EXPLORATORY RESEARCH

Automated Airport: problem definition

D2.1

TaCo

Grant:	**699382**
Call:	**H2020-SESAR-2015-1**
Topic:	**Sesar-01-2015 Automation in ATM**
Consortium coordinator:	**Deep Blue**
Edition date:	**02 February 2017**
Edition:	**01.00.00**

Founding Members

EUROPEAN UNION EUROCONTROL

SESAR JOINT UNDERTAKING

Authoring & Approval

Authors of the document

Name/Beneficiary	Position/Title	Date
Damiano Taurino/DBL	Project Coordinator	15/10/2016
Giuseppe Frau/DBL	Project Contributor	15/10/2016
Johan De Battista/MATS	Project Contributor	15/12/2016

Reviewers internal to the project

Name/Beneficiary	Position/Title	Date
Johan Debattista/MATS	Project Contributor	16/01/2017
Stéphane Conversy/ENAC	Project Contributor	16/01/2017
Mathieu Cousy/ENAC	Project Contributor	16/01/2017

Approved for submission to the SJU By — Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date
Damiano Taurino/DBL	Project Coordinator	16/01/2017
Johan Debattista/MATS	Project Contributor	16/01/2017
Stéphane Conversy/ENAC	Project Contributor	16/01/2017
Mathieu Cousy/ENAC	Project Contributor	16/01/2017

Rejected By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date

Document History

Edition	Date	Status	Author	Justification
00.01.00	01/09/2016	Draft	Damiano Taurino	Document initiated
00.01.01	01/11/2016	Draft	Damiano Taurino	Airport description included
00.01.02	01/12/2016	Draft	Damiano Taurino	Scenarios included
00.01.03	22/12/2016	Draft	Damiano Taurino	Draft consolidated for SJU review
01.00.00	02/02/2017	Final	Damiano Taurino	Final version including the integration of SJU's review

TaCo

TAKE CONTROL – AUTOMATED SOLUTIONS FOR THE MANAGEMENT OF GROUND AIRPORT MOVEMENTS

This deliverable has received funding from the SESAR Joint Undertaking under grant agreement No 699382 under European Union's Horizon 2020 Research and Innovation.

Abstract

TaCo project addresses the effective collaboration between the human operators and the automation as a solution to challenges brought by the management of complex airport operations.

This deliverable, together with "D2.2 – State of the art", paves the way to the research and design of innovative automation models and solutions, that is the core of TaCo. In addition, the document presents an overview of the placement of TaCo with respect to the Work Programme of SESAR.

The airport environment is here introduced starting from a high-level description of roles, responsibilities and main duties of tower and ground Air Traffic Controllers. The dissertation then addresses the specificities of Malta International Airport, the main use case of TaCo. The main focus is put here on the factors of complexity that have a major impact on the operations. The analysis of these complexity factors is here carried out through qualitative methods introduced by past studies conducted in European and US airports.

The main input from D2.1 for the next stages of TaCo are the operational scenarios. Through an active collaboration of operational experts from MATS, two different realistic traffic configurations and four scenarios for different runways' configurations have been defined. Those are the "baseline" scenarios for TaCo, that set the ground for the design and prototyping of effective and suitable automation and human-machine collaboration strategies

Table of Contents

1 Introduction

1.1 Purpose and Scope of this document

The purpose of this document is to provide the reader with the background of the research work conducted by the TaCo project. A general description of the airport environment, the reference operations and the involved actors and systems will help to define the scope and objectives of the overall project's activities. A first identification of the main users' needs and preliminary reference scenarios are here outlined, as first building blocks for the implementation of TaCo solutions that will be the main subject of the following Work Packages.

1.2 Deliverable Structure

Section 2 of this document will provide the reader with an introduction to the TaCo project, its scope and the main objectives.

Section 3 will introduce the airport environment, with a description of the roles and operations addressed by the project. The International Airport of Malta will be there described, and its project relevant peculiarities will be introduced.

Section 4 will introduce the first version of the scenarios, that will be the ground for the following automation design and prototyping.

Section 5 will depict how the work done in work package 2 will contribute to the following phases of the TaCo project.

1.3 List of Acronyms

ATCO	Air TrafficController
ATM	Air Traffic Management
ATZ	Aerodrome Traffic Zone
CA	Consortium Agreement
CTR	Control Zone

DoA	Description of Action
EASA	European Aviation Safety Agency
EC	European Commission
GA	Grant Agreement
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
KPA	Key Performance Area
KPI	Key Performance Indicator
LMML	Malta International Airport
MATS	Malta Air Traffic Services
MLS	Microwave Landing System
MRO	Maintenance, Repair and Overhaul
MRO	Maintenance, Repair, Overhaul
SAR	Search and Rescue
SESAR	Single European Sky ATM Research
SJU	SESAR Joint Undertaking
TBS	Time Based Separation
WP	Work Package

2 Scope and Objectives of TaCo project

2.1 Project scope

TaCo project fits in the contest of area 1 “ATM Excellent Science and Outreach” of Sesar Exploratory Research, requiring a maturity level from Science to TRL1.

The project will explores an innovative application of existing solutions (such as MoTa “Modern Taxiing”, Djnn, LabyEdit etc. [11][13]) with the aim to design and experiment a novel operational concept strongly focused on the human-automation collaboration in managing ground traffic in an airport environment. The analyses will be backed by feasibility considerations based on operational experience of the ATC expert involved in the project. The results will remain at the level of research ideas (pre-TRL 1) for most of the early concepts identified, while for the “automated airport” concept, as outlined in the DoA, it is planned to reach TRL 1. To achieve this level, an evaluation exercise is planned to investigate the fundamental characteristics of the concept, without reaching the proof of concept stage that is typical of higher levels of maturity [SESAR, 2013 [3]].

TaCo is a SESAR Exploratory Research project, thus will not explicitly address implementation and deployment issues. However, looking at the SESAR 2016 implementation plan [3], it could be expected a fruitful exchange of information and outcomes between TaCo and the SESAR key feature of “High-performing airport operations”. This key feature aims at a full integration of airports as nodes into the network by addressing the enhancement of runway throughput, integrated surface management supporting performing and efficient operations, airport safety nets and total airport management. In details, some of the implementation objectives within the High-performing airport operations may be of potential interest for TaCo:

- AOP04.1 - A-SMGCS L1: the Advanced Surface Movement Guidance and Control System (A-SMGCS) Level 1 provides ATC with the position and automatic identity of all relevant aircraft on the movement area and all relevant vehicles on the manoeuvring area, supporting the controller decision making.
- AOP04.2 - A-SMGCS L2: at L2 the A-SMGCS Level 2 will be complemented by dedicated function to detect potential conflicts on runways, providing the controllers with appropriate alerts.
- AOP13 - Automated assistance to controller for surface movement planning and routing: the routing and planning functions of A-SMGCS provide the automatic generation of taxi routes, with the corresponding estimated taxi times and management of potential conflicts.

