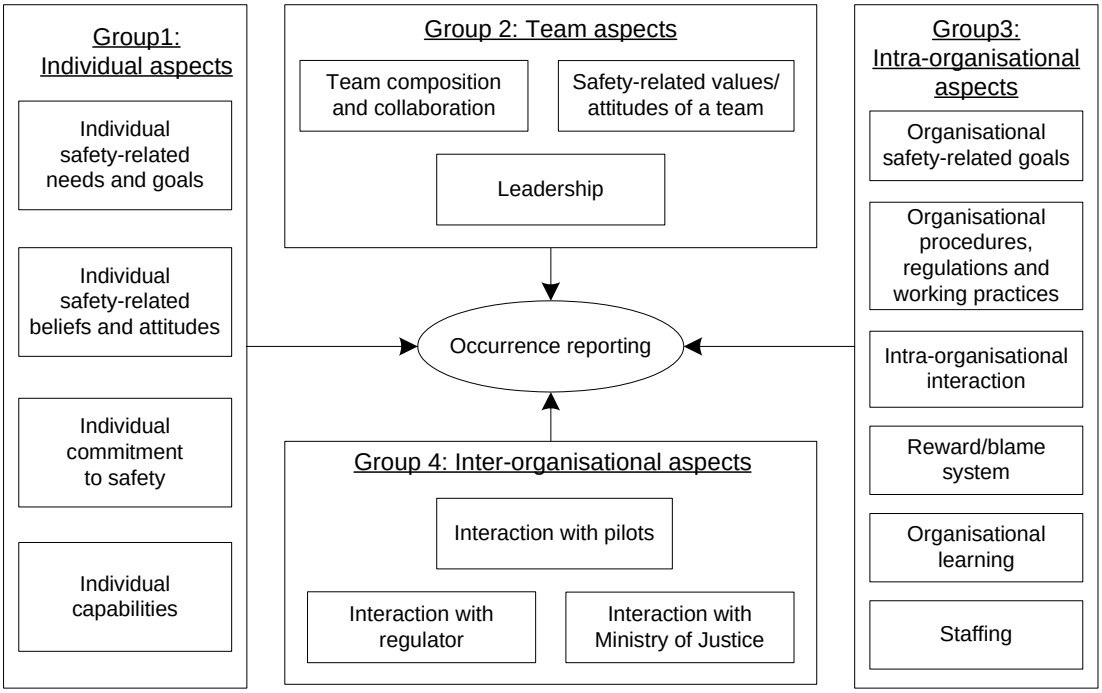


*Figure 1: The groups of aspects that influence safety occurrence reporting*

In the following subsections the chosen aspects within each of the groups are considered in more detail from the perspective of modelling. More specifically, for each aspect the related safety culture issues, the methods that could be used for modelling of the aspect, and data required for modelling are identified.

### 3.2 Modelling methods for selected individual aspects (group 1)

Organizational individuals will be modelled as agents – autonomous entities able to make decisions independently and to interact with other agents. The behaviour of an agent is considered to be goal-driven. Perception and interpretation of information provided to an agent are important to consider explicitly in the model. The situation awareness of an agent, as well as his/her trust in the confidentiality and effectiveness of reporting has an important impact on the agent's decision whether to report an occurrence. Thus, these aspects should be also considered in the model. Also individual professional, cognitive and psychological characteristics are modelled. At the individual level the model will focus particularly on the members of a team of controllers. Other organizational individuals will be modelled to the extent, to which they influence the behaviour of controllers related to reporting.

The individual aspects chosen for the inclusion in the organizational model based on the evaluation provided in Appendix B, are given in Figure 2 and listed in Table 4 with the related safety culture issues.

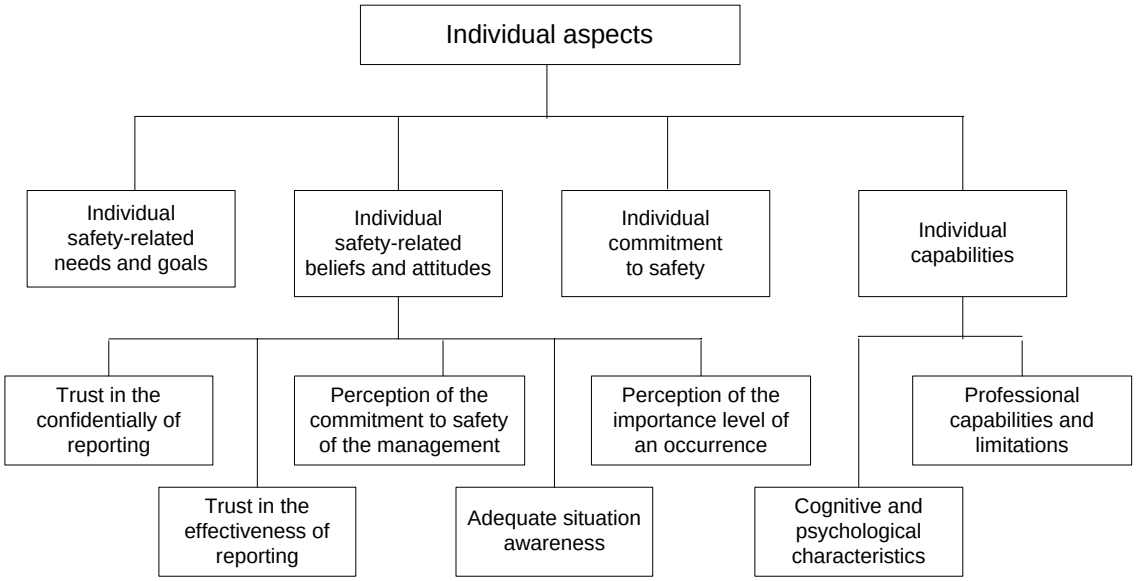


*Figure 2: The selected individual modelling aspects*

*Table 4: The selected individual modelling aspects and the related safety culture issues.*

| Model aspect | Related issues |
|---|---|
| Individual needs and goals | S1.1, S1.2, S1.3, S1.4, S1.5, S1.12 |
| Individual commitment to safety | S1.6, S1.13, S1.14 |
| Trust in the confidentiality of reporting | S.9, S1.12 |
| Trust in the effectiveness of reporting | S1.6, S1.8 |
| Adequate situation awareness | S1.15, S3.6, S3.8, S3.12, S3.13, S3.31 |
| Perception of the commitment to safety of the management | S1.15 |
| Perception of the importance level of an occurrence | S1.8, S1.11 |
| Professional capabilities and limitations | S1.10, S1.12, S1.16 |
| Cognitive and psychological characteristics | S1.11, S1.8, S1.9, S1.10, S1.12, S1.13 |

Based on the organization modelling experience of the project team members, the methods that can be used for modelling of the chosen individual aspects and the data required for modelling are identified and specified in Table 5.

