Appendix 1. Analysis of ADREP data for management factors

ICAO ADREP system had been established by the 1974 ICAO Accident Investigation and Prevention. The ICAO offers a standard report format, which has been adopted by ICAO member states throughout the world. Member states are urged to submit information for inclusion in the ICAO Accident/Incident Reporting (Adrep) database using a standard Adrep taxonomy and report format. The data we analyzed is from 1990 to 2006.

1. ADREP classification framework:

In the ADREP taxonomy, flight crew errors are classified into two levels of failures.

1) Errors in operating the aircraft: flight crew errors are coded into 122 descriptive factors in ADREP taxonomy, which are grouped into 5 categories:
   - Flight crew's perception/judgment (perception)
   - Flight crew's decision error (decision)
   - Flight crew's operation of equipment error (action)
   - Flight crew's aircraft handling error (action)
   - Crew action in respect to flight crew procedures (violation)

In each category, flight crew errors are described in more detail. For a complete listing, refer to [1].

2) In the ADREP taxonomy [1], the underlying causes that make a human error take place are described in more than 250 explanatory factors at the greatest level of detail in the ADREP taxonomy. The causes are clustered into 5 categories and table 1.1 gives some selected examples of the detailed causes fitting into each category.

- Human being
- Interface between human and the work environment
- Interface between the human and the hardware/software
- Interface between human and system support
- Interface between humans

Table 1.1: Selected examples of underlying causes

Human being	Flight crew's operation of auxiliary power Unit
Personal size	Flight crew's operation of electrical system
Loss of consciousness/fainting	Workplace seat design inadequate
Impairment-chronic alcohol abuse	Inadequate information/data sources
Fatigue-rest/duty time	User friendliness/usability

Psychological-confirmation bias	Reliability of automation
Experience of route	**Interface between human and system support**
Interface between human and the work environment	Standard Operating Procedures
Landing/take-off site infrastructure	emergency and abnormal procedures
Visibility from workspace/workplace	Company procedures
Cultural issues	Simulator training
Operational control personnel policies	**Interface between humans**
High workload due to staff/skills shortage	Interface between humans in relation to surveillance
Interface between the human and the hardware/software	Interface between humans in relation to cross-checking
Flight crew's operation of air conditioning	Interface between humans in relation to the use of teletype communications

2. Extracting evidence from ADREP

In ADREP, each accident contains several entries, representing the time sequence of the events in it. For each event ADREP can classify and record one related human error type and one related underlying cause. Therefore, one accident could have multiple human errors and underlying causes. However, this ‘unicasuality’ for each event is a limiting simplification of the data.

The pilot errors or undesired acts are viewed as arising from the interplay between human fallibility and context in the underlying causes. Based on the essence of the delivery systems, the SMS must deliver effective risk control and resources to minimize these human fallibilities, for example by better scheduling processes to prevent inexperienced pilot flight crew members from operating together. They can also be helpful by not creating contexts in which there are greater opportunities for human fallibility, such as landing in extreme weather. Therefore, we linked our management model into ADREP’s explanatory factors, based on the definition of the delivery systems These links demonstrate the feasible management actions to prevent the online problems via the delivery systems.

Each accident was also evaluated from the narrative of its accident report and coded into the different accident scenarios, or Event Sequence Diagrams (ESD), defined by the CATS project.

3. The data

In order to be consistent with the definitions in CATS, the data obtained from ADREP were chosen to cover heavy commercial, non Russian manufactured aircraft from 1990 to 2006. The same accident could have multiple management failures or contain different event types, which describes the accident sequence. Therefore 18427 data points (events) from 5876 accidents were exported from the initial search query. In only 2436 events (13%) from 543 accidents (9.2%) were data recorded about the associated background information of descriptive and explanatory factors. This gives the maximum potential number of events which can be given a management system coding.

In order to find out whether there had been an increase in the number of management factors recorded in the accidents through the years from 1990 to 2006, we counted the number of accidents which record any management factors and divided them by the total number of accidents in that year[1], to get a rate. The finding shows that management factors did not show an increase in recording through the years, but surprisingly shows an obvious decrease both in the world in general and within the different parts of it. This is the opposite of our expectation that we would find an increasing awareness of management factors and more efforts for investigation of management. The managerial factors considered in investigations for different fatalities were also examined. The result shows a similar decrease for different fatality types, but the result shows authorities do take into account more management factors in accidents than incidents.