TaCo aims to design an innovative operational concept where ATCOs will not only be supported by automation in monitoring relevant traffics and vehicles (and in detecting potential conflicts), but the system will also allow controllers to fine-tune the automation’s strategy according to emerging needs and events. The demonstration exercise planned in TaCo (in WP4) will provide a realistic example of the concept feasibility, allowing an early feedback collection for its future refinement. This evaluation exercise will not address the analysis of the key performance areas (KPAs) as defined in the ATM Master Plan Level 1. However, the project is expected to provide guidelines and recommendations for future studies and validation activities taking into account specific KPA and providing also potential indicators. The table hereafter reports a tentative identification of KPA and the associated operational aspects that can take advantage of the output of the TaCo project.

KPA	KPI	TaCo Expected benefits
Environment	CO_2 emissions Fuel burn per flight	Optimization algorithms developed by TaCo will contribute to shorten the taxiway and optimize its duration, with a positive impact on fuel burn and emissions.
Capacity	Departure delay Additional Flights at congested airports Network throughput additional flights	Automated solutions developed by TaCo will contribute to the optimization of traffic in the airport, with a positive impact on delay time related to ground movements and improving traffic throughput.
Operational Efficiency	Flight time per flight More efficient control of surface traffic.	Algorithms developed by TaCo will contribute to optimize control on surface traffics, improving system efficiency and predictability. It is also expected a positive impact on fuel burn through better timed operations.
Safety	Accidents with ATM contribution	TaCo automated solutions will support the tower controller in the management of ground movements, including tools to detect and solve possible conflicts.

2.2 Project objectives

TaCo aims to define an automated system sufficiently powerful to both accomplish complex tasks involved in the management of surface movements in a complex[1] airport and self-assess its own ability to deal with non-nominal conditions. When needed, such system should be sensitive enough to transfer responsibilities for traffic management back to the controller, in a timely and graceful manner and in way that makes him/her comfortable with the inherited tasks.

Automation is one of the key solution proposed and adopted by SESAR to tackle the challenges coming from the increase of capacity and complexity of the future ATM system. On the one hand, the programme aims at substantially reducing controller task load per flight through a significant enhancement of integrated automation support, whilst simultaneously meeting the established safety and environmental goals. On the other hand, it is envisaged that human operators will remain at the core of the system (mainly with the role of overall system managers) using automated systems with the required degree of integrity and redundancy. TACO proposes a dove tailed process to facilitate the controller's forward thinking, also in anticipation to A-CDM (Airport- Collaborative Decision Making) amongst others.

The main objectives of TaCo are the following:

- defining algorithms and solutions to automate and optimize both the decision making and implementation tasks for the controller involved in the ground movement of airport vehicles and aircraft;
- identifying and providing the controller with suitable and usable tools to supervise (monitor, tune and re-program) the system;
- studying the interaction between the human actors and the automation. Main focus will be on the identification of sensitive state transaction from a (fully) automated management system to conditions where the human is brought into the loop to handle situations where his/her cognitive resources are essential.

The involvement of final users and operational professionals is fundamental to achieve project objectives.

2.3 Glossary

(Taken from ICAO Doc 4444)[4]

The **runway (RWY)** is: «a defined rectangular area on a land aerodrome prepared for the landing and take-off of aircraft».

---

[1] Low Utilisation Simple Layout (LUSL) or High Utilisation Complex Layout (HUCL), following the definition provided in the European ATM Master Plan (https://www.atmmasterplan.eu/performance_needs)

The **taxiway (TWY)** is: «a defined path on a land aerodrome established for the taxiing of aircraft and intended to provide a link between one part of the aerodrome and another, including:

a) Aircraft stand taxilane. A portion of an apron designated as a taxiway and intended to provide access to aircraft stands only.
b) Apron taxiway. A portion of a taxiway system located on an apron and intended to provide a through taxi route across the apron.
c) Rapid exit taxiway. A taxiway connected to a runway at an acute angle and designed to allow landing aeroplanes to turn off at higher speeds than are achieved on other exit taxiways thereby minimizing runway occupancy times».

The **apron** is: «a defined area, on a land aerodrome, intended to accommodate aircraft for purposes of loading or unloading passengers, mail or cargo, fuelling, parking or maintenance».

The **runway holding position** is: «a designated position intended to protect a runway, an obstacle limitation surface, or an ILS / MLS critical / sensitive area at which taxiing aircraft and vehicles shall stop and hold, unless otherwise authorized by the aerodrome control tower».

3 Airport Environment

3.1 Airport Operations Description

The face of airports around the world today, is very much different than that we knew twenty years ago. Airports are operated by various entities including government authorities, private companies, consortiums and public corporations.

Above all airports differ from each other, and aside to the various data and statistics published from time to time, we understand that airports are complex. The various requirements related to airports can be broadly categorized as either economic or safety-related, in both scenarios under multi-disciplined authorities. The various approaches adopted worldwide are generally based on ICAO Annex 14 – Volume 1: Aerodrome Design and Operations.

The multifaceted challenges, along with environmental sustainability issues that rank highly on the industry's list of priorities, reiterate the volatility which aviation stakeholders are exposed to. Amongst others this include the reiteration by EASA's commitment to the Global Market Based Measures on Emissions. Airports are part of the equation and in order to ensure the sustainability of their operations, the international standards and recommended practices need to be developed within a contemporary mind-set which takes into account the issues faced by airport operators today, conscious of increasing traffic and further safety as well environmental awareness.

ICAO Annex 14 requires contracting states to set up a regime of aerodrome certification for their international that was intended to ensure that facilities, equipment and operational procedures. It is understood that one can find registered and other aerodromes too, but in particular for this project, airport operations are considered for certified airports only. Indeed, this project is in line with the process of EASA which responsibilities in the field were extended to aerodromes.

Airports are where the nation's aviation safety system connects with other modes of transportation and where quite often, national responsibility for managing and regulating air traffic operations intersects.

3.1.1 Control Tower operations at a glance

In Fig. 1 the main phases of the final approach and tower operations are graphically represented [5]. The aircraft (A/C) is delivered from the final approach/departure unit to the Tower (TWR) controller (responsible for arrivals and departures), and then to the Ground (GND) controller (responsible for the ground traffic). The area of responsibility of the aerodrome controllers covers the aerodrome space. The division of responsibilities between the tower and the approach units cannot be strictly defined and depends on local conditions [6].

