06.03.01 Validation Report Appendix A: HP Report

Document information	
Project title	The Airport in the ATM environment
Project N°	06.03.01.
Project Manager	EUROCONTROL
Deliverable	06.03.01 Validation Report Appendix A: HP Report
Deliverable ID	D149-001
Edition	00.00.03
Task contributors	
ALENIA, AIRBUS, ENAV.	

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Abstract

This document describes the result of the activities conducted to date according to the Human Performance assessment process to derive the Human Performance Assessment Report for the P06.03.01 VP719. It presents the HP Assessment Plan, the evidence gathered through the HP activities conducted according to the HP assessment process, and the resulting recommendations and requirements.

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Document History

Edition	Date	Status	Author	Justification
00.00.01	15/07/2016	Draft	██████████	New Document

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Executive summary

The Human Performance (HP) Assessment Process is the HP approach being adopted in SESAR to ensure HP issues are identified and addressed at the primary project level (See SESAR HP Reference material Ref. [1]).

The overall aim of this HP assessment is to evaluate the impact of introducing, within TMA in M/M (Medium density and medium complexity) environment, the following SESAR solutions:

- SESAR Solution #22 - Automated Assistance to Controller for Surface Movement Planning and Routing;
- SESAR Solution #02- Airport Safety Nets for controllers: conformance monitoring alerts and detection of conflicting ATC clearances;
- SESAR Solution #23 - D-TAXI service for CPDLC application;
- SESAR Solution #26 – Manual Taxi Routing;
- SESAR Solution #48 - Virtual Block Control in LVPs.

The assessment has been performed by involving both pilots and controllers in order to investigate about the air/ground interactions related the innovative studied operational concepts and procedures. Thus, these concepts must adhere to two fundamental HP principles, that is:

- The role of the human actors in the system is consistent with human capabilities and characteristics;
- The contribution of the human within the system supports the expected system performance and behaviour.

This document describes the result of the activities conducted according to the HP Assessment Process to derive the Human Performance Report for P06.03.01 and specifically the EXE-06.03.01-VP-719.

The simulation related to EXE-06.03.01-VP-719, led by ENAV (in cooperation with AIRBUS and ALENIA), is based on the Milano Malpensa TMA operational environment.

The scope of this document is the description of the HP assessment activities needed to investigate the deployment of those concepts.

The main addressed HP arguments were:

- **Arg.1:** The role of the human is consistent with human capabilities and limitations,
- **Arg.2:** Technical system support the human actors in performing their tasks,
- **Arg.3:** Team structures and team communication support the human actors in performing their tasks.
- **Arg.4:** Transition Factors.

The main preventive measures or mitigation initiatives identified to address potential issues and their associated impacts were:

- Intuitive and user friendly HMIs (this includes information displays, support tools and control input /output devices for both CWP),
- Clear, definitive and usable procedures,
- Clear and appropriate allocation of tasks and responsibilities.

As a result of the potential impacts on HP identified and the proposed preventive measures and/or initiatives, it is concluded that the main HP objectives at this stage of the project given the level of maturity the new operational concepts under evaluation are:

- To support the design and development of the HMI,
- To support the development of procedures for both nominal and non-nominal situations /

events, including procedures involving both air and ground actors

- To ensure task allocation and responsibilities are clear and appropriate between ATCOs and pilots.

In accordance with the HP Assessment Guidance process, and through consideration of project documentation, the following main HP objectives can be summarised:

- Demonstrating the usability of Virtual Block Control in LVPs, D-TAXI and Manual Taxi Routing function on board in an environment with high level of traffic load.

- Addressing potential reductions in ATCO situation awareness (especially in higher workload and with mixed communication modes).

- Ensuring that procedures are robust and cover degraded modes and transitions between R/T and data-link.

- Addressing any HMI usability issues, in particular those related to the integration of D-TAXI and Virtual Block Control in LVPs with other associated services and tools.

To assess the new operational concepts under evaluation on human performance in terms of the following activities have been executed:

- Activity 1: RTS-HP assessment,
- Activity 2: Situation awareness Assessment,
- Activity 3: Workload Assessment,
- Activity 4: Utility and Usability Assessment.

The above activities have been executed by applying the following data collection methods:

- Debriefings,
- Over the shoulder observations,
- Questionnaires.

1 Introduction

1.1 Purpose of the document

The purpose of this document is twofold:

- To describe the result of the activities conducted to date according to the Human Performance (HP) assessment process as described in the HP Reference material Ref.[1]. and following the guidance provided in Ref. [2], in order to derive the HP Assessment Report for EXE06.03.01-VP-719.

- To present the resulting report of the recommended HP activities given the level of maturity of the concept at this stage of the project V3 required addressing the specific HP issues and impacts identified from the application of the HP assessment process.

1.2 Intended readership

The intended audience for this document are the other team members of the project 06.03.01 under investigation, those of the 09.13 for the cockpit side, those of 06.07.02 and 06.07.03 for the ground side and those in the corresponding 12.03.03, P12.03.04, P12.04.04, 12.05.03 and 12.05.04 technical projects.

At the level of the transversal areas and federating projects, WP16.06.05 and 06.02 are also expected to have an interest in this document.

Other stakeholders that may be interested in this document are to be found among:

- Affected employee unions;

- ANS providers;

- Airport owners / providers;

- Airspace users.

1.3 Scope of the document

This document describes the result of the activities conducted to date according to the Human Performance assessment process to derive the Human Performance Report for P06.03.01.

1.4 Human performance work schedule within the project

The Human Performance activities for the 06.03.01 project started in 2010 and are expected to finish in 2016.

Within the context of P06.07.02, four Step 1-V1 validation exercises were conducted between November 2010 and April 2011 (i.e. a HMI usability test, a route generation verification test, a Real-Time Simulation, and a Fast-Time Simulation, all of them utilising the Roissy Charles-de-Gaulle runways and surface area).

A Step 1-V2 validation activity within the 06.07.02 context (but including elements from 06.07.03 projects) was conducted during March-April 2012. This comprised a fast-time simulation (EXE-06.07.02-VP-588) and a real-time simulation integrated air-ground exercise utilising the Roissy CDG North runways and surface area (EXE-06.07.02-VP-071).

Three Step 1-V3 exercises were undertaken during November 2012 in the context of 6.3.2 project

- EXE-VP-064 conducted by DSNA in Charles-de-Gaulle with CDG Airport operational scenarios,

- EXE-VP-065 conducted by ENAV in Malpensa Milan with Milan Malpensa Airport operational scenarios, and

- EXE-VP-401 conducted by AENA in Madrid with Madrid Barajas Airport operational scenarios.

The real-time simulations were performed with a contribution from HP Specialists during the planning and execution phases.

Forthcoming validation exercises are: VP-073, VP-665 (integrated air/ground exercise), and VP-674 [5]. These exercises performed within a P06.07.02 context (involving P09.13 and P06.07.03) also consider associated concept elements such as Conformance Monitoring Alerts (CMAC).

Exercise VP-614 by AENA (Step 1-V3) is also presently in the definition phase, and had elements in relation to the Routing & Planning functions / P06.07.02, also considering associated concept elements such as Airport Safety Nets.

Previous HP technical research on A-SMCGS routing and guidance was conducted in the FP6 European Commission EMMA and EMMA2 projects. These projects, and the associated Human Factors literature, have been taken into account in the production of this plan.

This first iteration the HP Report has been produced during the Step2-V2 phase of the project.

1.5 Structure of the document

The document includes:

- Section 1 presents the purpose of the document, the intended audience and the terminology used within the document;
- Section 2 presents the assessment process;
- Section 3 provides information about the concept and its implication in terms of Human Performance;
- Section 4 is intended to include all relevant reference material.

1.6 Acronyms and Terminology

Term	Definition
Human Factors (HF)	*HF is used to denote aspects that influence a human's capability to accomplish tasks and meet job requirements. These can be external to the human (e.g. light & noise conditions at the work place) or internal (e.g. fatigue). In this way, "Human Factors" can be considered as focussing on the variables that determine Human Performance.*
Human Performance (HP)	*HP is used to denote the human capability to successfully accomplish tasks and meet job requirements. In this way, "Human Performance" can be considered as focussing on the observable result of human activity in a work context. Human Performance is a function of Human Factors (see above). It also depends on aspects related to Recruitment, Training, Competence, and Staffing (RTCS) as well as Social Factors and Change Management.*
HP activities	*HP activities are evidence-gathering activities that are carried out as part of Step 4 (Arguments & Evidence) of the HP assessment process. They can comprise, among others, activities such as task analyses, cognitive walkthroughs, and experimental studies.*

Term	Definition
HP assessment	An HP assessment is the documented result of applying the HP assessment process to the SESAR project-level (i.e. WP4-15 projects). HP assessments provide the input for the HP case.
HP assessment process	The HP assessment process is the process by which HP aspects related to the proposed changes in SESAR are identified and addressed. It covers the conduct of HP assessments on the project-level as well as the HP case building over larger clusters of projects. Further development of this process constitutes the scope of Project 16.04.01.
HP benefit	An HP benefit relates to those aspects of the proposed ATM concept that are likely to have a positive impact on human performance.
HP Case	An HP case is the documented result of combining HP assessments from projects into larger clusters (e.g. Operational Focus Areas, deployment packages) in SESAR.
HP issue	An HP issue relates to those aspects in the ATM concept that need to be resolved before the proposed change can deliver the intended positive effects on Human Performance.
HP impact	An HP impact relates to the effect of the proposed solution on the human operator. Impacts can be positive (i.e. leading to an increase in Human Performance) or negative (leading to a decrease in Human Performance).
HP recommendations	HP recommendations propose means for mitigating HP issues related to a specific operational or technical change. HF recommendations are proposals that require additional analysis (i.e. refinement and validation). Once this additional analysis is performed, HF recommendations may be transformed into HF requirements.
HP requirements	HP requirements are statements that specify required characteristics of a solution from an HF point of view. HP requirements should be integrated into the DOD, OSED, SPR, or specifications. HF requirements can be seen as the stable result of the HF contribution to the project, leading to a redefinition of the operational concept or the specification of the technical solution.

2 The Human Performance Assessment Process

The purpose of the HP assessment process is to ensure that HP aspects related to SESAR technical and operational developments are systematically identified and managed.

Figure 1 provides an overview of the HP assessment process steps and the two main HP outputs: the HP Assessment Plan and the HP Assessment Report (current document), feeding respectively into the Validation Plan and the Validation Report.

