Société Française d'Études et Réalisations d'Équipements Aéronautiques
3, Carrefour de Weiden
92441 Issy-Les Moulineaux Cedex ; France
http://www.sofreavia.com

Identification of usable exits in the event of a survivable crash

IISU project

Final report

Reference : ATMC/C1121/IISU_ Final Report v1.1		Version : v1.1
Authors : Sofreavia team		Date : 25/02/02
Verified by : Eric Andlauer		Date : 04/03/02
Authorised by : Eric Andlauer		Date : 04/03/02
Addressees : SFACT/RE	Copies : British Airways, SNPNC	

DOCUMENT REVIEW

Version	Date	Description of evolution	Modifications
1.0	07 /02/02	Document elaboration	
1.1	25/02/02	Integration of SFACT comments	

ABSTRACT

Several accident analyses have shown that the survival rate of aircraft occupants in the event of an emergency landing could rise by improving the evacuation process. This study analyses the potential improvements in terms of assistance for aircraft occupants in identifying the usable exits and for PNC in guiding the passengers.

IISU is performed in the framework of the SFACT functional program 2000 dedicated to "occupant survivability" studies, on the behalf of the JAA.

The study process is divided into 5 main sub-tasks to be performed within one year :

- Task 1: Requirements analysis
- Task 2: Elaboration of the specifications
- Task 3: Inventory of usable technologies
- Task 4: Technologies evaluation
- Task 5: Proposition of solution(s)

This final document synthesises the work done during the project.

The requirements have been collected and examined through :

- An analysis of accident reports involving an evacuation (CAA database, see [1])
- The design of a tasks model (i.e. tasks performed by the aircraft occupants during the evacuation process).

These two axes of analysis have been mixed by relating the results of the analysed reports in each of the tasks described in the model. This work (detailed in [A] and [B]) enabled us to identify the tasks that should be improved and the situations of evacuation that we should focus on since they are more frequent and/or more dangerous (e.g. fire or ditching or overrun etc…).

The requirements collected by task have been gathered according to the evacuation process phase. In each of them, they have been presented according to the type of solution that could match the requirement : assistance tool, communication means, procedures and training.

The technical specification conducted in parallel with an inventory of usable technologies (see [C]) led to the proposition of various potential solutions meeting the initial requirements.

Among the technologies proposed, 5 solutions have been selected : Camera, CHECK, Sound, Headset, Spyhole. Then, technical and "non technical" solutions (see details in [D]) have been presented both aimed at improving the evacuation process.

Finally, recommendations have been formulated.

Table of Contents

ACRONYMS

a/c	Aircraft
BEA	Bureau d'enquêtes et d'analyses pour la sécurité de l'aviation civile (French institution)
CAA	Civil Aviation Authority
CC	Cabin Crew
CHECK	Check Exit and Communicate Knowledge
DGAC	Direction Générale de l'Aviation Civile
FAA	Federal Aviation Administration
FC	Flight Crew
IISU	Identification des Issues de Secours Utilisables (Identification of usable exits)
JAA	Joint Aviation Authorities
NTSB	National Transportation Safety Board (U.S.)
Pax	Passenger
SCCM	Senior Cabin Crew Member
SFACT	Service de la Formation Aéronautique et du Contrôle Technique (service of DGAC)
SNPNC	Syndicat National du Personnel Navigant Cabine
VLTA	Very Large Transport Aircraft
WP	Work Package

1. INTRODUCTION

1.1. IISU's context and objectives

A study was carried out by M.K.Hynes in 1998 on 519 emergency evacuations (see [2]). It stresses the high number of evacuations in the USA : in one year, 80 % of accidents involve an evacuation and one evacuation each week is precautionary (without an accident).

IISU study is performed in the framework of the SFACT functional programme. The study is done on the JAA's behalf. One of the more general objectives of the JAA is to design a cabin manual homologue of an existing one for the flight crew. This study may be an input in designing this manual.

Regulations for emergency exits are contained in JAR 25 section 1. The exits range from the largest, a "type A" which is a floor level door to the smallest, a "type IV" which is an overwing exit.

Before going further, we have to agree about a general definition of a "non usable exit". According to the two airlines participating in the study, it means an exit not usable due to a fire, to an impossibility of opening the door, to an incomplete opening of the door, to a deficiency of the slide (any deployment, any or insufficient inflating, incorrect positioning). In this case, the re-routing of passengers to the opposite door must be prioritised, otherwise the next door.

The objective of the study is to propose solutions improving :

- The identification of usable emergency exits.
- The communication between occupants.
- And the guidance of passengers toward the exits.

In [3], a study done on the analysis of 46 evacuations gives the following information :

- All exits have been used in only 4 cases /46
- Floor level exits used: 67/125
- Type III over-wing exits used: 44/121
- Floor level exits were not used because of being blocked: 34/58
- Type III exits were not used because of being blocked: 32/77

In the database used for the IISU study, 193 accidents out of 256 (75%) give information about the use of doors: 40% of the doors had been found to be opened (that does not mean that they were all used).

This information is a premise leading to our interest in improving the identification of usable exits. The questions to be replied to are presented in Figure 1.

In order to propose efficient solutions that are suitable to this context and reasonable from the cost-benefit point of view, the study process has been divided in to 5 main sub-tasks to be performed within one year :

- Task 1: Requirements analysis
- Task 2: Elaboration of the specifications
- Task 3: Inventory of usable technologies
- Task 4: Technologies evaluation
- Task 5: Proposition of solutions

The participants to the study are :

- Sofréavia
- British Airways
- SNPNC

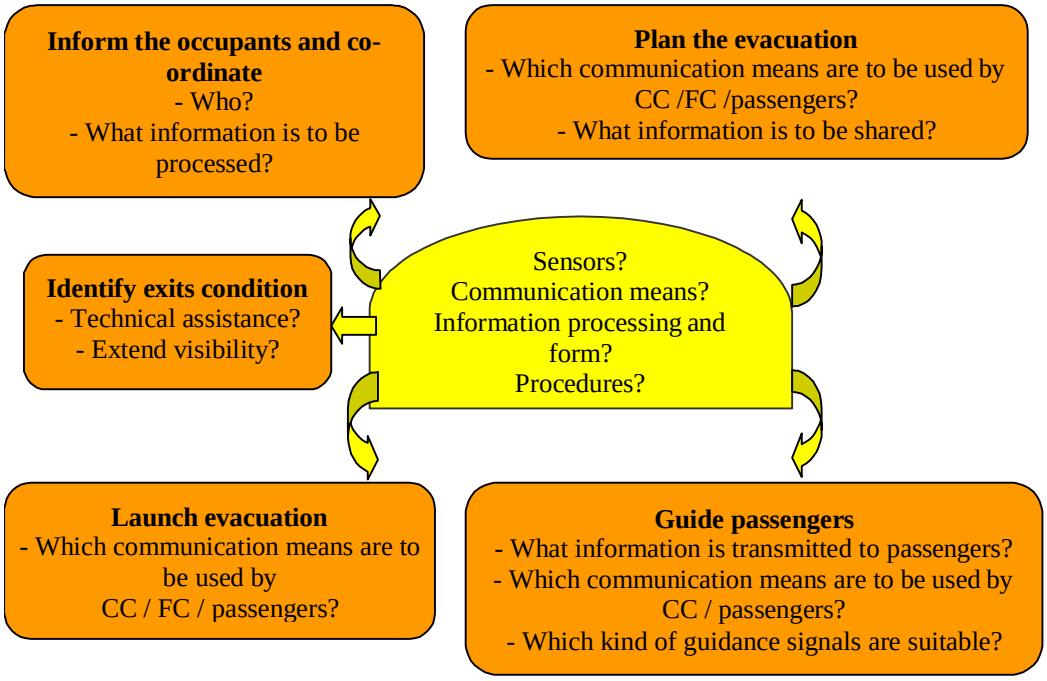


Figure 1 : Comprehension of the problem

1.2. Document structure

The present document is organised as follows :

- Chapter 2 presents the requirement analysis
- Chapter 3 explains the technical specifications process
- Chapter 4 describes the solutions finally proposed at the end of the project
- Chapter 5 presents the ensuing regulation recommendations.

Moreover, the following annexes are presented at the end of the document :

- Annexe 1 shows the results from the analysis of accidents reports
- Annexe 2 presents some operational comments on technological solutions.

2. REQUIREMENT ANALYSIS

The Requirement analysis is detailed in the documents [A] and [B].

2.1. Objective

The objective of this project phase is to identify what are the needs and constraints of occupants in an evacuation situation which should help in improving the evacuation process. The types of requirements concern assistance in : gathering information about situation, communication between people, the decision making process, management and guidance of crowds.

This first work-package has been divided into two sub-tasks performed in parallel :

- Analysis of survivable events.
- Design of a task model for an evacuation situation.

2.2. Process

Each of the two sub-tasks are described below.

2.2.1. Analysis of survivable events

Most of the evacuation reports analysed have been selected in the CAA accidents data base (ADB;[1]). One accident report comes from the BEA (Tahiti, 1993). There are 2426 accidents listed in this database, and 256 of the 2426 accidents (about 10.5%) involved an evacuation.

The whole database has been used to get general information about accident types :

1. 725 accidents occurred during day time while 441 occurred during night time. There are 1260 accidents where the evacuation data is not available. Of the 725 accidents, 62% of them took place during the day and 38% of them at night. The fact that darkness conditions-are worse than daylight ones must be taken into account in the research.