*Table 5: The methods and data required for modelling of individual aspects.*

| Aspects | Modelling methods | Required data |
|---|---|---|
| Individual needs and goals.<br>Individual commitment to safety. | Modelling goals and needs of actors based on the theory of needs (Pinder, 1998).<br>Goal-based modelling approach (Popova and Sharpanskykh, 2007a).<br>Motivation modelling methods (e.g., Pinder 1998, Vroom, 1964). | Types of individuals (controllers) with their characteristics.<br>Information on personal (prioritized) needs of individuals.<br>Information on the attitude and perceived responsibility for safety by controllers. |
| Adequate situation awareness. | Situation awareness modelling methods (e.g., Blom and Stroeve, 2004; Endsley, 1995).<br>Decision making modelling methods (Pinder, 1998). | Information on the correctness of recognition of occurrences by controllers.<br>Information on the measures (e.g., training) to improve situation awareness. |
| Perception of the commitment to safety of the management.<br>Perception of the importance level of an occurrence. | Belief/interpretation modelling and belief update modelling approaches (e.g., Boutilier, 1998). | Types of individuals with their characteristics.<br>Information on formal and informal information channels to deliver safety-related information.<br>Interpretation of safety-related information by individuals. |
| Trust in the confidentiality of reporting.<br>Trust in the effectiveness of reporting. | Trust modelling techniques (e.g., Gambetta, 1990). | Information on the means to ensure the confidentiality of reporting in the organization.<br>Information on the effects of reporting and communication of these effects to controllers.<br>Perception of the confidentiality and effectiveness of reporting by controllers. |

| | | |
|---|---|---|
| Professional capabilities and limitations. Cognitive and psychological characteristics. | Cognitive modelling techniques (Polk and Seifert, 2002). | Information on the capabilities of individuals involved in reporting, on relations between capabilities and reporting actions. Information on the psychological traits inherent in controllers that influence occurrence reporting |

### 3.3 Modelling methods for selected team aspects (group 2)

A team in which an individual is situated may exert a significant influence on the individual. Often the type of this influence is determined to a great extent by an informal/formal team leader. In this study a team of controllers will be modelled. To this end, different composition forms of a team of controllers and their influence on reporting will be considered. Further, the values and (formal/informal) norms of a team will be modelled. Also, trust relations between controllers to provide information related to occurrences will be considered in the model. At the group level the model will focus particularly on a team of controller.

The team aspects chosen for the inclusion in the organizational model are given in Figure 3 and listed in Table 6 with the related safety culture issues.

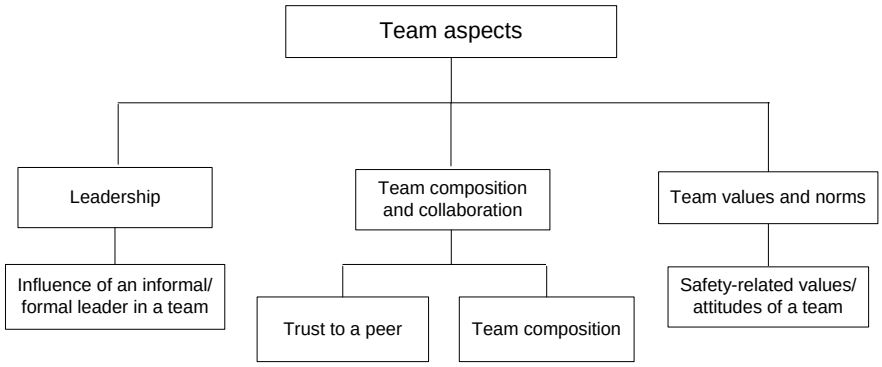


*Figure 3: The selected team modelling aspects*

*Table 6: The selected team modelling aspects and the related safety culture issues.*

| Model aspect | Related issues |
|---|---|
| Influence of an informal/formal leader in a team | S2.9 |
| Trust to a peer | S2.3, S2.4 |
| Team values and norms | S2.6, S2.7, S2.8 |
| Team composition | S2.1, S2.2, S2.3, S2.4, S2.5 |

In Table 7 the methods that can be used for modelling of the chosen team aspects are listed and the data required for modelling are specified.

*Table 7: The methods and data required for modelling of team aspects.*

| Aspects | Modelling methods | Required data |
|---|---|---|
| Influence of an informal/formal leader in a team. | Social network analysis methods (Scott, 2000).<br>Causal network analysis methods.<br>Informal influence modelling methods (Clegg, 1989). | Types of leaders and their influence on safety-related processes in a team. |
| Trust to a peer. | Trust modelling techniques (e.g., Gambetta, 1990). | Basis for (dis)trust in a team. |
| Team values and norms. | Organization modelling approach from (Popova and Sharpanskykh, 2007e). | Information of the values and norms related to safety in a team of controllers.<br>Influence of the safety-related values and norms of a controller team on reporting. |
| Team composition. | Social network analysis methods.<br>Graph theory.<br>Causal networks methods. | Ways to form a team.<br>Evidences on performance/collaboration in different types of teams.<br>Reporting in different types of teams. |

### 3.4 Modelling methods for selected intra-organizational aspects (group 3)

The processes and interaction during occurrence reporting take place in the framework of a formal organization. The formal organization defines such aspects as: organizational safety-related goals and their priority; responsibilities of the organizational roles; the degree of influence of an individual on organizational processes; the reward/punishment system, scheduling of training of different types; the allocation requirements on capabilities for roles; workload limits. Furthermore, the formal organization identifies interaction channels between roles and the types of information transferred through these channels.

Since the actual behaviour of organizational individuals may diverge from the prescriptions imposed by the formal organization, such deviant dynamics of the individuals should be also included (to some extent) in the organization model. In particular, the informal information channels to disseminate safety-related information should be modelled.