We further consulted an expert in ADREP data system and found out that management factors could only be expected on final reports[2]. Managerial factors are assigned when the investigation has been completed and a data report is compiled. Therefore management factors could only be expected on those 'data' reports. However, as seen in Figure 1.1, the number of data reports has decreased over time, because states do not submit the final reports to ICAO and this includes some major states from Europe as well. It is also important to realise that reports take some time to complete, submit and process, so that more recent reports will not have yet reached the 'data'stage.

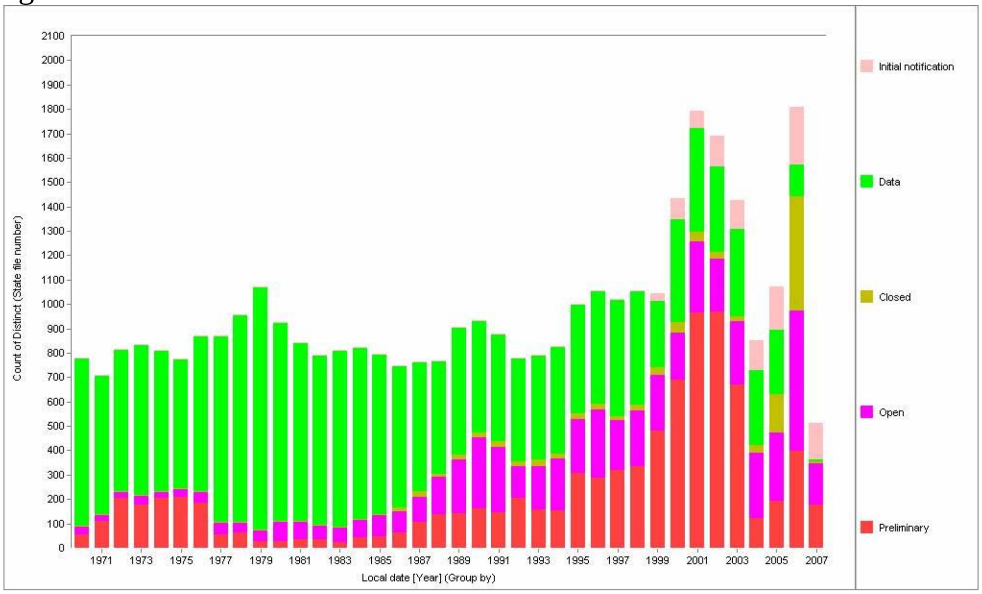

Figure 1.1 Report status

[1] We assume that in each of the accident there should be at least one managerial failure causing the accident to happen.

[2] In ADREP, the present status of the report is coded as *preliminary, initial notification, open, closed, or data.* These stages indicate increasing completeness of the report. 'Data' status indicates that the investigation has been completed and all relevant data have been transcribed into the data base and no further action is contemplated at the national level

Figure 1.2 shows that the accident/incident numbers show a dramatic jump in the years 2000 to 2003 in. The reason for this was that Canada, in a one off transfer of data, made available reports for many incidents in the years 2000 to 2003. For those incidents, no organisational factors were ever reported. They all stayed at the status "preliminary". Hence, if we compare the accidents number whether the managerial factors have been taken into account cross regions, there is a great number of accident without management factors in North America, as figure 1.3 shows.