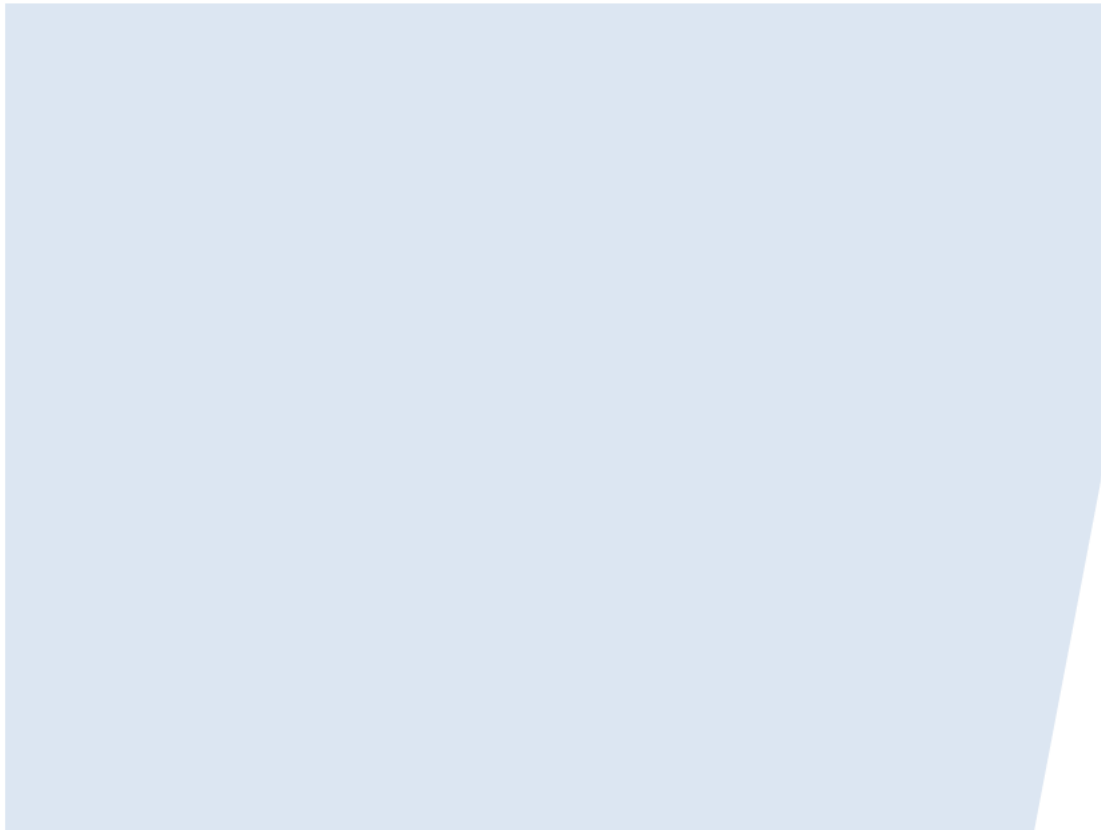For detailed description of the process, refer to Ref. [1] and Ref. [2].

Figure 1: Steps of the HP assessment process

3 Human Performance Assessment

The information presented in this section is based on the content of the filled-in templates provided in Ref. [2]. This section is organized in accordance to the 5 steps of the Generic TA process:

- TA Step 1: Baseline & Assumptions
- TA Step 2: Screening& Scoping
- TA Step 3: Impact & Issue Analyses
- TA Step 4: Arguments & Evidence
- TA Step 5: Decision Making

3.1 Description of Baseline and Assumptions - HP specifics

3.1.1 Description of the baseline/reference scenario

Based on P16.06.05 guidelines recommending to run at least two different scenarios:

- Reference scenario without the so called SESAR Solution.
- Solution scenario with the proposed SESAR Solution.

Two reference scenarios with the following characteristics could be envisaged as well in order to respectively make a comparison with the solution scenarios:

- Reference scenario 1 where the controllers establish aircraft sequences on the basis of the current procedures without the support of airport sequencing tools. The communication between controllers and pilots has been only handled via R/T;
- Reference scenario 2 where Low Visibility Procedures are in place. Therefore, the controllers applied control block based on the today procedures. Some unusual events referred to both non-conformance to ATC procedures / instructions (including runway incursions) and conflicting ATC clearances as following:
  - **Non-conformance to ATC procedures / Instructions:**
    - Taxi route deviation;
    - Push-back, taxi, line-up without clearance
    - Landing & Take-off without clearance
    - Exceeded speed limit on taxiways
    - Approach without any contact
    - Stationary after push-back, taxi, line-up and take-off clearance
  - **Conflicting ATC Clearances:**
    - Line-up vs. take-off on same or opposite runway
    - Line-up vs. land on same or opposite runway
    - Line-up vs. line-up on same or opposite runway

The definition of validation scenarios also included the execution of a flight trial involving AIRBUS. The scenarios have been built to validate:

- Manual taxi routing on on-board side
- D-TAXI service on both ground and on-board side.

3.1.2 Description of the solution scenario

In addition, in the preparation of the validation scenarios there is need to take care that, in the integrated validation context, the investigation of a specific functionality doesn't negatively impact the assessment of the other ones. To this end, the plan was to run two solution scenarios integrating respectively:

- Solution scenario 1 (D-TAXI + DMAN/SMAN) – D-TAXI service and Manual taxi routing integrated with Departure and Surface Management. The controllers have been supported by the provision of an accurate (pre-)departure sequence resulting from a full integration between departure and surface management. The accuracy of (pre-)departure sequence has been compared with the one established in the reference scenario. Communications between pilots and controllers have been established through data link service as well.
- Solution scenario 2 (Airport Safety Nets + VSBs) – Airport Safety Nets integrated with the alerting functionalities related to the use of Virtual Stop Bars when Low Visibility Procedures are in place.

Please refer to the 06.03.01 Validation Report chapter 6.1.3.2 [07] for a detailed description of the scenarios addressed during the validations.

3.1.3 Consolidated list of assumptions

The following assumptions (and attendant risks) are consolidated after producing the HP activities:

- Data-link (D-TAXI) shall not be used for runway operations or crossing.
- Data-link (D-TAXI) shall not be used for apron management except for transfer of frequency.
- Transfer of aircraft from the Runway Controller to the Ground Controller (and vice versa) shall be via voice.
- Data-link should not be used for 'Follow' or 'Give Way' situations.
- It is always possible to revert to R/T should data-link messaging prove impractical or problematic.
- First contact with aircraft should always be via voice for radio check.
- A-SMGCS surveillance data provides the position of aircraft taxiing, and of vehicles present on the manoeuvring area.
- The Surveillance System data provides the position of aircraft in flight.
- FDP/EFS provides information on assigned runway and holding point for each aircraft and vehicle.
- Ground vehicles are transponder equipped.
- The Tower ATCOs input the clearances given to aircraft and vehicles into the ATC system.

3.1.4 Related WP 4-15 projects to be considered in the HP assessment

N/A

3.2 Screening and Scoping the Impact of the Change

This section describes the main HP-related impacts of the changes resulting from the proposed concept in terms of who would be impacted and how, and identifies the impacted HP work areas on which to focus the HP assessments.

Table 1: Description of the change

HP WORK AREA/SUB-AREA	CHANGE & AFFECTED ACTORS
PROCEDURES , ROLES & RESPONSIBILITIES	
ROLES & RESPONSIBILITIES	Roles and responsibilities of the concerned actors (ATCO, flight crew, and vehicle driver) with regards to providing Air Traffic Services will not change.
PROCEDURES	Fundamentally the project involves a change in operating method. ATCO: the change in ATCO operating method concerns: • The transition from R/T to data-link for certain instructions and clearances for the Ground controller. • Movement management on the apron and taxiways with the support of the routing function. • System input with route update for the Ground controller and the Apron manager. Flight crew: flight crew will have to verify the route information sent to the aircraft and to acknowledge or request rerouting if necessary. Vehicle driver: depending on the local procedures, in situations such as runway crossing, vehicle drivers will have to request their taxi route and perform the same actions as the flight crews. The development and adaptation of procedures to support D-TAXI operations in all operating situations is a key aspect of the project. In particular, development of procedures to cover the transition between R/T and data link communications will be a notable change from current practices. It should also be noted that procedures (or working methods) associated with the integration between D-TAXI and other associated concepts (e.g. conflicting clearance alerts, conformance monitoring) will be required. Therefore, it can be concluded that changes to procedures and working methods would be a notable area of the project, and one requiring HP assessment contribution.

TASKS	Regarding D-TAXI, the current tasks will occur over a different communication medium in some cases (data-link rather than R/T).
	Regarding the routing function, new tasks will be introduced:
	- The CLD controller may have to manually modify the planned route if required by any operational changes (and if there are no automatic adjustments, or not as expected). - The GND controller will have to take into account the planned route before sending taxi clearances to the flight crews. He/she will either accept it as it is, or manually modify it if needed. - Flight crew will have to take into account the route information to prepare the landing and departure, which implies a new communication task on-board in these phases: request, verify the information and acknowledge or request a rerouting if necessary.
	This added task of route management is expected to increase the workload.
	There might also be an impact on ATCO situational awareness due to the time spent head-down either to inform the system, or to detect and read data-link messages (although both shared and individual situation awareness might benefit from the availability of the routing information).
	Therefore, it can be concluded that changes to tasks would require HP assessment contribution regarding procedures, workload and situation awareness.
	Virtual Block Control in LVPs could provoke slight tuning in conventional ATCOs working methods with potential consequence on workload and situational awareness.

HUMAN & SYSTEM	
ALLOCATION OF TASKS	The routing and planning function 'automates' the current existing task of route allocation. The Apron Manager and the Ground controller will build the aircraft route by automation support provided by the routing function. Route management constitutes a change in the allocation of tasks and would require HP assessment contribution.

PERFORMANCE OF TECHNICAL SYSTEM	Regarding D-TAXI, the data-link infrastructure is a new/changed technical system. D-TAXI is strongly associated with the A-SMGCS HMI and the route generation system.
	Regarding the routing function:
	• The DMAN (used by Clearance Delivery controller) will use more accurate estimated taxi-out time to build the departure sequence.
	• The A-CDM will use more accurate taxi time to give precise estimates of in block or take off times the controllers.
	• The surveillance function for conformance monitoring will use the route generated whilst taxiing to alert the controllers in case of route deviations.
	• The Airfield Ground Lighting systems will use the route generated to guide the flight crews on the airport platform.
	It is expected that the performance of these system will have an influence on the ATCO behaviour.

HUMAN – MACHINE INTERFACE	Regarding the routing function, today, the ATCO does not provide any planned route, flight crews anticipate what the expected taxi route will be according to their experience and the available information. Departure and arrival planned routes will be calculated by the system and provided on-board.
	The HMI will display the planned taxi route, and the cleared and un-cleared portions of any pending routes.
	The ATCO will have the possibility to modify the routes. System update is a critical issue related to alert functions (e.g. conformance monitoring). There should be no discrepancy between the voice or data link instruction and the route displayed on the HMI.
	The HMI should facilitate route management, especially manual edition, which proved to be time and effort consuming in previous validation exercises.
	Regarding D-TAXI, the ATCO will be provided with a data-link HMI to be informed on incoming data-link messages and on their status, and to enter and transmit messages on-board. The follow-up of data-link messages is demanding in terms of mental workload, as several messages could be opened in parallel. A message history window is useful and necessary to present the dialogues and indicate their status.
	The HMI should support the controllers by making the distinction between equipped and non-equipped aircraft very clear in order to avoid confusion, by clearly indicating the status of a message and by differentiating the aircraft that controllers have on frequency from those they have no more or not yet.
	From a HMI perspective, it should also be noted that there are very strong interactions between the routing and D-TAXI screen components and the HMI introduced by other tools, should they also be installed at the same airport working position. Potentially, should all of the airport tools be utilised, the Ground controller will move between route, D-TAXI, EFS, conformance monitoring, and wake vortex timers HMI elements. These elements should be addressed via HP assessment.
	The integration between associated tools, and how this may affect human performance, should also be considered. These aspects are addressed by 6.7.2, 6.7.3 and 6.9.2 projects.
	In the cockpit the planned and cleared route will be presented on the on-board display in a textual and, if the aircraft is fitted, in a graphical way, with the corresponding estimated taxi time which will be sent at the same time. It should will enhance pilots' situation awareness and support their routing preparation. At any rate, the necessary crosschecks between the taxi route display and the message to ensure the graphic reliability might have an impact on the flight crew task performance (this aspect requires HP assessment contribution and will be addressed through Activity 2).
	In a voice environment, pilots will have the possibility to enter manually a route into the aircraft systems in order to generate a graphical display of the taxi path. New HMI from route insertion may increase workload and should be easy-to-use for this reason, but the graphical display

TEAMS & COMMUNICATION	
TEAM COMPOSITION	No changes in the composition of teams are foreseen.
ALLOCATION OF TASKS	No changes to the allocation of tasks between ATCOs are foreseen. No change in the task allocation between the flight crew members is foreseen.

