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EMMA2 Recommendations Report

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DLR

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1 Executive Summary

The document provides the most important recommendations derived by analysing the results of the project “European Airport Movement Management by A-SMGCS, part 2” (EMMA2), an Integrated Project launched by the European Commission in its sixth framework programme.

EMMA2 developed a generic operational concept (SPOR, [2]) for higher-level A-SMGCS services, implemented the essential parts of the concept at three European airports, and performed comprehensive trials in simulation and in the field to evaluate the new services.

Multiple higher-level A-SMGCS services and their evaluation in several different test campaigns produced many meaningful recommendations, which will enable future research activities and industrial implementations to take the EMMA2 experiences into account in order not to start from scratch but to seamlessly build upon the large amount of knowledge accumulated by EMMA2.

This document provides the reader with recommendations on the operating procedures, the technical requirements and the operational requirements, and addresses specific recommendations to be considered when implementing higher-level A-SMGCS services.

2 Introduction

The project "European Airport Movement Management by A-SMGCS, part 2" (EMMA2), an Integrated Project launched by the European Commission in its sixth framework programme, was conducted between March 2006 and March 2009 and is the successor project of EMMA. EMMA basically aimed to mature and validate the A-SMGCS concept levels 1&2. The EMMA2 project focussed on higher-level A-SMGCS services, such as planning and onboard guidance.

EMMA2 developed a generic and innovative operational concept (SPOR, [2]) for all higher-level A-SMGCS services including their:

- service description,
- related procedures, and
- operational requirements.

In accordance to this generic concept, new A-SMGCS functions were developed, implemented, and evaluated at three European airports:

- Prague Ruzyne,
- Toulouse Blagnac, and
- Milan Malpensa.

In addition, simulation tools were implemented and simulation exercises were carried out on

- many different control tower and cockpit simulation platforms, and
- test vans and test aircraft.

Results of the validation activities are covered in the site-specific test reports [8], [9], [10], [11], [12], [13] and in the overall "Validation Comparative Analysis Report" [15]. The prevailing document "EMMA2 Recommendations Report" is the concluding EMMA2 document, which aims to make public the most important recommendations that could be derived from the EMMA2 evaluation results. The provided recommendations address the:

- operations of the new A-SMGCS services [4.1]
- technical and operational requirements [4.2],
- validation process [4.3],
- implementation issues [4.4],
- remaining open issues [5].

It should be noted that the recommendations given address different time horizons. There are short-term consequences expected, e.g. with recommendations to the requirements, but there are also recommendations given, particularly within the "implementation issues" section, that address a longer-term and rather uncertain future, which is caused by new and still quite immature services and their complex interaction.

Link to SESAR

In parallel to EMMA and EMMA2, the Single European Sky legislation (SES) launched by the European Commission in March 2004 has set the political frame for actions in Europe to unlock viable growth in air transport. The "technological" part to the legislative packages of the SES, called SESAR, (Single European Sky ATM Research Programme) was established and is proposing a new approach to reform the ATM structure in Europe.

In the SESAR Gate to Gate concept, the airport operations have become an integral part in which the A-SMGCS concept is identified to contribute to the SESAR programme defined in the master plan D5 [20]. The results of EMMA2 as a main A-SMGCS project have to be taken into account and this Recommendation Report, besides the SPOR document [2] and the Analysis Report [15] are to be considered as very important contributions.

3 Summary of EMMA2 Concept and Validation Results

3.1 EMMA2 A-SMGCS Concept of Operations

The 2-D1.1.1 '*A-SMGCS Services, Procedures, and Operational Requirements (SPOR)*' document expresses an extensive and innovative operational concept in terms of a description of:

- higher-level A-SMGCS **S**ervices
- related **P**rocedures, and
- **O**perational **R**equirements.

The concept has its roots in the ICAO A-SMGCS Manual [18] and the results of previous work done in predecessor projects (e.g. EMMA and EUROCONTROL A-SMGCS project). It reflects the opinions, experiences, and requirements of the EMMA2 consortium that is composed of stakeholders coming from the users' side, research and development, and the industry.

In several workshops the stakeholders also identified current problems and constraints with current surface operations. This information was very useful to outline new services and procedures and adapt them to the users' needs. The assessed constraints are further used to derive hypotheses addressing operational improvements as part of EMMA2 sub-project 6 'Validation'.

The EMMA2 A-SMGCS concept document (SPOR), that describes the higher-level A-SMGCS services, procedures, and operational requirements, has been commonly agreed among all project partners as a preliminary and generic concept. It is intentionally kept at a high level with the description of procedures and requirements of the new services, which are partly very immature so far. Hence, the concept admitted the freedom and flexibility to derive different procedural options and technical specifications to be validated in EMMA2 itself or to be validated in ongoing research activities, like SESAR.

There are three main users of an A-SMGCS: Air traffic controllers (ATCOs), pilots, and aerodrome vehicle drivers. In accordance to the requirements of these users the SPOR addressed the following A-SMGCS services:

- **Services to Air Traffic Controllers (ATCOs)**
  - Surveillance
  - Control
    - Conflict Prediction, Detection and Alerting
    - Conflict Resolution
    - TAXI-CPDLC
    - Sectorisation, Transfer of Control, and Co-ordination
  - Routing / Planning
    - Manual Routing
    - Semi-automatic Routing
    - Automatic Routing
    - Departure Management
  - Guidance[1]
    - Ground based Guidance
    - Onboard based Guidance

[1] "Guidance" is mentioned under the „ATCO services" as it is one of four basic A-SMGCS functions: Surveillance, Control, Routing / Planning, and Guidance. However, the real recipients of this service are pilots and aerodrome vehicle drivers, where the ATCO is supported by an A-SMGCS to provide the guidance service.

- **Services to Flight Crews**
  - Airport Moving Map Function
  - Surface Movement Alerting function
  - Ground Traffic Display Function
  - Traffic Conflict Detection Function
  - TAXI-CPDLC
  - Braking and steering cues Function
  - HUD Surface Guidance Symbology Function
  - Ground- Air Database Upload

- **Services to Vehicle Drivers**
  - Airport Moving Map Function
  - Surface Movement Alerting Function
  - Ground Traffic Display Function (Surveillance)
  - Vehicle Dispatch and Guidance by Data Link
  - Remarks on Vehicle Equipage

- **Integrated Human Machine Interfaces (for all users)**

Not all new services described in the SPOR have effectively been evaluated in EMMA2. This report exclusively provides feedback to those services that were assessed in EMMA2 validation activities (cf. §4.1)

3.2 EMMA2 Validation Strategy

The objective of the EMMA2 validation was to assess the potential operational impact of the proposed A-SMGCS Operational Concept (SPOR, [2]) and to explore its performance in terms of complying with the relevant requirements and needs of the stakeholders involved in the ATM. As mentioned above, there were several test platforms and local validation teams in EMMA2. In order to assure the maximum compliance with the E-OCVM and applying a harmonised EMMA2 generic validation strategy, two documents were developed:

- D6.1.1a “Validation Plan” [6] and
- D6.1.1b “Generic Experimental and Test Plan” [7].

These two guideline documents aimed to incorporate the E-OCVM steps into the EMMA2 validation process. They aimed to provide the different validation teams with the essential framework and guidelines for developing their site-specific test plans in terms of harmonised:

- high- and low-level objectives (HLO and LLO),
- metrics and indicators, and
- measurement tools (e.g. EMMA2 operational feasibility questionnaire (QE-OF))

The following figure illustrates this strategy:

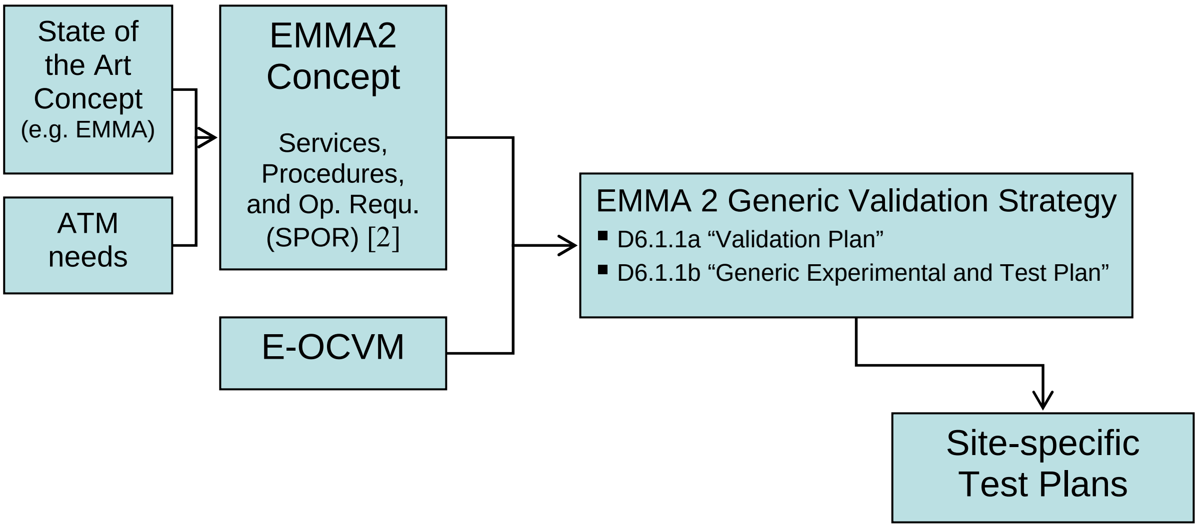

Figure 3-1: EMMA2 Validation Strategy

Planning the validation strategy it had to be considered that all the new higher-level services (mentioned above in §3.1) provide a different maturity, ranging from the "initial idea" to "in operation". Figure 3-2 below represents the E-OCVM maturity model, which was applied for the purposes of EMMA2 to determine the type of validation exercises and assessments that should be performed.