2. Regarding accident conditions, the percentage of accidents by phase of flight is :
   - Descent and approach phase represents 28%,
   - Landing phase represents 24%,
   - Cruise/flight phase represents 17 %,
   - Take-off and aborted phase represent 15%,
   - Climb phase represents 9%,
   - Parking, taxiing phase represent 5%,
   - Go-around phase represents 3%

   The previous data set into relief the critical phases of approach and landing, while passengers may be tired and briefing has been done a long time before.

Typology of accidents having conducted an evacuation :

Type of accident	Amount	Number of relevant reports
Impact and Fire (IF)	77	25
Impact only, (I)	65	20
Ditching, (D)	14	14
Fire only, (F)	48	8
Smoke only (S)	11	6
Other causes (bomb threat for example)	16	4
No information	25	0
Total	**256**	**77**

There are 256 accident reports and only 77 deal with passenger evacuation. They have been sorted out according to the cause of evacuation in order to have an idea of the types of situations within which an evacuation is performed : impact, impact and fire, ditching, fire only, smoke only, other causes.

According to the richness of the information included in the report, the typology of the reports analysed is not in agreement with the typology of the 256 accidents. We have decided to privilege the gathering of a maximum amount of information rather than to respect the typology.

A form (detailed in [A]) has been established to collect information from each of the reports analysed in order to get the relevant information for the study.

Having collected all the information according to the form established, a synthesis has been made, in order to stress the situations that are more frequent or that are specific to a given context.

The synthesis of the information analysed is presented in § 2.3.

2.2.2. Design of task model

2.2.2.1. Purpose

The purpose of building a task model is to analyse and formalise the tasks performed by the persons achieving a given objective (e.g. Perform an evacuation).

For that purpose, it is necessary to reply to the following questions :

- Why is the task performed (task goal) ?
- Who performs the task (which person) ?
- How is it performed (task procedure) ?
- What are the triggered events of the task (triggered event) ?
- What information is used and produced or the factors affecting the task ?
- What are the links between tasks (sequential, xor, or, etc) ?

The objectives of interest for a new system design are the formalisation of users' requirements and all information that could be exploitable for specification (e.g. information presentation, mode of use of means), training design (e.g. elaborate a training that is task oriented) and a validation process (e.g. identification of validation hypotheses).

In the IISU project, the need of a task model has been thought necessary due to a lack of knowledge of the CC activity. Within this project, the task model concerns only the "Perform an evacuation" task.

The task model has been used for several purposes :

- To have a synthetic view of what is the current situation and mainly the current weaknesses (e.g. in procedures, means).
- As a basis to identify what are the main tasks that must be improved (from a point of view of information, communication, and passenger guidance).
- As a framework to present the main knowledge learned from the survivable events analysis.
- As a means to identify the needs and constraints that are the bases for a specification elaboration.
- As a communication support tool between people involved in the project, mainly with the operational people (CC).

2.2.2.2. Process

Four sources of data have been used to build the task model:

- interviews of CC (SNPNC, British airways),
- observation of evacuation exercises, analysis of British Airways' procedures,
- CAA Accident Database,
- bibliography such as [2] and [4].

2.3. Lessons learned from event analysis

The table presented in Annex 1 presents the results obtained from the analysis of the reports on which are based the following comments.

Caution

The lessons learned must be taken with caution because the database does not cover all evacuations performed throughout the world. We had to suppose that the sample is a representative one. A second caution is related to the heterogeneity of the information written in the reports. This feature makes difficult the understanding of the event and the identification of improvement requirements.

- *Evacuation situations*

The most dreaded event is **fire** because it leads to a very urgent evacuation. In fire conditions, smoke in the cabin adds a problem for guidance. Ditching is also dreaded for some reason of urgency. In the database, evacuation involving fire or smoke are the most frequent (53% of the 256 accidents). **Approach or landing** represent the phases of flight the most concerned with an evacuation (53% of the 256 accidents). These two observations lead us to prioritise fire conditions and final phase of flight conditions for an improved solution.

- *Evacuation decision making process*

The decision making process is a critical phase that is influenced by several factors such as the airline's safety culture, the functioning status of the communication means, the estimation of danger on the basis of partial information. We have observed delays in the evacuation decision process. Obviously, we have not identified the evacuation decision cancellation process because we have only studied accidents involving evacuation.

- *Temporal factor*

Most of the evacuations analysed **are unplanned**, that is to say that the CC and FC had no time to prepare the cabin or even to choose the best evacuation orientation before evacuation itself. The NTSB [3]has found that 67%of evacuations are unplanned.

- *Rule on the exits usability*

Most of the time, it is the CC who estimates and rules on the usability of an exit. The collection of information is made by looking through the window or sometimes by half-opening the door (mainly in case of water) to detect a potential obstacle or fire.

- *Causes of non usability*

The non-usability of exits seems to be related to various factors:

- Difficulty even impossibility in opening an exit (jamming of opening mechanism, structural damage)
- Obstacle or fire or water behind the door
- Problem with the slides (problems of inflation, fire, split, etc…)

An exit can be **usable during only part of the time** of the evacuation (e.g. difficulty in opening, slide deflation, extinction or progression of fire)

- *Communication problem*

There is often a **problem of communication** between occupants because of a communication means failure or noise or impossibility to move to get verbal information.

- *Passengers pre-flight briefing*

The **pre-flight briefing** seems to be an important factor influencing passengers' behaviour during evacuation.

- *Passengers guidance*

Concerning the passengers' guidance, and more generally, the evacuation process, problems are essentially of 4 types :

- Guidance towards an exit is a critical problem in the case of smoke.
- Passengers' dangerous behaviour due to panic can impair the flow.
- Re-routing of passengers because of unusable exits is a source of panic and jamming.
- Emergency equipment mainly in case of ditching is often difficult to use because of a lack of briefing (difficulty in using life-jacket for example)

2.4. Task model and tasks to be improved

2.4.1. Task model

The tasks model is presented in the Figure 2. All the tasks are detailed in the document [B].

Remarks :

- Each task is represented by a rectangle.
- Each colour (or level of grey) represents a person or a group of persons.
- The tasks are related to each other in a hierarchical fashion.
- Six types of links exist: and, or, xor, sequential, parallel, undetermined, There is **no temporal link** between the tasks. The temporal aspect will be described in the task procedure.
- The trigger events of the tasks are represented by a trapezium-shaped box.
- Information used as input, produced as output or factors influencing a task are represented in a rectangular box with a shadow.

The general comments concerning the evacuation task model are presented hereafter.

Caution

The analysis has been mainly based on the knowledge acquired from two airlines. However, the analysis made on the accident reports provides an overview of evacuation situations and actions whatever the airline implicated.

- *Tasks described*

Although IISU focuses on the identification of usable exits and the guidance of passengers, we have decided to represent tasks such as danger estimation, evacuation decision and the leaving of the crew from the aircraft because we think that the analysis must take into account the whole evacuation process. However, the tasks outside of the study scope have been less deeply analysed than the others.

- *Role of the different occupants*

The model shows that each occupant (FC, CC, passengers) has a role to play in the evacuation process. According to the context of evacuation, a given task can be performed by one or another person. Even if the responsibilities are defined in the airline's procedures, situations are so different from one to another that the procedures can not always be applied in the same way.

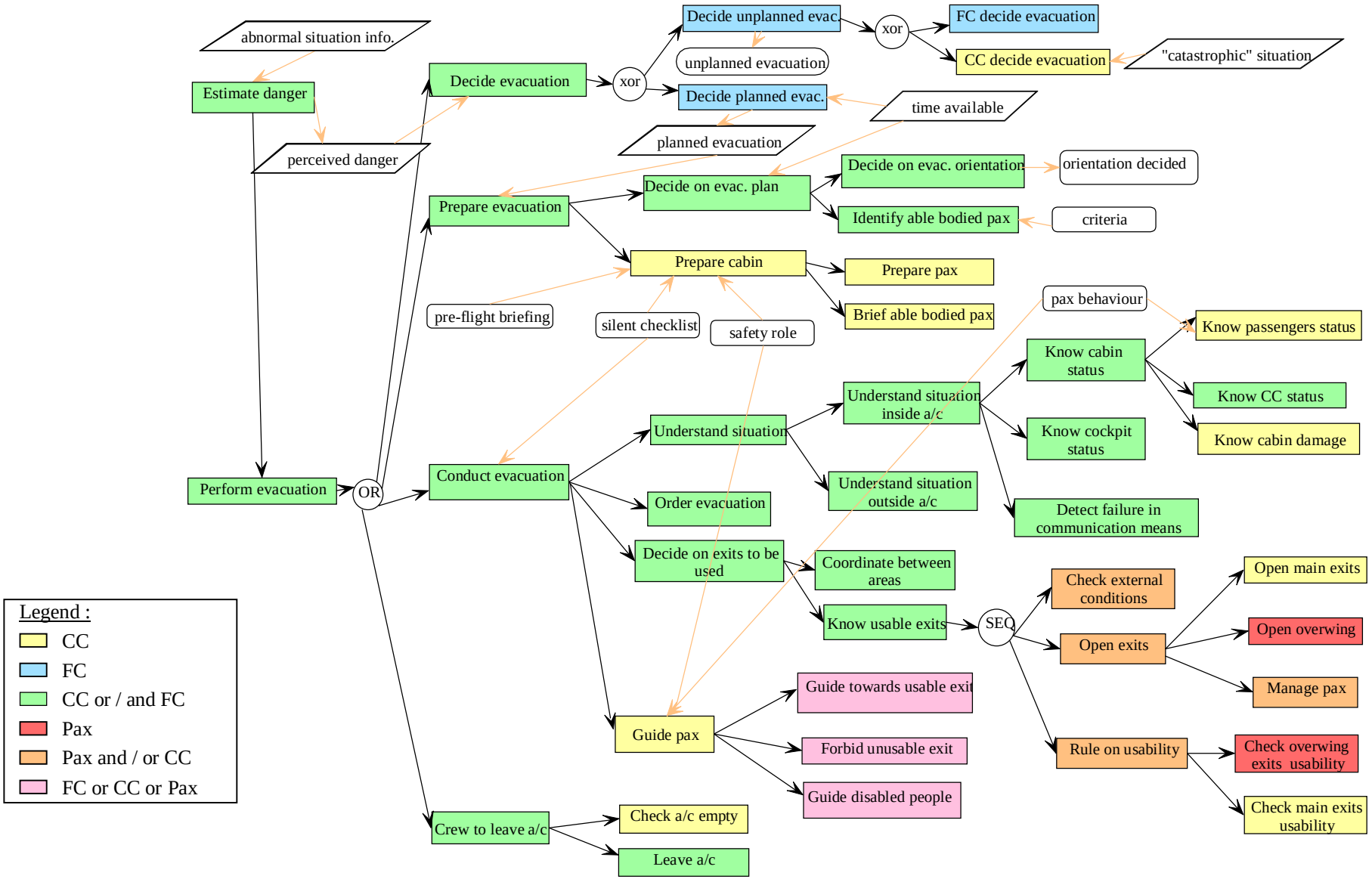
What must be stressed is the situation when neither FC nor CC have decided to evacuate while the passengers initiate an evacuation. This event has not been represented because it is a rare case and because we have preferred to consider that case as a non evacuation decision situation.