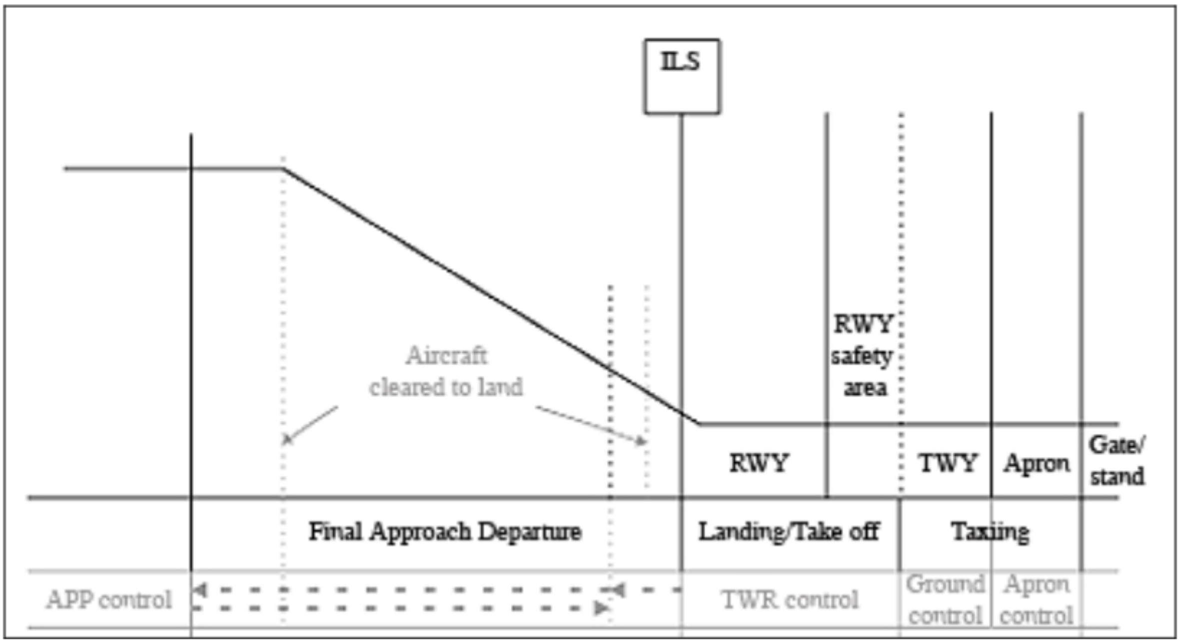


Figure 1: Control tower operations

As defined in [4] «the aerodrome controllers shall issue information and clearances to aircraft under their control to achieve a safe, orderly and expeditious flow of the air traffic on and in the vicinity of an aerodrome with the object of preventing collision(s) between:

a) aircraft flying within the designated area of responsibility of the control tower, including the aerodrome traffic circuits;
b) aircraft operating on the manoeuvring area;
c) aircraft landing and taking off;
d) aircraft and vehicles operating on the manoeuvring area;
e) aircraft on the manoeuvring area and obstructions on that area».

The manoeuvring area is defined in [4] as: «that part of an aerodrome to be used for take-off, landing and taxiing of aircraft, excluding aprons». Thus, the manoeuvring area is different from the so-called movement area, which includes also the aprons. This distinction is not trivial because it circumscribes the responsibilities of the controllers. For instance, only the manoeuvring area is dependent on the controllers' monitoring and guidance. According to Bergé [7], the surveillance service should cover aircraft in the apron area, since the controllers need to know the aircraft position with regards to the future conflict on the manoeuvring area; but there is no responsibility from the controllers' side for what is taking place on the apron. This fact is further stressed in [4]: «Aerodrome controllers shall maintain a continuous watch on all flight operations on and in the vicinity of an aerodrome as well as vehicles and personnel on the manoeuvring area». Interestingly, the last part of the sentence states that: «Watch shall be maintained by visual observation, augmented in low visibility conditions by radar, when available».

3.1.2 TWR Controller

This position is defined in [4] as being: «normally responsible for the operations on the runway and aircraft flying within the area of responsibility of the aerodrome control tower». In brief, the first responsibility of the TWR controller is to ensure that sufficient runway separation is kept between landing and departing aircraft (Nolan, 1999). Specifically, the TWR controller is responsible of:

1. the landing A/C until the RWY is vacated;
2. the departing A/C, from the holding position for the take-off, until the A/C is handed off to the approach unit.

The TWR is the first contact point for the arriving traffic, right after the approach unit. The TWR issues the "clear to land" instruction (or "clear to take off", for departing traffic) and gives to the pilot information about the weather and wind conditions. The TWR has to be aware of the conditions and of the status of all RWYs. The RWY occupancy status is checked through direct observation and radar display. The weather information is usually provided in a dedicated monitor (displaying visibility, temperature, wind direction, wind intensity, pressure). Once a departing A/C has left the area of responsibility of the aerodrome, the TWR hands over (i.e. transfers the control of) the A/C to the approach unit.

The TWR controller (in coordination with the approach control unit) is responsible of defining the most appropriate RWYs configuration, that is: «the RWY or RWYs that, at a particular time, are considered by the aerodrome control tower to be the most suitable for use by the types of aircraft expected to land or take off at the aerodrome» [4].

When an A/C has landed and vacated the RWY, the TWR hands over the aircraft to the GND. The hand over is marked by the radio communication with the pilot (who is instructed to change the radio frequency and invited contact the Ground) and with the transfer of responsibility[2], from the TWR to the GND. The same process is used for the departing traffic (which implies the change of radio frequency instruction and the hand over from the GND to the TWR).

3.1.3 GND Controller

This position is defined in [4] as being: «normally responsible for traffic on the manoeuvring area with the exception of runways». In other words, the GND is responsible for the safety of aircraft that are taxing on TWYs, from and/or to the RWY (Nolan, 1999).

The pilot contacts the GND for the push-back/taxi clearance, and (after the GND's approval) the A/C will be routed through the manoeuvring area until it has reached a holding point close to the RWY (then, the A/C will be handed over to the TWR).

[2] Typically done by transferring the (physical or electronic) flight strip.

The GND monitors and guide all the surface movements, is in charge of communicating to the pilots the taxi routes so as to avoid collisions with other A/C or objects, and minimizing the risk for the A/C entering an active RWY. The GND assigns priority to A/C (both arriving and departing) for the TWY occupancy.

The GND has several means to determine the position of the A/C within the manoeuvring area:

1. direct observation;
2. the ground radar;
3. the radio communications, as the controller can request to the cockpit to report and communicate the exact A/C position.

The GND may authorize an A/C to taxi an active RWY. This manoeuver has to be coordinated with and approved by the TWR.

3.2 Malta Airport specificities

The previous sections described the airport operations and roles in generic terms. The present one aims at providing an overview of the reference environment for the TaCo project, namely the Malta International Airport.