Different arrangements that ensure organizational learning (e.g., learning from mistakes, sharing of information, provision of feedback, supportive (non-punitive) culture, maintaining and using information about lessons learned) may have a (positive) impact on occurrence reporting. Thus, the aspect of organization learning is included in the model.

The intra-organizational aspects chosen for the inclusion in the organizational model are given in Figure 4 and listed in Table 8 with the related safety culture issues.

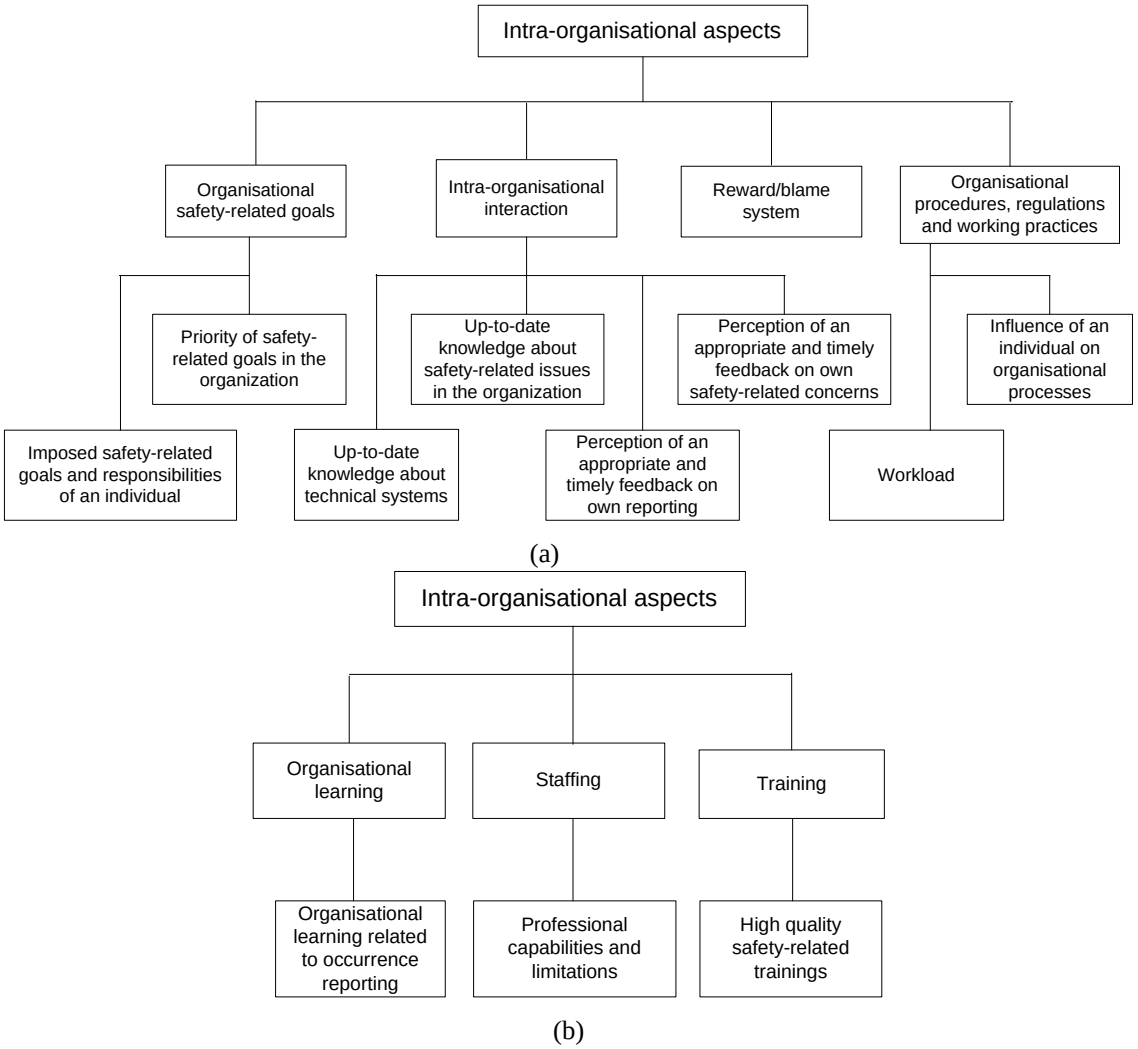


*Figure 4: The selected intra-organizational modelling aspects*

*Table 8: The selected intra-organizational modelling aspects and the related safety culture issues.*

| Model aspect | Related issues |
|---|---|
| Influence of an individual on organizational processes. | S3.18 |
| Priority of safety-related goals in the organization. | S3.1, S3.2, S3.22 |
| Reward/blame system. | S3.19, S3.20, S3.21 |
| Highly quality safety-related training. | S3.8, S3.31, S3.32, S3.34 |
| Professional capabilities and limitations. | S1.16, S3.31, S3.34 |
| Imposed safety-related goals and responsibilities of an individual. | S3.3, S3.5, S3.6, S3.7 |
| Workload. | S3.4, S3.7, S3.8, S3.36 |
| Intra-organizational interaction. | S3.11, S3.12, S3.13, S3.15, S3.16, S3.17, S3.24 |
| Organizational learning related to occurrence reporting | S3.27, S3.28 |

In Table 9 the methods that can be used for modelling of the chosen team aspects are listed and the data required for modelling are specified.