COMMUNICATION	The medium of communication is changed, compared with the baseline situation. Some pilot-ATCO dialogues will take place via data link, in accordance with the D-TAXI concept.
	
	It should be noted that data link communications does alter the perceptual and cognitive aspects of the communication for all associated actors. This alteration of the existing tasks may occur in a number of different ways:
	
	• Reduction overall in both shared and individual situation awareness due to loss of 'party line' effect inherent with R/T.
	• Reduction in 'redundant' information coding via voice tone, speed, timing, etc.
	• Asynchronous communication:
	   ○ It can lead to breakdown in communication flow, which can increase workload (i.e. communications are not sequential; a new communication with one aircraft can be initiated although the previous communication with another aircraft is still opened). Re-sending messages to an actor who is too busy to respond would only increase their workload, or potentially affect the working sequence.
	   ○ It may also lead to misunderstandings and potential errors when considering the transmission time: if a communication is performed in mixed-mode, a D/L message may arrive on-board after an update by voice. The question of which communication is the valid one will arise.
	
	• Data link communications require system update, which can lead to an increase of visual monitoring and manual inputs.
	
	These potential issues are recognised by the project and have been accounted for the D-TAXI procedures (different procedures will be proposed and their efficiency assessed).
	
	The transmission delay should also be considered in the definition of procedures allowing dealing with situations in which messages are received too late.
	
	D-TAXI messages have been identified by RTCA Special Committee 214/EUROCAE Working Group 78 for the communication of the planned route by data link. Changes to these existing data-link messages and new messages have been proposed by previous validation activities and are currently under consideration by the standardisation bodies.
	
	The current set of data-link messages should sufficiently cover the operational needs to effectively manage the traffic.
	
	Data-link will be used between ATC ground, on-board and vehicle systems to transmit information related to the planned and cleared route. However, R/T communications will remain for establishing a first contact and in some cases such as: data link failure, runway clearances, time-critical communication or for safety reasons.
	
	A possible impact on regulation and standard was identified in previous exercise (EXE_064). The first

WORKING ENVIRONMENT	
WORKPLACE LAYOUT	No change has been foreseen.
PHYSICAL ENVIRONMENT	No change has been foreseen.
ORGANISATION & STAFFING	
COMPETENCE REQUIREMENTS	The concepts and procedures under evaluation may require supplementary training to reach needed competences in managing them.
STAFFING REQUIREMENTS & STAFFING LEVELS	The concepts and procedures under evaluation may require supplementary training to reach needed competences in managing them.
REGULATORY REQUIREMENTS	No change has been foreseen.
TRAINING & DEVELOPMENT	
TRAINING REQUIREMENTS	The concepts and procedures under evaluation may require supplementary training to reach needed competences in managing them.
TRAINING DESIGN	No change has been foreseen.
HP RELATED TRANSITION FACTORS	
ACCEPTANCE & JOB SATISFACTION	Route management and D-TAXI impose a constraint in a high traffic load environment. There is a risk regarding ATCO acceptability and job satisfaction if the workload and situation awareness issues are not addressed.
	Flight crew and vehicle driver should have a better situational awareness and there should be a positive impact on their workload by providing them their location and the planned taxi route (if equipped with a moving map) thus increasing their comfort.
	The Routing & Planning functions should help reduce misunderstandings by providing the flight crew or vehicle driver with a textual, and possibly graphical, translation of the information.
COMPETENCE REQUIREMENTS	No changes impacts on competence requirements are currently foreseen.
	Training on the tools HMI, operating methods and abnormal/degraded modes is likely to be required.
STAFFING REQUIREMENTS & STAFFING LEVELS	No changes to staffing requirements & staffing levels are currently foreseen.

3.3 Summary of main HP Impacts - HP Assessment Objectives - HP Activities and Outcomes

This section presents:

- A list of potential HP issues and their associated impacts that may result from the introduction

of concepts addressed by P06.03.01, in all the HP work areas that are identified as impacted in the previous section. The HP assessment objectives identified as a result of the issue analysis are included in the validation objectives presented in the core validation plan.

- The description and planning of a set of proposed HP activities required to address the HP objectives, to be conducted in the next step of the HP assessment process.

3.3.1 Issues and impacts and HP assessment objectives

The following table represents the HP Log and gives an overview of the arguments, issues, objectives and recommendations all along the project existence and concept evolution. It also gathers the information extracted for table 2.

HP_LOG_D-TAXI_EX
E719_Validation_Outc

Hereafter it is provided a brief description of the method used to identify and prioritise the potential issues under study on the EXE 719.

Table 2 below presents a consolidated view of the content of Tables 7 and 8 from Ref. [2].

Table 2: For each impacted HP work area: potential HP issues and impacts, HP assessment objectives and proposed HP activities

Argument 1.2 - Operating methods are exhaustive and support human performance				
ISSUE ID	HP ISSUE & IMPACTS	OBJ. ID	HP ASSESSMENT OBJECTIVES	HP ACTIVITY/IES
VP719_HPAP-2015_ISS-001	Poorly defined operating methods and procedures of datalink and voice use between air and ground may lead to confusion regarding the way to communicate between operators, notably in mixed-mode environment which may increase the communication load and prevent operators to perform their tasks in an effective manner.

There is no intrinsic guidance within the D-TAXI HMI operational concept on when and how the ATCO or flight crew should revert to voice following a communication issue (e.g. no reply to a data link message). If procedures / working practices are unclear on how the transition between voice and data link communications is managed, this could impact ATCO workload and efficiency. | OBJ-06.03.01-VALP-0719.5020 | [Air/Ground] Assess usability of procedures on data link communication management (including mixed DL-R/T, logon, CPDLC) | Real Time Simulation Usability and Utility Assessment Acceptability Assessment Trust and Confidence Assessment |

Issue ID	HP Issue & Impacts	Obj. ID	HP Assessment Objectives	HP Activity/ies
VP719_HPAP-2015_ISS-010	Too short messages timers may impact negatively pilots and controllers communication performance by leading to multiplication of messages exchanges by voice and datalink. Working methods and behaviours associated with timer expiry have the potential to increase ATCO workload if it is unclear as to how actors should respond when a timer associated with a message has expired. For example flight crew could re-send expired messages that may increase workload for the ATCO at a busy time. If a timer expires, a vehicle driver / pilot may just re-send the request. If the ATCO has been unable to respond due to high workload or a more important issue, this extra message will potentially add to ATCO workload in an already high-demand situation.	OBJ-06.03.01-VALP-0719.5030	[Air/Ground] Validate that the timers associated with the exchange of D-TAXI messages are useable in an operational environment	Real Time Simulation Usability and Utility Assessment Situational awareness Assessment Cognitive workload Assessment

Argument 1.3 - Human actors can achieve their tasks

Issue ID	HP Issue & Impacts	Obj. ID	HP Assessment Objectives	HP Activity/ies
D-TAXI HPAP 2013 BEN-001	The taxi clearance display on the airport moving map should support pilots to perform taxi so efficiently that the navigation on ground should maintain their workload at a reasonable level by supporting them to represent mentally and follow the taxi path.	OBJ-06.03.01-VALP-0719.5120	[Air] Crew acceptable level of workload with D-TAXI function global management	Real Time Simulation Usability and Utility Assessment Acceptability Assessment Trust and Confidence Assessment
D-TAXI HPAP 2013 BEN-002	The taxi clearance display on airport moving map should support pilots' situation awareness by providing them a graphical representation of the taxi clearance, which permits a good representation of the taxi path and surroundings to perform taxi in normal and abnormal conditions.	OBJ-06.03.01-VALP-0719.5010	[Air] Benefits of D-TAXI on flight crew situation awareness, and in specific cases of mixed-mode (voice revision)	Real Time Simulation Usability and Utility Assessment Acceptability Assessment Trust and Confidence Assessment

D_TAXI_HPAP_2015_BEN_01	Manual taxi route building requires pilots to insert the taxi route elements into the cockpit systems. This may be time consuming and add workload if the interactions means are not adequate and intuitive enough to do the task. Besides workload is expected to be at least not increased compared to the current situation without the function, as taxi route display may supports the navigation efficiently.	OBJ-06.03.01-VALP-0719.6010	[Air] Impact of manual taxi routing use on Flight Crew workload	Real Time Simulation Usability and Utility Assessment Acceptability Assessment Trust and Confidence Assessment
D_TAXI_HPAP_2015_BEN_02	Manual taxi route function allows pilots to display the taxi route path on an airport moving map in the cockpit. It is expected to enhance pilots situation awareness on the own ship position and trajectory along the taxi route and therefore ease taxi execution compared to the current way of working	OBJ-06.03.01-VALP-0719.6020	Benefit of manual taxi routing use on Flight Crew situation awareness	Real Time Simulation Usability and Utility Assessment Acceptability Assessment Trust and Confidence Assessment
VBC_HPAP_2015_ISS_01	Enhancement of Virtual Block Control by means of VSB may be time consuming and add workload if the interactions means are not adequate and intuitive enough to do the task. Besides workload is expected to be at least not increased compared to the current situation without the function,	OBJ-06.03.01-VALP-0719.7020	To validate operational utility of Virtual Block Control during Low Visibility Conditions for controllers	Workload Assessment

Argument 2.2 - The performance of the technical system supports the human in carrying out their task.

ISSUE ID	HP ISSUE & IMPACTS	OBJ. ID	HP ASSESSMENT OBJECTIVES	HP ACTIVITY/IES
VP719_HPAP-2015_ISS-002	Technical limitations due to database accuracy or inconsistency between air and ground may lead the on-board system to display ambiguous or erroneous parts of the taxi route, and may require numerous head-down checks from pilots, which negatively impacts the human performance. Moreover, potential inconsistencies between ground and board information could lead to confusions a potential for errors.	OBJ-06.03.01-VALP-0719.5140	"[Air/Ground] Validate the consistency of air and ground HMI in order to ensure proper understanding of flight crew and controllers while performing their own operational task"	Real Time Simulation Usability and Utility Assessment Acceptability Assessment Trust and Confidence Assessment

Issue ID	HP Issue & Impacts	Obj. ID	HP Assessment Objectives	HP Activity/ies
VP719_HPAP-2015_ISS-003 VP719_HPAP-2015_ISS-004 VP719_HPAP-2015_ISS-005	"Several procedures are envisioned to make air and ground coordinate about the aircraft preferred exit: BTV setting can be a triggering and once the exit is downlinked, ATC system may send the expected route. Or, the expected route could be sent before or asked by the pilots before BTV to set BTV on the basis of the Exit given by ATC. In the two cases, and if the expected route is updated, or the crew cannot perform the exit, inappropriate coordination between air and ground could impact the operators workload by increasing the amount of messages to coordinate each other. Besides, the integration of a link between BTV settings and the expected message content should improve pilots' arrival preparation during approach by providing them accurate data (downlinked by the aircraft). Nevertheless if these two operations are not performed at the same time, this may have a negative impact on pilots' workload during approach, leading to reduced task efficiency and degrading pilots' interest in the Expect concept."	OBJ-06.03.01-VALP-0719.5110	[Air/Ground] Timing relevance, Flight Crew efficient management and usefulness of the expected routing (and updates) sent prior to and during the approach	Real Time Simulation Usability and Utility Assessment Acceptability Assessment Trust and Confidence Assessment
VBC_HPAP_2015_ISS_02	Implementation of Virtual Block Control is expected to increase the perceived situation awareness, not adequate performance of the technical system could provoke the country result.	OBJ-06.03.01-VALP-0719.7060	To validate the impact on ATCOs' situational awareness resulting from the use of Virtual Stop Bars when virtual block procedures are in place	Situational awareness Assessment

Argument 2.3 - Design of the Human-Machine Interface supports the human in carrying out their tasks

