



 Report

# **Evaluation of the feasibility of using MW inspection results as an input to CATS management model**

13 July 2008  
WQ 080713-07

Annex to Final Report of:  
Causal Model for Air Transport Safety (CATS)

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## 1 OVERVIEW

This report describes work done to evaluate the availability of data concerning the management factor being modelled in CATS. In particular it concerns the feasibility of getting the results of inspections into CATS, through inputs to the CATS software. In a discussion with IVW (maintenance Part 145)<sup>1</sup> in June 2007 about airworthiness compliance audits it was considered of interest to see if there was a way of coupling audit results with CATS risk assessment. At this stage it was thought it would be possible to access Dutch accident data analysed by Analyse Bureau Luchtvaartvoorvallen (ABL) in order to correlate audit findings with incident data but this was not made possible.

Professor Patrick Hudson at the expert group (1 July 2008) indicated that, given the results of this feasibility study, it would indeed be interesting to try to obtain incident data to correlate with the audit results. Hok Goei for IVW indicated that the results showed not only something about the specific companies being audited but also the company specific focus of IVW. In addition IVW expressed a wish to update the delivery system classification of the regulation.

The results of the analysis of the audit data in Storybuilder ([www.storybuilder.eu](http://www.storybuilder.eu)) are presented here. Currently 3 delivery systems have been analysed: competence, procedures and communications.

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<sup>1</sup> Hok Goei & Bert Verweij

## 2 APPROACH

In the BReS (Bedrijf registratie system) database the results of airworthiness (Part 145<sup>2</sup>) compliance audits can be found. Of interest to CATS are:

- a) The possibility to find management related data
- b) Considering how these data could be coupled to CATS to assist the regulator in risk prioritising

BReS contains the results of a number of inspections per company, specifying who is the auditor, the date of the audit, what has been audited and the findings. These results are confidential. About 200 audits a year are conducted.

It was considered by White Queen that these data could be analysed on the basis of results per article of the regulation, which in turn could be classified according to the delivery system scheme of the management model (see next section), following ideas presented by P.H. Lin who had classified the IOSA audit scheme in this manner<sup>3</sup>.

Since the BReS contain company specific data, an anonymous set of data with company names replaced with ciphers could also be used to look at whether there were company differences in audit findings per article of the regulation. This would be useful in contemplating whether management, as a factor to be modelled in CATS, could have relevant input variables identified from inspections which could link to the delivery system part of the CATS model.

Later this concept was taken up by IVW Operations and the feasibility of classifying the JAR-OPS regulation in the same way examined<sup>4</sup>

A team of 3 (Linda Bellamy, White Queen, Pei-Hui Lin (TUDelft) and Rene Roorda (IVW-Ops) classified the Part 145 regulation and a subset of the JAR-Ops as delivery systems. This Part 145 classification should be revisited by IVW responsible for maintenance audits.

<sup>2</sup> Part 145 of the regulation COMMISSION REGULATION (EC) No 2042/2003 of 20 November 2003 on the continuing airworthiness of aircraft and aeronautical products, parts and appliances, and on the approval of organisations and personnel involved in these tasks

<sup>3</sup> 5 July 07 Meeting of CATS expert group ; presentation " Management Factors and Quantification" by Pei-Hui Lin, Safety Science Group, TU Delft.

<sup>4</sup> Joint Aviation Requirements JAR-OPS 1 Commercial Air Transportation (Aeroplanes) 01-05-07 Amendment 13 JAR-OPS Part 1 prescribes requirements applicable to the operation of any civil aeroplane for the purpose of commercial air transportation by any operator whose principal place of business and, [if any, its registered office] is in a JAA Member State.

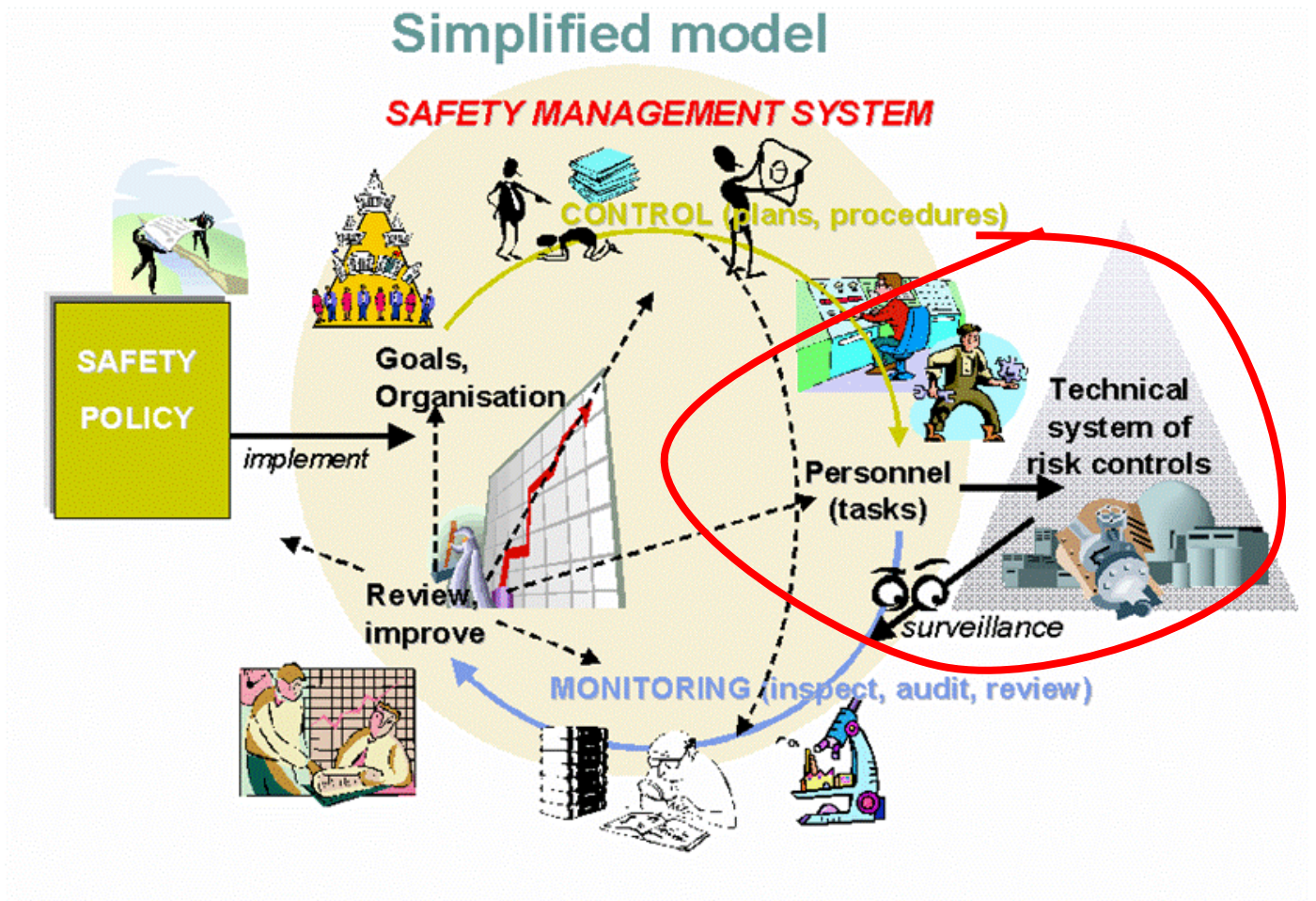
### 3 MANAGEMENT DELIVERY SYSTEMS

The state of a system depends amongst other things on the way humans interfere with the system. Humans can be divided into two classes - "operators" who interfere with the system directly and "managers" who interfere with the system indirectly through a management system. In this way the management system is thought of as being separate from the technical system. The relationship between the two can then be modelled as an interface, of which operators are a part. A simplified model of a management system developed by White Queen (Bellamy, n.d.) is presented in Figure 1 on the next page. The management system control loop is indicated as a variant of the well known plan do check act loop (Deming circle).