The Malta International Airport (LMML) is the only airport serving the islands; an aerodrome at the south of the biggest main island in the archipelago, operated by a private company in collaboration with other entities. The aerodrome has two runway strips at crossing directions and eight active aprons plus two maintenance aprons, scattered around the airfield.

Although LMML is not the busiest airport that one can analyse, its complexities are numerous. The aerodrome was built in the 1950s, with the aim of serving the military activity based on the island at the time. The aerodrome is the 5th built on the islands, and the only remaining. There are no alternative airports, and any aircraft unable to land at LMML shall proceed to the alternate airports preselected on the flight plan in another country, which are normally in Sicily (around 200 km far).

The airport was designed very much different than for today's aim, extended during the years with a design that exhibits limited idea of a long-term plan. Unfortunately, the airport is surrounded by built up villages, hence introducing constraints on further extensions, operate freely due to noise and develop appropriately.

Additionally, being the only airport on the islands, it has the obligation to serve all domestic and international aviation to / from Malta; from code A to code F aircraft (see table below), from training flights to rescue flights, from private to commercial aviation, from scheduled to charter, from leisure to maintenance activity. This translates into further complexities regarding the runways usage, for example an aircraft approaching the southern runway at 150 knots will indirectly impose restrictions to an aircraft approaching the easterly runway at 69 knots.

With a 6% increase in commercial traffic year on year, excluding training flights and Search and Rescue Operations (SAR) to / from LMML, the complexity will ever increase. The main runway does not have any parallel taxiing to facilitate its movement, while new aprons were lately developed without a long-term strategy. On the other hand, during the last fifteen years, the industry experienced positive growth not only in traffic but from aviation companies investing in Malta.

The Luqa Aerodrome Control Tower[3] is the coordinator for the Malta Airport, and shall issue information and clearances to aircraft under its control to achieve a safe, orderly and expeditious flow of air traffic on and in the vicinity of the aerodrome with the objective of preventing collisions between:

a) Aircraft flying within the designated area of responsibility of the control tower, including the aerodrome traffic circuits;
b) Aircraft operating on the manoeuvring area;
c) Aircraft landing and taking-off;
d) Aircraft and vehicles operating on the manoeuvring area;
e) Aircraft on the manoeuvring area and obstructions on that area;
f) Aircraft operating on the aprons.

The manning of the Luqa Tower is carried out by two personnel that deal with aircraft and vehicles from a single room; an aerodrome controller (ADC), a ground movement controller (GMC) and the tower coordinator (CORD). The unit providing Aerodrome Control Service at Luqa Aerodrome Control Tower (Luqa TWR) consists of the ADC with call-sign LUQA TWR and the GMC with call-sign LUQA GROUND. A coordinating support function is also provided by the TWR Coordinator (CORD). Annex B depicts the layout of the tower.

The ADC is responsible for:

a) Operations on the runway;
b) Traffic operating within the Luqa ATZ and the Luqa CTR including departing, landing and circuit traffic;
c) Handing over of VFR/IFR arrival plaques to GMC on transfer of communications and to insert stand number / apron on plaque;
d) Co-ordination with the Approach Controller (APC) on selection of Runway-In-Use (RIU);
e) Operation of stop bars;
f) Operation of THR23 vehicular traffic lights in coordination with the GMC;
g) Activation of the Runway Occupancy Indicator (ROI);
h) Application of CTOT as coordinated with the GMC;
i) Operation of aeronautical ground lights as applicable;
j) alerting services.

The Air Traffic Management tool should be used to assist the ADC in performing the following functions:

- Flight path monitoring of aircraft on final approach and initial departure phase;
- Monitoring the landing sequence, spacing and distance from touchdown of arriving aircraft;
- Applying the Minimum Departure Interval (MDI);
- Providing traffic information;
- Validating transponder code allocation of departing aircraft.

[3] For the purpose of the document

The GMC is responsible for:

a) Traffic on the manoeuvring area with the exception of runways;
b) Clearance delivery and start-up to departing IFR and VFR flights;
c) Taxi clearance of all departures up to the designated runway holding positions;
d) Taxi clearances of all arrivals to the assigned parking stand as allocated by MIA;
e) Application of ATFM procedures before start-up;
f) Updating of VFR and IFR departure plaques and their handover to the GMC on transfer of communications;
g) Operation of THR23 vehicular traffic lights in coordination with the ADC;
h) Operation of aeronautical ground lights as applicable.

The CORD is responsible for:

a) Ground-ground communications and control of vehicles on the manoeuvring area;
b) Obtaining approval from the ADC/GMC as applicable to authorise vehicles on the manoeuvring area;
c) Inputting of all VFR flights in the ATM by means of the IDENTIFY order in the EXECUTIVE drop-down menu according to the assigned transponder codes on the plaques;
d) Inserting of stand numbers in the respective electronic strips for both departure and arrivals;
e) Landing/departure and red time inputs in the SMART screen;
f) Answering telephone 5343 and tower access intercom;
g) Logging of VFR flights;
h) Co-ordination with the RFFS;
i) Logging of diversions to LMML;
j) Update runway in use on CITO[4].

The movements per hour at LMML peak to 40 an hour during the summer months, while the average at regular days of operation counts normally between 22 and 27 movements. Normal day of operations, sees both runways in action, which as previously noted are crossing each other (in Figure 2 Runway 13-31 is the longest one, with “1331” indicated at its end while Runway 05-23 is the “left” runway crossing the first almost perpendicularly). The longest and instrument runway; runway 13-31 normally takes commercial traffic, while the shorter and secondary runway 05-23 takes the other traffic, in example training flights, normally held by code A aircraft. Figure 2 is the representation of the airport elaborated by ENAC for the initial concept developments. Annex A contains the detailed aerodrome chart of LMML.

[4] CITO – Collaboration Interface for TOwers

Figure 2 - LMML Map representing runways, taxiways and aprons' position

The movements per hour at LMML peak to 40 an hour during the summer months, but this project is taking peaks at regular days of operation which counts normally between 21 and 26 movements an hour. Normal day of operations, sees both runways in use, which as previously noted are crossing each other (13-31 / 05-23). The longest and instrument runway; runway 13-31 normally takes commercial traffic, while the shorter and secondary runway 05-23 takes the other traffic, in example training flights, normally held by code A aircraft. Helicopters for SAR will normally hover as necessary from Apron 7 taking the shortest route possible for the mission.

The airport which hosts four flying schools which own around 20 aircraft, operate all year round from the northern parts of the aerodrome, namely aprons 1 and 3. Indeed lately a policy was introduced to allow only three aircraft performing circuit training on 05-23. Pilot ground instruction is held at premises close to apron 1; where the aircraft are parked, while refuelling and maintenance are held on apron 3. This means that every time an aircraft needs refuelling and / or checks, the pilot will communicate with the ground controller to taxi from one apron to another.