Issue ID	HP Issue & Impacts	Obj. ID	HP Assessment Objectives	HP Activity/ies
VP719_HPAP-2015_ISS-006	The D-TAXI function should provide controllers with relevant information resulting in a better mental representation of the situation.	OBJ-06.03.01-VALP-0719.5110	[Air/Ground] Timing relevance, Flight Crew efficient management and usefulness of the expected routing (and updates) sent prior to and during the approach	Real Time Simulation Usability and Utility Assessment Acceptability Assessment Trust and Confidence Assessment

D-TAXI HPAP 2013 BEN-004	The D-TAXI function should provide pilots with relevant information relative to taxi route necessary for navigation (graphical representation of taxi path and aircraft position all along the route) resulting in a better mental representation of the trajectory and a better taxi performance. However, one has to ensure that there is no negative impact of the route display o task performance. Having a taxi route displayed on board remains potentially attractive for pilots and easy to follow as it relieves them from heavy tasks to search position and directions on charts during taxi. There is a potential that, by force of habit, pilots rely exclusively on the display to navigate with the counter effect to decrease their awareness and vigilance about navigation aspects on the airport, and not detect potential errors.	OBJ-06.03.01-VALP-0719.5090	[Air] Assess the benefits of all information relative to the taxi route displayed in the cockpit to perform the navigation	Real Time Simulation Usability and Utility Assessment Acceptability Assessment Trust and Confidence Assessment
D-TAXI_HPAP_2013_ISS-008	In-adapted devices and displays may prevent pilots to achieve their tasks related to surface operations in a timely manner and may impact on-board task performance: the devices and display should ensure pilots to proceed to the sending and the reception of datalink messages, as well as facilitate the interaction with the taxi path on airport moving map. Head-down time induced by the handling of CPDLC HMIs may lead pilots to spend more time to manage the interfaces comparing to voice communication and then may negatively impact the human performance (workload) and taxi efficiency (slow-down the taxi operations) particularly when messages are received during the taxi	OBJ-06.03.01-VALP-0719.5100	[Air] Assess the flight crew efficiency to use all interfaces and devices related to D-TAXI in operational context.	Real Time Simulation Usability and Utility Assessment Acceptability Assessment Trust and Confidence Assessment
D_TAXI_HPAP_2015_ISS_01	In-adapted devices and displays may prevent pilots to achieve their tasks related to surface operations in a timely manner and may impact on-board task performance: the devices and display should ensure pilots to easily proceed to the manual insertion of a taxi route into the aircraft systems as well as facilitate the interaction with the taxi path on airport moving map.	OBJ-06.03.01-VALP-0719.6030	Usability of manual taxi routing HMI and procedures for Flight Crew	Real Time Simulation Usability and Utility Assessment Acceptability Assessment Trust and Confidence Assessment

ISSUE ID	HP ISSUE & IMPACTS	OBJ. ID	HP ASSESSMENT OBJECTIVES	HP ACTIVITY/IES
VBC_HPAP_2015_ISS_03	In-adapted devices and displays may prevent controllers to achieve their tasks related to surface operations in a timely manner and may impact ground task performance: the devices and display should ensure controllers to easily manage Virtual Block Control during Low Visibility Conditions.	OBJ-06.03.01-VALP-0719.7040	To validate operational usability of Virtual Block Control during Low Visibility Conditions for controllers	Real Time Simulation Usability and Utility Assessment Acceptability Assessment Trust and Confidence Assessment

Argument 3.3 - The communication between team members supports human performance

ISSUE ID	HP ISSUE & IMPACTS	OBJ. ID	HP ASSESSMENT OBJECTIVES	HP ACTIVITY/IES
VP719_HPAP-2015_ISS-007 VP719_HPAP-2015_ISS-008	CPDLC communication should enable controllers and pilots to communicate efficiently so that it should improve operators' understanding by contributing to safety. Indeed it should reduce pilots' potential for clearances misunderstanding which may impact controllers' workload positively (less repetition). Particularly, the hold short instruction can be sent alone by datalink if it concerns an instruction during taxi or be specified at the end of a datalink taxi clearance, or can be instructed by voice in time critical situation. In the three cases, the messages and actions following the instructions is relative to one of the three ways of instructing the hold short. The usability of the operating methods to handle the hold short should ensure to pilots to understand and to resume more efficiently their taxi after a hold short instruction.	OBJ-06.03.01-VALP-0719.5130	Evaluate whether the Situational Awareness of controller is improved with the integration and exploitation of D-TAXI service	Real Time Simulation Usability and Utility Assessment Situational awareness Assessment Cognitive workload Assessment

VP719_HPAP-2015_ISS-009	CPDLC communication should enable controllers and pilots to communicate efficiently so that it should improve operators' understanding by contributing to safety. Indeed it should reduce pilots' potential for clearances misunderstanding which may impact controllers' workload positively (less repetition). Particularly, the hold short instruction can be sent alone by datalink if it concerns an instruction during taxi or be specified at the end of a datalink taxi clearance, or can be instructed by voice in time critical situation. In the three cases, the messages and actions following the instructions is relative to one of the three ways of instructing the hold short. The usability of the operating methods to handle the hold short should ensure to pilots to understand and to resume more efficiently their taxi after a hold short instruction.	OBJ-06.03.01-VALP-0719.5060	Evaluate whether the Situational Awareness of controller is improved with the integration and exploitation of D-TAXI service	Real Time Simulation Usability and Utility Assessment Situational awareness Assessment Cognitive workload Assessment
VP719_HPAP-2015_ISS-011	The datalink communication involving a mixed-mode, a loss of party-line and head-down time to manage CPDLC interfaces may negatively impact the flight crew cooperation and ATCOs team cooperation (leading to an increased potential for workload to search the information or to communicate between them) and the efficiency of the taxi performance, increasing the potential for error and communication between pilots and controllers.	OBJ-06.03.01-VALP-0719.5070	Evaluate the impact on ATCO workload with the integration and exploitation of D-TAXI service	Real Time Simulation Usability and Utility Assessment Situational awareness Assessment Cognitive workload Assessment
VP719_HPAP-2015_ISS-012	The datalink communication involving a mixed-mode, a loss of party-line and head-down time to manage CPDLC interfaces may negatively impact the flight crew cooperation and ATCOs team cooperation (leading to an increased potential for workload to search the information or to communicate between them) and the efficiency of the taxi performance, increasing the potential for error and communication between pilots and controllers.	OBJ-06.03.01-VALP-0719.5030	Validate that the timers associated with the exchange of D-TAXI messages are useable in an operational environment	Real Time Simulation Usability and Utility Assessment Situational awareness Assessment Cognitive workload Assessment

VP719_HPAP-2015_ISS-013	CPDLC communication may have a negative impact on the ATCOs team shared situation awareness as it prevents controllers to both hear the communication (at the same time, contrary to the radio frequency), which may lead to reduced communication performances (additional communication between controllers compared to the use of radio frequency means).	OBJ-06.03.01-VALP-0719.5060	Evaluate whether the Situational Awareness of controller is improved with the integration and exploitation of D-TAXI service	Real Time Simulation Usability and Utility Assessment Situational awareness Assessment Cognitive workload Assessment

3.3.2 HP activities and outcomes

Table 3 presents a consolidated overview of the HP activities required to address the identified objectives.

Table 3: Consolidated list of HP activities

HP ACTIVITY	PRIORITY	STATUS	JUSTIFICATION OF STATUS
1.RTS-HP ASSESSMENT	HIGH	COMPLETED	DURING RTS
2.SITUATION AWARENESS ASSESSMENT	HIGH	COMPLETED	DURING RTS
3.WORKLOAD ASSESSMENT	HIGH	COMPLETED	DURING RTS
4.UTILITY AND USABILITY ASSESSMENT	MEDIUM	COMPLETED	DURING RTS

Table 4 to Table 7 contain detailed description of each of the proposed HP activities and main findings.

Table 4: Description of Activity 1- Real-Time Simulation Support

ACTIVITY 1.	REAL-TIME SIMULATION SUPPORT
DESCRIPTION/ OBJECTIVE	HP support will be provided to exercise VP719. This will ensure that appropriate evidence can be generated through these simulations, such that HP arguments and claims can be supported.
ADDRESSED HP ASSESSMENT OBJECTIVES	The objectives for this HP activity are provided against each of the 'related arguments' captured above (see also Annex A). In general terms this activity has the following objectives: • Confirm that the main benefits of D-TAXI and Virtual Block Control in LVPs with regard to efficiency and effectiveness are realised and/or maintained. • Confirm that the procedure(s) for transitions between data-link and voice are acceptable with regard to effectiveness, efficiency, and satisfaction. • Confirm ATCOs HMI usability. • Collect subjective satisfaction information from ATCOs participating in the simulation exercises. Further detailed HP objectives are integrated into the validation plan (section 3.6 of the VALP [6]). Specific airborne objectives are included in the HP assessment spread-sheet in Appendix A.
ISSUES ADDRESSED / INVESTIGATED (FROM ISSUE ANALYSIS)	The issues are provided in 3.3.1, in relation to the relevant arguments and HP objectives that are described above.
TOOL/METHOD USED	To be defined in relation to each exercise and to the HP objectives apportioned to each exercise (see corresponding sections 4.1.3, 4.2.3, and 4.3.3 of the VALP [6])

ACTIVITY INFORMATION	Support to real-time simulation involves the following steps: • Validation planning, development of HP objectives and associated scenario and measurement recommendations. • Attendance at simulation exercises. • Post-exercise data analysis. • Report contribution.
SUMMARY OF MAIN FINDINGS	The application of the HP assessment process and methods, and the involvement of Operational and Human Factors experts ensured that Real-Time Simulation activity provided the appropriate evidences through the simulation.
NEWLY IDENTIFIED ISSUES	-
RECOMMENDATIONS & REQUIREMENTS	-

Table 5: Description of Activity 2 - SITUATION AWARENESS ASSESSMENT

ACTIVITY 2	SITUATION AWARENESS ASSESSMENT
DESCRIPTION / OBJECTIVE	Situational awareness assessment has been be performed with the application of a set of methods that are all based on having evaluators rating their situational awareness with the introduction of the following concepts: •D-TAXI SERVICE FOR CPDLC APPLICATION; •AUTOMATED ASSISTANCE TO CONTROLLER FOR SURFACE MOVEMENT PLANNING AND ROUTING; •AIRPORT SAFETY NETS FOR CONTROLLERS: CONFORMANCE MONITORING ALERTS AND DETECTION OF CONFLICTING ATC CLEARANCES; •MANUAL TAXI ROUTING; •VIRTUAL BLOCK CONTROL IN LVP. Situational awareness is defined as "the continuous a extraction of environmental information, the integration of this information with previous knowledge to form a coherent mental picture, and the use of that picture in directing further perception and anticipating future events" (Dominguez et al., 1994). In this regard, situational awareness can be considered a mental state consisting of three phases: •perception of the situation (perception of important elements in the environment); •comprehension of the situation (integration of different pieces of data in order to determinate their relevance); •anticipation of future states of the current situation.