- *Links between tasks*

Links between tasks have been specified only when it was a sequential one or an exclusive one.

Most of the tasks with the same parent can been done in parallel.

Figure 2 : Evacuation task model figure



2.4.2. Task improvement

The tasks analysis shows that some improvement would be useful in all the phases of the evacuation process, from the decision making to the management of the evacuation itself.

The tasks associated with the “To be improved” comment on the Figure 3 are the main concern of the IISU project and should be improved.

The following list presents the tasks to be improved whatever their position in the hierarchy.

Evacuation Decision process

- Decide evacuation

Understand the situation

- Know passenger status
- Know CC status
- Know cockpit status
- Detect failure in communication means
- Understand the situation outside of the aircraft

Preparation of evacuation

- Decide evacuation orientation
- Prepare cabin (passengers and able bodied passengers)

Order evacuation

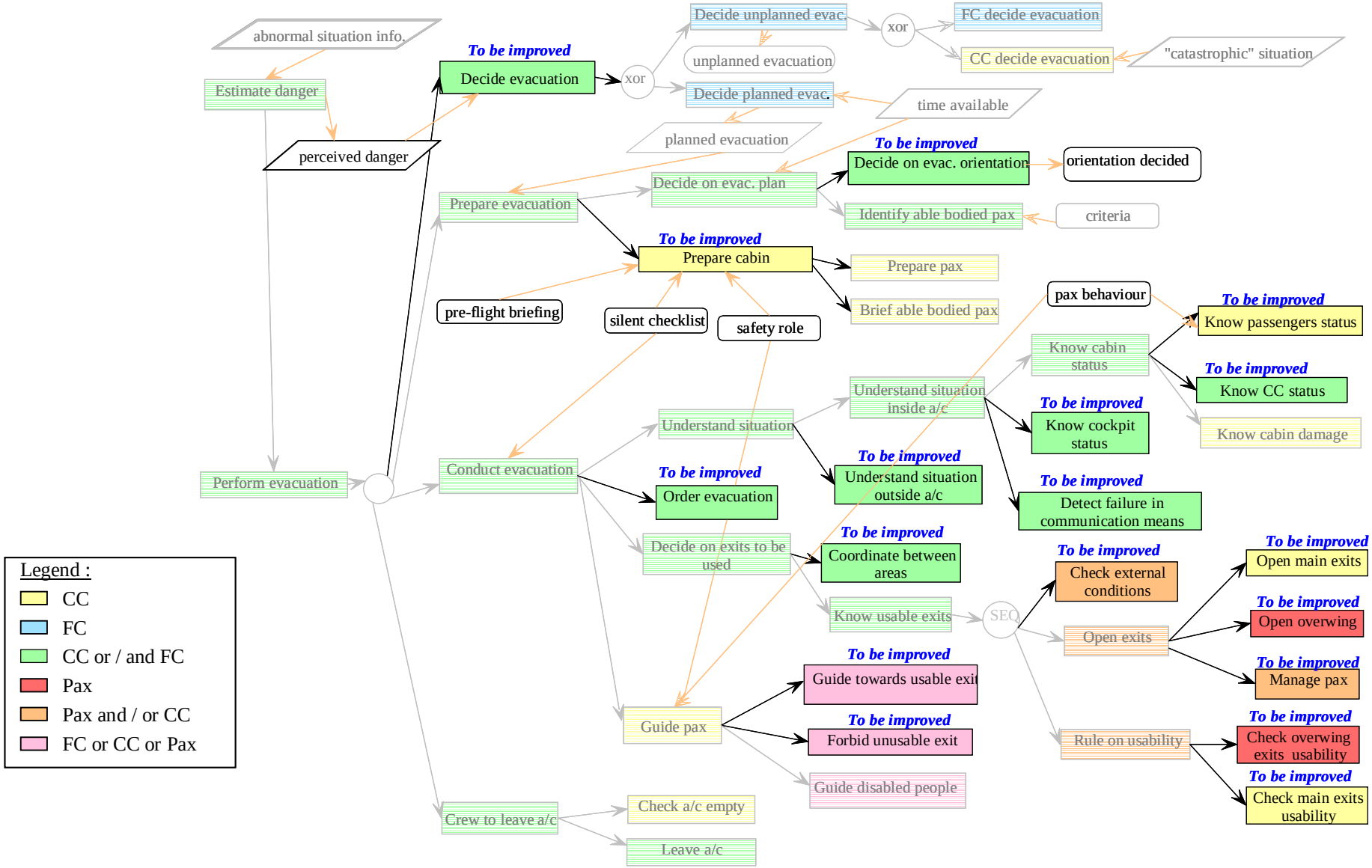
Decide on the exits to be used

- Co-ordinate between aircraft areas
- Check external conditions
- Open main exit
- Open over-wing exit
- Manage passengers (while opening exit)
- Check over-wing exit usability
- Check main exit usability

Guidance of passengers

- Guide toward usable exit
- Forbid unusable exit

Figure 3 : Tasks to be improved



2.5. Synthesis of requirements

The requirements identified during the first phase of the project are listed in the following table and sorted by domain. 8 different domains have been identified regrouping 40 requirements.

Domain	Requirements		Task(s) impacted
	N°	Description	
Data Access	RQ01	Provide information on communication means status	- Detect failure in communication means; - Order evacuation
	RQ02	Provide access for all CC to data about surroundings	- Understand situation outside a/c; - Check external conditions
	RQ03	Provide information on structural deformation	- Check external conditions - Know cabin damage
	RQ04	Improve determination of slide usability	- Check overwing exit usability; - Check main exit usability
	RQ05	Provide information of position of cabin floor with respect to water level	- Check external conditions; - Check overwing exit usability; - Check main exit usability
	RQ06	Provide information on location(s) of external fire(s)	- Check external conditions; - Check overwing exit usability
	RQ07	Provide information on external fire intensity	- Check external conditions; - Check overwing exit usability
	RQ08	Improve visual access of a/c surroundings to CC stationed at exits	- Check external conditions; - Check overwing exit usability; - Check main exit usability
	RQ09	Facilitate determination of usability of over-wing exits by body able pax	- Check overwing exit usability
Data Transmission	RQ10	Provide reliable and autonomous communication means	- Decide evacuation
	RQ11	Provide means of transmitting information to CC at non usable exits of nearest available exits	- Guide towards usable exits; - Forbid unusable exits
	RQ12	Improve knowledge of exit status for CC in charge of pax flow management	- Guide towards usable exits
	RQ13	Provide to each CC and FC the physiological status of CC	- Know CC status
	RQ14	Provide to each CC the physiological status of FC	- Know cockpit status

Domain	Requirements		Task(s) impacted
	N°	Description	
Co ordination	RQ15	Improve interaction between CC members	- Decide evacuation; - Co-ordinate between a/c area
	RQ16	Improve interaction between CC and FC	- Decide evacuation; - Decide evacuation orientation; - Co-ordinate between a/c area
	RQ17	Provide acknowledgement of evacuation decision	- Decide evacuation
	RQ18	Provide acknowledgement of evacuation order	- Order evacuation
	RQ19	Improve data sharing between CC members of the situation inside the cabin	- Co-ordinate between a/c area; - Know cabin status
	RQ20	Improve data sharing among CC about the surroundings	- Understand situation outside a/c
Briefing	RQ21	Improve emergency exit opening procedures for pax at over-wing exits	- Open overwing
	RQ22	Improve safety information provided to pax	- Prepare cabin
	RQ23	Improve knowledge of safety procedures and responsibilities for body able pax	- Prepare cabin; - Open overwing
Guidance	RQ24	Provide physical means to forbid use of an unusable exit	- Forbid unusable exits
	RQ25	Improve pax guidance to available exits	- Guide towards usable exits
	RQ26	Improve flow management of pax toward available exits	- Guide towards usable exits
Procedures	RQ27	Improve harmonisation of emergency procedures	- Conduct evacuation
	RQ28	Stress safety role of CC	- Prepare cabin; - Order evacuation
	RQ29	Improve body able pax selection	- Open overwing