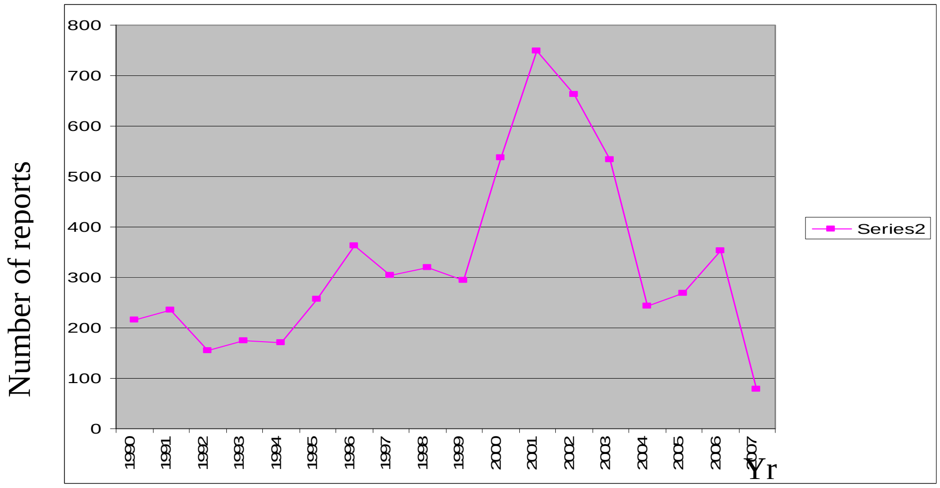

Figure 1.2 Report numbers over time

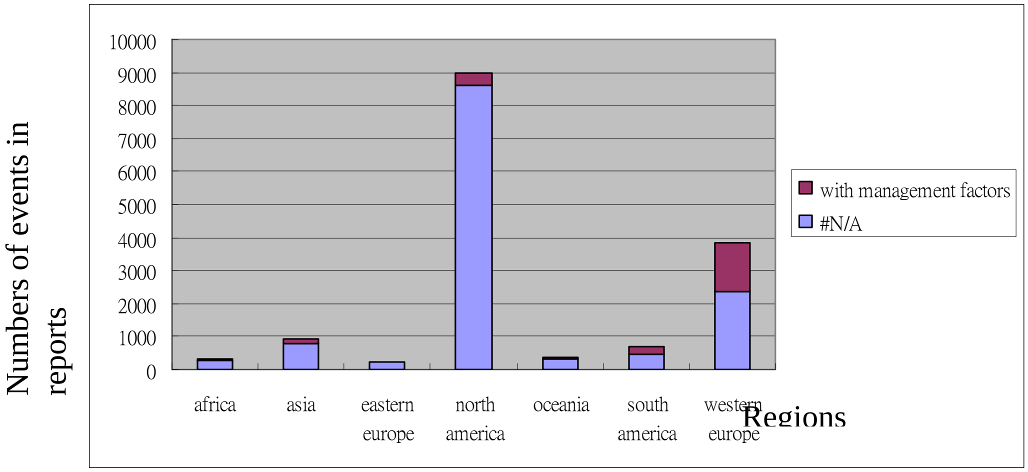

Figure 1.3 Report numbers with and without the managerial factors recorded across regions

We re-calculated numerically to what extent managerial factors have been taken into account only in the *final* accident reports by authorities across time. This analysis showed that management factors did not show an increase or decrease in recording through the years in the world in general.

Although the total of 2436 events (13%) from 543 accidents (9.2%) which record the associated background information of descriptive and explanatory factors is relatively small compared to the large panel of 5876 accidents, examination of the distribution of the accident scenarios in our dataset showed that it corresponded well with total distribution in the CATS ESDs. Therefore, we can assume that the results of our study will be representative of the total accident population.

4. The results

The main results are given below:

Delivery systems failure trend

Analysing the different management system failures through the years in the total available data set shows that failures in the Procedure delivery system are increasing slightly over the years; communication failures increase after 1997; commitment and conflict resolution failure has a decreasing trend over time; but there is no significant trend for failures in Competence, Availability and Man-machine interface.

Delivery systems failure across different regions

Figure 1.4 shows the management failure across different regions. Competence is the most common factor across regions except in Eastern Europe. Communication and coordination is the second most dominant failure in Western Europe whilst in North America it is commitment which is the second most dominant failing delivery system. We have to note here that the sample from Eastern Europe in figure 1.4 may not represent the real population well, because the report number was very small, due to the exclusion of the Russian manufactured aircraft in the initial data selection.