ADDRESSED HP ASSESSMENT OBJECTIVES	➢D-TAXI service for CPDLC application:
	  ○To validate Flight Crew / Controllers increased situational awareness
	OBJ-06.03.01-VALP-0719.5010
	OBJ-06.03.01-VALP-0001.0303
	OBJ-06.03.01-VALP-0001.0303
	➢Automated Assistance to Controller for Surface Movement Planning and Routing
	  ○To validate how the provision the impact on Human Performance resulting from an increase of controllers' situation awareness
	➢Airport Safety Nets for controllers: conformance monitoring alerts and detection of conflicting ATC clearances
	  ○To validate Controllers increased situational awareness
	➢Manual Taxi routing
	  ○To validate Flight Crew situation awareness
	OBJ-06.03.01-VALP-0719.6020
	➢Virtual Block Control in LVPsTo validate Controllers increased situational awareness

ISSUES ADDRESSED / INVESTIGATED (FROM ISSUE ANALYSIS)	Arg. 1 The role of the human is consistent with human capabilities and limitations Arg. 2 Technical system support the human actors in performing their tasks Arg. 3 Team Structures and team communication support the human actors in performing their tasks Arg. 4 Human Performance related transition factors are considered
ACTIVITY INFORMATION	**Over The Shoulder Observations** During each exercise run the HP and SAF EXPERTS sat behind the controllers, observing the radar display and taking time-coded notes of anything considered relevant. A particular role was attributed to ATM experts, as having a controller background. ATM EXPERTS were requested to join the HP&SAF validation team and to observe the activity performed during the REAL TIME and the LIVE TRIAL with "an expert eye". Airborne assessment: HP and cockpit operation specialist performed observations of pilots' tasks and took notes of anything considered relevant. **Questionnaires** Questionnaires allowed a wide variety of views to be obtained from the controllers and the pilots involved in the study that might have different but equally relevant perspectives about the use and the impact of the new system on a robust working environment. After each exercise run ATCOs and pilots were requested to fill questionnaire addressing issues related the specific run. At the end of the whole exercise session ATCOs and pilots were requested to fill questionnaire in order to collect their global feedback about the concepts investigated. Situational awareness assessment has been performed through SASHA questionnaire, The SASHA is part of the SHAPE questionnaires. The SHAPE questionnaires were developed to assess the effect of automation on controller workload, situation awareness, teamwork and trust in the system. The SASHA questionnaire serves to assess the effect of innovative operational concepts on controller situation awareness. Airborne assessment: no standard questionnaire was submitted to pilots, however a question was asked through a final post exercise questionnaire about situation awareness, in order to rate pilots' tendency. **Debriefings** At the end of each exercise day dedicated debriefing sessions have been conducted. During the debriefing sessions pilots and ATCOs provided with different kinds of information and they are typically required: • to discuss the performance of the system (accuracy, representation, reliability and so on); • reason about their activity performed with the information provided by the new concepts; • make a comparison between the activity carried out with or without the new concepts under evaluation. They were also asked to envision the use of the information provided by the system and the effectiveness of the system itself. What is important to notice is that debriefings and over the shoulders observations are deeply interconnected techniques. This means that on one hand, data collected though the observations are then verified and discussed during the debriefings, and from the other hand insights emerged during the debriefings are then used to guide the following observations. This combination of techniques is proved to ensure the correctness and the reliability of the results obtained.

SUMMARY OF MAIN FINDINGS	➤**D-TAXI service for CPDLC application**
	The controllers confirmed the potential reduction of misunderstandings with pilots. Furthermore, they highlighted their will to include the departure clearance in the list of instructions to be exchanged via data link. At the same time, it was strongly recommended to make the interface more usable to avoid any negative effects associated to excessive head-down time.
	Airborne findings:
	Pilots' situation awareness is supported by the taxi clearance display and data link communication, especially when taxi clearances are transmitted by data link when the aircraft is in static phase and pilots have time to check the message and the route display
	However head-down time and attractiveness of display during dynamic phases are increased and may decrease situation awareness during navigation in case of:
	o The display is no longer valid (voice revision);
	o Manipulation of the taxi route update in the system when it is given by voice which may prevent monitoring surroundings efficiently;
	o Lack of the overall picture of the airport on AMM;
	o Display discrepancy with the outside (accommodation required for matching external view and internal display can differ according to the scale chosen on the navigation display).
	➤**Automated Assistance to Controller for Surface Movement Planning and Routing**
	Controllers confirmed that the routing and planning function supported them in building a mental picture of the planned surface traffic movements. However, the usability of the interface was not appropriate to keep the expected situational awareness as any modification was too much time and effort consuming.
	➤**Airport Safety Nets for controllers: conformance monitoring alerts and detection of conflicting ATC clearances**
	Both Ground and Runway controllers confirmed that the display of CMAC and CATC alerts / warnings result in an increase of situational awareness. At the same time, they highlighted the need to proceed with an appropriate tuning of the alarms thresholds in order to have not many alerts and, therefore, affect negatively their capacity to build a mental picture of what is happening.
	➤**Manual Taxi routing**
	Overall benefits of Manual Taxi on situation awareness compared to the current operations are confirmed, especially at the gate in static environment, these benefits were confirmed with the test in flight trial. However, the insertion of the route by the PM should be easier in order to avoid significant decrease of PM's SA during taxi phase.
	➤**Virtual Block Control in LVPs**
	Apart from the first day when there were some problems afflicting the CWP, it can unequivocally state that the SA with Virtual Control Block is a significant improvement.
	However, even on the first day, they were also achieved excellent results even with some small technical clutter. The pilot surely suggests having such an instrument on board all aircraft.
	The controllers confirmed the increase of situational awareness by means of Virtual Stop Bars when virtual block control procedures are in place. The main benefit concerns with the alerting notification in case of VSB notification.
NEWLY IDENTIFIED ISSUES	-
RECOMMENDATIONS & REQUIREMENTS	Controllers provided recommendations also about the opportunity to receive a notification in case pilots send a wrong message via data link not coherent with the status of the flight (e.g. expect taxi instead of taxi request).

Table 6: Description of Activity 3 - WORKLOAD ASSESSMENT

ACTIVITY 3	WORKLOAD ASSESSMENT

DESCRIPTION / OBJECTIVE	Workload assessment have been performed with the application of a set of methods that are all based on having evaluators rating their workload with the introduction of the new concepts under evaluation:
	• D-TAXI SERVICE FOR CPDLC APPLICATION;
	• AUTOMATED ASSISTANCE TO CONTROLLER FOR SURFACE MOVEMENT PLANNING AND ROUTING;
	• AIRPORT SAFETY NETS FOR CONTROLLERS: CONFORMANCE MONITORING ALERTS AND DETECTION OF CONFLICTING ATC CLEARANCES;
	• MANUAL TAXI ROUTING;VIRTUAL BLOCK CONTROL IN LVP.
	There are two main parts in perceived workload: physical workload and cognitive workload.
	Cognitive workload has been defined as the "degree of processing capacity that is expended during task performance" (Eggemeier, 1998) and as being "the difference between capacities of the human information processing system that are expected to satisfy performance expectations and that capacity available for actual performance" (Gopher & Dochin, 1986).
	Physical workload, on the other hand, is related to the physical actions required to interact with the system in performing tasks (e.g. clicking, making a phone call, moving head to switch form a monitor to another, etc.).
	In ATM, the mission is to keep operators (ATCOs and pilots) global workload in a range where they are kept (at least mentally) stimulated without going to the point where they become overloaded and start to postpone tasks.
ADDRESSED HP ASSESSMENT OBJECTIVES	➢ **D-TAXI service for CPDLC application:**
	○ To evaluate Flight Crew / Controllers' workload
	OBJ-06.03.01-VALP-0719.5120
	OBJ-06.03.01-VALP-0001.0304
	➢ **Automated Assistance to Controller for Surface Movement Planning and Routing**
	○ To validate Controllers workload
	➢ **Airport Safety Nets for controllers: conformance monitoring alerts and detection of conflicting ATC clearances**
	○ To validate Controllers workload
	➢ **Manual Taxi routing**
	○ To evaluate Flight Crew workload
	OBJ-06.03.01-VALP-0719.6010
ISSUES ADDRESSED / INVESTIGATED (FROM ISSUE ANALYSIS)	Arg. 1 The role of the human is consistent with human capabilities and limitations
	Arg. 2 Technical system support the human actors in performing their tasks
	Arg. 3 Team Structures and team communication support the human actors in performing their tasks
	Arg. 4 Human Performance related transition factors are considered

ACTIVITY INFORMATION	**Over The Shoulder Observations**
	During each exercise run the HP and SAF EXPERTS sat behind the controllers, observing the radar display and taking time-coded notes of anything considered relevant.
	A particular role was attributed to ATM experts, as having a controller background. ATM EXPERTS were requested to join the HP&SAF validation team and to observe the activity performed during the REAL TIME and the LIVE TRIAL with "an expert eye".
	Airborne assessment: HP and cockpit operation specialist performed observations of pilots' tasks and took notes of anything considered relevant.**Questionnaires**
	Questionnaires allowed a wide variety of views to be obtained from the controllers and the pilots involved in the study that might have different but equally relevant perspectives about the use and the impact of the new system on a robust working environment.
	After each exercise run ATCOs and pilots were requested to fill questionnaire addressing issues related the specific run. At the end of the whole exercise session ATCOs and pilots were requested to fill questionnaire in order to collect their global feedback about the concepts investigated.
	Workload assessment have been performed through NASA TLX questionnaire; The NASA Task Load Index (NASA-TLX) is a widely-used, subjective, multidimensional assessment tool that rates perceived workload in order to assess a task, system, or team's effectiveness or other aspects of performance.
	Airborne assessment: no standard questionnaire was submitted to pilots, however a question was asked through a final post exercise questionnaire about workload, in order to rate pilots' tendency.
	Debriefings
	At the end of each exercise day dedicated debriefing sessions have been conducted.
	During the debriefing sessions pilots and ATCOs were provided with different kinds of information and they are typically required:
	• to discuss the performance of the system (accuracy, representation, reliability and so on);
	• reason about their activity performed with the information provided by the new concepts;
	• make a comparison between the activity carried out with or without the new concepts under evaluation.
	They were also asked to envision the use of the information provided by the system and the effectiveness of the system itself.
	What is important to notice is that debriefings and over the shoulders observations are deeply interconnected techniques. This means that on one hand, data collected though the observations are then verified and discussed during the debriefings, and from the other hand insights emerged during the debriefings are then used to guide the following observations. This combination of techniques is proved to ensure the correctness and the reliability of the results obtained.

SUMMARY OF MAIN FINDINGS	➤**D-TAXI service for CPDLC application**
	Controllers' workload is kept at an acceptable level with the implementation of D-TAXI service. A further reduction of Tower Clearance Delivery Controller workload is expected with the implementation of DCL and CONTACT messages with the objective to have a full data link equipped delivery position.
	Airborne findings:
	The use of data link does not increase pilots' workload compared to the current procedures. Workload is perceived as increased when data link is mixed with voice (especially for voice taxi revision and insertion in the cockpit) or in dynamic phases where pilots have already a lot of tasks to do (during descent, after runway vacated in taxi-in). On this point taxi insertion and display robustness on airport moving map should be improved.
	Flight crew may adapt their organisation to avoid being both head-down in the system, as an automatic transmission and associated display is a real benefit for task accomplishment when it works well.
	➤**Automated Assistance to Controller for Surface Movement Planning and Routing**
	The involved operational controllers confirmed that the workload associated to the investigated routing and planning function was not appropriate to perform their tasks. However, it was suggested to further assess that functionality with a more usable interface (e.g. less manual inputs to change the proposed taxi routes, mouse over effect to display the planned taxi routes).
	➤**Airport Safety Nets for controllers: conformance monitoring alerts and detection of conflicting ATC clearances**
	The controllers confirmed that their workload was not kept at an acceptable level mainly due to the low degree of both CMAC and CATC usability. Therefore, controllers recommended further investigating on that aspect with a more usable system. This issue can be solved with an opportune tuning of the alerts with appropriate thresholds in accordance with the local operational procedures.
	➤**Manual Taxi routing**
	Pilots felt their workload increased with the use of manual taxi compared to the current procedures. The HMI definition maturity and lack of usability contributed to pilots' difficulties in using the manual taxi function, and to the augmentation of pilot's perceived workload.
NEWLY IDENTIFIED ISSUES	-
RECOMMENDATIONS & REQUIREMENTS	UNABLE message. As it refers to the impossibility to comply with the instruction or with the request, controllers recommended not to exchange UNABLE message via data link but to directly manage that situation via voice.