Domain	Requirements		Task(s) impacted
	N°	Description	
Training	RQ30	Improve knowledge of steps of the decision making process	- Order evacuation
	RQ31	Improve CC knowledge of pax flow management	- Guide towards usable exits
	RQ32	Improve knowledge of the responsibilities of each and every FC and CC	- Order evacuation
	RQ33	Improve pax flow management through exits	- Guide towards usable exits
	RQ34	Prepare cabin in function of time available	- Prepare cabin
	RQ35	Improve CC knowledge of various emergency scenarios	- Prepare cabin
	RQ36	Determine pax psychological status by CC	- Know pax status; - Open overwing
	RQ37	Improve CC knowledge of aircraft type, specifically in terms of emergency exits and evacuation procedures	- Open main exit
	RQ38	Improve CC knowledge of panic management	- Guide towards usable exits
Emergency equipment	RQ39	Improve ergonomics for over-wing exit opening	- Open overwing
	RQ40	Improve harmonisation of emergency material	- Open main exit

3. TECHNICAL SPECIFICATIONS PROCESS

3.1. Explanation of the process

After the requirement analysis, the technical specifications was conducted in parallel with an inventory of usable technologies. In a regulatory oriented research process it was decided to match the potential solution definition to the technical specification. The objective was to provide a potential solution to an identified operational need.

To be sure to deal with all the needs, we took care that, for all the requirements which are project related and which concern the main evacuation tasks, a solution was always proposed. These solutions are presented in the next section.

Ten technical solutions have been proposed and studied :

1. Camera
2. CHECK
3. Sound
4. Light
5. Screen
6. Headset
7. Spirit level
8. Spyhole
9. Vibration
10. Water detector
11. Water level

3.2. Potential technological solutions

The tables hereafter shows the main characteristics (developed in [C]) of the possible technological solutions.

INSTRUMENT	CAMERA
DOMAIN	Data Access
DESCRIPTION	Video cameras placed in strategic parts of the a/c structure recording the overall view of the a/c live. They are connected to onboard screens on which these images can be seen.
REASON FOR PROPOSAL	This system provides real time image of the a/c external conditions to FC. It could assists them in evacuation decision making and planning (evacuation orientation)
OVERALL OPINION	• This device, we believe, can greatly aid FC to have a view of the external conditions of the a/c. This facilitates the determination and identification of exit usability hazards • Given that such devices are already in use on some a/c for taxiing etc, it seems possible to install them for our purpose.

INSTRUMENT	CHECK (CHeck Exit and Communicate Knowledge)
DOMAIN	• Data Transmission • Guidance
DESCRIPTION	• Displays situated at each main exit showing a layout of all a/c exits. • Each exit on display shows whether the exit is usable / non-usable • A command (lever) enabling validation of exit usability
REASON FOR PROPOSAL	• This supplies information about the usability of all the a/c exits to CC. • All CC see which exits are usable and which ones are not • All CC can also see whether an exit is manned or not (no decision made on the exits usability)
OVERALL OPINION	• This device can greatly aid the pax flow management in an emergency evacuation • It ensures that all CC can inform themselves on the usability of exits especially if their own exit is not usable

INSTRUMENT	SOUND
DOMAIN	• Data Transmission • Guidance
DESCRIPTION	This is a sound emitting loudspeaker installed in each emergency exit doorframe
REASON FOR PROPOSAL	Sound emitted attracts pax to available exits particularly in bad visibility conditions
OVERALL OPINION	• SOUND uses the sense of hearing to identify usable exits and hence can be greatly beneficial in darkened and smoke filled cabins • Sound Alert are now introducing this technology into a/c. Initial tests have already been carried out with a major a/c manufacturer (Airbus). The results (which are not yet general knowledge) suggest that it is a technology of great potential in terms of finding available exits

INSTRUMENT	LIGHT
DOMAIN	• Data Transmission • Guidance
DESCRIPTION	This is a light emitting device installed in the emergency exit doorframes
REASON FOR PROPOSAL	Green/Yellow/Blue electroluminescent light is easily seen and attracts pax to available exits particularly in the presence of smoke
OVERALL OPINION	• We think that this could be a possible solution. The fact that it is in use in helicopters shows us that it is a worthy technology • We do, however, recommend that tests and simulations be carried out on the technology for aeroplanes especially in terms of emission type and whether it actually attracts pax

INSTRUMENT	SCREEN
DOMAIN	Briefing
DESCRIPTION	Screens available for each pax on which safety information is shown
REASON FOR PROPOSAL	• This instrument transmits safety information to pax • It can also relay information about the nearest exit (but not about their usability) relative to the passenger's seating location in the cabin (it is not proposed to be shown during an evacuation)
OVERALL OPINION	• This instrument, we believe, will encourage pax participation in a/c safety matters. • Interactivity with safety information during a flight could possibly increase the pax's likelihood of proper behaviour in emergency situations (ability in determining the nearest available exit and to understand various emergency equipment, instructions …) • The fact that such entertainment systems are already used is a bonus. Installation costs are low: only the safety information (software) needs to be uploaded onto the entertainment system

INSTRUMENT	HEADSET
DOMAIN	• Data Access • Data Transmission • Co-ordination • Guidance
DESCRIPTION	This is a hands-free device enabling several users to communicate with one another
REASON FOR PROPOSAL	Information regarding usable / unusable exits can be relayed more quickly and securely facilitating evacuation co-ordination and pax flow management
OVERALL OPINION	• Provided a completely wireless device can be made, this could be an extremely useful instrument • This could greatly aid CC, particularly in darkness and smoke, since hands free communication will enable them to receive information about usability of exits and on evacuation co-ordination / orientation • Studies must be carried out with co-operation of a/c operators and CC in order to determine whether the introduction of such a device and its integration into a/c operations are feasible

INSTRUMENT	SPIRIT LEVEL
DOMAIN	Data Access
DESCRIPTION	It is a hollow closed cylindrical tube (shaped like a medicine capsule) consisting of two parallel lines on its outer side and normal to its longitudinal axis. It contains a non-viscous fluid (alcohol or ether) and an air bubble (or plastic ball)
REASON FOR PROPOSAL	It allows the attitude of the a/c to be determined with respect to the Earth's surface (two are required)
OVERALL OPINION	• We believe that it could be useful to know the attitude of the plane in order to determine whether the slide should be deployed or not • We do not believe that this is a possible solution as it seems to be quite complicated area but it is a field that needs further study

INSTRUMENT	SPYHOLE
DOMAIN	Data Access
DESCRIPTION	This is a lens through which the range of visibility is increased by forming a 'visibility cone'. It is of a convex shape
REASON FOR PROPOSAL	The external conditions in the vicinity of an emergency exit can be better determined from within the cabin due to an increased range of visibility
OVERALL OPINION	• The introduction of such an instrument, we believe, will greatly increase the range of visibility, thus the determination of external conditions is made easier • This is simple device to make and install • The cost-benefit ratio favours implementation of such a device

INSTRUMENT	VIBRATION
DOMAIN	Guidance
DESCRIPTION	A device that emits a vibration, at a certain frequency, in the floor in the vicinity of an exit
REASON FOR PROPOSAL	The sense of touch is used as a means to attract pax to the correct exit, especially in dense smoke and darkness
OVERALL OPINION	• We believe that this is a technology that has great potential. It makes use of the sense of touch which no other a/c attraction device aims to do • We recommend that serious thought be given so that tests can be carried on such a device

INSTRUMENT	WATER DETECTOR
DOMAIN	Data Access
DESCRIPTION	This is a solid cylindrical device which tells the user whether the cabin floor is above or below sea level
REASON FOR PROPOSAL	It enables the CC to determine whether an exit is usable in the case of a ditching situation
OVERALL OPINION	• We believe that this device could greatly aid CC in determining whether water is above the cabin floor level • This avoids CC having to open the emergency exit in order to check if the door is usable or not • It is an area to further look into.

INSTRUMENT	WATER LEVEL
DOMAIN	Data Access
DESCRIPTION	This is a tubular-type device which tells the user whether the cabin floor is above or below sea level
REASON FOR PROPOSAL	It enables the CC to determine whether an exit is usable in the case of a ditching situation
OVERALL OPINION	We do not think that this device can be easily installed and maintained

4. PROPOSITION OF SOLUTIONS

4.1. Technological solutions

Among all the proposed technical solutions, discussions with the SFACT experts and operational participants, led to select the 5 following most relevant technological solutions :

- Camera
- CHECK
- Sound
- Headset
- Spyhole

The operational comments on technologies are presented in Annex 2.

A further work was conducted around these techniques to provide a possible operational usage description.

All these solutions are developed in the [D] document.

The Figure 4 shows the link between the various solutions and the tasks to be improved.

4.1.1. CAMERA

The idea is to harden camera fitted for other main purpose as taxiing to become available in case of emergency evacuation.