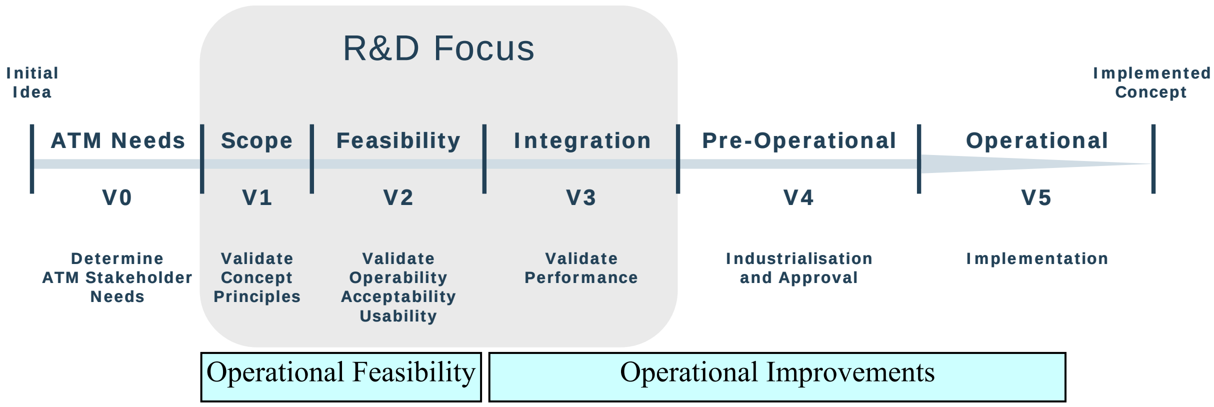

Figure 3-2: Validation stages throughout the life cycle of an operational concept (E-OCVM)

The focus of ATM concept R&D is most applicable to phases V1 to V3 (i.e. from the establishing of the scope of concept validation to integrated performance validation), whereas with level V1 and V2 the validation focus is on measuring operational feasibility and, beginning with level V3, on measuring operational improvements.

Most of the new services, like TAXI-CPDLC or ROUTING, did not reveal a maturity level higher than V2 and thus the feedback gathered was mainly on their operational feasibility. In this validation stage, 204 operational requirements were checked to see if they could be fulfilled from a technical and from an operational point of view, asking the users about their acceptance. The project concluded that nearly all of the operational requirements could be verified (see all results in the operational requirements checklist [9]).

Only when new procedures have been adapted and finally accepted, when the performance of the new service gets the user's acceptance, and when it is well integrated into a sophisticated real-time simulation platform, can operational improvements be assessed. This could be done with DMAN, for instance, that provided a V3 maturity.

3.3 Main Results

The higher-level A-SMGCS services concept was developed, integrated and tested on more than 15 different test platforms by the EMMA2 consortium:

- 5 Tower Simulation Platforms
- 4 Cockpit Simulation Platforms
- 3 European Airports (PRG, MXP, TLS)
- 2 Test Aircraft
- 1 Test Van and several other Test Vehicles

The following table gives an overview about all EMMA2 validation activities including the validation site, the platform, the validation technique and the A-SMGCS service under evaluation.

Validation Site	Validation Platform	Validation Technique	A-SMGCS Service
Paris CDG	DSNA Athis Mons Tower Simulator	Human-in-the-loop Real-time Simulations (RTS)	SCA (A-RSN)
			DMAN
			EFS
Prague Ruzyně	DLR Tower Simulator (linked with the DLR Cockpit Simulator)	Full-scale Human-in-the-loop RTS	EFS
			Route Planning
			DMAN
			TAXI-CPDLC
			Taxi Route Conformance Monitoring
	Prague On-site Platform	Shadow-mode Trials in the Tower test bed	EFS
			Route Planning
			DMAN
			TAXI-CPDLC
			TIS-B (technical)
Toulouse Blagnac	Toulouse On-site Platform	Shadow-mode Trials (linked with the Airbus 320 Cockpit Simulator)	DMAN
			TAXI-CPDLC
			Taxi Route Conformance Monitoring
			TIS-B (technical)

Validation Site	Validation Platform	Validation Technique	A-SMGCS Service
Milan Malpensa	SICTA/SELEX Tower Simulator	Small-scale Human-in-the-loop RTS	EFS
			Route Planning
			SCA
	NARSIM-Tower	Full-scale Human-in-the-loop RTS for Safety Assessment	EFS
			SCA
	Malpensa On-site Platform	Shadow-mode Trials in the Tower test bed	EFS
			Route Planning
			1090 ES ADS-B out
			TAXI-CPDLC
			TIS-B (technical)
Onboard	Airbus A320 Cockpit Integration Simulator	Full-scale Human-in-the-loop RTS (linked via real ATN with the TATM Ground Station)	TAXI-CPDLC
	DLR Generic Cockpit Simulator	Full-scale Human-in-the-loop RTS (linked with DLR Tower Simulator)	TAXI-CPDLC
			Ground Traffic Display (GTD)
			Traffic Conflict Detection (TCD)
	THALES Avionics Simulation Platform	Full-scale Human-in-the-loop RTS	Integrated Moving Map (IMM)
			GTD
			Head-up Display
	TU Darmstadt Fixed-base Research Flight Simulator	Full-scale Human-in-the-loop RTS	Ground-Air Database Upload
			Surface Movement Alerting (SMA)
			TCD
	DLR ATTAS test aircraft	Field trials in Prague Ruzyně and Milan Malpensa	TAXI-CPDLC
			GTD fed by TIS-B
			TCD
	DLR ATTAS test aircraft	Field trials in TLS Blagnac	GTD fed by TIS-B
	FAV Piper Archer test aircraft	Field trials in Prague Ruzyně	SMA
			GTD fed by TIS-B
			TCD
	TU Darmstadt test van	Field Trials in Prague Ruzyně	SMA
			GTD fed by TIS-B
			TCD
	DSNA test vehicle	Field trials in Toulouse Blagnac	Vehicle Moving Map

Table 3-1: Overview of EMMA2 Validation Activities

Several iterative test campaigns were conducted at these test platforms and as a conclusion the following **main results** can be summarised (for more details see document 2-D671 [15]).

Main Results:

- Proof of **technical feasibility**
- User acceptance of new procedures and operational requirements proved the overall **operational feasibility**
- Feedback regarding **204 operational requirements**
- **Improved situational awareness** of controllers, pilots and vehicle drivers
- **Workload maintained** at a moderate level
- **Reduced congestion** of the voice radio channel by TAXI-CPDLC
- **Reduced waiting time** at runway entry points, DMAN provided a 26% overall reduction of taxi time

4 Recommendations

4.1 Recommendations related to the Operations of A-SMGCS Services

4.1.1 Services to Air Traffic Controllers

4.1.1.1 Surveillance through ADS-B and TIS-B Technology

A-SMGCS surveillance is a mature concept that currently utilises Mode S Multilateration (MLAT) technology, for the detection and identification of cooperative aircraft and vehicles, and Surface Movement Radar (SMR) for the detection of all aircraft, vehicles and obstacles. These technologies and the associated requirements have been validated in EMMA and in many operational installations throughout Europe and other parts of the world.

The EMMA2 tests have not led to any recommendations for replacing or improving these current technologies in the short term.