Table 7: Description of Activity 4 - UTILITY AND USABILITY ASSESSMENT

ACTIVITY 4	UTILITY AND USABILITY ASSESSMENT

DESCRIPTION / OBJECTIVE	Usability assessment have been performed with the application of a set of methods that are all based on having evaluators rating the usability with the introduction of the new concepts under evaluation:
	• D-TAXI SERVICE FOR CPDLC APPLICATION;
	• AUTOMATED ASSISTANCE TO CONTROLLER FOR SURFACE MOVEMENT PLANNING AND ROUTING;
	• AIRPORT SAFETY NETS FOR CONTROLLERS: CONFORMANCE MONITORING ALERTS AND DETECTION OF CONFLICTING ATC CLEARANCES;
	• MANUAL TAXI ROUTING
	• VIRTUAL BLOCK CONTROL IN LVP.
	The Usability is the Extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use. Where:
	• Effectiveness is accuracy and completeness with which users achieve specified goals.
	• Efficiency is resources expended in relation to the accuracy and completeness with which users achieve goals.
	• Satisfaction is freedom from discomfort, and positive attitudes to the use of the product.
	• Context of use is users, tasks, equipment (hardware, software and materials), and the physical and social environments in which a product is used.
	• User is individual interacting with the system.
	Usability assessment was aimed at finding usability problems in the design, though some methods also address issues like the severity of the usability problems and the overall usability of an entire system.
	Finally Utility assessment is to ensure that the proposed concepts and new tools provided really "fit for purpose", that they are not "gadgets" but fulfilled real needs. The question raised is -- Do the concepts and tools help the controllers and/or the pilots in achieving the collaborative work of "providing a fluid, safe and expeditious flow of traffic?

ADDRESSED HP ASSESSMENT OBJECTIVES	➤**D-TAXI service for CPDLC application:**
	    ○To validate usability of D-TAXI service
	    ○To validate utility of D-TAXI service
	
	OBJ-06.03.01-VALP-0719.5020
	
	OBJ-06.03.01-VALP-0719.5090
	
	OBJ-06.03.01-VALP-0719.5100
	
	OBJ-06.03.01-VALP-0719.5110
	
	OBJ-06.03.01-VALP-0719.5130
	
	OBJ-06.03.01-VALP-0001.0301
	
	OBJ-06.03.01-VALP-0001.0302
	
	➤**Manual taxi routing:**
	    ○To validate manual taxi utility and usability from Flight Crew perspective
	
	OBJ-06.03.01-VALP-0719.6030
	
	➤**Departure Management integrating Surface Management constraints:**
	    ○To validate system utility and usability
	➤**Automated Assistance to Controller for Surface Movement Planning and Routing**
	    ○To validate system utility and usability
	➤**Airport Safety Nets for controllers: conformance monitoring alerts and detection of conflicting ATC clearances**
	    ○To validate utility of both CATC and CMAC;
	    ○To validate usability of both CATC and CMAC;
	➤**Virtual Block Control in LVPs**
	
	Utility and usability of virtual block control

ISSUES ADDRESSED / INVESTIGATED (FROM ISSUE ANALYSIS)	Arg. 1 The role of the human is consistent with human capabilities and limitations Arg. 2 Technical system support the human actors in performing their tasks Arg. 4 Human Performance related transition factors are considered

ACTIVITY INFORMATION	**Over The Shoulder Observations**
	During each exercise run the HP and SAF EXPERTS sat behind the controllers, observing the radar display and taking time-coded notes of anything considered relevant.
	A particular role was attributed to ATM experts, as having a controller background. ATM EXPERTS were requested to join the HP&SAF validation team and to observe the activity performed during the LIVE TRIAL and the REAL TIME with "an expert eye".
	Airborne assessment: HP and cockpit operation specialist performed observations of pilots' tasks and took notes of anything considered relevant.
	Questionnaires
	Questionnaires allowed a wide variety of views to be obtained from the controllers and the pilots involved in the study that might have different but equally relevant perspectives about the use and the impact of the new system on a robust working environment.
	After each exercise run ATCOs and pilots were requested to fill questionnaire addressing issues related the specific run. At the end of the whole exercise session ATCOs and pilots were requested to fill questionnaire in order to collect their global feedback about the concepts investigated.
	Usability assessment has been performed through SUS questionnaire; The SUS Questionnaire is a widely-used, subjective, multidimensional assessment tool that rates perceived system usability.
	Airborne assessment: no standard questionnaire was submitted to pilots, however some questions were asked through a final post exercise questionnaire about utility and usability of the concept and solutions, in order to rate pilots' tendency.
	Debriefings
	At the end of each exercise day dedicated debriefing sessions have been conducted.
	During the debriefing sessions pilots and ATCOs were provided with different kinds of information and they are typically required:
	• to discuss the performance of the system (accuracy, representation, reliability and so on);
	• reason about their activity performed with the information provided by the new concepts;
	• make a comparison between the activity carried out with or without the new concepts under evaluation.
	They were also asked to envision the use of the information provided by the system and the effectiveness of the system itself.
	What is important to notice is that debriefings and over the shoulders observations are deeply interconnected techniques. This means that on one hand, data collected though the observations are then verified and discussed during the debriefings, and from the other hand insights emerged during the debriefings are then used to guide the following observations. This combination of techniques is proved to ensure the correctness and the reliability of the results obtained.

SUMMARY OF MAIN FINDINGS	➤**D-TAXI service for CPDLC application**
	Generally speaking, D-TAXI service has been considered useful for most of the investigated messages. The controllers confirmed that the main benefits are achieved for those messages (such as START-UP, PUSH-BACK) exchanged in a "static phase" of the flight. The same level of benefits is not expected to be achieved with the provision of TAXI clearance via data link especially in a complex environment as Malpensa Airport. However, it was suggested to further investigate it with a more usable interface).
	Furthermore, the operational controllers requested to implement extra messages (as DCL and CONTACT) for future validation activities.
	Controllers confirmed the usability of D-TAXI service for performing the exchange of the expected messages mainly in a static environment (such as START-UP, PUSH-BACK). Furthermore, in order to improve the effectiveness of that service, the controllers requested to introduce further messages as DCL and CONTACT.
	The operational controllers confirmed the need further investigate the procedures to be applied in a mixed mode environment. At the same time, they confirmed that, in the so called nominal situations, data link communications worked efficiently.
	Airborne findings:
	The procedure of sending taxi-in clearance without request once runway vacated was well applied and is validated as it prevents aircraft waiting at exit holding point and contributes to the traffic fluidity.
	The data link in itself was efficiently managed by the flight crew.
	The fact that, in data link environment, voice has still to be monitored for the management of time-critical communications is well understood by pilots. There is still confusion about the use of data link and voice when they are used in a mixed way for usual exchanges (dialog initiation, dialog order). Rules and airport practices should made be clear and known by pilots in order for them to be prepared to use voice and data link for the adequate requests. This is particularly true in case pilots often change destination and may be confused by the different airport practices or message set implementation. Specific procedures for the use of voice and data link may be defined through airport charts.
	The management of the radio (frequency change) and data link (no change) could be confusing as data link dialogs can be made to the inappropriate sector. It has to be confirmed if the use of CONTACT data link message could mitigate this confusion.
	Current concept to display cleared route on AMM is validated. Some slight design upgrade could be performed. These design ameliorations have been identified, but they will not replace basic airmanship (at least one pilot head-up when the aircraft is moving on the ground) and the novelty aspect which should be quickly overcome by pilots.
	For pilots used to fly in CPDLC environment, current HMI exposed is adapted and usable. Current training and SOP are validated.
	The expected taxi routing usefulness is confirmed to support pilots' preparation of the taxi phase, especially in flight. However display differentiation with a taxi clearance should be kept in order to make pilots understand that this message is informational.
	The time to receive the expected taxi route is not validated, as its utility and integration in pilots' tasks is limited when it is from 20 min, as defined in the SESAR concept. The effective support of this information is given when it can be integrated during the arrival briefing done just before TOD (around 45 min before landing), or above FL100 in short-haul context.
	The current message set is accurate and complete for basic operations taxi operations. The full message set (with REVISED TAXI and CONTACT) needs to be evaluated to confirm their usability in dynamic environment.
	➤**Manual taxi routing:**
	The concept of manual taxi is clearly an advantage and a benefit regarding today's operations, especially on complex and/or unknown airport as it provides a visualization of the trajectory and the aircraft position along it. However, it should be associated with an appropriate means to enter it manually in a timely manner, easily and so that it reflects exactly the initial voice clearance.
	Besides, other interaction means more user-friendly is to be further studied in the future.
	The task sharing should be further addressed in future studies.
	➤**Automated Assistance to Controller for Surface Movement Planning and Routing**
	The usability and utility of the investigated routing and planning function was not considered acceptable by the involved controllers. However, the whole assessment has been significantly affected by not stable behaviours of the routing and planning function during traffic peaks situations where any change of the taxi route required too many manual inputs. To be further investigated with a more stable prototype.
	➤**Airport Safety Nets for controllers: conformance monitoring alerts and detection of conflicting ATC clearances**
	Controllers confirmed the utility of the investigated CATC alarms. However, they stressed on the importance to improve their usability in order not to negatively affect the reliability of the system.
	The controllers confirmed the utility of the investigated CMAC functions. They confirmed that it is really beneficial to be notified in case of non-conformance to ATC clearances especially if those events occurring after off block.
	The usability of CMAC functions was not fully considered appropriate by the involved operational controllers. In any case, with the opportune modifications and tuning in the colours / acronyms, setting and in the thresholds adjustment, it is expected an increase of CMAC functions usability by solving the issues raised by the ATCOs. About setting aspects, the main issue concerns the

NEWLY IDENTIFIED ISSUES	-

RECOMMENDATIONS & REQUIREMENTS	• Tower Clearance Delivery position to be fully data link equipped – In addition to the messages investigated during VP-719, it is also recommended to exchange via data link:
	
	  ○ Departure Clearance instruction as it is considered the one causing the highest number of misunderstandings between controllers and pilots
	
	  ○ Contact message
	
	• Contact message to handle the transfer procedures between Tower Clearance Delivery and Tower Ground Controller as well as between Tower Ground and Tower Runway Controller is recommended to be further investigated.
	
	• The main recommendation collected through the operational feedback regards the implementation of a more dynamic Virtual Block Control by giving the controllers the opportunity to edit "new" Virtual Stop Bars also during taxiing execution.
	
	• Manual taxi usability: It is recommended to improve HMI and usability of manual taxi route interface in order to decrease pilots' head-down time to insert the route and avoid compromising outside monitoring task. Other detailed recommendations of improvements were already raised internally in Airbus and will be taken into account for future studies.
	
	• Planned taxi-in route timing: It is recommended that the planned taxi-in route is sent earlier than 20min before landing (e.g. above FL100 for short-haul flights and before decent for long-haul flights i.e. about 45min), in order to provide the optimum support and utility to pilots: being able to deal with the information during a phase where workload is lower and to integrate the information in their task (arrival briefing).
	
	• Updates of expected taxi routing were not played during the simulation, the objective has not been assessed
	
	• It is recommended to do further assessments of the full data link concept (with REVISED TAXI and CONTACT messages) are needed in order to confirm their usability in dynamic environment.

3.4 HP Assessment Findings and Conclusions

3.4.1 Main findings per HP assessment objective

The HP Log contains the updated information on the HP arguments, issues & benefits, HP activities and evidence after exercise 719.

For detailed information on the collected evidences please refer to the 06.03.01 Validation Report Chapter 6.1.4 [07].

3.4.2 HP maturity of the concept addressed by the project

Based on the current understanding of the concept, the HP maturity is the same as described section 2.3 from Validation Plan (VALP) EXE 719 [6]. However a specific maturity assessment from an HP perspective has been performed for V3, in accordance with the Human Performance Reference Material [1]:

Table 88: HP Maturity Assessment for V3 of D-TAXI and Manual taxi operational concepts for air, ground and air/ground perspectives.