4.1.1.1. Purpose and reference to tasks

The purpose of such a system is to provide a real time image of the a/c external conditions to FC. This could assist them in evacuation decision making and planning.

Task concerned by Camera	Task objective
Decide on evacuation orientation	To decide and communicate the side of a/c that will be used for evacuation because of the danger location (e.g. fire).

4.1.1.2. Main technical specifications

Components

Video camera

This camera should present real-time capabilities and should be sufficiently strong to be shockproof.

It should enable both daytime and nigh time vision

Display

A display that provides FC the a/c outside conditions filmed by the camera.

Functions

The camera should record a global view of the external conditions at the vicinity of all emergency exits. It should provide a convenient view of the a/c surroundings so that FC could see fire or obstacle that could hinder evacuation through some exits.

Positioning and power supply

Video camera

The camera should be placed in **strategic parts of the a/c** in order to show a global and sufficient plunging view of the external surroundings.

Display

It has been decided to provide only FC with external image.

Power supply

The camera should be linked with the emergency power supply in order to be efficient in evacuation situation.

Cost in relation to the existing equipment

If there is one for the a/c studied, the idea would be to use the existing camera, and modify the present use for an evacuation purpose : for example by changing the orientation, the power supply (emergency), etc. … Additional cost would not be very important.

4.1.1.3. Proposed procedures

The image would be available on a cockpit screen in order to be used during the critical phases of flight and in emergency case.

4.1.1.4. Recommendations on training

The specific training should be oriented on hazard identification and location using the camera under various light conditions.

4.1.1.5. Further studies

Another usage of the camera could be to check if the slides are well positioned on the ground, particularly for VLTAs.

4.1.2. CHECK (Check Exit and Communicate Knowledge)

4.1.2.1. Purpose, description and reference to tasks

Purpose

The purpose of such a system is to provide CC with the contextual status of the usability of all a/c exits. All CC stationed at exits can see which exits are usable and which ones are not. The CC can also see whether an exit is manned or not.

Description

This solution consists of displays situated at each main exit showing the dynamic usability status of the a/c exits. A command enabling a CC to modify the status of his exit if needed during evacuation.

The different elements of CHECK are not autonomous. Because of the information has to be shared all over the cabin, all displays and corresponding commands are linked to each other as an interactive network.

Task concerned by CHECK	Task objective
Guide passenger towards usable exits	To guide passengers as quickly as possible towards the usable exits.
Forbid unusable exits	To prevent passengers from using the unusable exit and to redirect passengers towards usable exit.
Know CC status	For CC (and eventually FC) to be aware of the availability of the CC in order to help at an exit if required.
Manage passengers	To avoid panic and dangerous behaviour during the identification of usable exits.

4.1.2.2. Main technical specifications

Functions

During a normal situation concerning all the phases of the flight, CHECK is only used in mode defused and mode stand-by.

If there is an emergency situation, CHECK has to be changed from mode stand-by to mode active : automatically or manually.

During the evacuation, if the surrounding conditions change, CHECK is able to display the dynamic status of the exits.

Positioning and power supply

Positioning

In order to allow CC to use CHECK without moving from their position near the door, each unit (display and command) should be located close to main exits.

Power supply

All the CHECK components should be powered by the emergency bus.

Cost in relation to the existing equipment

Instrument

Since CHECK is a simple system, the cost of all the units is not really high. In any case, it will also be necessary to take into account the hardwiring cost.

Maintenance

CHECK is not a complex system so the maintenance is not very complicated.

4.1.2.3. Proposed procedures

We do recommend a review of the current procedures concerning the checking of external a/c conditions, declaration of usability of exits, the pax guidance and management during evacuation.In all cases, when the CC has to re-direct passengers to another exit, the priority of re-direction is first to the usable exits.

In an emergency situation, when the evacuation command has been ordered by the pilot and the alarm has been set off, the procedures that CC would follow regarding CHECK operation are :

- If CC decides that his/her **exit** is **USABLE**, the CC :
  - checks that the door is in armed position
  - catches the assist handle and operates the door
  - when the slide is totally inflated, the system automatically shows the “usable” status of this door on the screen. The CC verifies that the “usable” status appears on the screen for his/her door
  - evacuates the passengers coming at this door

- If CC decides that his/her **exit** is **UNUSABLE** :

- The CC blocks the exit
- At once blocking his/her exit:
  - ➤ pushes the control in order to input the “unusable” status to the system;
  - ➤ re-directs passengers to the usable exits.

- If the **exit usability changes** during evacuation, the CC uses the control to input the new exit status to the system**.**

4.1.2.4. Recommendations on training

The training associated to the CHECK solution should be composed of two aspects, a theoretical one, and a practical one.

- **Theoretical aspect** : The training should include a description of the CHECK components and the network notion. The CHECK functioning should also be explained to CC.
- **Practical aspect** : The training should allow CC to use this system

Cost related to training :

The CHECK solution will imply a cost for CC training. The aim of the training would be that they could use dynamic interfaces in emergency situation and under stress.

4.1.2.5. Further studies

CHECK should be tested in evacuation simulated situation with a real wide body or VLTA evacuation simulator in order to study this solution in an operational and dynamic context.

4.1.3. SOUND

4.1.3.1. Purpose, description and reference to tasks

Purpose

The purpose of such a system is to highlight the location of usable exits.

The directional sound emitted attracts passengers to usable exits.

We consider SOUND and CHECK (see §2.2) to be linked together.

Description

This is a directional (multi frequency wide spectrum pulses) sound emitted by loudspeaker installed near the emergency exit doorframe, and in the vicinity of stairs for double deck a/c.

Task concerned by Sound	Task objective
Guide passenger towards usable exits	To guide passengers as quickly as possible towards the usable exits.
Manage passengers	To avoid panic and dangerous behaviour during the identification of usable exits.

4.1.3.2. Main technical specifications

Functions

- **Sound at exits**

At the beginning of evacuation, SOUND is automatically emitted at exits when the emergency alarm is shut off by a CC. This enables passengers to go towards the nearest exit from their allocation seat, from the beginning of evacuation.

Then, from the moment which CHECK is active the exit status is transmitted from CHECK to the SOUND systems :

- if the exit was usable and becomes unusable, sound is no longer emitted from that door
- if the exit was unusable and becomes usable, then the sound is emitted from that door

- **Sound at stairs**

The sound is launched when necessary to indicate for example upper deck passengers to go down to evacuate via the main deck exits.

Power supply

The SOUND system can function with independent power supply or rely on the emergency bus.

Cost in relation to the existing equipment

The SOUND system is easy to install and replace, and requires little maintenance but for the battery if adopted..

4.1.3.3. Proposed procedures

We propose to use SOUND to be automatically linked to CHECK.

Impact on passenger briefing

The introduction of such a system on aircraft implies that the passengers should be briefed about the meaning and function of SOUND emissions at exits and stairs. This system would also increase the briefing attractiveness.

4.1.3.4. Recommendations on training

The theoretical and practical training associated to SOUND is included in the CHECK training.

4.1.3.5. Further studies

In case of smoke-filled cabin, the possible passenger disorientation related to a usable exit becoming unusable during evacuation, needs to be tested to assess the existence and consequence of such a problem.

SOUND coupled with CHECK should be tested in evacuation simulated situation in order to study this solution in an operational dynamic context.

4.1.4. HEADSET

4.1.4.1. Purpose, description and reference to tasks

Purpose

During a/c evacuation, the communication and co-ordination are essential. However, the communication means such as the intercom and PA systems are often difficult to use and sometimes not operational.

The headset solution could greatly help CC, particularly in darkness and smoke conditions, when conventional hands signs cannot be used.

Description

This is a hands-free device enabling crew members to communicate with one another while being able to hear sounds from the cabin, to use the megaphone or to wear a smoke hood.

Task concerned by Headset	Task objective
Understand situation outside a/c	To be aware of situation outside a/c that could cancel evacuation decision or that could hinder or help evacuation.
Know usable exits	To identify the exits that can be used that is to say : - no fire close to the exit - complete opening - slide inflated and correctly positioned
Guide towards usable exits	To guide passengers as quickly as possible towards the usable exits
Co-ordinate between aircraft areas	CC to communicate in order to make the evacuation as smooth as possible using the appropriate exits.
Know CC status	For CC (and eventually FC) to be aware of the availability of the CC in order to help at an exit if required.

4.1.4.2. Main technical specifications

Components

One earpiece, compatible with smoke hood, easily placed in ear is proposed. This earpiece is composed of a microphone and a loudspeaker. The earpiece could be independent or linked to a portable "radio"[1] set.

Everyone in the cabin should receive the information via the Headset.

Functions

Different types of headset could be proposed :

- Full duplex : speak when one wants
- Half duplex : CC pushes a button to talk
- Listen only.

The half duplex proposition seems the most relevant solution but further study should be conducted. Connection with outside world (SAR…) should also be studied.

Positioning and power supply

The different components of the Headset solution should be stored in an accessible place for CC. The system must be capable of operation within 3 seconds from the time microphone is removed from its stowage.

The Headset is powered by the radio battery.

Cost in relation to the existing equipment

Instrument : the Headset earpiece should be provided individually for each CC.

Installation : battery chargers.

Maintenance : regular power supply checks.

4.1.4.3. Proposed procedures

The headset solution should be used by all CC during the landing and take-off phases of flight, and in emergency cases.