The airport also hosts four maintenance, repair and overhaul (MRO) facilities, which service from code A (in example Diamond 40) to code E (Airbus 340-600) aircraft, with no engine-run facilities. This means that taxiways and the secondary runway are at times closed and used for engine run purposes.

Table 1: Aircraft Reference Code

Code letter	Wingspan	Outer main gear wheel span
A	Up to but not including 15 m	Up to but not including 4.5m
B	15 m up to but not including 24 m	4.5m up to but not including 6m
C	24 m up to but not including 36 m	6m up to but not including 9m
D	36 m up to but not including 52m	9m up to but not including 14m
E	52 m up to but not including 65 m	9m up to but not including 14m
F	65 m up to but not including 80 m	14m up to but not including 16m

Two out of four MROs facilities are found at areas which are not under the management of the Airport Managing Body – Malta International Airport plc (LMML), this is due to the fact that they are situated in a portion of government land, managed by Malta Industrial Parks (MIP). This means that ground movement policies involve more than one actor.

Currently terminal ATM does not use Time Based Separation and aircraft separation at approach stage are normally kept at 5 miles apart, all dependant on navigational aids operations and weather.

The two positives element that saves runway time is that the length of runway (13/31) permits a significant percentage of code C aircraft - scheduled movements take-off at reduced runway length a beam taxiways.

However, it should be highlighted that in the event of the southern runway in use, when any aircraft is exiting the maintenance facility, aprons 2, 3, 4 and 8 for departure, taxying entails runway occupancy of over five minutes at a time, due to runway backtracking requirements. This is also a fact with Code D+ aircraft when using the northern runway to any aircraft leaving the main apron.

Linked to the main runway the airport has speed taxi runway exits but does not have Rapid Exit Taxiways (RET). Due to same infrastructure, which does not allow for multiple taxiways, all taxiways are used as two ways and the only perpendicular taxiways are only found at runways ends.

It is the responsibility of the ADC in coordination with the APC to select the Runway In Use (RIU). The runway selection criteria at LMML shall be based on the Preferential Runway Scheme (PRS) which is applicable to IFR and VFR flights as per underneath highlighted.

RWY13/31 IFR Preferential Runway Scheme (IFR PRS)

i. The RIU selected in LMML shall be **RWY31** from **0600** – **1800 LT** and **RWY13** from **1800 – 0600 LT**. It is best practice to plan for the change in RIU at least 30 minutes before 0600 and 1800 to ensure that all aircraft will land or take-off on the appropriate runway at the time of landing and departure.

ii. The IFR PRS is established to ensure safety and efficiency and also to meet noise abatement/distribution requirements as endorsed in the Malta AIP. Requests to depart/land on the runway reciprocal to the declared IFR RIU shall not be allowed, irrespective of the traffic load at the time the request is made except in cases of emergency, urgency or priority landing or when no other option exists in the prevailing circumstances.

Normally, an aircraft will land and take off into wind unless safety, the runway configuration, meteorological conditions and available instrument approach procedures or air traffic conditions determine that a different direction is preferable.

RWY05 / 23 VFR Preferential Runway Scheme (VFR PRS)
[normally applicable to LIGHT aircraft]

i. The VFR PRS for domestic and international VFR flights shall be RWY05 or RWY23. This is applicable to all VFR departures and arrivals. Tailwind components exceeding 5 kts will determine whether RWY05 or RWY23 is selected as the preferred VFR runway.

ii. When RWY05/23 is the VFR RIU and requests are made for circuits for RWY 13/31 (IFR RIU), the initial departure should be authorised on the VFR RIU only.

iii. The VFR PRS is not applicable when the crosswind component on RWY05/23 exceeds 12 kts, in which case RWY13/31 is declared as the RIU, as applicable to IFR flights. In this configuration, departures, arrivals and circuits on RWY05/23 are only allowed when requested by the pilot, subject to traffic and restrictions applicable to the use of crossing circuits / reciprocal runways.

Any aircraft movement between the main Aprons, in example aprons 8 and 9 maintenance aprons, or between same aprons entails crossing of an active runway.
Having noted Apron 9 above and its positive elements, unfortunately the same Apron has several limitations, in particular when any taxiways are closed or any works are being carried on the Apron. Even in normal operations, the Apron is subject to several restrictions, in example taxilane X and T restricted to aircraft proceeding to Stand 18X or 21. Annex C contains a detailed description of the limitations and procedures in place for Apron 9.