*Table 9: The methods and data required for modelling of intra-organizational aspects.*

| Aspects | Modelling methods | Required data |
|---|---|---|
| Influence of an individual on organizational processes. | Organization modelling approach from (Popova and Sharpanskykh, 2007e).<br>Cognitive modelling.<br>Causal network analysis methods. | Job descriptions of the individuals involved in occurrence reporting.<br>Evidences on the actual influence of individuals (e.g., controllers) on organizational processes. |
| Priority of safety-related goals in the organization. | | Documents on goals in the organization (strategy, job descriptions).<br>Information on the level of priority of safety-related goals. |
| Reward/blame system. | | Reward/punishment system related to reporting |

| Aspects | Modelling methods | Required data |
|---|---|---|
| Highly quality safety-related training. | | Types of evaluation before/after trainings and available data.<br>Types of trainings, content and scheduling (who is responsible). |
| Professional capabilities and limitations. | | Data on the required and available capabilities of the roles involved in occurrence reporting. |
| Imposed safety-related goals and responsibilities of an individual. | | Job descriptions of the individuals involved in occurrence reporting. |
| Workload. | | Information on the nominal and actual workload of controllers. |
| Intra-organizational interaction. | | Data on formal and informal information channels.<br>Types of information disseminated through informal and formal information channels.<br>On which conditions and how often are these channels used? |
| Organizational learning related to occurrence reporting | Organization modelling approach from (Popova and Sharpanskykh, 2007e).<br>Organization change modelling techniques.<br>Techniques to model organizational learning (Jones, 2003). | Information on means and procedures to acquire, to maintain and to use organizational knowledge.<br>Information on measures taken after occurrences.<br>Information on means to identify safety-related problems proactively.<br>Information on the actual organizational learning w.r.t. occurrence reporting over time. |

### 3.5 Modelling methods for selected inter-organizational aspects (group 4)

Occurrence reporting involves interaction of an air navigation service provider with a number of different organizations. Some of these organizations represented by particular roles will be included in the model. In particular, interaction between pilots (i.e., representatives of airlines) and controllers is considered after an occurrence took place. The decision whether and what to report is sometimes influenced significantly by such interaction. Further, flows of safety-related information from and to a regulator will be modelled. Such flows may provide useful information on safety-related issues and lessons learned from other ANSP's, as well as feedback on reporting of the ANSP. Another important organization that influences the effectiveness of reporting is Ministry of Justice. The motivation of controllers to report occurrences may be influenced directly by varying legal liability policies related to them.

The inter-organizational aspects chosen for the inclusion in the organizational model are given in Figure 5 and listed in Table 10 with the related safety culture issues.

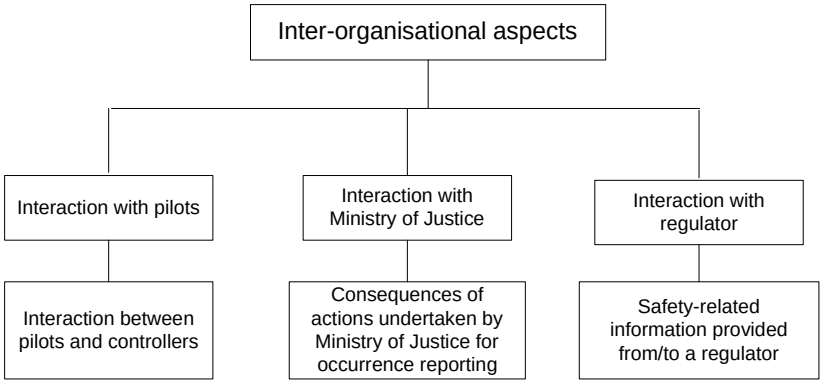


*Figure 5: The selected inter-organization modelling aspects*

*Table 10: The selected inter-organization modelling aspects and the related safety culture issues.*

| Model aspect | Related issues |
|---|---|
| Safety-related information provided from/to a regulator | S4.10 |
| Consequences of actions undertaken by Ministry of Justice for occurrence reporting | S4.11 |
| Interaction between pilots and controllers | S4.1, S4.3 |

In Table 11 the methods that can be used for modelling of the chosen inter-organizational aspects are listed and the data required for modelling are specified.

*Table 11: The methods and data required for modelling of inter-organizational aspects*

| Aspects | Modelling methods | Required data |
|---|---|---|
| Safety-related information provided from/to a regulator | Organization modelling approach from (Popova and Sharpanskykh, 2007e).<br>Causal network analysis methods. | Types of information related to occurrence reporting provided from/to a regulator.<br>Evidences of the effects of information on occurrence reporting provided by a regulator. |
| Consequences of actions undertaken by Ministry of Justice for occurrence reporting | Cognitive modelling.<br>Decision making modelling methods (Shapira, 2002).<br>Causal network analysis methods. | Information on the legal liability of a controller.<br>Information on change in occurrence reporting after a prosecution of a controller. |
| Interaction between pilots and controllers | Organization modelling approach from (Popova and Sharpanskykh, 2007e).<br>Decision making modelling methods. | Actual data that describe interaction between pilots and controllers after an occurrence has been detected (by one of them or by both of them). |

# 4 Conclusions

Modern air traffic organizations are characterized by complex structures, processes and interactions between roles. The culture of an air traffic organization influences (significantly) its structures and dynamics, and the satisfaction of its goals. Safety-related goals usually have a high priority in an air traffic organization. Thus, when an air traffic organization is analyzed, the essential aspects of its safety culture (a sub-set of the organizational culture related to safety) should be considered explicitly. Such aspects can be examined at different aggregation levels. In this report the following aggregation levels have been distinguished: (1) the level of an individual in the organization (e.g. a controller, a supervisor, a manager); (2) the level of a team; (3) the level of an organization (i.e. intra-organizational structures, as departments in an ANSP); (4) the level of inter-organizational interaction (i.e. influences from other organizations on an ANSP). At each of these levels a great diversity of safety culture aspects can be distinguished. Since the focus of this study is on occurrence reporting and on organizational learning that influences reporting, only safety culture aspects related to occurrence reporting need to be considered at each level. To identify such aspects the following approach has been applied.

First, the most prominent safety culture issues have been identified from a number of sources, among which safety culture surveys performed by EEC, interview sessions, and safety culture literature. The issues with the strongest evidences identified in these sources, have been aggregated and attributed to the corresponding aggregation levels.

Then, based on the set of the identified safety culture issues and expertise on organizational modelling, a wide set of potentially suitable modelling aspects has been identified. For these aspects, specific modelling techniques are specified and data requirements are specified.

After that, the most suitable aspects, which will be used further for safety modelling and analysis, have been selected. For the selection process the following criteria have been used: (a) the level of importance of the aspect for safety occurrence reporting; (b) availability of data on the aspect; (c) level of maturity of the modelling techniques for the aspect.