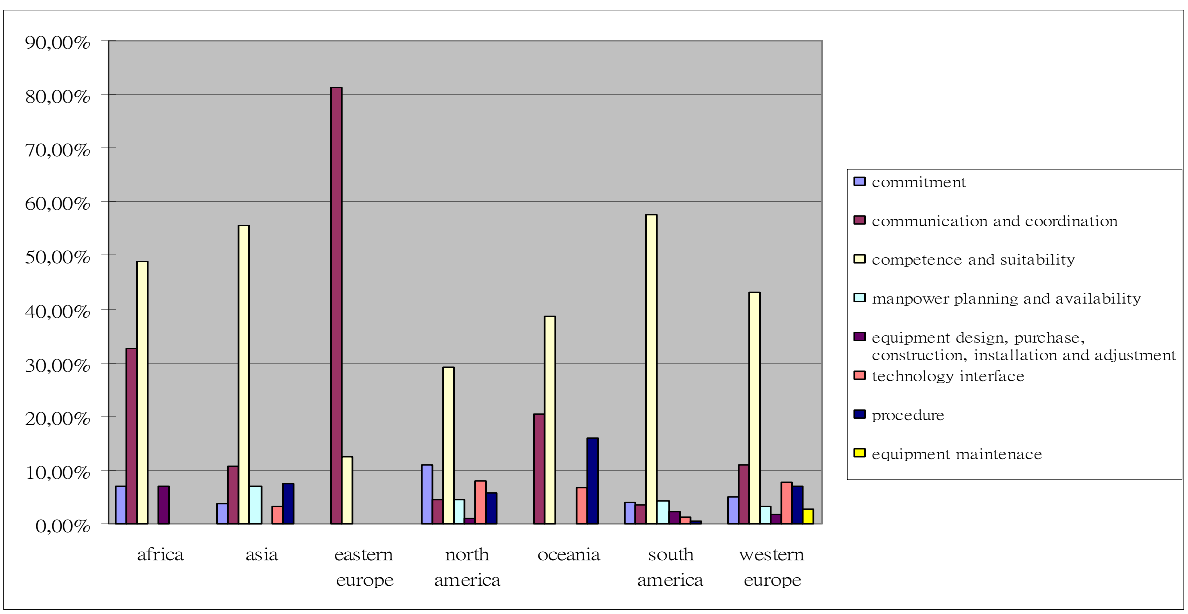

Figure 1.4 Management failures across regions

The influences of the delivery systems on online errors

Table 1.2 and figure 1.5 show the frequencies of management delivery system failures in the 7 delivery systems in relation to online human error and technological failures. Note that the online human error here includes all the possible direct human errors in the first line of operations that ultimately led to the adverse outcome, i.e. both pilot and air traffic controller errors are included. The total frequency of SMS failure in the Table 1.2 will not be equal to our entry sample size, because in many cases more than one management factor was associated with one online error. Failures in delivering the managerial functions of competence, communication, commitment, and availability dominate with a combined 80% of all online failures.

Table 1.2: Frequency counts for SMS failure for all 543 accidents

SMS failure	Frequency	Percentage
Competence and suitability	1,228	39,84
Communication, coordination and online supervision	553	17,94
Commitment, motivation and conflict resolution	522	16,94
Manpower planning and availability	267	8,66
Procedure, rule, and checklist	265	8,60
Technology-Man-machine interface design	155	5,03
Technology-Function	92	2,99
Total	3082	100,00

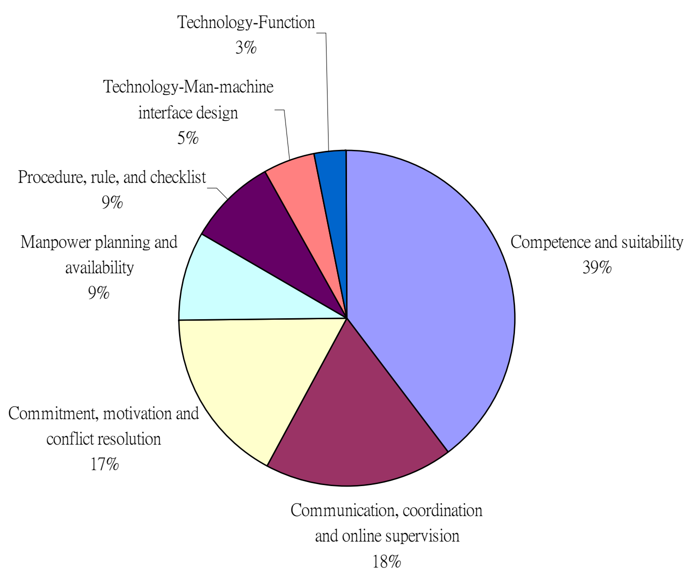

figure 1.5 Frequency counts for SMS failure for all 543 accidents

What are the most dominate factors coded as underlying (explanatory) causes for human errors?