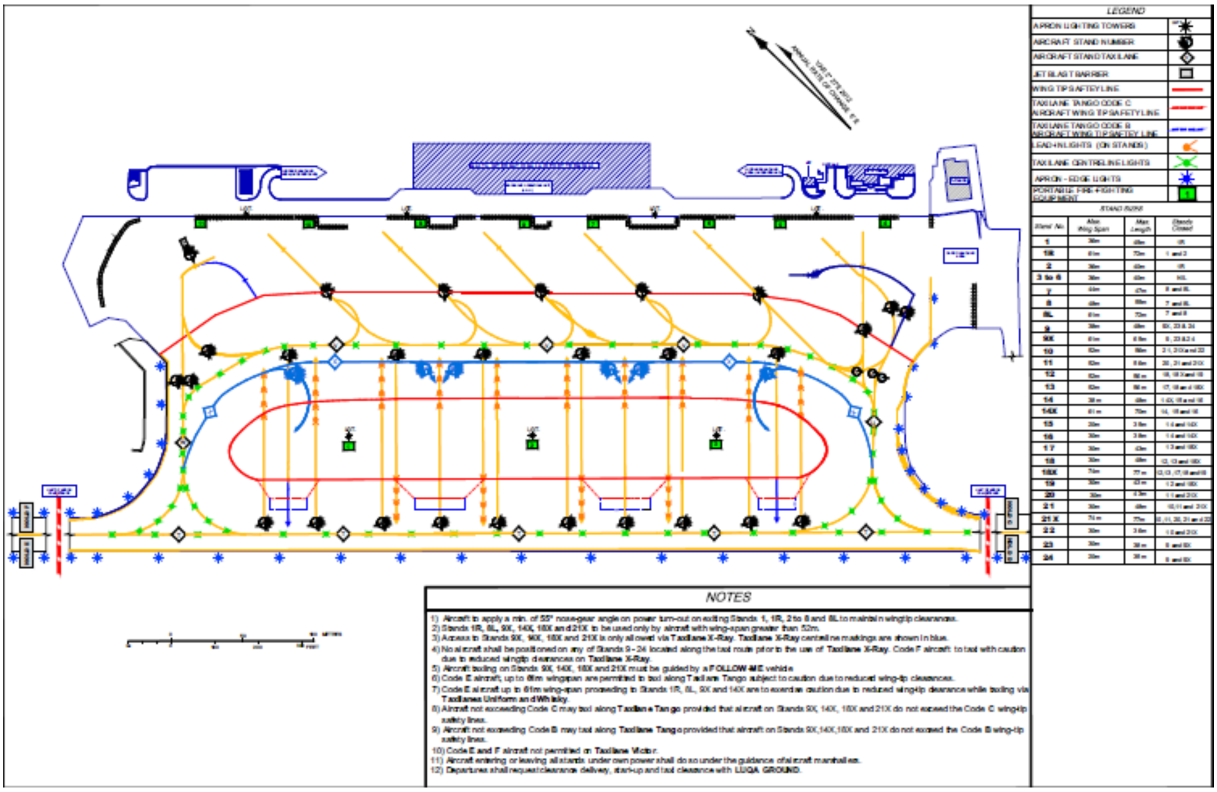


Figure 3 – Apron 9 of International Airport of Malta

The here provided description depicts a quite complicated picture of the International Airport of Malta. The following sub-section introduces the concept of complexity in the airport environment, its evolution in literature and how the factors identified in past studies may help the consortium in the identification and analysis of complexity aspects relevant for the project.

3.3 Airport Complexity

Studies about complexity in air traffic control are numerous but the great majority of them focuses on en-route air traffic complexity [15]. In particular, such studies aim at finding the relationships between controller's workload and traffic complexity. The workload construct is often studied together with the complexity as the latter is usually defined in terms of the former [16][17][18]. Much less research efforts can be found as the focus approaches the terminal areas, included the airports. Among those works, complexity is usually broken down into several factors: Krstic[15], for example, focusing on the complexity of airport traffic, addresses the problem of choosing the right parameters for faithfully represent the traffic complexity: a dynamic complexity measure is defined for continuously capturing the traffic characteristics and nine measurable traffic complexity factors are identified ranging from the traffic density to the number of potential separation violations.

While the trend of the dynamic complexity can be useful for observing fluctuations during a given time period, for the purposes of TaCo it is more meaningful to adopt a complexity concept that allows a static characterisation of the target scenario, namely the LMML environment. From this perspective, an interesting approach is provided by the studies conducted by the FAA [19] where complexity factors and their incidence are investigated in six different US sites and analysed with the input of 62 Air Traffic Control Specialists. The result is a set of 29 factors reported in the following table.

Complexity Factor	*Description*
Runway/taxiway restrictions	Unavailable or restricted runways and taxiways impede traffic flow, limiting options, thereby increasing planning, communication, and coordination.
Active runway crossings	Timing is critical. This kind of crossings requires sustained vigilance and increased coordination and communication, especially if the local or ground positions are split.
Runway/taxiway configuration	The taxiways, coordination, airspace, trouble areas, etc. change based on the operational configuration. Changing configurations adds to communication, coordination, and SA demands. Some sites have 23+ configurations available.
Non-Visibility areas	Controllers lose their primary means of gathering information—visual observation. They must rely on other information sources (Air Surface Detection Equipment [ASDE], DBRITE, pilot reports, etc.) to compensate for this loss, adding complexity and workload.
Airspace configuration	Airspace configuration determines runway/taxiway usage, coordination, trouble areas, and so on. Configurations change depending on conditions, adding to communication, coordination, and SA demands. Efficient aircraft sequencing can be especially challenging.
Terrain/obstructions	Cranes, buildings, mountains, and other obstructions require controllers to reroute aircraft to alternate runways and taxiways. Often the aircraft must travel in the opposite direction of the standard flow of traffic, increasing coordination and workload.
Satellite Airports	Satellite airports increase traffic volume and communication/coordination requirements and require controllers to prioritize the traffic to each airport. Some facilities may have six or more satellite airports.
High traffic volume	Traffic volume results in high workload (number of tasks, communication, coordination, etc.) and frequency congestion. It requires sustained SA,

	pushes the limits of the airport, and raises the potential for error. It is especially challenging when it occurs in conjunction with other factors.
Aircraft differing in performance characteristics	Mixing traffic types raises the likelihood of overtakes, requires sustained SA, and increases the number of speed and heading directives required. As the number of heavy jets increases, wake turbulence requirements can slow the operation.
Emergency operations	These situations are non-routine and require controllers to adjust their priorities dynamically. They increase communication and coordination requirements. Controllers have limited time to gather and prioritize the information.
Wake turbulence	Controllers must meet different separation requirements based on aircraft type. The challenge is sequencing aircraft effectively, particularly those subject to wake turbulence restrictions, to maintain traffic flow.
Special flights	These require coordination and add complexity by contributing to the traffic volume and mix. Helicopters, though common at some sites, may not have standard routes, contributing to communications requirements.
Overflights (No factor-specific interviews)	Overflights are non-routine and take the controller's focus away from scanning the airport surface, potentially decreasing SA. They add to workload because they require flight strips for the point-out.
Vehicular traffic	Vehicles require communication, coordination, and sustained vigilance. Construction can lead to a large number of vehicles, multiple runway crossings, removal of airport signs, a mix of vehicle types, unfamiliar users, and other complicating factors.
At or below minimums	These conditions require the use of much more restrictive procedures and may be more challenging if these conditions rarely occur. Under these conditions, resequencing aircraft is common. Complexity increases due to the loss of visibility.

Reduced visibility (weather)	This requires the use of non-routine, much more restrictive procedures. Complexity increases due to the loss of visibility and reliance on alternate information sources.
Inclement weather	Workload and complexity increase because of changes in configuration and runway usage. There is increased vectoring, more pilot requests for alternate headings, increased monitoring, and the addition of weather-related activities (e.g., coordination for snow removal vehicles).
Airport surface activity	This can close taxiways and runways, requiring rerouting and sustained vigilance. This increases communication and coordination requirements. Some vehicle operators may have limited knowledge of airport procedures.
Equipment malfunctions	Malfunctions introduce non-routine situations and require the use of standby equipment and procedures. Though rare, the most significant malfunction is the loss of communications.
Frequency congestion	This contributes to blocked transmissions, requiring repeats, increasing workload, and occupying additional controller time. Splitting a busy position is beneficial but results in additional coordination.
Equipment location	The non-integration of systems increases the controllers' head down time, workload, and scanning time. Though the primary information source is outside, the controller must consult multiple sources within the tower cab.
Reduced visibility (equipment) (No factor-specific interviews)	Glare on a display can result in the inability to gather valuable information. The presence of a piece of equipment can restrict or obstruct the controller's ability to scan the airport surface. These may result in a loss of SA.
Unfamiliar pilots	They require sustained attention and often require progressive taxi instructions. They may require repeats, adding to frequency congestion and workload. The controller is unaware of what the aircraft will do and must plan for every contingency.