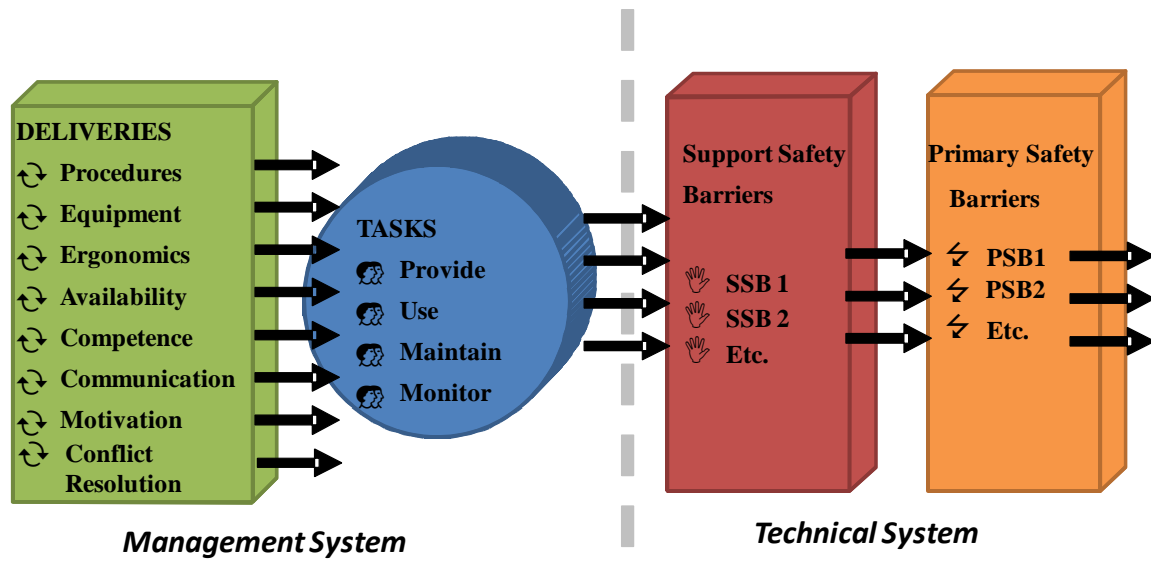
In the I-Risk Project (Bellamy et al 1999) an interface was built between the management and technical system. This concept was used later in the WORM project (Ale 2006, Bellamy et al 2007) to connect the management system to safety barriers. The purpose of the management system is to have and keep safety barriers in place. Safety barriers contribute to preventing the occurrence of the unwanted event and their failures are modeled in CATS in fault trees and subsequently in a Bayesian belief net. E.g. one safety barrier might be the integrity of the aircraft pressure boundary. Another might be the separation between aircraft.

Management is considered to be the process for delivering criteria and resources to keep such safety barriers intact. These resources and criteria are categorised into eight systems called DELIVERIES. These deliveries are delivered to the safety barriers by four categories of barrier TASKS. These are **P**rovide, **U**se, **M**aintain, **M**onitor. This is shown in Figure 2. In this figure a primary safety barrier is a barrier which if it fails will result in the occurrence of the release of the hazard agent (like loss of separation between two aircraft). The support safety barriers supports the primary safety barrier by making it less likely to fail. For application to classification of the regulations the idea is to determine what aspect of the management of a safety barrier(s) the regulation/article is intended to support.

Definitions of the tasks and delivery systems are given in Annexes 1 and 2 to this report.



• Figure 1 simplified model of a Safety Management System



• Figure 2 Management Deliveries-Tasks-Barriers

## 4 CLASSIFICATION OF THE REGULATION

Initially Part 145 was classified according to the delivery system definitions of Annex 2.1 as a first pass. The regulations were then analysed according to the CATS delivery system definitions in Annex 2.2 and the task definitions of Annex 1 where appropriate.

Figure 3 gives the classification for Part 145 and Figure 4 for part of JAR-OPS

		DELIVERY SYSTEMS							PROCESSES					
		Procedures	Competence	Availability	Commitment	Communication	Technology function	Man-machine system						
									provision	use	monitoring	maintenance/improvement		
SECTION A														
145.A.10	NR													Scope
145.A.15	NR													Application
145.A.20		X			X									Terms of approval
145.A.25a)						X								Facility requirements
145.A.25b)							X							Facility requirements
145.A.25c)							X							Facility requirements
145.A.25d)						X								Facility requirements
145.A.30a)		X2						X						Personnel requirements
145.A.30b)		X2	X2						X	X	X			Personnel requirements
145.A.30c)		X2								X				Personnel requirements
145.A.30d)			X											Personnel requirements
145.A.30e)		X												Personnel requirements
145.A.30f)		X												Personnel requirements
145.A.30g)		X												Personnel requirements
145.A.30h)		X	X											Personnel requirements
145.A.30i)		X												Personnel requirements
145.A.30j)		X												Personnel requirements
145.A.35		X												Personnel requirements
145.A.40a)						X		X	X					Certifying staff and category B1 and B2 support staff
145.A.40b)						X				X	X			Equipment, tools and material
145.A.42						X								Equipment, tools and material
145.A.44						X								Acceptance of components
145.A.45		X												Maintenance data
145.A.47a)		X		X		X								Production planning
145.A.47b)				X										Production planning
145.A.47c)					X									Production planning
145.A.50		X												Certification of maintenance
145.A.55		X												Maintenance records
145.A.60					X									Occurrence reporting
145.A.65a)				X										Safety and quality policy, maintenance procedures and quality system
145.A.65b)		X		X										Safety and quality policy, maintenance procedures and quality system
145.A.65c)1				X2					X					Safety and quality policy, maintenance procedures and quality system
145.A.65c)2				X2							X			Safety and quality policy, maintenance procedures and quality system
145.A.70				X2	X2									Maintenance organisation exposition
145.A.75	NR													Privileges of the organisation
145.A.80				X2										Limitations on the organisation
145.A.85				X2	X2									Changes to the organisation
145.A.90	NR													Continued validity
145.A.95				X										Findings

• Figure 3 Part 145 classification. X = identified in the article, X2= second level of delivery (higher level), NR=Not relevant to delivery system classification