We found that 15 explanatory factors dominated the underlying causes in the ADREP data, as shown in Table 1.3

Table 1.3 **T**he most dominate factors coded as underlying

Number of Factors	Factors	Examples
5	Fundamental limitations in the human's sensory, cognitive and motor processes	Failure to monitor the outside situation; Lack of attention and action in the chain of human information processing
4	Commitment & Conflict resolution	Routine violation; Pilots discouraged from making go-around due to cost implications
3	Online supervision	Failing to notice that a task has been carried out incorrectly
2	Online communication and coordination problems	With ATC and between team members
1	Competence of airmanship and crew resource management skills	

- Five factors are related to fundamental limitations that exist in the human's sensory, cognitive and motor process, e.g. failure to monitoring the outside situation, lack of attention and action in the chain of human information processing.
- Four factors are related to conflict resolution; one to the incentives which online personnel have to carry out their tasks and activities according to the appropriate safety criteria and procedures specified for the activities by the organization, i.e. routine violation; and the other three to conflicting pressures for online people arising from personnel policies in instructions and directives from management level, e.g. pilots discouraged from making go-around due to cost implications or conflicts between management requirements and operational supervisory responsibilities. In these cases, problems should be solved by the delivery system of commitment and conflict resolution.
- Three factors are related to online supervision, e.g. failing to notice that a task has been carried out incorrectly. This failure of cross-checking can be seen as a failure of commitment to carry out these procedures
- Two factors are related to online communication and coordination problems, with ATC and within and between cockpit (and cabin) crew members.
- One factor is related to competence of airmanship and crew resource management skills.

These factors are the major factors which may make human errors take place in the ADREP data. They can be treated as references for selecting the performance shaping factors for human performance model.

Is there any different pattern of delivery system failures influencing the different “flight crew error” types?

As stated earlier, flight crew errors are classified into 5 categories:

- Flight crew’s perception/judgment (perception)
- Flight crew’s decision error (decision)
- Flight crew’s operation of equipment error (action)
- Flight crew’s aircraft handling error (action)
- Crew action in respect to flight crew procedures (violation)

We are interested in whether there is a different pattern of delivery system failures for different types of flight crew errors. 326 of the 543 accidents were analyzed further for pilot errors. Table 1.4 and Figures 1.6-1.10 show the frequencies of management failure in 6 delivery systems in relation to different types of flight crew errors. Competence and communication are the most important factors across different flight crew error types. Commitment is relatively more important in pilot “action errors”. They are 17% of the total management failures in operating equipment and 10% of the total management failures in aircraft handling, respectively. More communication failures (24%) are in found in Crew action in respect to flight crew procedures. Technology function is more likely to cause flight crew perception and judgment problems (13%) than in the other human error types.

We further tested whether there is a significant difference in managerial influences on human error for pilots in Table 1.5. A chi- squared test between errors types shows that the human errors of flight crew differ in the underlying failures in how management provides resources and controls to their online pilots. Perception/judgment errors are significantly different from the rest of the error types. On the other hand, there are no significant differences between decision errors and violations (two-tailed p = 0.3018). This might be explained by the notion that decision error and violation are both errors in planning, which in consequence cause “intentional” actions [2].

Table 1.4 The frequencies of management failure in 6 delivery systems

DS_subject	Flight crew's perception /judgment	Flight crew's decisions	Flight crew's operation of equipment	Flight crew's aircraft handling	Crew action in respect to flight crew procedures	Grand Total
commitment	10	10	56	37	30	143
communication and coordination	27	37	42	34	94	234
competence and suitability	95	82	108	156	141	582
manpower planning and availability	8	14	22	20	19	83
procedure	5	12	31	18	19	85
tech-ergonomics+function	26	10	9	19	7	71

Others (monitoring+weather+regulatory)	22	19	33	33	30	137
not specific	7	24	26	48	48	153
Grand Total	200	208	327	365	388	1488