The selected safety culture aspects at the individual level focus particularly on the members of a team of controllers. Other organizational individuals will be modelled to the extent, to which they influence the behaviour of controllers related to reporting. At the group level the model will focus particularly on a team of controller. The processes and interaction during occurrence reporting take place in the framework of a formal organization. Aspects of the formal organization that influence occurrence reporting identified in the report will be included in the model. Different arrangements that ensure organizational learning may have a (positive) impact on occurrence reporting. Thus, the aspect of organization learning will be also modelled. Furthermore, three inter-organizational aspects are considered important for

modelling of occurrence reporting. Among them: safety-related information provided from/to a regulator, consequences of actions undertaken by Ministry of Justice for occurrence reporting, interaction between pilots and controllers. The extent to which these aspects influence the effectiveness of safety occurrence reporting will be determined by this study.

At the next step the selected safety culture aspects will be integrated in an agent-based organizational model with a particular focus on safety occurrence reporting and on organizational learning. To this end, the identified modelling techniques together with the partially available data will be used. Simultaneously with the model development process, missing data will be acquired. The modelling results will be presented in the following deliverable.

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# Appendix A Wide list of methods for modelling of ANSP safety culture issues

In this appendix a wide list of safety culture modelling aspects is provided identified based on the set of safety culture issues from Section 2 and the expertise on organizational modelling possessed by the project team. The aspects are structured along the adopted four organizational aggregation levels and the groups within these levels. The modelling concepts have been identified for each group by considering roles, relations between roles, processes, and (common) characteristics of individuals covered by the group that are also of relevance for safety occurrence reporting. Most of the identified modelling concepts are related to the safety culture issues from Section 2. The modelling aspects, for which no related safety culture issues were found, are still included due to their relevance from the organization modelling standpoint. Furthermore, specific modelling techniques and data requirements are specified for the identified aspects.

## A.1 Group 1: Individuals

### A.1.1 Group 1A: Individual safety-related goals, needs and motivation

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 1.1 | Individual needs, goals and values of actors, their priority | S1.1, S1.2, S1.3, S1.4, S1.5 |
| 1.2 | Change of goals | - |

*Modelling methods*

- Modelling goals and needs of actors based on the theory of needs (Pinder 1998).
- Goal-based modelling approach (Popova and Sharpanskykh, 2007a).
- Motivation modelling methods (e.g., Pinder 1998).

*Required data*

- Types of actors with their individual characteristics.
- Information on personal (prioritized) needs of actors.
- Information about (compulsory, voluntary) involvement of controllers in decision-making processes, solving safety-related issues and their attitude.

### A.1.2 Group 1B: Individual safety-related beliefs and attitudes

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 1.3 | Formation of beliefs on safety-related information | S1.6, S1.7, S1.8, S1.9, S1.11 |
| 1.4 | Influence of psychological, cognitive and other individual characteristics on (the attitude towards) reporting | S1.8, S1.9, S1.10, S1.12, S1.13 |
| 1.5 | Influence of individual characteristics on situation awareness (for the correct recognition of an occurrence) | - |
| 1.6 | Change of beliefs and attitudes | - |
| 1.7 | Trust in confidentiality of reporting | S.9, S1.12 |
| 1.8 | Trust in the effectiveness of reporting | S1.6, S1.8 |

*Modelling methods*

- Belief/interpretation modelling and belief update modelling approaches (e.g., Boutilier 1998).
- Situation awareness modelling methods (e.g., Blom and Stroeve, 2004; Endsley, 1995).
- Decision making modelling methods (Pinder 1998).
- Trust modelling techniques (e.g., Gambetta, 1990).

*Required data*

- Types of actors with their individual characteristics.
- Information on formal and informal information channels to deliver safety-related information.
- Interpretation of safety-related information by individuals.
- Information about involvement of controllers in decision-making processes, solving safety-related issues and their attitude.

### A.1.3 Group 1C: Individual commitment to safety.

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 1.9 | Aspects that influence commitment to safety | S1.14 |
| 1.10 | Evidences for commitment to safety | S1.15 |

*Modelling methods*

- Commitment modelling (e.g., Bisin and Benhabib, 2004)
- Trust modelling techniques (e.g., Gambetta, 1990).

*Required data*

- Types of actors with their individual characteristics.
- Perception of commitment to safety of individuals themselves and perception of individuals of commitment of other organizational individuals.
- Information on safety arrangements in (a part of) the organization in focus.

### A.1.4 Group 1D: Individual capabilities.

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 1.11 | Influence of individual capabilities on safety-related processes | S1.16 |

*Modelling methods*

- Cognitive modelling approaches

*Required data*

- Information on the capabilities of individuals involved in reporting.

## A.2 Group 2: Teams.

### A.2.1 Group 2A and 2B: Team composition and team collaboration.

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 2.1 | Modes of team composition and their influence on safety (reporting in particular) | S2.1, S2.2 |
| 2.2 | Collaboration in different types of teams and its influence on safety | S2.3, S2.4, S2.5 |
| 2.3 | Collaborative decision making (e.g., by controllers to report an occurrence). | - |
| 2.4 | Influence of a group on an individual | S2.5, S2.6, S2.7, S2.8 |

*Modelling methods*

- Social networks methods.
- Graph theory.
- Collaborative decision making methods.
- Causal networks methods.

*Required data*

- Ways to form a team.
- Evidences on performance/collaboration in different types of teams.
- Reporting in different types of teams.

### A.2.2 Group 2C: Safety-related values/attitudes of a team.

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 2.5 | Group values and norms and their influence on safety (reporting in particular). | S2.6, S2.7, S2.8 |
| 2.6 | Influence of the organizational context on the team values and norms. | - |
| 2.7 | Change of group values and norms based on positive/negative experience. | - |
| 2.8 | Trust to a peer | - |

*Modelling methods*

- Trust modelling techniques.
- Causal networks methods.
- Problem-solving methods.

*Required data*

- Teams and their values and norms.
- Reporting in different types of teams.
- Change of the attitude to safety in a team based on changes in the organizational context.
- Basis for (dis)trust.
- Evidences of influence of a team on an individual.

### A.2.3 Group 2D: Leadership

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 2.9 | Role of a leader in a group and his/her influence on team members. | S2.9 |

*Modelling methods*

- Social networks methods.
- Causal networks methods.

*Required data*

- Types of leaders and their influence on safety-related processes in a team.