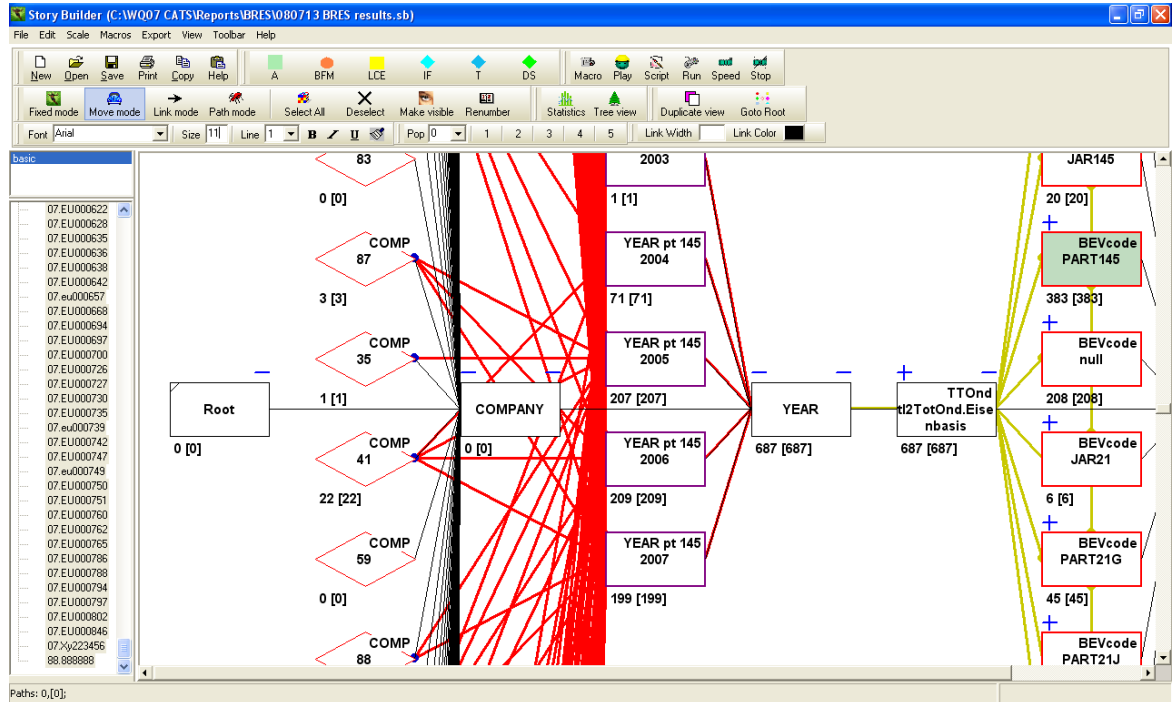
**DELIVERY SYSTEMS**

		Procedures	Competence	Availability	Commitment	Communication	Technology function	Man-machine system	
	SUBPART N								FLIGHT CREW
SUBPART N	OPS 1.940(a)(1)			X					Composition of Flight Crew
SUBPART N	OPS 1.940(a)(2)			X					Composition of Flight Crew
SUBPART N	OPS 1.940(a)(3)		X						Composition of Flight Crew
SUBPART N	OPS 1.940(a)(4)			X					Composition of Flight Crew
SUBPART N	OPS 1.940(a)(5)					X			Composition of Flight Crew
SUBPART N	OPS 1.940(a)(6)			X					Composition of Flight Crew
SUBPART N	OPS 1.940(a)(7)		X						Composition of Flight Crew
SUBPART N	OPS 1.940b)			X	X				Composition of Flight Crew
SUBPART N	OPS 1.943		X						Initial Operator's Crew Resource Management (CRM) training
SUBPART N	OPS 1.945		X						Conversion Training and checking
SUBPART N	OPS 1.950		X						Differences Training and Familiarisation Training
SUBPART N	OPS 1.955		X						Nomination as commander
SUBPART N	OPS 1.960		X						Commanders holding a Commercial Pilot Licence
SUBPART N	OPS 1.965		X						Recurrent Training and Checking
SUBPART N	OPS 1.968		X						Pilot qualification to operate in either pilot's seat
SUBPART N	OPS 1.970		X						Recent experience
SUBPART N	OPS 1.975		X						Route and Aerodrome Competence Qualification
SUBPART N	OPS 1.978		X						Alternative Training and Qualification Programme
SUBPART N	OPS 1.980		X						Operation on more than one type or variant
SUBPART N	OPS 1.981						X		Operation of helicopter and aeroplane
SUBPART N	OPS 1.985		X						Training Records
	SUBPART Q								FLIGHT AND DUTY TIME LIMITATIONS AND REST REQUIREMENTS
SUBPART Q	OPS 1.1090 1.			X					Objective and scope
SUBPART Q	OPS 1.1090 2.			X					Objective and scope
SUBPART Q	OPS 1.1090 3.			X					Objective and scope
SUBPART Q	OPS 1.1090 4.				X				Objective and scope
SUBPART Q	OPS 1.1090 5.			X					Objective and scope
SUBPART Q	OPS 1.1095	NR							Definitions
SUBPART Q	OPS 1.1100			X					Flight and duty limitations
SUBPART Q	OPS 1.1105			X					Maximum daily flight duty period (FDP)
SUBPART Q	OPS 1.1110			X					Rest
SUBPART Q	OPS 1.1115			X					Extension of flight duty period due to in-flight rest
SUBPART Q	OPS 1.1120			X					Unforeseen circumstances in actual flight operations — commander's discretion
SUBPART Q	OPS 1.1125			X					Standby
SUBPART Q	OPS 1.1130			X					Nutrition
SUBPART Q	OPS 1.1135			X					Flight duty, duty and rest period records

• Figure 4 JAR-OPS classification (to date)