ADS-B
EMMA2 has investigated the use of Mode S ADS-B technology to augment the surveillance function and to provide improved situational awareness for air traffic controllers and other A-SMGCS users.

The findings were that Mode S ADS-B technology as currently specified in DO-260A [19] **may <u>not</u> meet the needs of A-SMGCS**.

- In order to be useful for A-SMGCS applications, ADS-B will need to meet the requirements of A-SMGCS, in particular with regard to position accuracy, update rate, latency (timeliness) and integrity. Adequate coverage and continuity of service needs also to be ensured.
- Line-of-sight coverage is needed, which means that multiple ADS-B receiving stations will be required to provide complete coverage of the entire manoeuvring area of an aerodrome.

a) It is recommended that the EUROCONTROL CASCADE OFG and EUROCAE WG-51 working groups take heed of the A-SMGCS performance requirements in their current work on ADS-B APT and ATSA-SURF.

b) The use of portable Mode S squitter beacons is recommended for surface vehicles.

TIS-B[2]
EMMA2 has investigated the use of Mode S TIS-B technology to augment the surveillance function and to provide improved situational awareness for pilots and vehicle drivers (cf. results in document 2-D671 [15]).

The TIS-B ground system equipment demonstrated technical maturity and operational feasibility. For the on-board side, it is important to ensure that requirements for avionic equipment capture the level of integrity and timeliness needed to provide true situational awareness in the rapidly changing aerodrome surface traffic environment.

Additional observations and recommendations for TIS-B:

a) Requirements for update rate and timeliness of information transfer need to be ensured.

[2] TIS-B is a service to pilots and vehicle drivers, not to ATCOs. This section addresses only the ground station part of the TIS-B service. Refer to section 4.1.2.2 “Ground Traffic Display” for services to flight crews.

b) Adequate coverage and continuity of service needs also to be ensured.
c) Line-of-sight coverage is needed.
d) More than one TIS-B antenna and transmitter is likely to be required to provide complete coverage of the entire manoeuvring area of an aerodrome.
e) Be aware that MLAT systems installed prior to 2005 may not be able to distinguish between ADS-B and TIS-B messages. This would result in two problems:
   - The jumping target problem, when targets are detected by the MLAT system both at their real position and at the position of the TIS-B transmitting antenna, and
   - in the loop-back problem, when targets detected by the MLAT system are processed by the SDF and transmitted by the TIS-B system, and then again received by the MLAT system, causing a continuous loop. Steps must be taken to address this problem.

4.1.1.2 Electronic Flight Strips (EFS)

Using the higher-level A-SMGCS services requires proper human-machine-interfaces (HMIs), that is, properly represented system output and proper input devices. Beside the traffic situation display (TSD) electronic flight strips (EFS) were demonstrated to play an important role here. EFSs provide a means to operate the new A-SMGCS services by displaying the system output and allowing the ATCO the necessary interaction. Well-designed human-machine interfaces are an absolute pre-condition for a safe and efficient handling of the new A-SMGCS services.

Beside the operational HMI requirements compiled in the SPOR document (§4.12, [2]), the following recommendations should be considered when developing EFS systems:

a) Follow a user-centred approach with a sufficient number of iterative validation loops!

b) Benefit from well-tried paper strips by modifying as little as possible the operating methods and workflow, BUT be also sufficiently open-minded to exploit the new opportunities electronic strips can provide and fit them to the current needs!

c) Even when not all higher-level services are used in the beginning, the EFS design should be made flexible enough to easily adopt higher-level services at a later stage (e.g. dealing with data link clearances).

d) Still valid and still of utmost importance: Keep the need for controller interaction to an acceptable minimum!

e) The information shown in the different fields of a flight strip should always be represented at the <u>same position</u> on the strip independent of the life-cycle of the strip and independent of the controller working position at which the strip appears.

f) Ensure that the movement of each flight strip is under the full control of the controller responsible for the flight.

4.1.1.3 Conflict Prediction, Detection and Alerting

With the introduction of A-SMGCS level 1&2 concept an alerting function relies on surveillance data. With the introduction of A-SMGCS services beyond the level 1&2 concept– and in particular with the introduction of the input of clearances via e-strip – the behaviour of the movements is monitored to check if they do what they are supposed to. Further on, the set of clearances provided at the same time on an airport is to be cross checked in order to ensure that the set of instructions provided is consistent. In EMMA2 both a surveillance-based E-SCA (Enhanced Situation Conflict Alerting) and an Advanced Runway Safety Net (A-RSN) were tested.

E-SCA was tested in support of a safety assessment, which is considered in Section 4.4.5. Based on the safety assessment, the following recommendation is made:

a) When implementing a system that provides runway incursion alerts to the controller, it is recommended to be cautious in consuming its potential safety benefit by e.g., introducing a change in the operation or allowing a capacity increase. The positive effect of runway incursion alerts in good visibility conditions appears to be limited, as in good visibility conditions the time needed for conflict alerting, controller reaction and R/T is very often larger than the time needed for the pilots to detect a runway incursion situation themselves.

The A-RSN is based on an electronic flight strip (EFS) environment. The A-RSN was integrated in an environment already using a basic surveillance-based runway safety net (B-RSN). In that context, the A-RSN adds a safety layer to the B-RSN by taking into account the instructions given by ATCOs, which are processed via EFS inputs. The A-RSN is considered as an add-on to the B-RSN. The A-RSN detects aircraft in the Runway Protection Area (RPA) whose behaviour is incompatible with the instructions given by the ATCO.

The advantage of an A-RSN is twofold:

- it improves the anticipation of conflict detection through the processing of instructions issued by the controllers; and
- it is designed to complement a B-RSN in an airport already provided with a well configured one, thus improving the runway safety net capability without having to configure entirely a new system.

The following recommendations should be considered when developing an A-RSN:

b) Although the implementation of an A-RSN can be rather simple, the design of the EFS (interaction means for the ATCO) shall be elaborated enough to allow applying working methods in use so as not to reduce the A-RSN capabilities.
   - *If the system does not allow the input of necessary information (e.g. conditional clearance: such as a line-up behind another aircraft on the same runway), nuisance alerts are triggered that may diminish the A-RSN utility and acceptability.*

c) Use A-RSN in conjunction with A-SMGCS level 1 information.
   - *Alerts cannot be triggered with control instructions only. Surveillance data seem necessary to determine the distance between the aircraft and/or vehicles and their relative position.*

d) Display the alert in a way that allows controllers to easily understand the situation. For instance, one should avoid:
   1. False and nuisance alerts, creating doubt.
   2. Incoherent display on EFS HMI and traffic situation display (i.e. alert times or alert levels).
   3. Situations involving more than two aircraft in alert.

e) Regarding the introduction of an A-RSN in an operational context, follow a stepwise approach.
   - *Assessing together a whole set of alert situations makes the evaluation rather difficult. It would seem more effective to implement one or two rules at a time (in a prioritised order locally defined), make them work for some months, and then progressively add other rules. The most frequent cases of runway incursions are caused by movements entering the runway without authorisation. Those should be given priority while considering controllers' own experience.*

f) The definition of speed test areas around each holding point can improve anticipation of unauthorised stop-bar crossing[3].
   - *Speed test areas are meant to improve anticipation of runway incursion. The test is designed as a pre-alert phase to complement the A-RSN by providing alerts on aircraft approaching stop-bars and risking crossing them due to their speed and without authorisation.*

g) The same rules of alerting might not be applicable for both mixed-mode runways and single-mode runways. Further assessment would be necessary to provide information on that issue.

4.1.1.4 TAXI-CPDLC

Data link communication for surface movement control (TAXI-CPDLC) is a quite promising new service, whose complex operational nature is still not fully validated. However, EMMA2 performed several intensive validation trials that revealed meaningful results and recommendations both for pilots and ATCOs. This section focuses on the ATCO side, §4.1.2.4 on the onboard side:

a) From an operational point of view, consider data link communication for surface movement control (TAXI-CPDLC) as a very promising service that could be made operational in the not too distant future, solving safety and efficiency problems associated with the anticipated increase in traffic.

b) An easy to use HMI, which for each flight regards the current operational state and automatically proposes the next clearance to be issued and transmitted via TAXI-CPDLC, is strongly recommended to keep manual interaction at a minimum and to assure the ATCO’s acceptance.
   - *Consider that an ATCO has to provide clearances to several pilots within a short timeframe, and thus will not be able to type in clearances or select clearance elements from menus. An easy-to-use selection menu might be provided only for the exception that an ATCO has to transmit an alternative clearance.*
   - *In EMMA2, it was proven that an appropriately designed EFS can provide the required functionality.*

c) A highly sophisticated and responsive routing function, that is able to cope with all operational circumstances in order to provide the ATCO with the right taxi route, whenever called upon, is an absolute must to keep manual interaction to a minimum and to get the ATCOs acceptance to transmit taxi routes by TAXI-CPDLC.

d) Handover instructions to the cockpit can easily be transmitted by data link but, in any case, adhere to the pilot’s initial voice call with each R/T frequency change in order to guarantee that voice can be used as back up.
   - *However, think about technical means assuring that voice communication is established as back up. This would further relieve the user’s workload and the voice channel congestion.*

e) What data link instructions/clearances are supported by the ATCOs from an operational point of view?