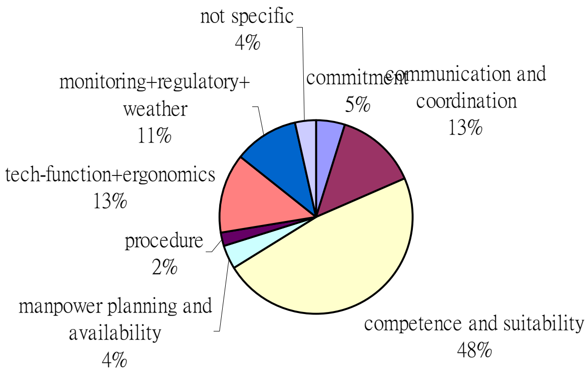

Figure 1.6 Flight crew's perception /judgment

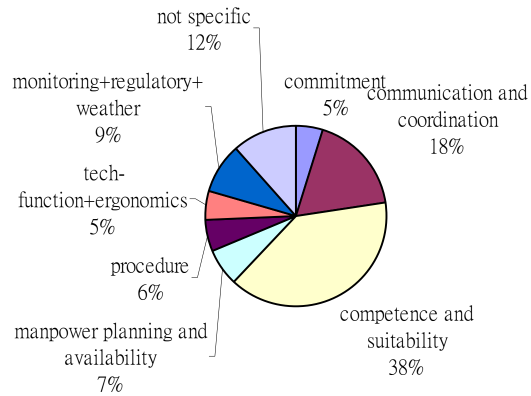

Figure 1.7 Flight crew decision

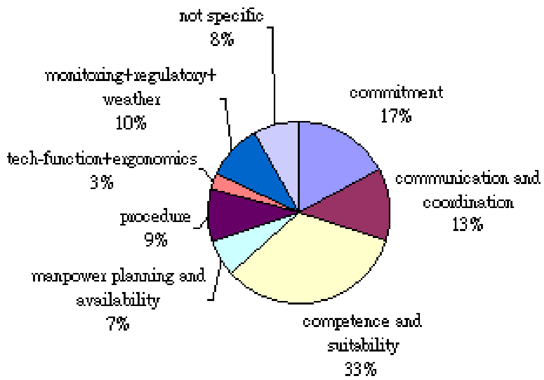

Figure 1.8 Flight crew's operation of equipment error

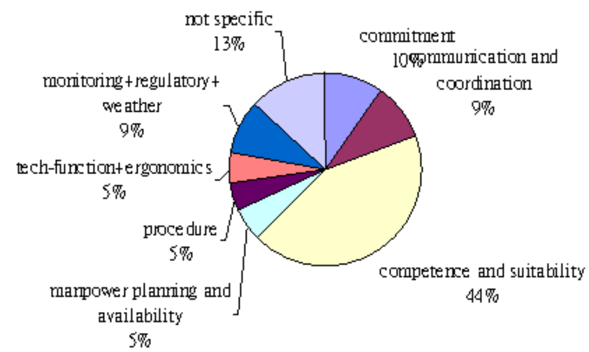

Figure 1.9 Flight crew's aircraft handling error

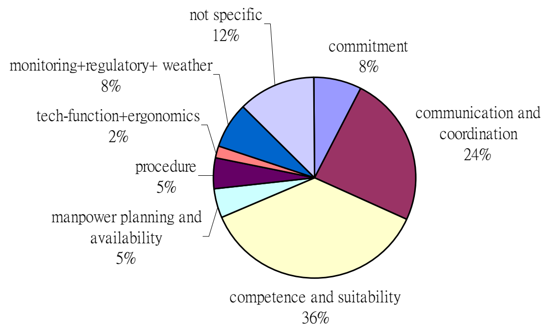

Figure 1.10 Flight crew action in respect to flight crew procedures

Table 1.5 A significant test in managerial influences on human error

	flight crew's decisions	flight crew's operation of equipment	flight crew's aircraft handling	crew action in respect to flight crew procedures
flight crew's perception/judgment	0.000612176	6.21748E-11	0.000556885	3.73521E-16
flight crew's decisions		0.019356645	0.121420046	0.2346341758
flight crew's operation of equipment			0.023696465	0.000817026
flight crew's aircraft handling				0.012876677

Summary

The experience of analyzing the Adrep data shows there is still a great lack of managerial factors recorded in the accident/ incident investigations all over the world and also a lack of detail in what is recorded. Failures in delivering the managerial functions of competence, communication, commitment, and availability dominate with 80% of all online failures. The factors in Table 1.3 show the major factors influencing the human errors in the ADREP data. Some of them are considered in the PSFs in the flight crew model in CATS but operationalized in different terms. From the data analysis, it is clear that managers have to change different resources and controls (delivery systems) to prevent different types of flight crew errors.

The PSFs we have modeled in CATS for the flight crew are fewer than those considered in the descriptive factors of ADREP taxonomy. However the operationalisations used in CATS to translate the influences into factors for which there were objective data (e.g. total number of hours flown) were not found in the ADREP data. These are at a different level of abstraction than the ADREP categories. Therefore, we are map the ADREP data onto that in CATS for quantifying the management factors.

References

1. International Civil Aviation Organization, 2000, Accident/Incident Reporting Manual (ADREP), ICAO, Montreal, Canada.
2. J. Reason, 1990, Human Error, Cambridge University Press, New York.