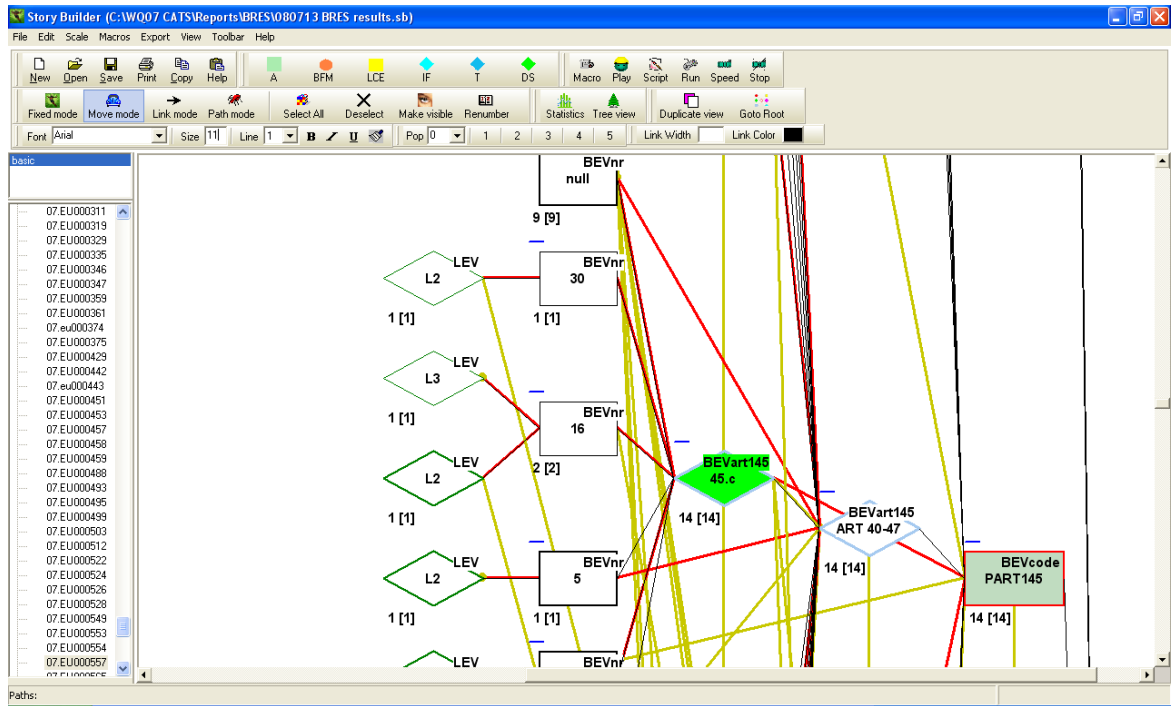
## 5 ANALYSIS OF THE AUDIT DATA

BReS Audit data supplied by IVW had to be pieced together to create a suitable table of data that could be imported into Storybuilder for the purpose of analysis. From the original data supply only the Part 145 audits from 2004 (when the regulation changed) were used. There were 687 such audits carried out across 73 companies of which 383 audits had findings



- Figure 5 View of BRes Storybuild showing numbers of audits below the boxes. On the left are shown the individual audit report identity numbers

The results were imported into and analysed in storybuilder, preserving all the information provided by IVW (storybuild file 080630 BRES results.sb)



• Figure 6 Part of the storybuild showing article 45c with 14 findings broken down into finding numbers and levels. The numbers below the boxes indicate the number of audit reports

The method of quantifying the company results was to measure:

- 1) The frequency of an audit per company
- 2) The frequency of an audit with findings per company
- 3) Frequency of regulation articles with findings, classified as delivery systems and per company
- 4) Probability of a specific delivery system (eg. Competence) finding per audit report per company
- 5) Frequency of levels (1, 2 or 3) of seriousness (with 1 being most serious) per company

Only delivery systems competence, communications and procedures were analysed in detail for illustrative purposes

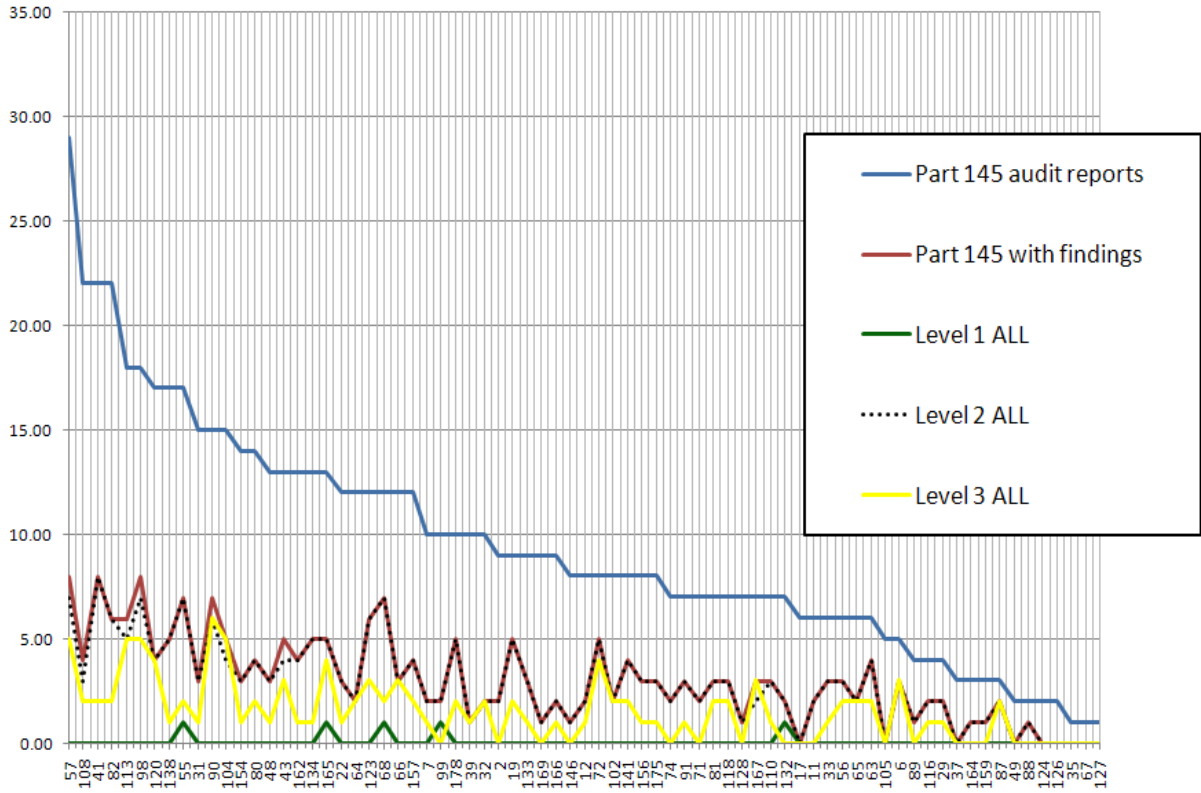
## 6 RESULTS

Figure 7 shows the overall frequencies of audits, in series for the companies from most to least, reflecting company size. The patterns of *report with findings frequency* differ between company. A small company might have more reports with findings than a bigger one despite far fewer audits.