Procedures concerning the use of a headset with a smoke hood should be given to CC.

During evacuation, this solution enables CC to exchange information with others crew members concerning the usability status of exits, and the passenger management. To enable CC to communicate effectively, two communication aspects must be particularly studied :

- the speech hierarchical structure : e.g. what are the priority messages? who speaks ? when ? to whom ?…
- like present phraseology used by FC to communicate to Air Traffic Control, an appropriate phraseology for Headset use by CC should be studied. It will enable simple, quick and unambiguous information transmission between crew members during evacuation.

[1] Other transmission means as infrared could be used.

4.1.4.4. Recommendations on training

The training associated to the Headset solution should be composed of two aspects, a theoretical one, and a practical one specially on communication procedures.

Cost related to training

The Headset solution will imply a cost for training because CC should assimilate a lot of new concepts: a specific phraseology, a speech hierarchical structure, and the use of such a solution while attending to their evacuation duties.

4.1.4.5. Further studies

The following aspects must be particularly studied for the Headset solution :

- the hierarchical organisation of CC communications;
- an appropriate phraseology for Headset use by CC;
- important theoretical and practical training;
- communication with outside a/c world.

4.1.5. SPYHOLE

4.1.5.1. Purpose and reference to tasks

This solution will provide CC with an increased range of visibility concerning a/c external conditions and enable him to determine, from within the cabin, the presence of obstacle or fire in the vicinity of his emergency exit.

Task concerned by Spyhole	Task objective
Check external conditions	For each CC managing a door, and eventually for passengers next to an overwing exit , to check that the external conditions allows to use the exit in a safe manner.
Check main exit usability	CC to check that slides are inflating correctly and/or that external conditions are not dangerous (water, obstacles etc…)

4.1.5.2. Main technical specifications

Component

This is a lens through which the range of visibility is increased by forming a 'visibility cone'.

The characteristics of the Spyhole solution are :

- Dimensions : in the region of 10 cm in diameter
- The field of vision would be about:
  - ➤ 180° about longitudinal axis
  - ➤ 180° about vertical axis with respect to the cabin cross sectional plan
- The spyhole should be placed in each exit door, next to the window.

Cost in relation to the existing equipment

Instrument.

Installation : modify today's doors.

Maintenance : same as for windows and windshields.

4.1.5.3. Proposed procedures

Before opening the door, CC can check the external conditions by looking through the spyhole.

4.1.5.4. Recommendations on training

The training should enable CC to become familiar with the vision of outside hazards through the spyhole, as the convex lens can give a distorted external view.

4.2. Non technical solutions

4.2.1. PASSENGER BRIEFING

4.2.1.1. Purpose and reference to tasks

Analysis of accident reports and previous study [A] have shown that the passenger briefing seems to be an important factor influencing passenger's behaviour during evacuation. However, the present briefing needs to be improved. The purpose of the recommendations on procedures and associated training is to enable passengers to be better prepared to evacuation situation.

Task concerned by Spyhole	Task objective
Check external conditions	For each CC managing a door, and eventually for passengers next to an overwing exit , to check that the external conditions allows to use the exit in a safe manner.
Check main exit usability	CC to check that slides are inflating correctly and/or that external conditions are not dangerous (water, obstacles etc…)

4.2.1.2. Recommendations on procedures

- ***Common passenger briefing***

The first stage of the project pointed out that information given to passengers before take off has an influence on the cabin preparation for evacuation. The first aim of such pre-flight briefing is to enable all passenger to have a minimal shared knowledge concerning what they are supposed to do in an emergency case. Feedback from experience put into evidence the weakness of briefing in terms of content and form (they do not sufficiently attract passenger's attention).

Attracting passenger's attention for the briefing

The NTSB study (see [3]) pointed out that in general, passenger pay little attention to oral or written briefing because they are passive participants who are unaware of the importance of the safety information they are given. Many other reasons for passenger's inattention are given in [5].

Some recommendations could be formulated to make the oral briefing more attractive :

1) In order to provide passengers with safety information at the more appropriate time during the flight, the briefing could be split as the following :
   - **before take–off** : the information concerning the seat-belt, the passenger guidance instrument and the main emergency procedures;
   - **when passing the altitude of 10 000 ft** : the oxygen mask demonstration;
   - **on cruise phase :** the 'no smoking' instruction and associated hazards
   - **before crossing water :** the water emergency equipment;
   - **during the descent phase :** the security instruction linked to the emergency procedures

2) Methods should be studied to gain passenger's attention during the briefing, notably the use of assistant tools such as video, animation and interactive games. In [5] several initiatives are described concerning the use of briefing assistant tools.

Recommendations on briefing just before evacuation

The previous recommendations are dealing with passenger briefing made in nominal situations.

In addition to these briefings, the work done in [A]and [B] has shown that in planned evacuation, the cabin preparation includes a safety information reminder. However, presently little guidance is given to CC to perform it. Air carriers should propose detailed procedures concerning the way to prepare the cabin according to different time availability conditions (e.g. item priority, attitude CC should adopt, the content of a "short briefing"…)

- ***Able bodied passenger briefing***

Able bodied passengers are supposed to help CC during evacuation. The work done in the IISU first phase pointed out what should be improved to enable them to react appropriately during emergency occurrence.

1) It seems important to make sure that passengers occupying overwing seats respect the airline criteria.
2) It is important to generalise the providing of an additional briefing for overwing exit passengers. Indeed, the analysis of accident reports has shown some difficulties for pax to open and use overwing exits. Moreover, in an urgent situation and because a lack of knowledge, passengers seemed to have the tendency to leave the aircraft through the overwing exit without having checked the external conditions or having thought about what they are going to do once in they are on the wing.

4.2.1.3. Recommendations on training

The previous recommendations concerning procedures modifications will also have an impact on the CC training in relation to passenger briefing.

Crews should master optimum use of the PA system and video system, noticing and reporting promptly any problems that could compromise safety.

4.2.1.4. Further studies

Further studies should be carried out in order to provide briefings with interactive tools (like video, recorded messages, animations, interactive games…) to increase the passenger's attention capture concerning the safety information.

Another way to make passengers aware of their active role in evacuation situation, and the importance of the safety briefings, should be studied.

4.2.2. STRESS SAFETY ROLE OF CC

4.2.2.1. Purpose and reference to tasks

The work done in the beginning of the IISU project has shown that during a flight, CC must assume both commercial and safety functions. Moreover, training, airline culture, experience, and uniform impact the ability of a CC to switch from her/his commercial to her/his safety role. Presently, passengers seems to have difficulty to perceive this role modification. The solution proposed here will enable CC to emphasise for passengers the moment when they are in their safety duty, whereas being relatively cheap in comparison with the other solutions described in this document.

Task concerned by the passenger briefing	Task objective
Prepare passengers	During cabin preparation, CC to make the passengers having the best behaviour as possible during crash and/or evacuation.
Brief able bodied passengers	CC to explain and show actions that could be done by these passengers to help evacuation.
Open overwing exit	Passengers to open an overwing exit if required during evacuation.
Check overwing exit usability	Passengers to check that external conditions are not dangerous (water, obstacles etc…).

4.2.2.2. Recommendations on procedures

All airlines should provide CC with a distinctive sign in their uniforms (like the orange cap used at British Airways) that they could wear during the briefing and in evacuation cases (and why not during the critical phases of flight). This solution would enable CC to make passengers understand that they will practice their safety role.

More generally, CC should wear a specific uniform in order to be different from the ground staff (playing only a commercial role) and from the passengers.

4.2.3. TRAINING IMPROVEMENT

4.2.3.1. Purpose and reference to tasks

The work done in the first step of the IISU project has shown that the CC training has an influence on the way CC will react and conduct theirs duties during evacuation. The following paragraphs describes the recommendations for improving CC training.

Task concerned by training improvement	Task objective
Decide evacuation	CC and/or FC to decide that occupants must leave the aircraft because of an emergency situation (fire, smoke, bomb threat, ditching, overrun, etc…) that puts lives in danger.
Decide evacuation orientation	CC and/or FC to decide and communicate which side of the aircraft should be used for evacuation because of the location of danger (e.g. fire).
Prepare passengers	During cabin preparation, CC to make the passengers having the best behaviour as possible during crash and/or evacuation.
Know passenger status	CC to be aware of the psychological status of passengers and associated behaviour in order for them to adapt their behaviour.
Order evacuation	CC and /or FC to order immediate evacuation to all occupants.
Open main exit	CC to open an exit after having checked that external conditions are favourable for evacuation.
Manage passengers	CC to avoid panic and dangerous behaviour during the identification of usable exits.
Guide towards usable exit	CC or FC to guide passengers as quickly as possible towards the usable exits.

4.2.3.2. Recommendations

CC training should be more frequent and more realistic.

The second type of recommendations is related to an improvement of training content.

1) The work done in the IISU project has shown that airlines' procedures recommend CC to mentally perform a security checklist before take-off and before landing. It should help to increase efficiency in case of emergency. According to CC having already performed an evacuation, this checklist is important and having or not having done it influences the CC's behaviour in cabin preparation. CC training should therefore insist on the necessity to do it.

2) Concerning the cabin preparation in general, the training should describe various realistic emergency scenarios in order to enable CC to initiate more instinctive actions and be familiar with the ways to prepare a cabin according to different time availability.