   1. See START-UP, PUSHBACK, TAXI-in, TAXI-out, and the HANDOVER clearances/instructions as the most promising ones to be used operationally.

[3] It should be noted that an A-SMCGS, as currently defined, is not able to give an accurate estimate of an object's speed and direction, particularly if the object is stationary, moving slowly, or changing speed or direction.

2. REVISED TAXI; Taxi route updates by data link while the aircraft is taxiing was tested and showed its potential but needs further testing and procedural adaptation to fully validate it.

3. Perform further investigation with the time-critical clearances such as CROSSING, LINE-UP, TAKE-OFF, and LANDING, to fully validate or reject them (cf. also g) below).

f) Voice communication remains the primary communication means. Particularly in abnormal, complex-, safety-, and time-critical situations, rely on voice as a very efficient communication means in a first implementation step, but:

g) For time- and/or safety critical clearances investigate the procedure sending data link clearances in parallel to voice communication, e.g. for purposes of crossing clearances. This would allow using voice in safety-critical situations but would also keep the onboard system informed about ATC instructions.

h) Do not anticipate major constraints with a mix of TAXI-CPDLC and voice communication for different phases of a single flight and a mix of equipped and non-equipped aircraft - it did not lead to confusion and safety critical communication errors.

i) Check the real-life technical feasibility of the VDL-2 and ATN data link solution with more than one equipped aircraft.

j) When performing further validation activities: Use always a complete experimental setting including both ATCOs in a tower and pilots in a cockpit environment in order to be able to derive reasonable results based on a complete communication loop.

4.1.1.5 Routing / Planning

4.1.1.5.1 Routing

From an EMMA2 perspective, routing is not a real service. ATCOs have no problems to mentally process the right taxi route within fractions of a second. It is more an enabler for higher-level A-SMGCS services like TAXI-CPDLC, safety nets, or DMAN by what all A-SMGCS stakeholders benefit from. Important is that the cleared taxi route is made available within the system without major extra expenses by the ATCO.

Beside the operational routing requirements compiled in the SPOR document (§4.8, [2]), the following recommendations should be considered when developing and implementing a routing service:

a) ATCOs have to be strongly involved in the definition of the pool of taxi routes and which taxi route should been assigned by the automation depending on all different operational situation.

b) When alternative taxi routes are to be selected out of a menu, privilege and give priority to standard or most common taxi-routes.

c) Preferably enable working with the routing service both via the traffic situation display (TSD) and the EFS.
   - *Some of the interactions like route selections, changes, or display, can be operated more efficiently via the TSD, other via the EFS human-machine interface.*

d) Guarantee high accuracy of start and end point of the route, in order to better enable other services like “route deviation alerting” that depend on the information.

e) Design the routing function that it takes into account surveillance information in order to detect the current position of the aircraft or vehicle and to define the start point of the taxi route (e.g. automatic detection of RWY exit for landing aircraft).

f) Plan a routing service able to give partial routes, if ground-taxi control is shared by more than one ATCO. Each ATCO will then receive only the required information.

4.1.1.5.2 Departure Management (DMAN)

In EMMA2 a DMAN provided the ATCOs with DMAN-computed flight plan data, to support the ATCO to better time and sequence the outbound traffic. DMAN times like a target start-up approval time (TSAT) or/and a target take-off time (TTOT) were shown in the electronic flight strips. Additionally the sequence number, proposed by DMAN, was always displayed for each outbound flight.

The ATCOs liked this additional information and admitted that it would help them to plan the outbound traffic more efficiently, to avoid excessive queues at the runway holding points and to shorten the stop times during taxiing. In a simulation environment, stop times during taxing in a departure peak time could significantly be reduced from an average of 1:33 to 1:09 minutes, which correspond to a **26% reduction of stop times** [15].

Nevertheless, the DMAN could only show portions of its anticipated benefit. To exploit the full benefit in the near future, the following recommendations should be considered:

a) Consider a DMAN as most beneficial under conditions of extensive departure peaks.

b) Plan to integrate the DMAN into a CDM environment, which would enable the DMAN to work with a broader planning horizon, which would of course also improve the DMAN planning output.
   - *For instance, within CDM the TOBT information is more reliable. This improves DMAN optimisation and also sequence stabilisation.*

c) Take into account that a considerable amount of time is needed to adapt the tool to the particularities of the concerned airport and its local procedures (e.g. runway configuration, intersection take off- and de-icing procedures, helicopter operations or pushback constraints).

d) Keep the DMAN always informed about the current operational status of each flight (e.g. pushing back or taxiing) by information provided by the surveillance and clearance inputs of the ATCO.

e) Consider TSAT as the clearance delivery controller’s most important planning element to initialise and implement the DMAN-planned outbound traffic.

f) Consider TTOT and the sequence number as the ground and runway controller’s most important planning element to implement the DMAN-planned outbound traffic.

g) Display TSAT and TTOT information so that it is accessible to controllers at a glance.

h) Use colour-coded “Recommended Time Until next Clearance” (RTUC) information to support the ATCO to implement the DMAN-planned outbound traffic.

i) Clearly highlight slotted flights (e.g. colour-coded) so that they can be easily distinguished from other flights.

j) A DMAN should consider spatial pushback constraints.
   - *If a DMAN plans pushbacks of two flights at the same time and their pushback tracks are spatially not independent of each other, both flights cannot be pushed at the same time and one of those two aircraft will be delayed in accordance to the DMAN planning. The DMAN adapts its planning to this circumstance after the pushback has been performed but this dependence should be considered with the initial planning.*

k) A DMAN should consider whether a pushback procedure is needed or not.
   - *Usually there are nose-in stands at the terminals that always need a pushback. There are also remote stands from which aircraft start taxiing without the need for a pushback, but there are also remote stands that need a pushback, whereas jet aircraft would require a pushback while turbo-props can perform a power back procedure and can commence taxi on their own without a push-back procedure.*

l) A DMAN should consider stand allocations.
   - *For instance, a departure flight, which is held back at the stand because no free runway slot is anticipated, may cause stand conflicts with an arrival flight that is planned to park at this stand.*

m) Besides the wake vortex category of aircraft ("heavy", "medium", and "light"), a DMAN should also consider the aircraft type.
   - *Particularly jets, in contrast to props, which can belong to the same WVC, but have different flight performances like take-off speed and climb rates, influence the decisions of the ATCO to sequence the runway traffic and thus should also be known to a departure manager.*

n) Consider a "what-if assessment option" in order to get an impression of the consequences of a change of the initially planned outbound sequence.

4.1.2 Service to Flight Crews

4.1.2.1 Surface Movement Alerting

This section deals with recommendations about surface movement alerting in the cockpit. The function can be used in two modes. When TAXI-CPDLC functionality is not available, the function uses only D-ATIS/NOTAM information. In case TAXI-CPDLC is available, the function uses clearance information to enable a more precise alerting scheme.

a) The status information about runways and taxiways that should be provided to the crew is:
   - *Active runway direction.*
   - *Closed or partially closed runways and taxiways.*

b) The information stated in a) should be visually available to the pilot directly on the Electronic Moving Map (EMM) to minimize the workload.

c) The crew should get a visual indication when approaching a runway: this indication shall include the active runway direction.

d) The crew should be alerted in case they try to land on, start on or cross a runway which is completely closed or closed respectively for landing or starting. The alert should come early enough to give the crew time to change their course.

e) In case TAXI-CPDLC is available, the crew should be alerted when trying to enter a runway without the corresponding clearance.

f) The alerts described in d) and e) should be in keeping with the general alerting scheme in the cockpit, associating visual alerts on both the navigation display and the primary flight display (PFD) as well as aural alerts corresponding to master caution and master warning alerts.