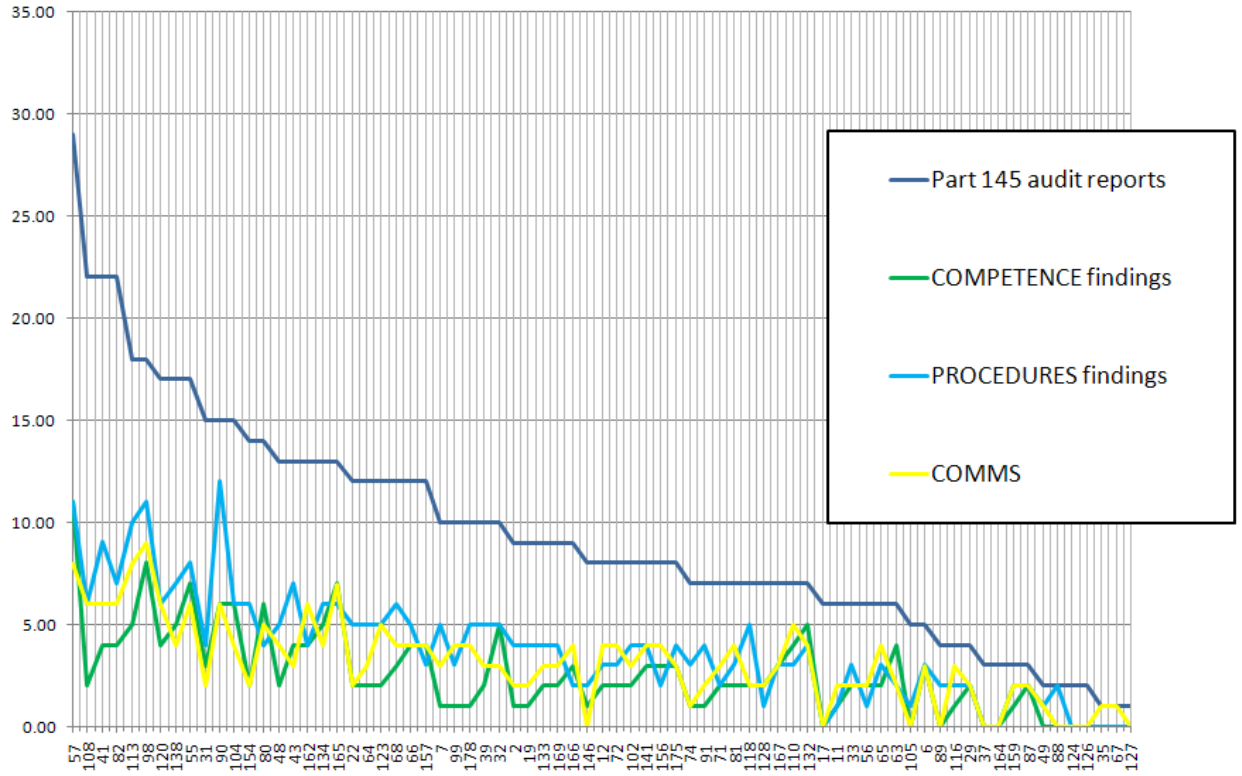
Figure 8 shows frequency of audit reports with a delivery system finding for competence, procedures and communications.

Figure 9 translates this into a probability of there being a specific delivery system finding (one or more relevant articles) per audit report. It can be quite clearly seen that there are differences between companies.

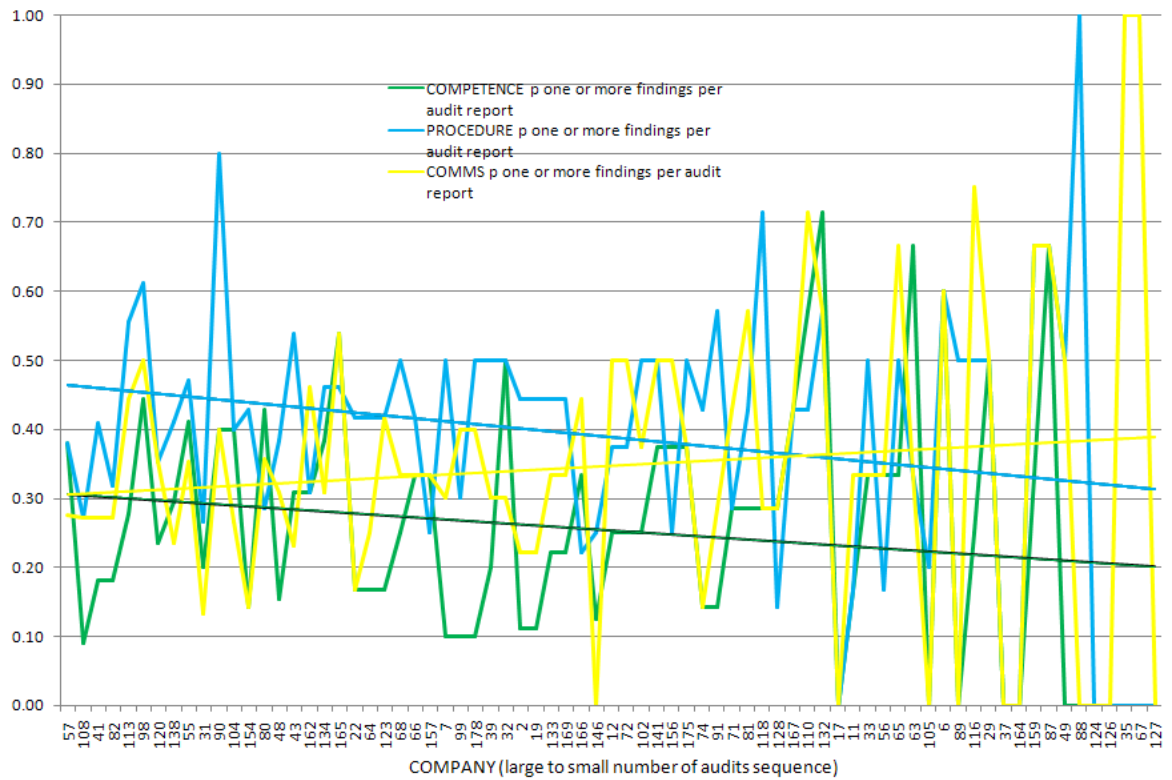
Figure 10 shows how the delivery system results are not correlated.



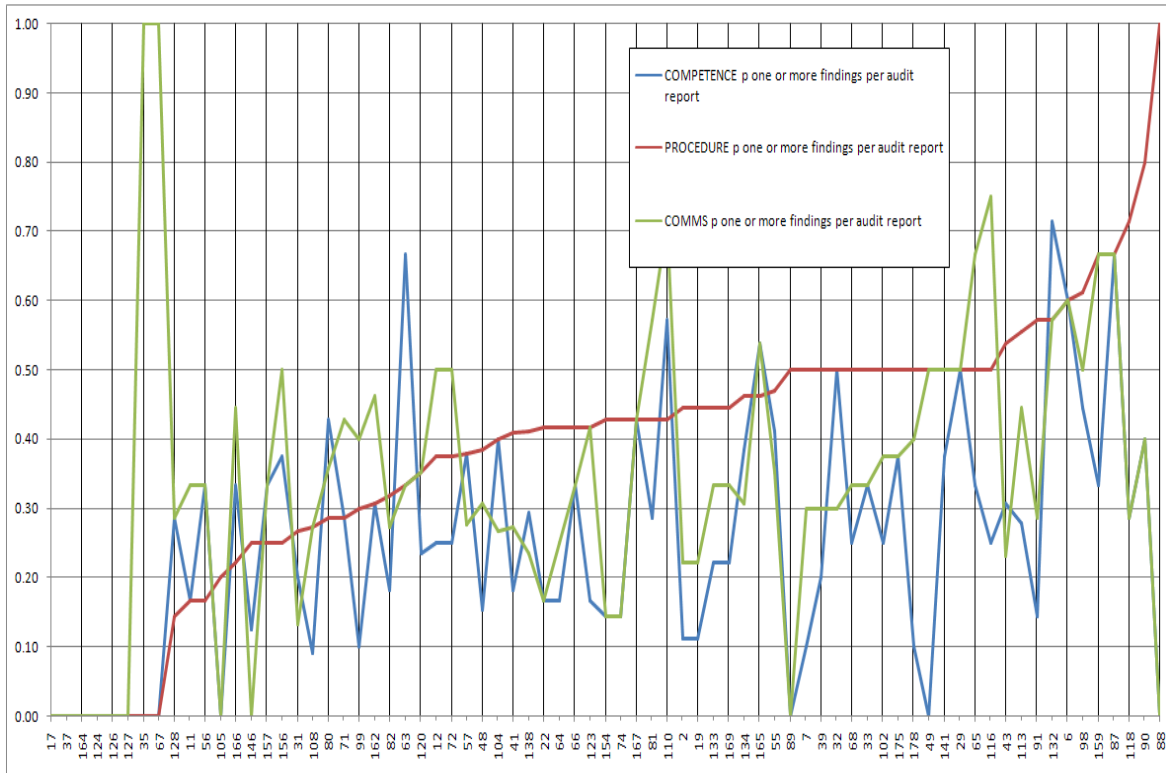
• Figure 7 Frequency of an audit report (vertical axis) per company (horizontal axis). The top line shows the total number of Part 145 audits which orders the companies in sequence from largest to smallest. The next line shows the frequency of reports with findings. Level 2 findings almost parallel this line. Below that are level 3 and then least are Level 1, the most serious.