3) Training should provide CC with guidance for "impact in water" situations. More generally, it is important to give CC appropriate information concerning the safety equipment, in order to present during the training the same equipment as what is actually used in the aircraft.

4) The training should make CC used to understanding and managing the generic psychological status of passengers.
   Analysis of accident reports and article referenced in [6] raised important issues relating to several factors influencing the passengers' psychological and physiological conditions. These points should be explained to CC thanks to both theoretical and practical training (CRM, test case and simulation). Indeed, the more they are aware of such factors, the more they will be able to react appropriately during evacuation.

5) Accident analysis have shown that recurrent training would be useful, mainly through practice, enabling CC to be prepared specifically for each flight type.

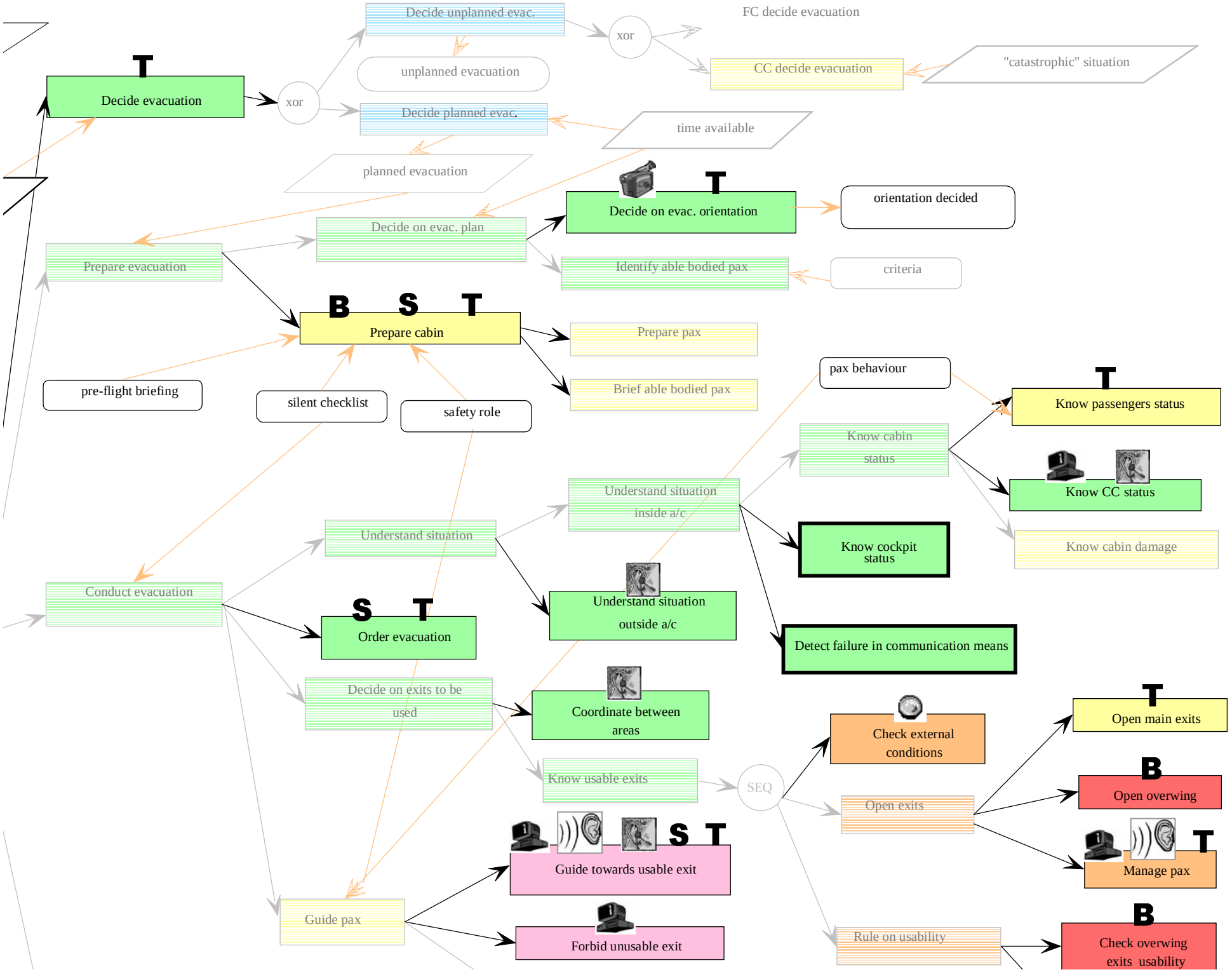
6) Training should inform CC about non accident evacuation practices.

7) As interviews with operationals pointed out problems of communication and responsibility sharing between crewmembers when taking decisions during evacuation situation, joint CRM for both CC and FC would be useful. The following recommendations could be formulated :

   a) Training involving FC and CC together should be efficient in informing all crew members of the decision making process steps and therefore enabling FC to have a realistic knowledge of the situation and to make the evacuation decision at the right time.

      Moreover, such common training would also be helpful in clarifying the role and responsibilities of each and every CC and FC, and consequently could improve the co-operation between crew members for evacuation situations.

   b) Analysis of accident reports and studies (see [1] and [3]) have pointed out a communication problem between team members that is crucial in the evacuation process. It would be interesting to conduct periodic joint evacuation exercises aimed at changing the present mentalities and enabling all crew members to communicate more easily.


Decide unplanned evac.
xor
FC decide evacuation
unplanned evacuation
CC decide evacuation
"catastrophic" situation
T
Decide evacuation
xor
Decide planned evac.
time available
planned evacuation
Decide on evac. orientation
T
orientation decided
Decide on evac. plan
Prepare evacuation
Identify able bodied pax
criteria
B S T
Prepare cabin
Prepare pax
Brief able bodied pax
pre-flight briefing
silent checklist
safety role
pax behaviour
T
Know passengers status
Know cabin status
Know CC status
Know cabin damage
Understand situation inside a/c
Know cockpit status
Understand situation
Conduct evacuation
Understand situation outside a/c
S T
Order evacuation
Detect failure in communication means
Decide on exits to be used
Coordinate between areas
T
Open main exits
Check external conditions
Know usable exits
SEQ
B
Open overwing
Open exits
S T
Guide towards usable exit
T
Manage pax
Guide pax
Forbid unusable exit
Rule on usability
B
Check overwing exits usability

5. RECOMMENDATIONS

General

GR1 : Define clear responsibility allocation (and transfer when requested) between the cockpit crew and the cabin crew for emergency evacuation.

GR2 : Incorporate into the emergency evacuation regulations specific scenario (night, ditching, smoke, door unavailability…)

GR3 : Require fast time simulation evacuation performance checked on scenarios built from real events.

GR4 : Improve the collection, the processing and the availability of the information concerning evacuations (precaution, incidents, accidents).

GR5 : Encourage qualitative and quantitative analysis studies concerning evacuations.

Identification of available exits

IR1 : Require the availability of the existing camera data for emergency exit purpose.

IR2 : Conduct real time evacuation experimentation to validate the CHECK and SOUND systems.

IR3 : Conduct specific organisation and management study on the use of HEADSET in a cabin.

IR4 : Require a broad visual access to the outside of the main emergency exits, at least on day time.

Non technical aspects

NTR 1 : Require improvement in the quality of the emergency information to the passengers.

NTR 2 : Require to conduct the safety briefings close to the potential use.

NTR 3 : Require a safety briefing before landing.

NTR 4 : Require a specific briefing to able bodied passengers before take off and landing.

NTR 5 : Train the CC to pre-evacuation emergency briefings and cabin preparation.

NTR 6 : Identify clearly and physically the CC in their safety role.

NTR 7 : Emphasise the training to safety role of CC.

NTR 8 : Require CC training to passengers behaviour under stress.

NTR 9 : Require CC training to ditching.

NTR 10 : Require CC and FC co-training to evacuation procedures.

6. CONCLUSION

The objectives of this study were to identify and evaluate technologies to improve the evacuation process and to propose regulatory evolutions.

The requirements related with the identification of usable exits, the communication between occupants and the passengers guidance during an evacuation have been determined thanks to :

- the analysis of survivable accidents involving an evacuation
- the elaboration of a task model (tasks performed by a/c occupants during an evacuation).

Through this analysis, several problems in different phases of the evacuation process have been set into relief. After analysing them, it was concluded that improvements could be done in terms of technical tools and changes of crew procedures and training.

The technological research was carried out in parallel with the technical specification. Consequently, five technologies, among the eleven firstly proposed, were selected. They were basically proposed as assistance tools for communication and guidance activities during evacuation. Other non-technical complementary solutions were also proposed. We could not find any reliable and acceptable solution to improve the tasks “Know cockpit status” and “Detect failure in communication means”. However, they are marginal situations often corresponding to partial destruction of the a/c where the survivability is not always established.

Finally, recommendations have been formulated from a regulatory point of view.

Some of the technological solutions will be tested in a life-sized simulator to assess their impact and their effectiveness in a dynamic context.