## A.3 Group 3: Intra-organizational structures, relations, goals and processes

### A.3.1 Group 3A: Organizational safety-related goals

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 3.1 | A hierarchy of safety-related organizational goals with the attribution of these goals to roles/individuals | - |
| 3.2 | Actual recognition, prioritizing of safety-related goals | S3.1, S3.2 |
| 3.3 | Evidences for a high priority of safety-related goals | S3.1, S3.2 |

*Modelling methods*

- Goal-based modelling approach (Popova and Sharpanskykh, 2007a).
- Causal networks methods (propagation of influences, data reduction).
- Backward reasoning.
- Dynamic modelling.

*Required data*

- Documents on goals in the organization (strategy, job descriptions).
- Information on the level of priority of safety-related goals.
- The role of the Safety Department and Management in promoting safety.
- Evidences for importance of safety-related goals.

### A.3.2 Group 3B: Organizational procedures, regulations and working practices

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 3.4 | The formal reporting procedure | S3.3, S3.4, S3.6, S3.8 |
| 3.5 | Formally defined responsibilities of roles | S3.5, S3.7 |
| 3.6 | Influence of roles on organizational policies | - |
| 3.7 | Workload and its influence of situation awareness | - |

*Modelling methods*

- All model aspects can be addressed by the organization modelling approach from (Popova and Sharpanskykh, 2007e).

*Required data*

- The description of the formal incident reporting procedure (with durations if possible).
- Organization of safety-related activities.
- Information on how organizational individuals adhere to the formal organization in reality.

### A.3.3 Group 3C: Intra-organizational interaction (communication).

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 3.8 | Safety Investigation Unit | S3.14, S3.15, S3.16, S3.17 |
| 3.9 | Controller team | S3.10, S3.12 |
| 3.10 | Management | S3.9, S3.15, S3.16 |
| 3.11 | Operation Assessment Unit | - |
| 3.12 | Operation Design Unit | S3.9, S3.10 |
| 3.13 | Maintenance | S3.12 |
| 3.14 | Influence of regulator on ANSP | - |
| 3.15 | Influence of Ministry of Justice on ANSP | - |
| 3.16 | Influence of airlines on ANSP | - |
| 3.17 | Safety-related meetings | S3.11 |
| 3.18 | Formal and informal communication channels to disseminate safety-related information: new procedures and changes in existing procedures/systems, monthly reports, lessons learned, consultations, feedback on reporting. | S3.13, S3.16, S3.17 |

*Modelling methods*

- Organization modelling approach from (Popova and Sharpanskykh, 2007e).
- For informal communication: identification and modelling of social networks: existence and stability of information channels in such networks; completeness/correctness of information provided through these channels; spreading speed; trust and reputation.

*Required data*

- Information about existing formal structures and relations within and between the organizational roles.
- Data on formal and informal information channels.
- Types of information disseminated through informal and formal information channels.
- On which conditions and how often are these channels used?

### A.3.4 Group 3D: Authority

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 3.19 | Formal authority relations in ANSP | S3.18 |

*Modelling methods*

- Organization modelling approach from (Popova and Sharpanskykh, 2007e).

*Required data*

- Information about existing authority relations within and between the organizational roles.

### A.3.5 Group 3E: Reward/blame system

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 3.20 | Reward/blame system in ANSP | S3.19, S3.20, S3.21 |

*Modelling methods*

- Organization modelling approach from (Popova and Sharpanskykh, 2007e).

*Required data*

- Reward/punishment system related to reporting.

### A.3.6 Group 3F: Organizational support for safety

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 3.21 | Relation between the implemented SMS and the formal organization (does the formal organization support the SMS or does it hinder it?) | S3.26 |
| 3.22 | Managerial support for safety | S3.22, S3.23, S3.24 |
| 3.23 | Electronic information system and its influence on the organization: what kind of safety-related information it provides, is it easy to use, which roles are supposed to use (and actually use) it? | - |

*Modelling methods*

- Organization modelling approach from (Popova and Sharpanskykh, 2007e).

*Required data*

- Information about existing formal structures and relations within and between the organizational roles.
- Organization of safety-related activities.

### A.3.7 Group 3G: Organizational learning

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 3.24 | Means to acquire, to maintain and to use organizational knowledge | S3.27 |
| 3.25 | Means for the proactive identification of safety-related problems | - |
| 3.26 | Organizational change after an occurrence | S3.28 |
| 3.27 | Learning from occurrences | - |
| 3.28 | Prerequisites for organizational learning | - |
| 3.29 | Promotion and support for organizational learning | - |
| 3.30 | Organizational goals related to learning | - |

*Modelling methods*

- Organization modelling approach from (Popova and Sharpanskykh, 2007e).
- Organization change modelling techniques.
- Techniques to model organizational learning.

*Required data*

- Information on means and procedures to acquire, to maintain and to use organizational knowledge.
- Information on measures taken after occurrences.
- Information on means to identify safety-related problems proactively.
- Organizational goals.
- Information on promotion and support for organizational learning.
- Information on the actual organizational learning w.r.t. occurrence reporting over time.

### A.3.8 Group 3H: Interaction with technical systems

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 3.31 | Awareness of problems in technical systems. | S3.29 |
| 3.32 | Trust in technical systems. | S3.29 |
| 3.33 | Maintenance and diagnostics of technical systems. | S3.29, S3.30 |

*Modelling methods*

- Modelling of causal networks.
- Data reduction
- Trust modelling techniques.
- Situation awareness methods.
- Error propagation techniques.

*Required data*

- How often and thoroughly maintenance of technical systems is performed?
- Information exchange between maintenance personnel and controllers about technical problems.

### A.3.9 Group 3I: Training

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 3.34 | Types of training | - |
| 3.35 | Conditions for each type of training | S3.33 |
| 3.36 | Scheduling of training | S3.31, S3.32 |
| 3.37 | Content of training (typical, emergency situations used for training). | S3.31, S3.34 |
| 3.38 | Quality of training. | S3.31 |
| 3.39 | Consequences of training. | - |
| 3.40 | Influence of training on individual characteristics. | - |
| 3.41 | Influence of training on situation awareness. | - |
| 3.42 | Means to evaluate (gained) knowledge and skills. | - |

*Modelling methods*

- Cognitive modelling.
- Modelling of causal networks.
- Framework for modelling performance indicators (Popova and Sharpanskykh, 2007b)

*Required data*

- Types of evaluation before/after trainings and available data.
- Types of trainings, content and scheduling (who is responsible).