• Figure 8 Frequency of audit report with DS article findings (vertical axis) against company (horizontal axis) arranged in size sequence from largest to smallest based on number of audit reports . Frequency indicates reports with findings in articles classified per delivery system (only 3 deliveries shown)



- Figure 9 Probability (vertical axis) of a delivery system article finding per audit report per company (horizontal axis) showing also trendlines. While the probability per audit of a procedure or competence finding appears to decrease with decreasing company size, that for communications appears to increase with a decrease in company size. The important point is that the companies look very different in the patterns of delivery system results.



• Figure 10 Companies (horizontal axis) placed in order of smallest to highest probability (vertical axis) of a procedure delivery system finding showing how competence and communications vary around this line.

## 7 CONCLUSIONS

Companies produce different results which appear to be partly size related and partly company specific. These differences could be a mix between inspection bias (deliberately focusing on specific areas) and company performance. Delivery systems do not seem to have correlated results across companies although no statistical tests have been performed.

This is the first time delivery system results have been measured for specific companies with such a rich source of data. If maintenance incident data for aircraft serviced by these companies could be identified a very important source of data for assisting with the management model part of CATS would be provided. In addition, it assists with the mapping of the regulation onto CATS in order to support a more risk based approach to inspections.

Further to this report IVW for Part 145 want to add to the classification of the articles.

This and the analysis of all the delivery systems is a task to be undertaken in future work.

## 8 REFERENCES

Ale B.J.M., 2006, The Occupational Risk Model, Final report of the Workgroup on ORM, TU Delft, The Netherlands

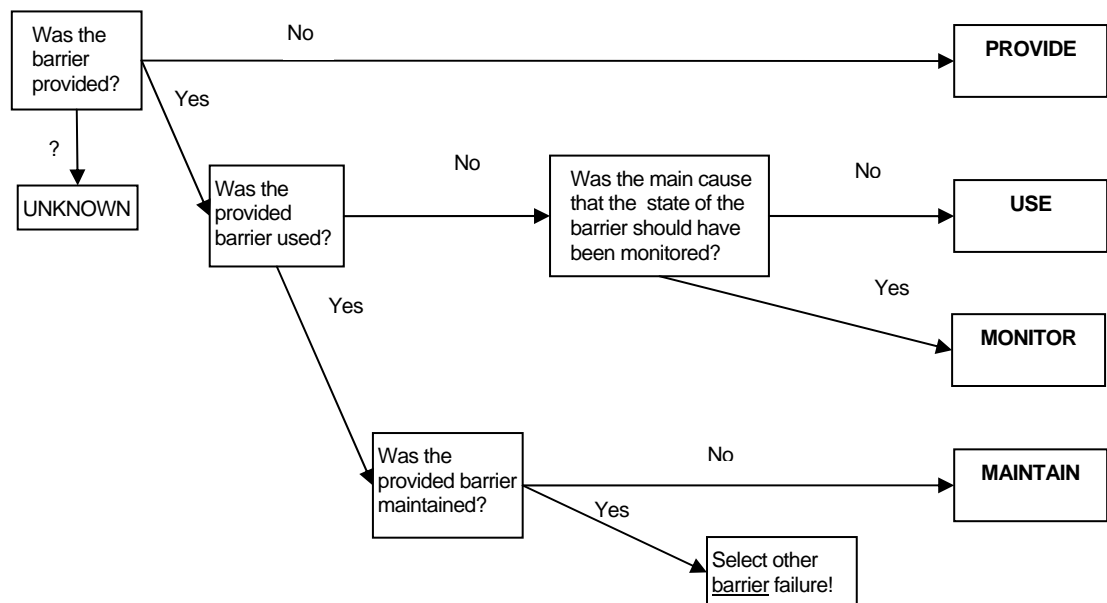
Bellamy L.J., Papazoglou I.A., Hale A.R., Aneziris O.N., Ale B.J.M., Morris M.I., Oh J.I.H., 1999. I-Risk: Development of an integrated technical and management risk control and monitoring methodology for managing and quantifying on-site and off-site risks. Contract ENVA-CT96-0243. Report to European Union. Ministry of Social Affairs and Employment, Den Haag.

Bellamy L.J., Ale B.J.M., Geyer T.A.W., Goossens L.H.J., Hale A.R., Oh J.I.H., Mud M.L., Bloemhoff A, Papazoglou I.A., Whiston J.Y., 2007. Storybuilder—A tool for the analysis of accident reports, Reliability Engineering and System Safety 92 (2007) 735–744

## ANNEX 1: BARRIER TASK FAILURES

The tasks, particularly the use and maintain tasks, are operable on a lower level in the overall system: i.e. at the barrier level where operators/workers and maintenance fitters are working. The provide task is, on the other hand often a management task.

- **Provide-[barrier]**  
= It does not exist, has not been well designed, or it is not provided and / or sufficiently/easily available when you want to use it. Such a barrier can be hardware or a specific method (sequence, composition, or other parameter(s) with safe limits).
- **Use-[barrier] failure**  
= the correct barrier is provided, but the way in which the provided barrier is used is incorrect, it is only partially used, or it is not used at all. A 'use' failure is also the case, when somebody chooses to use a barrier other than the correct one, despite the correct one being available.
- **Maintain-[barrier] failure**  
= the barrier is not kept available according to its designed function; i.e. in an adequate state. This does not only cover the maintenance aspect but also the management of change aspect of a barrier, i.e. a barrier is modified without ensuring that it maintains its barrier function.
- **Monitor-[barrier] failure**  
= the barrier condition is not checked/ measured/observed/inspected. This task relates directly to the state of the barrier, or to the supervision of the use of the barrier.



## ANNEX 2: MANAGEMENT DELIVERY SYSTEM FAILURES

The delivery systems are modelled to show whether the criteria and resources failed to have been delivered to the technical system through the task.