REFERENCES

1. ADB (Accident Data Base), version 4.3; CAA; 2001.

2. Etude réglementaire sur les évacuations d'urgence; (Study made by Dédale for SFACT) 1999.

3. Safety study : Emergency evacuation of commercial airplanes ; NTSB ; NTSB/SS-00/01

4. Les PNC à l'intérieur de l'équipage comme collectif de travail. CETCOPRA, October 2000

5. Cabin Crew must capture passengers' attention in predeparture safety briefings (Cabin Crew Safety) 2000, Vol.35 No.4.

6. Investigation to focus on Human Factors and emergency evacuation (Air Safety Week) 2001 Vol.15 No.10.

IISU REPORTS *(Sofreavia for the SFACT)*

A. IISU_T1-Requirements analysis_v1.1 ; June 2001

B. IISU_T1-Requirements_ANNEX3_v1.1 ; June 2001

C. IISU_T2-T3 Technical specification_v1.1 ; October 2001

D. IISU_Proposition of solutions_v1.0 ; January 2002

ANNEXES

ANNEX 1 : Results from the analysis of accident reports

Analysis for 77 evacuations	
Evacuation initiated by	CC: 11[2] FC: 33 Passengers: 2[3] ?: 31
Planned/unplanned evacuation	**Planned:** 21 **Unplanned:** 34 ?: 22
	The initial plan had not been followed (plan evolution) : 7
Door problems	**Number of cases where exits were not used for several reasons :** Fire: 17 Impact (deformation, half buried,…): 10 Utilisation (impossible to be opened,…): 10 Slide inflation impaired opening: 10 Outside obstruction: 4 Inside obstruction : 2 Engine still running: 1
	Number of cases where doors were partially used : Slide problems : 14 Fire : 7 Difficult to open (because of slides or other reason) : 3 Difficult to open : 5 Attitude Aircraft : 1 Outside debris : 1

[2] 1 Passenger opened over-wing exit without authorisation from crew

[3] 1 passenger began evacuation as the pilot ordered not to evacuate

Slides which did not work / or difficulty in work	**Causes** : Fire (bursting or deflation) : 5 Inflation problems : 9 Water hindered : 4 Misalignment : 5 Deflation, splitting : 3 Too short : 2 Slide deployed inside cabin : 2 Inclination too steep : 1 Inclination not steep enough : 1 Utilisation (bar,…) : 40 Aircraft position : 5 Untying problem : 1 Raft related problem: 1 ? : 5
Obstacles (water included) that hindered evacuation	Cabin Fire : 22 Smoke in the cabin : 20 Obstacle in the cabin (shoes, luggage, CC trolleys, seats, debris, dividers,…) : 16 Fuselage damage : 12 Passengers : 2 Obscurity : 5 Passengers picking up their carry-on luggage : 3 Outside obstacles : 2 Passengers piled up at the bottom of the slide : 2 Water : 5 Heat : 1

Problem in communication	**Communication means failure** : PA usable but not used : 1 PA not usable : 8 Megaphone not usable (wet) : 1 CC/FC was not aware that her PA announcement was not audible throughout the aircraft : 2 Lack of sufficient megaphones : 2 Evacuation signal not operating : 1
	Audibility and understanding of problem : Broken fuselage : 2 Noise : 8 Examples : 1 Pilot thought that the evacuation order was heard in the cabin : PA was not functioning. 1 CC had not heard the plan 1 CC shouted not to use the over-wing exits : was not heard 1 CC was attempting to calm passengers while another used PA to order evacuation (not heard)
Signals and guidance	Emergency light not operating : 3 Emergency light ok but insufficient illumination: CC used a flash light : 1
"Human errors" in using the means	Emergency lighting has been turned off : 1 Problem with megaphone volume button : 1 Accidental disarming of door : 2 Passenger(s) not opening door enough to cause slide inflation : 1 Conscious change in procedure of disarming door before opening in order to check external conditions : 1 1 CC inadvertently pulled the release handle when she attempted to use the manual inflation handle (both handles are quite similar)
Briefing	Yes : 17 No/ ?: 60 *(despite the lack of information in the reports and according to the nature of these evacuations it seems that no briefing had been made for 60 events)*
Guided by whom ?	CC : 26 CC + Passengers : 10 FC : 2 CC + FC : 6 FC + Passengers : 1 FC + CC + Passengers : 2 (these passengers were off-duty crew members) ? : 30

Active behaviour of passengers (aiding evacuation)	Passengers had memorised the number of rows between their seat and the exit : 1 Passengers said "sit down, stay calm" : 1 Help CC to open the door, make the passengers wait for slide to inflate, help to inflate slide : 2 Passengers helping each other (to reach exit, to leave aircraft, to release seat belt) : 11 Open over-wing exits : 12
Active or passive behaviour of passengers (hindering evacuation)	**Lack of respect of the crew instructions :** Passengers taking personal items : 6 Unbuckling seatbelt before aircraft stops : 2 Passengers went over seat backs to avoid congested aisles : 2 Passengers evacuated without any order : 2 Passengers evacuating through another exit to those recommended by the CC : 2 Passengers evacuated through the fuselage : 1 **Over-wing exits :** Problem in opening over-wing exit (one passenger trapped in her seat by the door) : 1 Unable to open an over-wing exit due to fear : 1 **Panic behaviour** : CC being jostled by passengers while opening doors (because all occupants have been informed of evacuation at the same time) : 1 Bottleneck next to an opened exit : 1 Altercation between passengers at an opened exit : 1 Passengers did not remain at the bottom of the slide to help other passengers : 2 Some confusion when passengers have to change their route because the exit became unusable (after having been used) : 1 **Resistive behaviour** : Difficulty in making passengers react quickly enough (not aware of fire) : 1 Passengers who were unwilling to jump down slides : 1 **Specific ditching** - Because of short time available and the crush of people struggling towards an exit, most people didn't have enough time or were unable to find their life jacket, or did not succeed in inflating them : 1 - Passengers mistakenly believed that seat cushions were buoyant and threw them in the water : 1
Other	1 (loss of time because of airline company procedures and mentality which gave the FC reason not to believe the CC) 1 FC had not used all the information available to him/her in order to estimate the danger

Annex 2: Operational comments on technological solutions

Here are some comments (extracted from meetings minutes and questionnaire) formulated by operational participating in the study on the selected instruments.

CAMERA

The main objective of such an instrument is to identify fires and obstacles situated around the a/c in the vicinity of exits.

If used for evacuation purposes :

- the camera should be operative and could be used on demand during critical phases of the flight: taxiing, take-off, and landing.
- the image should only be viewable from the cockpit. Although the image provided by the camera seems to be useful for CC , in order to help them to assess the external conditions, it seems too unrealistic to set up this system for each door all the more SCCM are also responsible for a door during the evacuation. Thus, the image will be available only for FC, like today for taxiing camera on A340-500/600, which may help them to decide on the evacuation orientation (in planned evacuation cases).
- Another objective of this camera could be to check if the slides are well positioned on the ground, particularly for the A380.

CHECK

Regarding CHECK, comments have been made on the following points :

- Coding: 3 different coding are proposed corresponding to the three following different status: “usable exit”, “unusable exit”, “no information” (for the case where no CC is available at the exit). A 4^{th} element corresponding to the “passenger evacuation fluidity” at a precise exit have been suggested during the study. After consideration, it seems that adding a new code will probably make the system too complex and its utilisation less reactive.

- Reliability: Operational set into relief the issue of the reliability of such a system. Indeed, it seems very important to provide CC with malfunctioning indicators in order to prevent all catastrophic situations. One idea proposed by one CC was to cancel the CHECK system at one exit by touching the screen. But, this suggestion seems to present a potential risk because the screen could be touch unintentionally by passengers during the evacuation.

- Positioning: In order to allow CC to use CHECK without moving from their position near the exit, the screen should be located at eye level. However, this implementation will probably depend on the a/c type and configuration.

- Moreover, a lever instead of a push button, seems to be the better type of command for CHECK, very easy to use without ambiguity.

- According to the operational participants, the CHECK system will undoubtedly permit to save time during the evacuation process, particularly during comfort evacuations, allowing a better co-ordination between a/c areas. Regarding unplanned evacuations, this system may be relevant when coupled with SOUND.

- According to CC answers to a questionnaire, a good use of CHECK, in all scenarios, can only be achieved through a technical training (H-M interface), and practice (manipulation) within the framework of realistic simulations (integrating other aspects as the situation comprehension, the time management under stress, etc…).

SOUND

A CC has tested the Sound Alert product under thick smoke conditions in a building. She was pleasantly surprised and convinced by the product and thinks this would really help passengers to be guided towards the right usable exits.

She gave us some characteristics of the Sound system:

- The sound rhythm is different depending on where passengers are located in the aircraft: the further people are from the nearest usable exit, the lower the rhythm is. On the contrary, when people come closer to the exit, the rhythm becomes faster.
- To distinct the presence of stairs, another type of sound is produced. The sound goes from low to high frequencies to indicate to go upstairs. On the contrary, the sound goes from high to low frequencies to indicate to go downstairs.
- The Sound system can function with an independent power supply, and requires little maintenance

HEADSET

During a/c evacuation, all the CC in the cabin are positioned close to exits. During this critical situation, the communication and co-ordination are essential but the experience shows that the communication means such as the intercom and PA systems are often difficult to use and sometimes not operational.

The headset would help CC to receive and give information and enable them at the same time to :

- Have their hands free;
- Hear the sound from the cabin;
- Use megaphone;
- Communicate with a smoke hood;

According to project operational participants, everyone in the cabin should receive the same information via the headset. This information should be as simple as possible, in order to be understood very quickly by everyone. There are different types of headset :

- Full duplex: speak when one wants;
- Half duplex: push a button to talk;
- Listen only.

The half duplex proposition seems the most relevant solution with a control button to speak in order to avoid chaotic situation.