4.1.2.2 Ground Traffic Display

This section deals with recommendations about ground traffic displayed on the moving map. The function strongly relies on the quality of received traffic data from ADS-B or TIS-B systems. The function will be useless and even hazardous if the accuracy of the traffic data (position, heading, ground speed, etc…) is not sufficient (see also chapters 4.1.1.1and 4.1.2.3).

a) The traffic information that should be provided to the crew is:
   - *the position, the heading and the ground speed indications to allow pilots to anticipate potential conflicts.*
   - *the call sign and the type of each traffic because it facilitates the communication with ATC.*

b) The displayed traffic symbols should be bigger than or equal to the real traffic size to prevent pilot using the system to misinterpret the distance between the own aircraft and other traffic.

c) A mere traffic display is not sufficient. The conflicting traffic should be highlighted on the map.

d) The traffic filtering should be a corner stone to the success of the traffic display function. Particularly, the traffic filtering should be compliant with operational needs and not saturate the map display. Basically, the movements that should not be displayed are:
   - *aircraft or vehicles behind the own ship*

- *aircraft or vehicles in front of the own ship but located after a certain safety distance (this distance depends on the way the own ship is located on: taxiway or runway, however, it must be paid particular attention to a pop-up effect: the movement appear suddenly on the moving map)*
- *parked aircraft or vehicles*
- *The vehicles that have not priority on the aircraft unless they may conflict with the own ship*[4]

4.1.2.3 Traffic Conflict Detection

The Traffic Conflict Detection (TCD) function was successfully tested. Pilots agreed that the Traffic Conflict Detection function is capable of being used appropriately on the surface movement area. The visual warnings presented on the EMM and on the PFD as well as audible warnings attracted the pilots' attention in case of traffic conflicts. The chosen HMI for the alerting was deemed intuitive, easy to interpret and acceptable by the pilots.

In the TCD trials three different data source configurations were exploited:

- *TIS-B data only (fed by the A-SMGCS ground surveillance function, based on MLAT, SSR and SMR)*
- *ADS-B data only*
- *both TIS-B and ADS-B data*

The result was that ADS-B data alone could not meet the needed accuracy to reliably detect potential conflict situations.

Further recommendation could be derived from the test results:

a) As long as the accuracy of ADS-B does not meet the A-SMGCS performance requirements it is recommended to use only TIS-B or TIS-B and ADS-B data together.

b) It is recommended to implement an intelligent traffic filter onboard in order to limit the traffic amount to those aircraft and vehicles that might enter into a conflict with the own-ship, i.e. traffic in the vicinity. Such a filter would prevent overloading the onboard TCD function with irrelevant traffic that could delay the TCD processing.

c) When solving a conflict there is always the risk to enter into another conflict (secondary conflict). In order to avoid such secondary conflicts intelligent resolution software shall be used.

d) It is recommended to further develop a harmonised safety net, which exploits best the co-existence of on-board or/and ground detected conflicts, and to bring it to a regulatory basis.

4.1.2.4 TAXI-CPDLC

Expect Routing Information:

a) The "expect routing" information enables the crew to anticipate the preparation of the taxi phase if information is provided timely and is reliable enough. In particular for taxi-out, it is thus recommended to receive onboard the EXPECT message with the departure clearance, either following pilots request or not, to have enough time to prepare the future taxi-out phase.

[4] For instance, if the received traffic information is conformed to DTIF format defined in ARINC 735B specifying if a surface vehicle is a service or an emergency vehicle, service vehicle could be hidden where as emergency vehicle should be displayed.

b) Moreover, it is recommended to continue assessment to consolidate the need of EXPECT message in taxi-in phase by defining a scenario initialized before the initiation of the descent phase, including specific features such as the simulation of agreement between controllers and pilots about the runway exit after ATIS reception or by coupling the CPDLC ground clearances with a function like BTV.
   - *The feasibility of such function depends also on the availability of “ground forwarding” between the Approach and Airport Control centres (SWIM concept).*

Taxi route clearance:

c) In order to reduce frequency congestion and misunderstandings between pilots and controllers that could possibly lead to critical events, it is recommended to support the flight crew during surface movement operations thanks to TAXI-CPDLC taxi clearances and their associated display on the airport moving map.
   - *However, different implementation steps may be envisioned to comply with the TAXI-CPDLC service according to the constraints imposed on onboard and ground sides. It is recommended to further determine which steps should be relevant, with regard to the global operational procedure which is under definition.*

Mixed mode communication:

d) The priority of voice over datalink communications was assessed and recognised as fundamental. Indeed, it is recommended to carry on datalink communication in case of long term revision/traffic management whereas voice should be used in case of short term revision/traffic management.

e) Therefore, to handle appropriately the voice/datalink switch, it is recommended that there should be a procedure that imposes the ATC to address the aircrew on the voice frequency to make clear that the ATC intends to deliver messages in voice when previous exchanges were in datalink and to disregard the previous relative message, which is invalidated. Afterwards, when switch back to datalink is envisioned, it is recommended that there should be a procedure that imposes the ATC to address the aircrew on the voice frequency to make clear that the ATC intends to deliver messages through datalink.

f) In particular, it is recommended to further assess the appropriateness of voice phraseology used for a switch from datalink to voice to clearly invalidate a previous datalink clearance when voice is required. One proposal for the phraseology would be to start voice exchange by "DISREGARD CPDLC <xxx> message", where <xxx> stands for the invalidated clearance (e.g. Taxi).

Runway clearance management:

Trials also provided feedback to time-critical runway related clearances and thus to the impaired party line effect.

g) Therefore, it is recommended in a first step to use voice as a primary clearance delivery means for runway.

h) Nevertheless, it is recommended to deliver the datalink version of the voice clearance related to runway to ensure graphical consistency. Since the runway clearance would be handled through voice and the associated datalink message would only aim at supporting graphical consistency, it is recommended that the runway clearance should be acknowledged only through voice radio to limit pilots’ workload.

i) Considering the previous output, further testing of runway related data link clearances should be performed.

Operational timer:
The operational timer related to datalink message may be seen as a reminder for a dialogue still open.

j) It is recommended to provide a feedback on a datalink message without answer in order to prevent that a data link dialogue becomes open-ended.

k) Besides, it is recommended to envision different timer values according to the datalink messages category (short/easy to understand vs. long/hard to understand assuming the answer could be provided as soon as read, but not analyzed) to prevent systematic time-out. Therefore, it is recommended to perform trials to define convenient value for main cases, assuming the answer could be provided as soon as read, but not analyzed.

l) Further on, it is recommended to define a procedure related to the expected behaviour in case of datalink message time out (e.g. switch to voice).

Information to be shared between ATC and flight crew:
The TAXI-CPDLC service relies on the exchange of taxi route related information between the ATCO and the crew. To provide a safe and efficient service, it is then recommended that:

m) both ground and cockpit systems integrity should be guaranteed and that the databases for routing should be shared between ground and onboard .

n) Moreover, the provided data should be defined in such a way that it enables the graphical system to represent the complete seamless trajectory.
   - *For instance, if the voice phraseology and taxi way designations currently used were directly transferred into datalink messages, ambiguities would quite often prevent the onboard system to recreate a complete seamless trajectory. Phraseology and shared data between the flight crew should be based on logical routings with logical nomenclature.*

Procedures and messages:
Preliminary procedures can be envisaged; though several open points need to be further studied. A proposal further to all trials done is presented in the airborne validation reports [12] [13] and a PowerPoint presentation [14]. The documents also provide the list of messages recommended as technical enablers for standardisation.

Open issues:
Some general issues need to be addressed in order to enable these new services:

o) Deployment on airports should be harmonised in the sense that services should be “clustered”: On-board procedures cannot change drastically from one airport to another (counterpart of the handling of “mixed’ equipped/non-equipped traffic for the controller).

p) It has to be noted that for the same reasons, the list of possible messages should be concise and unambiguous (one purpose / one type of message).

q) The onboard procedure should not differ from airport to airport.

r) The cockpit HMIs should remain intuitive.

s) Ground forwarding/SWIM concept is needed for the taxi-in.

t) Further studies should be conducted on the capacity with nominal and high number of users on the network. If risks are identified, means different from TAXI-CPDLC could be studied in order to be able to cope with network capacity.

4.1.2.5 HUD Surface Guidance Symbology

A head up display (HUD) turned out as a very promising tool to support the taxiing pilot to navigate and steer the aircraft along its cleared taxi route, particularly in very adverse sight conditions. A HUD increases the pilots' local situation awareness by emphasising the outside view and providing of additional information, which are superimposed on the real outside view, e.g. the edges of taxiways or other traffic. The following information should be displayed on the HUD:

a) The name of the current taxiway the own ship is taxiing and the name of the taxiway connected to the current taxiway[5].

b) SMA indications concerning the runway should be displayed on the HUD.

c) The taxi route should be displayed in a conformal way in the HUD. The expected route should not be displayed.

d) The border symbols of the taxi route should be inside the real pavement.

e) The distance between consecutive border symbols should be normalized in order to help the pilot to estimate its ground speed and the distance to another aircraft.

f) The ground speed should be indicated on the HUD. Over-speed indication should be visible (closer to the pilot vision area) or a vocal alert should be attached to over-speed.