### Annex 2.1 Delivery system definitions WORM project

Delivery System (What's delivered)	Description
Plans & procedures [NL: Plannen & Procedures]	<p>Procedures refer to specific performance criteria which specify in detail, usually in written form, a formalised 'normative' behaviour or method for carrying out tasks, such as: checklist, task list, action steps, plan, instruction manual, fault-finding heuristic, form to be completed, etc.</p> <p>Plans refer to explicit planning of activities in time: either how frequently tasks should be done, or when and by whom they will be done within a particular time period (month, shutdown period, etc.). It includes: maintenance regime, maintenance scheduling (including shutdown planning), and testing and inspection activities. This delivery system also refers to rules, permits, programs and risk assessments.</p>
Availability [NL: Beschikbaarheid (van mankracht)]	<p>Availability refers to allocating the necessary time (or numbers) of competent and suitable (incl. anthropometrics and biomechanics) people to the tasks to be carried out. It emphasizes time-criticality, i.e. people available at the moment (or within the time frame) when the tasks should be carried out.</p> <p>This delivery system includes the availability of staff for repair work on critical equipment outside normal work hours, incl. coverage for absence and holidays.</p>
Competence [NL: Deskundigheid]	<p>Competence refers to the knowledge, skills and abilities of the people selected for the execution of tasks. It also covers the selection and training function of a company to deliver sufficient staff for overall manpower planning.</p> <p>This delivery system also refers to 'right person for the job', i.e. with the proper knowledge to provide, use, maintain or monitor the barrier effectively.</p>
Communication, collaboration [NL: Communicatie, samenwerking]	<p>Communication/ Collaboration refers to internal communication and coordination. Internal communications are those communications which occur implicitly or explicitly, within any primary business activity, i.e. within one task or activity in order to ensure that the tasks are coordinated and carried out according to relevant criteria.</p> <p>This delivery system also refers to task instructions and communication channels and means (such as meetings, logs, phones, radio).</p> <p>Note: this delivery system is only relevant if the activity is carried out by more than one person (or group), who have to coordinate or plan joint activities.</p>
Motivation/ Commitment [NL: Motivatie/ Instelling]	<p>Motivation/ Commitment refers to incentives and motivation with which people have to carry out their tasks and activities, i.e. with suitable care and alertness and according to the appropriate safety criteria and procedures specified for the activities by the organisation.</p> <p>This delivery system also includes the aspect of alertness, care &amp; attention, concern for safety of self and others, risk avoidance and willingness to learn &amp; improve.</p> <p>Note - This delivery system is fairly closely related to Conflict resolution, in</p>

Delivery System (What's delivered)	Description
	<p>that it deals with the incentives of individuals carrying out tasks not to choose other criteria above safety, such as ease of working, time saving, social approval, etc.</p> <ul style="list-style-type: none"> <li>- Organizational aspects of conflicts are covered by Conflict resolution.</li> <li>- More personal aspects, such as violation of procedures, are covered by Motivation/ Commitment.</li> </ul>
<p>Conflict resolution [NL: Prioriteitstelling (het stellen van de juiste prioriteiten)]</p>	<p>Conflict resolution deals with conflicts between safety and other goals within the performance of tasks. It deals with the mechanisms (such as supervision, monitoring, procedures, learning, group discussion) by which potential and actual conflicts between safety and other criteria in the allocation and use of personnel, hardware and other resources, are recognised, avoided or resolved.</p> <p>Note:</p> <ul style="list-style-type: none"> <li>- This delivery system is closely related to Motivation/ Commitment.</li> <li>- Issues of violations within tasks at an individual level are covered by Motivation/ Commitment.</li> <li>- Conflict resolution covers the organisational mechanisms for resolving conflicts across tasks, between people at operational level and at management level.</li> </ul>
<p>Ergonomics [NL: Ergonomie]</p>	<p>Ergonomics/ MMI deals with the fit between the man and the task. It refers to the ergonomics of all equipment used/ operated by operations, inspection or maintenance to provide, use, maintain or monitor the barriers.</p> <p>This delivery system covers both the appropriateness of the interface for the task and the user-friendliness to carry out tasks. It includes:</p> <ul style="list-style-type: none"> <li>- appropriate equipment, tools and software,</li> <li>- robust/ appropriate/ good interface and labelling, and</li> <li>- operability and maintainability.</li> </ul> <p>Ergonomics/ MMI also covers:</p> <ul style="list-style-type: none"> <li>- design and layout of control rooms and manually operated equipment,</li> <li>- location and design of inspection and test facilities,</li> <li>- the maintenance-friendliness of equipment, and</li> <li>- ergonomics of the tools used to maintain it.</li> </ul> <p>Note: MMI stands for Man - Machine Interface</p>
<p>Equipment (tools, spares, parts) [NL: Equipement (gereedschap, materieel, (reserve) onderdelen)]</p>	<p>Equipment refers to the hardware needed for provision, maintenance and monitoring of barriers.</p> <p>This delivery system covers both the correctness of the equipment for their use (compatibility, suitability, quality), and the availability of equipment where and when needed to carry out the activities. It includes: spares &amp; parts (incl. those needed for maintenance) and adequate &amp; correct stocks.</p>

### Selection of delivery system failures in relation to tasks

After identifying which task has failed, ask: "What was the most likely delivery not being delivered? e.g.:

- ✓ Failed to deliver good plans, procedures, rules or criteria for how and when something should be done in relation to the barrier. This could be a delivery failure:
  - Through the "provide" task: no plans or procedures to provide the barrier.
  - Or through the "use" task : the barrier has not been used because of a plans & procedures delivery failure (e.g. user followed the wrong procedure, or the procedures were delivered but were misinterpreted).
  - Or through the "maintain" task: no procedures/ plans to maintain the barrier
  - Or through "monitor" task: no procedures to monitor the barrier state.
- ✓ Failed to deliver communication/coordination about how/what/when. This could be a delivery failure:
  - through the "provide" task: no communication and/or coordination among the different people with respect to providing the barrier: i.e. crucial information not communicated. (e.g. wrong information given to provider)
  - or through the "use" task: no communication/ coordination among the different people delivered with respect to providing the barrier, but not with respect to using the barrier.
  - or through the "maintain" task: no communication and/or coordination among the different people with respect to maintaining/ the proper maintenance of the barrier.
  - or through the "monitor" task: no communication and/or coordination provided among the different people with respect to the proper monitoring of the barrier state.
- ✓ Failed to deliver sufficient people to be available. This could be a delivery failure:
  - through the "provide" task: not sufficient people available (at all) to provide the barrier.
  - or through the "use" task: insufficient people available to use the barrier (this makes sense if the task requires more than one person in order to do the job properly, or requires one person present and there was nobody).
  - or through the "maintain" task: not sufficient people available to properly maintain the barrier.
  - or through the "monitor" task: not sufficient people available to enable proper monitoring of the barrier state.
- ✓ Failed to deliver appropriate competence. This could be a delivery failure:
  - through the "provide" task: insufficient competence to provide the barrier. This could be a lack of competence in the process of selecting people, or a lack of skill in routine use, or knowledge of how and when to use a barrier in unusual or unexpected circumstances.
  - or through the "use" task: competence provided but not used.
  - or through the "maintain" task: insufficient competence to properly maintain the barrier.
  - or through the "monitor" task system: insufficient competence provided to enable proper monitoring of the barrier state.
- ✓ Failed to deliver the appropriate equipment/support/tools spares when these are required for the barrier (job). This could be a delivery failure:
  - through the "provide" task: no adequate equipment to provide the barrier: e.g. wrong or no equipment (or spares) in stock.
  - or through the "use" task: no adequate tools or parts delivered or present to use the barrier: e.g. wrong parts selected/ used.