### A.3.10 Group 3J: Staffing

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 3.43 | Required and available amount of actors (safety experts, controllers). | S3.34, S3.35 |
| 3.44 | Knowledge and competences of the available staff. | - |

*Modelling methods*

- The organization modelling approach from (Popova and Sharpanskykh, 2007e).

*Required data*

- Information on the available and required staff, their competences.

## A.4 Group 4: Inter-organizational interaction

### A.4.1 Group 4A: Interaction with regulator

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 4.1 | Safety-related information provided from/to a Regulator. | S4.1, S4.3 |
| 4.2 | Trust of an ANSP to a Regulator and vice versa. | S4.3, S4.8 |
| 4.3 | Positive and negative consequences of high/low trust. | S4.3, S4.7, S4.8 |
| 4.4 | Influence of the quality of checks by a Regulator on safety. | S4.6, S4.7 |
| 4.5 | Consequences of cooperation with inexperienced regulators for an ANSP and their propagation in an ANSP. | S4.5, S4.6, S4.7 |

*Modelling methods*

- Causal networks methods.
- Trust modelling techniques.

*Required data*

- Examples of positive/negative consequences of high/low trust relations between an ANSP and a Regulator for safety. Basis for trust relations.

### A.4.2 Group 4B: Interaction with pilots / airlines

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 4.6 | Interaction between pilots and controllers | S4.10 |
| 4.7 | Influence of pilots on controllers and vice versa | S4.10 |

*Modelling methods*

- Causal networks methods.
- The organization modelling approach from (Popova and Sharpanskykh, 2007e).
- Decision making techniques.

*Required data*

- Actual data that describe interaction between pilots and controllers that an occurrence is detected (by one of them or by both of them)

### A.4.3 Group 4C: Interaction with Ministry of Justice

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 4.8 | Legal liability of a controller | S4.11 |
| 4.9 | Occurrence data provided to Ministry of Justice and interpretation of these data by Ministry of Justice | S4.11 |
| 4.10 | Consequences of actions (e.g., prosecutions) undertaken by Ministry of Justice for occurrence reporting | S4.11 |

*Modelling methods*

- Causal networks methods.
- The organization modelling approach from (Popova and Sharpanskykh, 2007e).
- Cognitive modelling.

*Required data*

- Actual data on the involvement of Ministry of Justice in the occurrence investigation process.
- Information on legal responsibilities of a controller.
- Information on change in occurrence reporting after a prosecution of a controller.

### A.4.4 Group 4D: Interaction with others

*Potential modelling aspects*

| Item | Model aspect | Related issues |
|---|---|---|
| 4.11 | Media influence on occurrence reporting | S4.12 |
| 4.12 | Influence of Union on controllers and on occurrence reporting by them | S4.13 |

*Modelling methods*

- Causal networks methods.
- Cognitive modelling.
- Informal power (influence) modelling techniques.

*Required data*

- Information related to occurrences that reached media.
- Interpretation of information related to occurrences by media.
- Instructions provided to controllers by Union.
- Information on influence of Union on controllers

# Appendix B Evaluation list of modelling aspects

This appendix presents the results of the evaluation of all potential modelling aspects and the related modelling techniques, such as described in Appendix A. The modelling aspects are evaluated along the following dimensions:

- *Importance for modelling*; for each modelling aspect a degree of relevance for safety occurrence reporting in an ANSP is represented on a scale 1 (low) – 2 (average) - 3 (high);
- *Availability of data* required for modelling on a scale 1 (difficult to obtain) – 2 (attainable) – 3 (available);
- *Maturity level of modelling techniques* on a scale 1 (immature) – 2 (intermediate) – 3 (mature).

The evaluation of the importance of an aspect for modelling is based largely on the degree of its relevance to (significant) safety culture issues described in Appendix A. Furthermore, the modelling results of the safety occurrence reporting process presented in Stroeve et al. (2007c) are also taken into account in the evaluation.

The evaluation of the availability of data is based on the information currently gathered and on the (potential) availability of information sources that could be used in the future by direct contacts with organizational individuals, allocated to roles involved in safety occurrence reporting (e.g., a safety manager, a safety investigator, a regulator, an air traffic controller).

The evaluation of the maturity level of modelling techniques is based on the modelling experience of the project team members.

| Item | Modelling aspect | Importance for modelling | Availability of data | Maturity level of modelling techniques |
|---|---|---|---|---|
| *Individuals* | | | | |
| 1.1 | Individual needs, goals and values of actors, their priority | 3 | 2 | 3 |
| 1.2 | Change of goals | 2 | 1 | 2 |
| 1.3 | Formation of beliefs on safety-related information | 3 | 2 | 3 |
| 1.4 | Influence of psychological, cognitive and other individual characteristics on (the attitude towards) reporting | 3 | 1 | 2 |
| 1.5 | Influence of individual characteristics on situation | 3 | 1 | 2 |

| Item | Modelling aspect | Importance for modelling | Availability of data | Maturity level of modelling techniques |
|---|---|---|---|---|
| | awareness (for the correct recognition of an occurrence) | | | |
| 1.6 | Change of beliefs and attitudes | 2 | 1 | 2 |
| 1.7 | Trust in confidentiality of reporting | 3 | 2 | 2 |
| 1.8 | Trust in the effectiveness of reporting | 3 | 2 | 2 |
| 1.9 | Aspects that influence commitment to safety | 3 | 1 | 2 |
| 1.10 | Evidences for commitment to safety | 3 | 3 | 3 |
| 1.11 | Influence of individual capabilities on safety-related processes | 2 | 1 | 1 |
| *Teams* | | | | |
| 2.1 | Modes of team composition and their influence on safety (reporting in particular) | 3 | 3 | 2 |
| 2.2 | Collaboration in different types of teams and its influence on safety | 3 | 2 | 2 |
| 2.3 | Collaborative decision making (e.g., by controllers to report an occurrence). | 2 | 1 | 2 |
| 2.4 | Influence of a group on an individual | 3 | 1 | 2 |
| 2.5 | Group values and norms and their influence on safety (reporting in particular). | 3 | 3 | 2 |
| 2.6 | Influence of the organizational context on the team values and norms | 1 | 1 | 1 |
| 2.7 | Change of group values and norms based on positive/negative experience | 1 | 1 | 1 |
| 2.8 | Trust to a peer | 3 | 2-3 | 2 |
| 2.9 | Role of a leader in a group and his/her influence on team members. | 2 | 2 | 2 |