Particularly for large aircraft, HUD surface guidance symbology (SGS) should provide specific means to not taxi off the pavement into the grass:

g) A 2D top sight view should be displayed inside turns or near the end of the cleared route particularly for large aircraft to help pilots to keep their wheels on the pavement. Indeed, in sharp turns, all conformal symbols defining the taxi route may disappear for large aircraft. The 2D top sight view should pop up with a smooth transition.

h) The end of the cleared taxi route should be indicated by conformal stop symbols and should be indicated in the 2D top sight view.

i) Specific symbols to help the pilot to taxi its aircraft on taxiways should be displayed on the HUD. These guidance symbols should be filtered in order to maximize the usability of the guidance without loss of accuracy concerning the aircraft taxiing. Anticipation indications should not interfere with guidance ones. Indeed, pilots shall interpret in the same time two different cues (anticipation and guidance) and they do not know which one they shall follow up.

4.1.2.6 Ground to Air Database Upload Function

The following main recommendations about a ground to air database upload function shall be mentioned:

[5] If a taxi route is digitally available, only most important taxiways connected to the route should be displayed in order to not saturate the Head-Up-Display.

a) D-ATIS/NOTAM Information concerning the status of runways and taxiways of the origin, destination and alternate airports should be electronically available in the cockpit. The active runway direction and closed or partially closed runways and taxiways are the most relevant information.

b) The crew should have the possibility to interact with the uploaded information: changing the status of a given runway for example. The MCDU has proven to be a good means for this interaction.

4.1.3 Service to Vehicle Drivers

Since every equipped car broadcasts its GPS position, it is proposed to display this position on a moving map in order to enhance the situational awareness of drivers. Besides displaying the vehicle position, the device is meant to trigger an alert when the vehicle infringed a restricted pre-defined area.

The following recommendations are to be considered when implementing service to vehicle drivers:

a) Ensure that the system accommodates every speed and direction necessary for operational use.

b) Ensure that the alerting system triggers alerts at incursion of restricted area.

c) Ensure that the equipment is easy to install.

d) Check that boot time is quick.

e) The design of the map should be carefully considered so that HMI usability requirements are met (e.g. use of colour, information readability, thickness of the lines…).

f) Ensure the timeliness and integrity of the information presented.

Two types of drivers are to be distinguished:

- regular drivers, who know the airport very well, use cars that are permitted to drive on taxiways and are equipped as such; and
- occasional drivers, who are authorised to drive on the airport but mostly, have a dedicated mission (i.e. they do not do this frequently).

These two kinds of users may have different needs. When regular drivers know the airport well, they seem to particularly need a moving map display in low visibility conditions. But they would remain very reluctant to use it in low visibility if the surrounding traffic is not displayed. Occasional drivers would need a moving map display in any visibility condition, but the system would have to be portable and for plug-in use in order to be able to equip all cars equally. Regarding occasional drivers, be aware that the use of a moving map will not improve their knowledge about the airport or its layout.

4.2 Recommendations related to Technical and Operational Requirements

The EMMA2 project generated a generic set of operational and technical requirements for higher-level A-SMGCS. Where possible and relevant, these requirements were derived or extracted directly from the source documents from ICAO, EUROCONTROL, EUROCAE and RTCA. The operational requirements were the parent requirements for most of the technical requirements.

A series of exercises has been carried out to verify different subsets of the requirements, both in simulation and during the on-site tests.

In some cases, it has been found that the operational requirements, which mostly originate from the ICAO Doc 9830 Manual of A-SMGCS [18], appear to be inadequately or imprecisely defined, or defined so stringently that implementation costs would become prohibitive. This was not the case with the EUROCONTROL and EUROCAE requirements, which are more recent and address only A-SMGCS Levels 1 and 2. Most of the latter requirements were already validated during the EMMA project. The requirements in Doc 9830 were written before A-SMGCS was widely implemented and they have not been validated outside of EMMA.

Recommendations for Update of ICAO Doc. 9830

The EMMA2 consortium recommends that **EUROCONTROL approach ICAO to take action to revisit Doc. 9830 Manual of A-SMGCS** and, where necessary, to modify the relevant requirements. In particular, the following paragraphs should be modified or in some cases suppressed:

a) 2.5.2.3. This paragraph proposes a function for automatic calculation and assignment of a route. The EMMA2 consortium is of the opinion that route assignment should be done manually by the controller on giving the taxi clearance. The routing tool may calculate and propose a route automatically but, since there is always a requirement for human monitoring and a manual override of the function, the routing function should only be considered as having two modes of operation: “manual” or “semi-automatic”. We recommend ICAO to modify the paragraph accordingly.

b) 2.6.9.4. This paragraph states that an A-SMGCS should be restartable with a recovery time of a few seconds. No rationale is given for this requirement but presumably it refers to the restart of automated parts of the A-SMGCS, i.e. items of equipment. While it is understandable that rapid recovery after an equipment failure is desirable, modern computer systems (commonly employed for A-SMGCS and other ATM applications) require up to several minutes to boot up. Employing redundant configurations to ensure that no single failure can cause the loss of vital functions provides mitigation in the event of failure. In the unlikely event of simultaneous multiple failures, contingency procedures need to be applied to safely handle traffic until normal service is restored. Once a system has failed to this extent, a recovery time of a few minutes should not be significant. We therefore recommend that ICAO relax this requirement.

c) 3.4.1.15 This paragraph suggests that a longitudinal accuracy of at least 20m is needed but it makes a recommendation for 6m accuracy. This is not entirely consistent with the ±7.5m requirement in §4.2.3 of the same document (see below).

d) 3.4.5.2. This paragraph is identical to §3.4.4.2 in the same document. We recommend ICAO to delete it.

e) 3.5.7.1. This paragraph recommends the use of a common A-SMGCS position reference point on aircraft and vehicles (but not other objects?) and lists four possible alternatives. We recommend ICAO to standardise on a single common reference point, namely the mid-point of the longitudinal axis.

f) 4.1.1.2 and 4.1.1.3 on Safety. These paragraphs provide target levels of safety that at best are only rough generic guidelines. We recommend that the paragraph be suppressed to avoid possible misunderstanding or misuse. Safety requirements can only be established through a thorough safety assessment of each A-SMGCS site. In addition, a continuous safety assessment process must be established to ensure that safety is maintained as traffic levels increase and as the airport and the A-SMGCS evolve.

g) 4.1.1.8. This paragraph sets a speed accuracy requirement of ±2km/h (1kt), which no existing A-SMGCS surveillance is able to achieve. No rationale is given for this requirement, and it is inconsistent with the position accuracy requirement of ±7.5m (§4.2.3) at the required update rate of once per second (§4.2.4). In practice, the achievable accuracy needs to be related to the speed of the object being tracked. The stated speed accuracy may be achievable for targets moving at steady speeds greater than about 15kt, but at lower speeds the requirement must be relaxed. Alternatively, a more exacting figure for overall position accuracy (e.g. ±0.5m) and/or a higher update rate needs to be specified.

h) 4.1.1.10. This paragraph sets a direction accuracy requirement of ±1°, which no existing A-SMGCS is able to achieve. No rationale is given for this requirement, and it is inconsistent with the position accuracy requirement of ±7.5m (§4.2.3) at the required update rate of once per second (§4.2.4). In fact, the achievable accuracy needs to be related to the speed. The stated speed accuracy may be achievable for targets moving at steady speeds greater than about 15kt, but at lower speeds the requirement must be relaxed. Alternatively, a more exacting figure for overall position accuracy (e.g. ±0.5m) and/or a higher update rate needs to be specified.

i) 4.2.3. The first sentence of this paragraph sets a position accuracy requirement of ±7.5m. The EUROCAE ED-87B MASPS document specifies ±7.5m on the manoeuvring area and ±12m on apron areas (both with a 95% confidence level). Furthermore, the MASPS states that for airborne aircraft arriving or departing the aerodrome, the position and speed requirements can be relaxed to those of the approach surveillance radar system. We recommend that ICAO either suppress the paragraph or harmonise with the EUROCAE requirements.