Pilot's weak mastery of English language	These pilots require sustained visual attention because of a lack of understanding on both ends of the communication. The number of communications is often increased. The aircraft may not perform as instructed.
Controller fatigue	Although fatigue can result from extended heavy workload conditions, it can also be shift work related. Fatigue can result in loss of focus, missed calls, increased thought possessing time, and impaired SA.
TMIs	These initiatives increase heads down time, coordination, communications, re- sequencing, and workload. TMIs restrict controller options and may necessitate the use of progressive instructions.
Equipment distractions (No factor-specific interviews)	Aural alerts and other equipment distractions interrupt the current task and, if particularly loud, may lead to speech interference.
Other distractions	Ambient and equipment noise can result in the loss of focus and SA, thereby requiring repeats and increased workload. If not effectively supervised, visitors may block visibility of equipment, restrict movement through the tower cab, or raise noise levels.
On-the-job training	Developmental controllers are unpredictable, may make poor judgments, and can slow the operation. They require close supervision, possibly focusing the instructor's attention inside the tower cab.

Table 2 - Complexity factors identified by the FAA study

The factors are sufficiently general to be reused in other studies. The aim of this section is to look at the complexity factors from the LMML point of view, and to provide a structured way to characterise this environment. In order to achieve this result, each factor was assessed by MATS operational experts in terms of its presence and the impact it has on the operations. The following table lists the factors identified through the just described process. During the process, some complexity factors from the original FAA work were merged or adjusted to be adapted to LMML context, in particular:

- "Vehicular Traffic" and "Airport Surface activity" factors were merged into a single factor named "Surface Activity Complexity"

- "Runway/Taxiway configuration" and "Runway/Taxiway restrictions" factors were merged into a single factor named "Runway/Taxiway configuration and restrictions"
- An additional complexity factor named "Apron Congestion" was identified by the expert

Factor	*Importance for LMML*
Surface Activity Complexity	There are a number of surface activities in the aerodrome movement area, affecting the operations: vehicular traffic (fuel trucks moving among the aprons), MROs activities (engine runs and airplanes ground manoeuvres).
Active Runway Crossings	In LMML there are two runways crossing. They may be both in use during operations. Some taxiing may be conducted through them and vehicles may cross them to reach some parts of the airport.
Runway/Taxiway configuration and restrictions	The Aprons configuration (e.g. some F category aircraft parked) may impact the availability of some taxi lanes, leading to taxiing rerouting. Some operations (e.g. engine runs from MROs) may have temporary impact on availability of runways. Some categories of flights need to be served by the main runway (13-31).
Aircraft differing in performance characteristics:	Flights served by LMML range from A to F category
Apron congestion	Some Aprons (e.g. Apron 9, see subsection 3.2) may be congested during operations
Unfamiliar pilots (from training schools)	LMML serves several training schools, thus with different levels of experience among the pilots
Special Flights	LMML also serves search & rescue and hospital flights
Non visible areas	Part of one runway and aprons are not fully visible from the tower

Table 3 - LMML specific complexity factors

4 TaCo Scenarios

The definition of operational scenarios provides the project with a picture of how the management of LMML is conducted on a daily basis by the tower and ground controllers. The scenarios have been built through a continuous and substantial involvement of MATS. A dedicated workshop has been held in Malta with the aim to capture operational experts' inputs to define both the structure and the content of the scenarios. MATS Senior Head of Tower has been involved in this activity.

The main objectives of the operational scenarios definition are the following:

- Investigate the current operational settings in terms of volume of traffic and its characteristics;
- Investigate the impact of different runways/taxiways configurations on ground operations;
- Define how current procedures and working methods deal with the complexity factors previously reported

The definition of realistic scenarios sets the current baseline of operations. This common understanding allows the identification of main user needs and specific solutions to the challenges brought by complexity factors both in the current operational setting and its potential future evolution (including traffic increase and higher levels of automation).

The scenarios definition is an iterative activity as they will be refined, more detailed and potentially adapted during the next stages of the project. As the project advances, the TaCo solutions will mature and the operational experts will become more familiar with the concept. Accordingly, the scenarios here reported will evolve to reflect such progress.

4.1 Assumptions

The scenarios have been collected starting from two potential traffic configurations, varying both in terms of density and nature:

Average traffic density

Aircraft density (in & out)	22 aircraft/hour
Flows	45% outbound + 45% inbound + 10% local[5]
General Aviation Rate	Code A (school flights) and B (business aviation) - 30%
Commercial aviation rate	Code C to F - 70%
Other surface movements	1 movement/hour from MRO + 10 vehicular movements/hour on taxi and runways

Peak traffic density

Aircraft density (in & out)	40 aircraft/hour
Flows	45% outbound + 45% inbound + 10% local
General Aviation Rate	Code A (school flights) and B (business aviation) - 30%
Commercial aviation rate	Code C to F - 70%
Other surface movements	2 movement/hour from MRO + 15 vehicular movements/hour on taxi and runways

[5] Circuits are flown by Code A school flights

4.2 Scenarios

This section collects the scenarios elaborated by the team with the active involvement of operational experts. Each scenario may consider both the traffic configurations above introduced.

4.1.1 Scenario 1 – Crossing Runways

Addressed Roles	Tower, Ground, Delivery
Runway Configuration	Crossing runways in use Main: runway 31 for commercial Secondary: runway 23 for GA
Addressed Complexity Factors	• Surface Activity Complexity • Active Runway Crossings • Runway/Taxiway configuration and restrictions • Aircraft differing in performance characteristics • Unfamiliar pilots (from training schools) • Non-visible areas

4.1.2 Scenario 2 – Single runway in use (RWY 31)

Addressed Roles	Tower, Ground, Delivery
Runway Configuration	Single runway in use (runway 31 for departures and arrivals)
Addressed Complexity Factors	• The ones addressed by Scenario 1 • Runway/Taxiway configuration and restrictions: all aircraft from Aprons 1, 2, 3, 4, 5, 7 and 8, to depart runway 31 shall back track on the runway • Apron congestion: in case of traffic approaching runway 31, aircraft on the ground may taxi via Apron 9, creating further congestion on the park, safety risks, noise and emissions. • Aircraft differing in performance characteristics

4.1.3 Scenario 3 – Single Runway in use (RWY 13)

Addressed Roles	Tower, Ground, Delivery
Runway Configuration	Single runway in use (runway 13 for departures and arrivals)
Addressed Complexity Factors	• The ones addressed by Scenario 1 • Runway/Taxiway configuration and restrictions: all aircraft from Aprons 1, 2, 3, 4, 5, 7 and 8, to depart runway 31 shall back track on the runway • Aircraft differing in performance characteristics

4.1.4 Scenario 4 – Single Runway in use (RWY 23)

Addressed Roles	Tower, Ground, Delivery
Runway Configuration	Single runway in use (runway 23 for departures and arrivals)
Addressed Complexity Factors	• The ones addressed by Scenario 1 • Runway/Taxiway configuration and restrictions: all departing aircraft from Aprons 9, shall vacate via Echo / Fox – taxi on the runway vacate via Golf to Hotel and Juliet to line up on Runway 23. All arriving aircraft shall enter either Taxiway Lima or Papa back track to the end of the taxiway, enter Runway 05 back track to the intersection and then back track on Runway 13 for either Park 8 or Park 9 • Aircraft differing in performance characteristics • Non-visible areas: runway does not have navigational aids • Active Runway crossing: Part of Taxiway Juliet is active all the time with vehicular crossing traffic • Surface Activity Complexity: vehicles of all type including slow moving, cross on the runway threshold from one part to the other.