| Item | Modelling aspect | Importance for modelling | Availability of data | Maturity level of modelling techniques |
|---|---|---|---|---|
| *Intra-organizational structures, relations, goals and processes* | | | | |
| 3.1 | A hierarchy of safety-related organizational goals with the attribution of these goals to roles/individuals | 3 | 2 | 3 |
| 3.2 | Actual recognition, prioritizing of safety-related goals | 3 | 2 | 3 |
| 3.3 | Evidences for a high priority of safety-related goals | 3 | 3 | 3 |
| 3.4 | The formal reporting procedure | 3 | 3 | 3 |
| 3.5 | Formally defined responsibilities of roles | 3 | 3 | 3 |
| 3.6 | Influence of roles on organizational policies | 2 | 2 | 1 |
| 3.7 | Workload and its influence of situation awareness | 3 | 2 | 2 |
| 3.8 | Safety Investigation Unit | 3 | 3 | 3 |
| 3.9 | Controller team | 3 | 3 | 3 |
| 3.10 | Management | 3 | 2 | 2 |
| 3.11 | Operation Assessment Unit | 1 | 2 | 3 |
| 3.12 | Operation Design Unit | 1 | 2 | 3 |
| 3.13 | Maintenance | 1 | 2 | 3 |
| 3.14 | Influence of regulator on ANSP | 2 | 2-3 | 2 |
| 3.15 | Influence of Ministry of Justice on ANSP | 3 | 2-3 | 2 |
| 3.16 | Influence of airlines on ANSP | 1 | 1 | 2 |
| 3.17 | Safety-related meetings | 3 | 3 | 2 |
| 3.18 | Formal and informal communication channels to disseminate safety-related information: new procedures and changes in existing procedures/systems, monthly reports, lessons learned, consultations, feedback on reporting. | 3 | 2-3 | 2-3 |

| Item | Modelling aspect | Importance for modelling | Availability of data | Maturity level of modelling techniques |
|---|---|---|---|---|
| 3.19 | Formal authority relations in ANSP | 2 | 3 | 3 |
| 3.20 | Reward/blame system in ANSP | 3 | 2-3 | 3 |
| 3.21 | Relation between the implemented SMS and the formal organization (does the formal organization support the SMS or does it hinder it?) | 2 | 3 | 2 |
| 3.22 | Managerial support for safety | 3 | 2 | 2 |
| 3.23 | Electronic information system and its influence on the organization: what kind of safety-related information it provides, is it easy to use, which roles are supposed to use (and actually use) it? | 2 | 1 | 2 |
| 3.24 | Means to acquire, to maintain and to use organizational knowledge | 3 | 2-3 | 3 |
| 3.25 | Means for the proactive identification of safety-related problems | 3 | 3 | 1 |
| 3.26 | Organizational change after an occurrence | 3 | 2 | 2 |
| 3.27 | Learning from occurrences | 3 | 2 | 1 |
| 3.28 | Prerequisites for organizational learning | 3 | 3 | 3 |
| 3.29 | Promotion and support for organizational learning | 3 | 3 | 2 |
| 3.30 | Organizational goals related to learning | 3 | 2 | 3 |
| 3.31 | Awareness of problems in technical systems. | 2 | 2 | 2 |
| 3.32 | Trust in technical systems. | 2 | 2 | 2 |
| 3.33 | Maintenance and diagnostics of technical systems. | 1 | 1 | 1 |
| 3.34 | Types of training | 1 | 2 | 2 |

| Item | Modelling aspect | Importance for modelling | Availability of data | Maturity level of modelling techniques |
|---|---|---|---|---|
| 3.35 | Conditions for each type of training | 1 | 2 | 2 |
| 3.36 | Scheduling of training | 2 | 2 | 3 |
| 3.37 | Content of training (typical, emergency situations used for training). | 1 | 2 | 2 |
| 3.38 | Quality of training. | 1 | 1 | 2 |
| 3.39 | Consequences of training. | 3 | 2 | 2 |
| 3.40 | Influence of training on individual characteristics. | 3 | 2 | 2 |
| 3.41 | Influence of training on situation awareness. | 3 | 1 | 2 |
| 3.42 | Means to evaluate (gained) knowledge and skills. | 2 | 1 | 2 |
| 3.43 | Required and available amount of actors (safety experts, controllers). | 3 | 3 | 3 |
| 3.44 | Knowledge and competences of the available staff. | 3 | 2 | 3 |
| *Inter-organizational interaction* | | | | |
| 4.1 | Safety-related information provided from/to a Regulator. | 2 | 2-3 | 3 |
| 4.2 | Trust of an ANSP to a Regulator and vice versa. | 2 | 1-2 | 1-2 |
| 4.3 | Positive and negative consequences of high/low trust. | 1 | 1 | 1 |
| 4.4 | Influence of the quality of checks by a Regulator on safety. | 2 | 1 | 1 |
| 4.5 | Consequences of cooperation with inexperienced regulators for an ANSP and their propagation in an ANSP. | 1 | 2 | 1 |
| 4.6 | Interaction between pilots and controllers. | 2 | 2 | 3 |
| 4.7 | Influence of pilots on controllers and vice versa. | 2 | 2 | 1 |

| Item | Modelling aspect | Importance for modelling | Availability of data | Maturity level of modelling techniques |
|---|---|---|---|---|
| 4.8 | Legal liability of a controller. | 2 | 1 | 2 |
| 4.9 | Occurrence data provided to Ministry of Justice and interpretation of these data by Ministry of Justice. | 1 | 1 | 2 |
| 4.10 | Consequences of actions (e.g., prosecutions) undertaken by Ministry of Justice for occurrence reporting. | 3 | 2 | 2 |
| 4.11 | Media influence on occurrence reporting. | 1 | 1-2 | 1 |
| 4.12 | Influence of Union on controllers and on occurrence reporting by them. | 2 | 1-2 | 2 |