Checklist for finalising the V3 assessment			
ID	Question	Answer Y/N	Comments *Please substantiate your answer.*
1	Have all relevant arguments been addressed and appropriately supported?	Y	**Air: Y** Relevant arguments identified in the 9.13 project scope have been assessed. Even though not all arguments are addressed in the HP log, most of the arguments were indirectly addressed through their link to other arguments. Detailed information is available in the HP log D-TAXI. **Ground: Y** Relevant arguments identified in the 6.03,01 project scope have been assessed. Detailed information is available in the HP log D-TAXI. Arguments at OFA level remain to be considered.
2	Are the benefits and issues in terms of human performance and operability related to the proposed solution sufficiently assessed (i.e. on the level required for V3)?	Y	**Air/Ground:** The benefits and issues have been assessed in the frame of these validations, but the lack of procedures and insufficient maturity of the HMI (on air and ground side) did not allowed to demonstrate V3 maturity. Detailed information is available in the HP Log in the following sections: - Arguments addressed and associated evidence - Identified HP benefits and issues - Outcomes of HP activities (including validation exercises)
3	Have all the parts of the solution/concept been considered?	N	**Air/Ground:** Only a part of D-TAXI service was addressed (i.e. not the full set of messages), therefore the solution assessed was not representing the full implementation possible but only a part.
4	Have potential interactions with related projects/concepts been considered and addressed?	N	**Air/Ground:** Interactions between projects/concepts were addressed; they are done when organizing coupled assessments. However there is lack of interactions with other/complementary projects/concepts like AGL, RWSL, and more globally at OFA level. Related projects: 6.2, 6.7.2, 6.7.3

5	Is the level of human performance needed to achieve the desired system performance for the proposed solution consistent with human capabilities?	N	**Air: N** Workload: The use of data link does not increase pilots' workload compared to the current procedures. Workload is perceived as increased when data link is mixed with voice (especially for voice taxi revision and insertion in the cockpit) or in dynamic phases where pilots have already a lot of tasks to do (during descent, after runway vacated in taxi-in). On this point taxi manual insertion and display robustness on airport moving map should be improved. Situation awareness: Pilots' situation awareness is supported by the taxi clearance display and data link communication, especially when taxi clearances are transmitted by data link when the aircraft is in static phase and pilots have time to check the message and the route display However head-down time and attractiveness of display during dynamic phases are increased and may reduce situation awareness during navigation (e.g. surrounding traffic and airport markings/trajectory). Human errors have been observed, the analysis is provided in Appendix C of the document. **Ground: Y** Situational Awareness The controllers confirmed the potential reduction of misunderstandings with pilots. Furthermore, they highlighted their will to include the departure clearance in the list of instructions to be exchanged via data link. At the same time, it was strongly recommended to make the interface more usable to avoid any negative effects associated to excessive head-down time. Workload Controllers' workload is kept at an acceptable level with the implementation of D-TAXI service. A further reduction of Tower Clearance Delivery Controller workload is expected with the implementation of DCL and CONTACT messages with the objective to have a full data link equipped delivery position.
6	Has the proposed solution been tested with end-users and under sufficiently realistic conditions, including abnormal and degraded conditions?	Y	**Air/Ground:** Scenarios played during the simulation were operationally representative of the operations on Milan-Malpensa airport. Furthermore, pilots and controllers' involvement created a very realistic context of simulation and their behavior, communication and tasks were closed to the reality, which have enriched the quality and significance of the operational results. However on air side with only two sessions and without airspace users, the representativeness was not the one expected, but all pilots were sensitive to airline operations, one with a former experience. Despite this deviation, quality was ensured with pilots' involvement and projection capacity in the operational concept use and through their attitude and comments in debriefing provided valuable operational feedback. This led to have results of good quality that can be re-used.
7	Have all relevant SESAR documentation been updated according to the HP activities outcomes (OSED, SPR)?	Y	**Air/Ground:** Requirements in the OSED and SPR have been updated according to the results of HP activities (e.g. recommendation about the timing of the expected taxi route sending). To be considered at OFA level.
8	Do the outcomes satisfy the HP issues/benefits in order to reach the expected KPA?	Y	**Air/Ground:** Results on KPA have been identified. General concepts overall satisfy the HP issues and benefits but the proposed solutions need for design improvements reassessment. Refer to VALR 6.3.1 (D149) and HP Log for: - Arguments addressed and associated evidence - Identified HP benefits and issues - Outcomes of HP activities (including validation exercises)

9	Have HP recommendations and HP requirements correctly been considered in HMI design, procedures/documentation and training?	Y	**Air/Ground:** Limitations remained on air side prototypes and on the validation in itself (in terms of scope addressed), but they have been considered in the result analysis and are identified in the HP Log (open recommendations)
10	Have the major factors that can influence the transition feas bility (e.g. changes in competence requirements, recruitment and selection, training needs, staffing requirements, and relocation of the workforce) been addressed? Are there any ideas on how to overcome any issues?	Y	**Air/Ground:** The major factors have been considered. They do not present any major impediment neither in the implementation of the D-TAXI and Manual taxi functions nor in pilots' competence evolution. To be considered at OFA level.
11	Have any impacts been identified that may require changes to regulation in the area of HP/ATM? This includes changes in roles & responsibilities, competence requirements, or the task allocation between human & machine.	Y	**Air/Ground:** No impacts have been identified that may require changes to regulation in the area of HP/ATM. To be considered at OFA level.
12	Has the next V-phase sufficiently been prepared (additional testing conditions, open HP issues to be addressed)?	Y	**Air/Ground:** The list of open issues and benefits and recommendations is available in the HP Log. To be considered at OFA level.

3.4.3 Conclusions

3.4.3.1 SESAR Solution #02 – Airport Safety Nets for controllers: conformance monitoring alerts and detection of conflicting ATC clearances

Controllers appreciated the operational concept associated to the investigated Airport Safety Nets (including both Conflicting ATC clearances and non-conformance to ATC procedures) and confirmed the suitability for TWR environment. It was clear the operational need to receive safety relevant notifications concerning mainly runway operations. That's why they confirmed the utility to display runway related alerts on all the controllers working positions as they concern events which could affect the whole airport.

On the other side, the controllers confirmed that the display of too many alarms / warnings results in a significant reduction of system reliability. Therefore, even if the display of both CMAC and CATC alerts / warnings has been considered useful, the controllers stressed on the need to increase their usability.

Display on the controllers' HMI of the graphical objects related to the airport safety nets is recommended to be redesigned in order to take into account the following suggestion:

- List of the alerts to be customized per each controller working position. However, there are specific alerts which could be relevant for more than one working position:
  - RWY incursion – it is such a relevant event from safety perspective that it is important that all the operational controllers are aware of the occurred event.
  - Taxi deviation – generally speaking, it is an event whose only the Tower Ground Controller should be take care of. However, some specific taxi deviations (e.g. in the MXP environment, all the taxi deviation concerning taxiway "F" could be relevant also for the Tower position).
- Appropriate tuning of the identified thresholds to be compliant with the operations executed at the airports where the safety nets are implemented. In such a way, the controllers will be supported in timely detecting potential conflicting situations and making the right decision and reacting.
- Unambiguous and self-explicative information shall be provided on the label of the involved flight on the Ground Radar Picture.
- Warnings should be displayed with yellow colour (and not orange) and alarms with red one.

3.4.3.2 SESAR Solution #22 – Automated assistance to Controller Surface Movement Planning and Routing

It has to be clarified that controllers really appreciated routing and planning function concept. But notwithstanding that the collected results are quite negative due to the fact that the experimented prototype was not tuned enough to fulfil with the main operational requirements.

Controllers considered Routing and Planning function scarcely usable. The proposed system is to complex and requires too much effort and number of interaction in case the controller has the need to modify the planned taxi route.

The main recommendations provided by the involved operational controllers about the routing and planning function are intended to increase its usability and, at the same time, reduced the controllers' workload.

- Even if the display of the different taxi routes status was considered acceptable, the controllers stressed on the operational need to minimize as much as possible the number of actions required to visualize information. That is also the case for the taxi routes display which is recommended to be activated through the mouse over event.
- Minimize the number of actions required to change the taxi routes propose by the routing and planning function.

Furthermore, the controllers recommended implementing a routing and planning functionality which doesn't impact the flexibility of the today procedures they used to manage surface traffic operations. With regard to that, it is recommended to:

▪ Extend the power to change the taxi routes also outside the corresponding Area of Responsibility. Of course, it is clear that a proper coordination with all the concerned controller shall be required;

▪ Give to the Tower Ground Controllers the possibility to change the proposed taxi routes for the arriving flights even if they are not his / her responsibility. It is not intended to be sent as an updated EXPECT TAXI route but it will be used by the Tower Ground Controller as input for organizing future surface traffic operations.

3.4.3.3 SESAR Solution #23 – D-TAXI service for CPDLC application

The current message set is accurate and complete for basic taxi operations. The full message set (with REVISED TAXI and CONTACT messages) needs to be evaluated to confirm their usability in dynamic environment. The assessment confirmed the utility of the D-TAXI service mainly for the instructions considered as static one, such as EXPECT TAXI ROUTING, START-UP, PUSH-BACK and TAXI (only for some specific cases). At the same time, it has been confirmed that the provision of all the time critical instructions (such as GIVE WAY, TAXI REVISED, and CONDITIONAL CLEARANCES) shall be managed via voice.

Ground assessment led to the following recommendations

▪ Tower Clearance Delivery position to be fully data link equipped – In addition to the messages investigated during VP-719, it is also recommended to exchange via data link:

o Departure Clearance instruction as it is considered the one causing the highest number of misunderstandings between controllers and pilots

o Contact message

▪ Contact message to handle the transfer procedures between Tower Clearance Delivery and Tower Ground Controller as well as between Tower Ground and Tower Runway Controller is recommended to be further investigated.

In addition to the list of the messages recommended to be implemented, controllers provided a recommendation also about the opportunity to receive a notification in case pilots send a wrong message via data link not coherent with the status of the flight (e.g. expect taxi instead of taxi request).

A further recommendation regards the exchange of UNABLE message. As it refers to the impossibility to comply with the instruction or with the request, controllers recommended not to exchange UNABLE message via data link but to directly manage that situation via voice.

For pilots used to fly in CPDLC environment, the current HMI exposed is adapted and usable. Current procedures are validated.

Pilots' situation awareness is supported by the taxi clearance display and data link communication, especially when taxi clearances are transmitted by data link when the aircraft is in static phase and pilots have time to check the message and the route display.

However head-down time and attractiveness of display during dynamic phases are increased and may decrease situation awareness during navigation in case of:

o The display is no longer valid (voice revision);

o Manipulation of the taxi route update in the system when it is given by voice which may prevent monitoring surroundings efficiently;

o Lack of the overall picture of the airport on AMM;

o Display discrepancy with the outside (accommodation required for matching external view and internal display can differ according to the scale chosen on the navigation display).

The use of data link does not increase pilots' workload compared to the current procedures. Workload

is perceived as increased when data link is mixed with voice (especially for voice taxi revision and insertion in the cockpit) or in dynamic phases where pilots have already a lot of tasks to do (during descent, after runway vacated in taxi-in). On this point, improvement for taxi insertion and display robustness on airport moving map is recommended.

The time to receive the expected taxi route is not validated, as its utility and integration in pilots' tasks is limited when it is from 20 min, as defined in the SESAR concept. The effective support of this information is given when it can be integrated during the arrival briefing done just before TOD (around 45 min before landing), or above FL100 in short-haul context.