- or through to the “maintain” task: no spares or parts or appropriate apparatus to properly maintain the barrier.
- or through to the “monitor” task: no equipment provided to enable proper monitoring of the barrier state.
- ✓ Failed to deliver motivation/incentives for the desired behaviour. This could be a delivery failure:
  - through to the “provide” task: no motivation (of management) to provide the barrier.
  - or through the “use” task: no motivation (of the user) to use the barrier, e.g. to choose the correct barrier, or to accept the psychological or physical costs of using barriers which demand extra time, effort or discomfort.
  - or through to the “maintain” task: no motivation (of management) to maintain the barrier, and/or no incentives to carry out maintenance fully or adequately
  - or through the “monitor” task: no motivation (of and/or from management) to monitor the barrier state.
- ✓ Failed to deliver criteria for conflict resolution with production/time/ pressures. This could be a delivery failure:
  - through the “provide-barrier” system: no clear (or other than) safety priorities in place (set by management) to provide the barrier.
  - or through the “use” task: the user has other priorities than using the barrier (the safe way).
  - or through the “maintain” task: no clear criteria or no priority to maintain the barrier (or other priorities than for safety)
  - or through the “monitor” task: no priority to monitor the barrier state.
- ✓ Failed to deliver ergonomic support for the job (e.g. right lighting, enough space). This could be a delivery failure:
  - through the “provide” task: the ergonomic aspect of the design is such, that the barrier is not provided in a specific situation.
  - or through the “use” task: the ergonomics of the equipment, tools or auxiliary equipment is such, that the desired behavior/ proper use of the barrier is not sufficiently enforced.
  - or through the “maintain” task: the design did not take into account the (ergonomics of) maintenance of the barrier.
  - or through the “monitor” task: the design did not take into account the ergonomic aspect of properly monitoring the barrier state.

## Annex 2.2. Delivery systems redefined for CATS (Lin and Hale)

At TUDelft, Pei-Hui Lin and Prof. Andrew Hale have redefined the delivery systems for CATS. In this new definition Motivation and Conflict resolution have been merged as Commitment, Equipment is replaced by Technology Function and Ergonomics is replaced by Man-Machine Interface

**1. Provision of procedures, rules, checklists and goals:** procedures and rules are specific performance criteria, which specify in detail, usually in written form, a formalised ‘normative’ behaviour or method for carrying out an activity (checklist, task list, action steps, plan, instruction manual, fault-finding heuristic, form to be completed, etc.).

Output goals are performance measures for an activity which specify what the result of the activity should be, but not how the results should be achieved.

**2. Provision of competence and suitability:** the knowledge, skills and abilities in the form of first-line personnel who have been selected and trained for the safe execution of the critical primary business functions and activities in the organisation. This system covers the selection and training function of the company which delivers sufficient staff for overall manpower planning. This competence pertains to both physical suitability (strength, and colour vision, health, etc.) and cognitive qualities of persons (situation awareness, decision making, etc.). Competence covers the cognitive aspects of behaviour, which can be learned through training, experience and practice.

The output of this delivery system is competent workers with adequate situational awareness and decision making who can handle the safety-critical tasks they are assigned in routine/proceduralised situations or during unplanned or unexpected situations.

**3. Provision of manpower planning and availability:** allocating the necessary time (or numbers) of competent people to do the safety-critical primary business tasks which have to be carried out. This factor emphasises time-criticality, i.e. people available at the moment (or within the time frame) when the tasks should be carried out. It also considers the availability of critical personnel at all times for emergency situations, coverage for peak loads, holidays, etc.

The output of this delivery system is the presence of the right people, with the right competence (previous delivery system) at the right place and time, with the time to operate the risk control measures defined.

**4. Provision of commitment to safety:** Commitment is the incentives and motivation which personnel have to carry out their tasks and activities with suitable care and alertness, and according to the appropriate safety criteria and procedures specified for the activities by the organisation. Commitment also relates to non-compliance with and deviation from the procedures; violating the rule can be necessary in some situations to which standard procedures do not apply and is not of itself proof that commitment is an issue. The ability to deviate when necessary is delivered by the competence delivery system.

Some of the conflicting pressures of online people are created in the management hierarchy, which places incompatible demands on front-line personnel in their roles as risk control measures. These pressures can come from conflicts in the commitment of more senior managers in the hierarchy and how managers treat and motivate their online staff to stick to or violate the rule of safety.

This delivery system is defined as motivating online staff to decide to commit to safety procedure above other personal and organisational goals. This is not the same as commitment to work, which can lead to organisational goals such as productivity, punctuality, or economy being preferred above safety goals. Conflicts across tasks at management level are not directly covered by the first line delivery system, since it only deals with the on-line choices made in controlling risk. These higher level conflicts could be modelled by a second use of this delivery system feeding in to the functioning of this (but also of other) delivery systems.

#### **5. Provision of communication, coordination and online supervision:**

**Communication:** Communications refers to exchange of information and instructions between people within the steps of any primary business activity. They are only relevant to

this protocol if the activity is the on-line control of risk carried out by more than one person (or group), who may be working for more than one organisation (esp. pilot and ATC). Communications between tasks, which are represented in the other parts of the management system, are not included here, since they are represented by the continuity of activity within those delivery systems and protocols.

Communication occurs as follows:

- 1) verbally: face-to-face, or talk through communication channels such as (mobile) telephone, radio
- 2) by passive written message emanating from: data link, e-mail, memo, briefing
- 3) Where the communication is via instrumentation, this can be covered under the delivery system for the equipment interface

**Coordination** covers those mechanisms designed to ensure the smooth interaction of actions between individuals and groups working on a joint task or responsible for the correct functioning of a given risk control measure. These include plans, meetings, authorisation and communication procedures.

This protocol links to the protocol on competence delivery system, since communication is also a procedure and skill which has to be learned, e.g. CRM training. It also links to the protocol on procedure delivery system, since many communication processes are formalized and subject to procedures, e.g. crosscheck and verbal confirmation.

## **6. Provision of technology function**

These are the equipment & spares which are installed. This delivery system covers both the correctness of the technologies for their use (like with like), and the availability of spares when and where needed to carry out the activities.

**7. Provision of man-machine interface:** The ergonomics of all aspects of the plant which are used/operated by operations, inspection or maintenance. This covers design and layout of control rooms and manually operated equipment, location and design of inspection and test facilities, the maintenance-friendliness of equipment and the ergonomics of the tools used to maintain it. This delivery system covers both the appropriateness of the interface for the activity and the user-friendliness needed to carry out the activities.