j) 4.2.3. The second sentence of this paragraph sets a height accuracy requirement of ± 10m, which is more stringent than the requirement for current barometric altitude measurement equipment on-board aircraft. No rationale is given for this requirement. Downlinked altimeter information (Mode C) is the usual source of height information for existing A-SMGCS. A-SMGCS users (tower controllers) are generally not concerned to know the exact height of aircraft, only to know whether they are arriving or departing, airborne or on the ground. Normal barometric altitude information combined with "weight-on- wheels" indication is perfectly adequate for this. We recommend ICAO to change the requirement to ± 25m.

k) 4.2.4. This paragraph sets an identification update rate requirement of once per second, which is inconsistent with the current performance requirements for aircraft transponders from which the A-SMGCS receives identification information. No rationale is given for this requirement. With current technology, it is not possible to achieve an update rate of once per second for confirming the identification of stationary aircraft. This is because the on-board Mode S transponder automatically selects 'low squitter rate' (4.8s - 5.2s) when the aircraft is stationary on the ground. The identification information output from the A-SMGCS can still be updated once per second but the confirmation from the transponder will only be received every five seconds. We recommend ICAO to change the requirement to once every 10 seconds, which EMMA2 controllers believe is sufficient.

l) 4.3.1. This paragraph sets failure rates for the routing function. Since no rationale is given and no corresponding failure rates are given for other elements of the system, we recommend ICAO to suppress the paragraph.

m) Appendices A-E. The information in these appendices is outdated and we recommend ICAO to remove them.

4.3 Recommendations related to the Validation Process

Validation of operational concepts should be considered as an integrated element of their development and refinement with the objective to verify their feasibility, acceptability and contribution to achieve defined performance objectives. The European Operational Concept Validation Methodology (E-OCVM) describes a standardised approach to concept validation for European projects which was also implemented by the EMMA2 project. EMMA2 experienced the typical challenges to be expected in the validation of a complex operational concept, which depends heavily on the availability of adequate technological enablers related to different operational requirements and functionalities.

A very important first step is the mapping of concept elements to be validated, together with the underlying enablers, against the overall operational concept. Depending on technologies chosen, local circumstances of validation sites, the maturity of concept and technologies, individual validation exercises can be quite different. One of the most important steps for a technological project like EMMA2 is therefore a validation process which is well organised and agreed by the partners, including the establishment of a common validation strategy.

The EMMA2 validation activities led to the development of the following main V&V recommendations:

a) Assuming common guidelines, a common and coordinated validation strategy and plan, it is highly recommended to foresee continuous exchanges on their implementation in view of a common analysis of results, in particular validation activities are performed on different test sites and on different services/functions. This approach is essential if the conclusions from the validation activities should be valid not only for one or more specific experimental settings, but at a more general level.

b) In order to take account of local requirements and developments during the development and validation process, feedback mechanisms and appropriate flexibility to adapt the validation plan should be built in. This requires also a Risk Management Plan as part of the validation strategy, listing all possible risks occurring from step 2.1 to step 4.3 of E-OCVM and offering mitigation plans addressing the identified risks.
   - *The EMMA2 validation activities were for example influenced by the (un)availability of mature enablers for high level services, which represents an important constraint on the validation of future concepts. EMMA2 experienced an increased attention to further develop and refine certain enablers, which can run into the risk of distracting efforts from the validation of other services/tools that were initially foreseen by the project objectives. A risk management plan could establish acceptability thresholds, e.g. for the enablers, and back-up solutions in order to keep an overall balance between adaptation of enablers and service validation.*

c) When investigating services with a strong interaction between Tower and cockpit, like TAXI-CPDLC, always use a complete experimental setting including both ATCOs in a tower and pilots in a cockpit environment in order to be able to derive reasonable results based on a complete interaction loop.

d) In real-time simulations **use** very high density traffic scenarios in order to evoke current surface management problems (high workload, stop and go taxiing, overloaded R/T frequency, etc.) in order to enable the new services to reveal their effects in terms of expected benefits (e.g. reduced taxi time or improved punctuality).

e) Real-time simulations (RTS) and on-site trials (OST) are complementary validation exercises in terms of measuring operational feasibility and improvements. It is recommended to always perform both exercises and to compare and integrate the results when new system/services or procedures have to be validated.

- *However, the EMMA2 experience shows that on-site trials (field trials) do only add value if the new prototype system is stable and mature, otherwise is strictly recommended to replace them with more RTS cycles, helping in refining and tuning system requirements.*

f) Depending on the maturity level of the service/system, plan different validation activities and take into account several validation cycles depending on the validation results.

- *operational improvements can be assessed in parallel to operational feasibility assessments, but as long operational feasibility has not been proven, operational improvement results should not be taken into account beyond a doubt*
- *when operational feasibility is not given, take the new user comments/requirements into account by improving the system and perform a further iteration as long as feasibility is given finally*

g) In order to find evidence to validate a new service, it is useful to consider both quantitative (e.g. measured performance such as taxi time, or workload questionnaire) and qualitative assessments (i.e. ATCOs' debriefing comments, observations). Differences in both results could point to previously unnoticed biases in the validation set-up or misinterpretations by simulation subjects, and should be further elaborated in debriefing sessions. Such assessments could bring valuable input to both technological and concept development activities.

h) In order to be able to compare results of different A-SMGCS validation campaigns, worldwide harmonised and accepted indicators, measurement tools and metrics should be defined, developed and used finally. The EMMA2 validation strategy could deal as the basis (see [6] [7]).

i) RTS offer excellent possibilities for support of safety assessments. In RTS, critical scenarios can be evaluated and more detailed information on possible operational bottlenecks can be obtained. Evaluation of these scenarios can help to improve the quality of frequency assessments and risk tolerability assessments. Finally, further application of detailed risk modelling could deliver more precise insight into the risk, and use of more measured or reported data instead of expert opinion could decrease uncertainty.

4.4 Recommendations related to Implementation Issues

4.4.1 Training & licensing

Recommendations related to ATCOs

For already licensed ATCOs, implementation of A-SMGCS will require upgrade training. It is recommended to develop training associated with the subsequent levels of A-SMGCS implementation. For student and trainee ATCOs, the unit training plans should be amended to reflect the competence required to operate the implemented services of A-SMGCS [3].

With respect to licensing issues in the reference documentation it is concluded that working with A-SMGCS lower levels requires no additional endorsement to ADI-rated ATCOs. EMMA2 fully supports this position, and recommends further studies to be performed to assess whether to introduce an additional endorsement to work with higher-level A-SMGCS services[6].

Recommendations related to flight crews

It is recommended with the implementation of A-SMGCS at several airports that flight crew training should include the knowledge of those A-SMGCS aspects relevant for flight crews. Flight crews should be provided with the training necessary for them to understand the system and their associated duties in terms of the introduced transponder operating procedures. It is necessary that training permits flight crews to comply with aerodrome, A-SMGCS, and ATC procedures.

In accordance with ICAO Annex 1, the Joint Aviation Authorities (JAA) have developed Joint Aviation Requirements for flight crew Licensing (JAR-FCL). For aeroplane flight crews JAR FCL – 1 is applicable for training and licensing of private, commercial and airline flight crews. It is recommended that the JAA should incorporate relevant provisions in JAR FCL-1 for the use of A-SMGCS, e.g. required minimum level of theoretical and practical knowledge, training syllabi, skill test contents, and requirements considering up-to-date knowledge for the prolongation and renewal of licenses. Up to now, no specific licensing requirements have been developed with regard to A-SMGCS.

Recommendations related to vehicle drivers

It is recommended for the implementation of A-SMGCS that training should provide the knowledge of those A-SMGCS aspects that are relevant for vehicle drivers active on the movement area, including the use of radio-telephony, use of Mode-S transponders and, when full A-SMGCS services will be implemented, use of moving map displays and Data Link (with associated operational procedures) if applicable. Adequate training should be therefore provided to vehicle drivers, and a corresponding certification should be issued upon successful training completion.

4.4.2 Implementation Roadmap

A roadmap for the implementation of A-SMGCS services at 2008-2013, 2013-2020 and 2020+ timeframes has been prepared by EMMA2 [4]. At this stage, it only represents an initial view of the operational availability of the EMMA2 services at ECAC airports in line with the SESAR Master Plan for European ATM.

The roadmap has been established by considering:

- Deployment of service steps (increments)
- A set of qualitative decision criteria used for rating the services individually
- Availability of technological enablers and dependencies between automated systems

[6] It is important to note that ATCOs buy-in regarding licensing matters will be achieved in practice only if such studies will involve a strong ATCOs associations / union's participation.

- One generic airport case and a set of key airport characteristics influencing A-SMGCS implementation.