The assessment led to the following recommendations:

Operating methods:

> D_TAXI_RTS2016_RecomOps_1: Planned taxi-in route timing:

> It is recommended that the planned taxi-in route is sent earlier than 20min before landing (e.g. above FL100 for short-haul flights and before decent for long-haul flights i.e. about 45min), in order to provide the optimum support and utility to pilots: being able to deal with the information during a phase where workload is lower and to integrate the information in their task (arrival briefing).

Data link message set accuracy and sufficiency:

> The objective remains open as further assessments of the full data link concept (with REVISED TAXI and CONTACT messages) are needed in order to confirm their usability in dynamic environment.

In addition to the recommendations identified separately from controllers and pilots perspectives, dedicated debriefing sessions allowed the identification of common suggestions to guide the future evolution of the concept. The main one concerns with the need to define clear procedures to be applied in a mixed mode environment.

3.4.3.4 SESAR Solution #26 – Manual Taxi Routing

Benefits of Manual Taxi on situation awareness compared to the current operations are overall positive, especially at the gate in static environment, but the insertion of the route by the PM should be easier to not decrease too much SA.

Pilots felt their workload increased with the use of manual taxi compared to the current procedures. The HMI definition maturity and lack of usability contributed a lot to pilots' difficulties in using the system.

The concept of manual taxi is clearly an advantage and a benefit regarding today's operations, especially on complex and/or unknown airport as it provides a visualization of the trajectory and the aircraft position along it. However, it should be associated with an appropriate means to enter it manually in a timely manner, easily and so that it reflects exactly the initial voice clearance.

Besides, other interaction means more user-friendly is to be further studied in the future.

The assessment led to the following design recommendation:

> D TAXI_RTS2016_RecomDesign_1: Manual taxi usability:

> It is recommended to improve HMI and usability of manual taxi route interface in order to decrease pilots' head-down time to insert the route and avoid compromising outside monitoring task.

3.4.3.5 SESAR Solution #48 – Virtual Block Control in LVPs

The investigated Virtual Block Control by means of Virtual Stop Bars has been confirmed to increase the level of safety thanks to an improvement of both pilots' and controllers' situational awareness. Here below the main conclusions collected from both ground and airborne perspectives:

▪ With the Virtual Stop Bars placed in the correspondence of already existing intermediate holding position, no changes are expected in terms of procedures. It means that the same block control

procedures as today will be applied;

- Increase of controllers' situational awareness – the alerting functionality associated to the implementation of Virtual Block Control notifies the controllers about any VSBs infringement (with a positive impact on safety level);

- Increase of pilots' situational awareness – the on-board display of VSBs position and status has been confirmed to support pilots' navigation during surface ground operations especially during low visibility conditions.

The main recommendation collected through the operational feedback regards the implementation of a more dynamic Virtual Block Control by giving the controllers the opportunity to edit "new" Virtual Stop Bars also during taxiing execution. The resulting reduction of block sizes is recommended to be "monitored" by a specific functionality performing a sort of "taxiway conflict monitoring / alerting" notifying the controllers of any occurred "spacing reduction". Therefore, the main objective will be to improve the resilience of airport capacity during low visibility conditions ensuring, at the same, time, the same level of safety.

4 References

[1] **16.06.05 SESAR Human Performance Reference Material – Guidance Edition,** D26, Edition 00.01.01

[2] **16.06.05 Templates for application of the HP Reference Material,** in 16.06.05 SESAR Human Performance Reference Material – Guidance Edition, D26, Edition 00.01.01 – **Appendix B**

[3] **06.07.02 Updated OSED**, D73, 00.01.00, November 2012

[4] **06.07.03 Final OSED**, D10, 00.01.01, February 2013

[5] **06.07.02 Preliminary Validation Report**, D18, 00.00.10, September 2012

[6] **06.03.01 Release 5 Validation Plan**, D148 (Section 4.1 - EXE719)

[7] **06 03 01 Release 5 Validation Report**, D149 (Section 6.1 - EXE719)

Appendix A - Human Performance Issues and recommendations Register

Please refer to the HP Log for detailed information.

Appendix B - Human Error Analysis Register

Three flight crew behaviours have been identified as human errors during the real time simulation of D-TAXI. According to AMC 1309: "*Error is an omission or incorrect action by a crewmember or maintenance personnel...*"

These errors related to HP assessment have been subject to a qualitative study aiming at understanding the nature of errors and identifying appropriate mitigation means.

The first error observed was a **detection error**, which is defined by the fact that the flight crew did not pick the suitable information that would allow properly understanding, planning and executing as expected.

The two other errors observed were **execution errors**, meaning that despite the crew have elaborated a correct plan of actions, they did not apply it properly.

Error #1: detection

Observation:

> **The crew passed the stand 610. At this stage they mainly looked down to the displayed map, and missed the stand 610.**
> Note: The other flight crew almost missed it in the same scenario but realized it at the last moment and turned to the right stand.

Detection and recovery:

> The flight crew detected their error but too late. Once pilots became head-up again, they were taxiing between stands 610 and 611. When they saw the ground marking "611", they realized that they missed the stand 610. They finally parked on stand 611.

Cause:

> Pilots were focused on the airport navigation system and following the taxi path. At this specific moment there was a position discrepancy between the system and the outside view, the system which showing the stand a bit further away than reality. As pilots were both head down and focused on the navigation display, they continued to follow the drawn path and missed the stand.
> Pilots were not completely in usual configuration and task sharing during the evaluation, as the flight crew was composed of one flight test pilot and one flight test engineer. The flight test pilot was endorsing the role of PF and PM. Usual task sharing was not respected and increased the workload of the pilot who tried to perform all the tasks. If he focused on the AMM this may be due to the need to pick information by himself (instead of PM guidance).
> The simulation situation could have led pilots to more focus on the system assessed than in reality.
> Discrepancies between external view and airport moving map may be caused by simulator limitations but also may happen in reality
> Besides the assessment in simulator involves a bias in pilots' concentration which should be reduced in real environment.
> The other flight crew in the same situation almost missed the stand too, but they detected just in time with outside markings and could turn and park at the right one.

Consequence:

No consequence during the RTS as the stand 611 was free.
In real operations possible consequences:

- FC informs ATC and a new routing to the stand 610 is given (if airport layout permits)
- FC informs ATC who attributes a new stand to the aircraft.
- FC informs ATC, a new routing to the stand is not possible and no other stand is free, a tow tug may be required to push back the aircraft until the stand 610.

In any case the Airline may be involved in the decision process on the resolution.

Current mitigation means:

No prevention by the system exists.
However training and attitude permit to prevent this type of errors, as pilots are supposed to do the taxi head-up and not relying on the airport moving map.
Recovery means is the outside view ensured by both pilots which allows reading airport ground markings, and see other aircraft already parked at stands.

Safety criticality:

The consequences mainly concern a lack of efficiency of airport operations.

Proposed means of mitigations

As a result, the application of basic airmanship of ground navigation and procedures should reduce the occurrence of this type of error.

Error #2: execution

Observation:

On a data link departure scenario, one flight crew forgot to change the frequency and to contact ground. They started taxiing (upon taxi clearance given by data link) and were still on the delivery frequency.

Detection & recovery:

The pilot realized his error when he heard a communication of another aircraft dealing with frequency change. Pilot partially recovered the error by changing frequency but he did not contact ATC for radio check.

Cause:

First, it has to be noticed that the situation was preceded by a lot of log-on problems which may have distracted pilots' attention.
Pilots were also less prepared than in reality to the procedures linked to the use of voice and data link, we can expect that in real operations this would not be case. However the use of mixed voice and data link is already confusing regarding which instruction/clearance is given with which means, we can expect that if airports are differently equipped or chose different implementation of messages there might be confusions.
The simulation situation concerning communication was the following:

- the frequency management be voice was done through several sectors
- the data link management through a unique sector all along the airport operations.

When all data link exchanges are made through one sector whereas radio frequencies must be changed it may lead to confusion and errors, as observed.
Besides, pilots were not completely in usual configuration and task sharing during the evaluation, as the flight crew was composed of one flight test pilot and one flight test engineer. The flight test pilot was endorsing the role of PF and PM. Usual task sharing was

not respected and increased the workload of the pilot who tried to perform all the tasks.

Consequences:

Once the data link taxi clearance is received on board, pilots start taxiing whereas they are still on the delivery controller frequency (instead of ground frequency). They are therefore unable to hear ground controller in case of time-critical event (e.g. hold position instruction because of traffic conflict).

Besides it is thanks to the surrounding traffic communication that pilots realized they made an error, in the future with data link communication, this kind of party-line communication will be lost.

Current mitigation means:

Current task sharing (one pilot in charge of the communication) should ensure that one pilot has sufficient resources in nominal situation to not oversight a frequency change.

If operational context is the same as simulated (one sector for data link vs several for voice):

If pilots are not on the correct frequency they anyway monitor the outside view and surrounding traffic behaviour. When approaching a taxiway intersection they may slow down the aircraft if another one is close. If they try to contact ATC to confirm the threat, the controller will answer them that they are connected with the incorrect frequency.

Safety criticality:

The consequence may be linked to a time-critical event not managed because the aircraft was not on the frequency.

Proposed mitigations means:

If operational context is different from the one simulated (several sectors on data link too, with the use of data link CONTACT message): Pilots would be aware of the frequency change in a textual way and corresponding to the operational division of airport sectors, which would reduce the occurrence of error.

With data link and voice use for airport operations, there is a global need of procedures felt by pilots to operate efficiently and with confidence using data link mixed with voice. Like other specific airport procedures, pilots expect to find them on the airport charts. Instructions on specific airport procedures on the data link and voice use would ensure pilots' confidence and efficiency in the communication.

A recommendation from 2013 exists on air/ground procedures and is still applicable:

D_TAXI_RTS2013_RecomOps_1: Mixed-mode management:

It is recommended to define clear procedures to delineate voice and data link use between pilots and controllers, particularly to manage the transitions between the two means of communication (e.g.: when and how to revert to data link after a voice taxi revision), in order to avoid confusion about the current mode of communication and clearances validity.

Error #3: execution

Observation:

One pilot used the message REQUEST TAXI instead of REQUEST EXPECTED TAXI ROUTING to request an expected taxi routing.

Detection & recovery:

Pilot immediately detected it and sent the right request message just after.

Cause:

The expected taxi routing at departure is a new concept and pilots did not really know when

they could request it. It is then first a matter of training. Theoretically, once departure clearance is given pilots could request it to support the departure briefing (as well as the expected route for arrival briefing), but as the simulation focused on taxi phase they would have liked to request it before.

The crew also discovered the associated HMI. and the presence in the list of REQUEST EXPECTED TAXI ROUTING; even if they well understood the concept of planned route, REQUEST TAXI is a message more synthetic and natural to use than EXPECTED TAXI ROUTING, which might have been unconsciously disregarded.

Pilots were obviously less prepared than in reality to the procedures and associated data link messages, we can expect that in real operations this would not be case.

Consequences:

Pilots recovered immediately by sending the correct message and the inappropriate request has not been answered by ATC.

Possible consequences:
- no ATC response
- ATC response is UNABLE or STD BY
- ATC response but as the aircraft was parked at the gate, he could not comply with TAXI instruction (expected taxi routing is just an information for preparation)

Current mitigation means:

Several means of mitigations:
- According to who detects the error, ATC or FC crew manage the issue by voice
- ATC responds to the message by UNABLE or STD BY and coordinate with flight crew by voice.
- FC re-sends the correct message.

Safety criticality:

The consequences mainly concern a lack of efficiency of airport operations.

Proposed mitigations means:

No additional mitigations means with regards to the existing ones are needed to manage the situation.

Several means of mitigations:
- According to who detects the error, ATC or FC crew manage the issue by voice
- ATC responds to the message by UNABLE or STD BY and coordinate with flight crew by voice.
- FC re-sends the correct message.

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