For the time being it is a rather rough roadmap as the uncertainties of the complex system “airport” are rather numerous. It is built using a number of early estimates for the size of operational improvements or related costs and timescales required for service development. EMMA2 developed a comprehensive description of A-SMGCS services, procedures and operational requirements. However, the new higher level services are not fully validated as not all options of the generic concept (SPOR, [2]) could be tested and the maturity of the new services in their initial validation cycle was not yet that high that they could reveal all expected benefits. *For instance the service TAXI-CPDLC was predominately accepted by pilots and ATCOs but the focus during the trials was laid on fine tuning and adaptation of the service to the user needs instead of having a stable system that is expected to reveal operational improvement by several repeated test runs with an untouched system.*

Further on, many services can only show their benefit when other services or a particular environment is in place already (e.g. a DMAN provides better planning results when it is embedded in a CDM environment, or TIS-B or TAXI-CPDLC will provide more benefit when nearly all aircraft are equipped). This equipment status however depends on the users’ decision to equip their aircraft or airports, whereas the users’ decision heavily depends on

- the demand (traffic growth),
- on the to be expected operational benefit,
- cost of the equipment,
- technology evolution,
- new prescribed national and international regulations and standards (e.g. ICAO), and
- political decisions made by the European Commission (e.g. support by research programmes, new ordinances, financial support, etc.).

Such hardly predictable circumstances cause of course problems in the prediction quality of the implementation roadmap, particularly the broader the time horizon is. However, as far as a reasonable prediction could be made, EMMA2 derived following generic roadmap (see more details in 2-D151 [4]).

Short-term implementation, prior to 2013

a) Surveillance and control services, on the ATCO side, are implemented. Routing, Planning (DMAN) and onboard (by data link) and ground guidance (by A-SMGCS operated ground guidance means) services are partially deployed; indeed no datalink services is mandatory so far. On the aircraft side, navigation on the layout and braking action on the runway support the flight crew for ground movement.

Medium-term implementation, 2013-2020

b) Additional exploitation of services regarding the coordination between ATCOs and between ATCOs and flight crew is expected. They are heavily supported by communication infrastructure and air-ground datalink services.

Long-term implementation 2020 onwards

c) The traffic situation and on board safety net are available for the flight crew. The onboard airport data are uploaded through data-link with the ground.

4.4.3 Certification and Approval Roadmap

ATM certification is not (yet) common practice, and it is not a simple or easy job, and it needs appropriate attention. In EMMA2 an important step has been made in this, by the development of a roadmap for certification and approval of A-SMGCS [5] that uses the EMMA2 A-SMGCS implementation roadmap (see Section 4.4.2) as starting point. The roadmap provides a first, general version of a certification and approval roadmap for A-SMGCS.

For a specific certification and approval process of an individual A-SMGCS implementation, the specifics of the considered equipment, the specifics of the airport, the A-SMGCS configuration chosen, the related procedures and operations, and the traffic characteristics should be taken into account. Then, a more specific roadmap can be developed, for which the details in [5] provide valuable input.

Some of the effort-estimates for the ATS domain may change when the European Agency for Safety in Aviation (EASA) takes over responsibility for safety in this domain. It is recommended that, earlier to this occurrence, harmonisation and/ or integration in terms of certification and approval concepts, processes and standards be encouraged to a large extent between airborne and airspace & airport environments.

The roadmap for a specific certification and approval process of an individual A-SMGCS implementation depends to a large extent on equipment developed, including on-board equipment. Hence the effort should be continued on development of common industry standards and minimum operational performance specifications for airborne equipment such as: Communication, Navigation and Surveillance equipment, Airport Navigation, and crew awareness related equipment in the cockpit.

4.4.4 Cost/benefit considerations

Inefficient management of airport ground resources lead to:

- Unnecessary workload for airport stakeholders that cap the overall airport capacity
  Supportive systems were assessed in EMMA2 to alleviate overall workload for instance by automating routine tasks (cf. routing and planning systems and associated TAXI-CPDLC).

- Non-optimal use of the airport resource
  EMMA2 proposed an integration of DMAN functionalities in surface management in order to better optimise the use of the planned capacity and reduce delays. Augmentation of the situational awareness of the actors (traffic situation display, route conformance monitoring, onboard route and traffic display) will also support ad hoc decisions for a better use of the actual capacity.

- Unnecessary pollution
  Early start-up of engines and unnecessary stop during taxiing were shown to be avoidable through a better traffic management (use of CDM-DMAN tools, the milestones approach, etc.).

- Safety impairment
  EMMA2 has also shown that the safety level could be increased through the use of advanced ground and board safety nets.

- Development Costs
  EMMA2 has finally tried to propose interoperable and modular solutions to influence, early in the definition of the tools, the cost of technological solutions for a better surface management.

4.4.5 Safety Assessment

A safety assessment of parts of EMMA2 A-SMGCS operations was done. In the assessment, identified hazards were structured into a number of conflict scenarios, which were next assessed on risk based on inputs from real-time simulations, Monte Carlo simulations with a dynamic risk model, historic accident risks, and expert opinions. The following recommendations are made regarding safety assessments of A-SMGCS operations:

a) Real-time simulations (RTS) offer excellent possibilities for support of safety assessments. In RTS, critical scenarios can be evaluated and more detailed information on possible operational bottlenecks can be obtained. Evaluation of these scenarios can help to improve the quality of frequency assessments and risk tolerability assessments.

b) Application of dynamic risk modelling can deliver more precise insight into risk. Use of more measured or reported data instead of expert opinion can decrease uncertainty in risk assessments.

5 Remaining open Issues

With this chapter the EMMA2 consortium intents to highlight general but very important recommendations on the next steps to be envisaged:

a) EMMA2 has demonstrated
   - operational feasibility
   - operational improvements of selected A-SMGCS higher services

   now ANSPs, airports and airlines should investigate local implementation needs for these services..

b) Ensure the **coordination** of A-SMGCS activities in the different SESAR projects, e.g.:
   - operational procedures
   - technical enablers.

c) A-SMGCS research should **continue seamlessly**.
   - A gap of A-SMGCS research after the end of EMMA2 and the beginning of SESAR is anticipated. This gap should be kept as small as possible. Further on, not all A-SMGCS main players are involved in SESAR so far. This could cause a risk of loss of A-SMGCS experience. The EMMA2 consortium proposes to use the results of the EMMA2 project as starting point for airport related activities in SESAR.

d) A-SMGCS activities should form an **important part of future research activities**.
   - EMMA2 partners consider that Airport related research deserves more importance in the SESAR programme, as bringing new A-SMGCS service into operation as soon as possible could/would support the overall gate to gate concept.

6 Annex

6.1 References

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6.2 Acronyms and Abbreviations

Abbreviation	Full term
ADS-B	Automatic Dependent Surveillance Broadcast
A-RSN	Advanced Runway Safety Net
A-SMGCS	Advanced Surface Movement Guidance and Control Systems
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
B-RSN	Basic Runway Safety Net
BTV	Brake To Vacate

CDM	Collaborative Decision Making
CPDLC	Controller Pilot Data Link Communication
CTOT	Calculated Take Off Time (CFMU)
DCDU	Data Link Control And Display Unit
DCL	Departure Clearance
DGPS	Differential Global Positioning System
DMAN	Departure Manager
EASA	European Agency for Safety in Aviation
EFS	Electronic Flight Strips
EMM	Electronic Moving Map
EMMA	European airport Movement Management by A-SMGCS
EOBT	Estimated Off-Block Time
E-OCVM	'EUROPEAN' Operational Concept Validation Methodology
E-SCA	Enhanced Situation Conflict Alerting
EUROCAE	European Organisation for Civil Aviation Equipment
FDPS	Flight Data Processing System
FMS	Flight Management System
JAA	Joint Aviation Authority
JAR	Joint Aviation Requirements
LVP	Low Visibility Procedures
MCDU	Multifunctional Control and Display Unit
MLAT	Multilateration
OST	On-Site Trials
PSR	Primary Surveillance Radar
RPA	Runway Protection Area
RTS	Real Time Simulations
RWY	Runway
SDF	Surveillance (Sensor) Data Fusion
SGD	Surface Guidance Display
SGS	Surface Guidance Symbology
SPOR	A-SMGCS Services, Procedures, and Operational Requirements document
STCA	Short Time Conflict Alert
SWIM	System Wide Information Management
TAXI-CPDLC	TAXI – Controller Pilot Data Link Communication
TIS-B	Traffic Information System Broadcast
TOBT	Target Off-Block Time
TSAT	Target Start-up Approval Time
TSD	Traffic Situation Display
TTOT	Target Take-Off Time