5 TaCo Support to Airport Operations

The previous section of this document provided the reader with an introduction to the objectives and scope of the TaCo project. The definition of the airport environment and the following description of the specificities of the main TaCo use case, the International Airport of Malta, paved the way for the following definition of the reference scenarios.

The scenarios are the starting point for the following developments of TaCo and they will be among the main tools of the collaborative design workshop, that will start the activities of Work Package 3, devoted to the design of end user programming solutions able to address the project objectives (see D2.2 – State of the art). The design workshop will involve final users (controllers and operational experts by MATS), and the designers of automation solutions, namely experts from ENAC and Deep Blue. The description of the Malta Airport and its complexity factors, together with the identified operational scenarios, provide the workshop's participants with a common understanding of the current operations and working methods in the tower, and constitute a solid grounding for the identification of operational needs, and their conversion in requirements for the design and prototyping of the solutions.

In addition, the already identified scenarios will contribute to the definition of an experimental setting for the evaluation of the early demonstrator delivered by the project. The evaluation of the demonstrator will be conducted in work package 5 and will involve the end users of the system.

Starting from TaCo's objectives (see Section 2.2), the work in the next work packages will focus on the following:

- defining algorithms and solutions to automate and optimize both the decision making and implementation tasks for the controller involved in the ground movement of airport vehicles and aircraft;
- identifying and providing the controller with suitable and usable tools to supervise (monitor, tune and re-program) the system;
- studying the interaction between the human actors and the automation. Main focus will be on the identification of sensitive state transaction from a (fully) automated management system to conditions where the human is brought into the loop to handle situations where his/her cognitive resources are essential.

The following subsections briefly describe how the TaCo approach to airport management may be beneficial for the stakeholders of Malta International Airport.

5.1 Automation Strategies

This subsection focuses on the support nature that TaCo will be able to provide to controllers through the system automation. It consists of a first tentative to map airport complexities with "tools" that address these complexities. From the design process point of view, the airport complexities can be considered as a preliminary expression of user needs as these are factors that ATCOs need to deal with when conducting the operations. From this perspective, the automation strategies can be defined as tools available to the controllers for reaching their goals while overcoming the specific complexities. By applying an automation strategy, the controller indicates the system a way to manage the various agents of the airport system (aircraft, vehicles, etc.). Specific priorities and behaviours (rules) are then assigned to each agent, in order to reach the high-level goal. For example, a possible strategy may consist in "*minimize the overall noise produced by the airport*". This approach would deal with proximity of the airport with the surrounding villages, the traffic increase and, on a lower level, would adopt a noise reduction algorithm for the management of the movements (e.g. minimizing the movements close to airport's boundaries and/or minimizing engines' running time). The following table is a preliminary list of strategies, associated with the LMML complexity factors expected to be impacted. The list has been validated by operational experts from MATS. It is important to highlight that TaCo will not implement all the identified strategies but will rather focus on the most promising ones and explore the interactions (i.e. management and handover) within the reference scenarios. The selection of the most suitable strategies will be conducted together with the final users (controllers) and operational experts at the beginning of Work Package 3.

Strategy	***Impacted Factors***	***Roles***
Maximize predictability*: airport agents are instructed in order to respect all the estimated times*	Surface Activity Complexity, Runway/Taxiway configuration and restrictions	GND and TWR
Optimize runway usage*: instructions/clearances are given in order to minimize the time of occupancy on the runway*	Active runway crossing, Special Flights, Runway/Taxiway configuration and restriction, Aircraft differing in performance characteristics	TWR
Minimize possible conflicts*: movements of vehicles and traffic are cleared in order to minimize the probability of having intersections and, therefore to intervene with solving instructions*	Surface Activity Complexity, Apron Congestion, Non-visible areas	GND
Minimize fuel consumption/CO2*: ground movements and aircraft engine starts are arranged in order minimize fuel consumptions and CO2 emissions*	-	GND

***Minimize noise**: ground movements and aircraft engine starts are arranged in order minimize noise*	-	GND and TWR
***Maximize capacity**: aircraft and vehicles are handled to accommodate the maximum traffic volume of the airport*	Apron congestion, Surface Activity Complexity, Runway/Taxiway configuration and restrictions	GND and TWR
***Prioritization of specific categories:** aircraft of specific categories are assigned with higher priorities by the system (e.g. commercial flights over general aviation, or special flights over commercial flights)*	Special Flights, Unfamiliar pilots, Runway/Taxiway configuration and restrictions, Surface activity complexity	GND and TWR

By adopting an automation strategy, a controller is requesting the system to handle the current situation through a specific set of priorities and rules. However, there will always be circumstances during which the system will not be able to guarantee the application of the strategy over certain levels. These circumstances can be unexpected events, or traffic configurations that are not compatible with the strategy and will be identified during the following stages of the project. When such conditions are met, it is necessary to initiate a different kind of interaction between the system and the controller to establish whether the control -and what type of control- should be handed back to the operator. An outline of the handover problem is provided in the following subsection.

5.2 Focus on the handovers

The automated airport concept addressed by TaCo starts from the assumption that the human operator is at the centre of the system. This means that the tasks related to the management of airport operations are shared between the human and the automation, in a manner that this tasks allocation is dynamic and flexible, but still under control of the human operator.

One of the main objectives of TaCo is identifying, designing and developing (at an early demonstration stage) effective strategies of tasks handover between the human and the automation (and the other way around). As described in "D2.2 – State of the art", a good human-automation collaboration lies on two principles:

- *"visibility" by the user over the functioning of the automation*. If the user has a clear picture of how automation is working and is supposed to evolve in time, s/he will be more inclined to trust the system and engage a good collaboration, based on a flexible and effective share of tasks between the two actors (the man and the machine)[21]. On the contrary, an "opaque" behaviour of automated tools leads to a weaker confidence in the system and a consequent dichotomy in the usage of automation (all or nothing), that prevents the advantages of designing and implementing a flexible collaboration between user and automated solutions, including different Levels of Automation for different tasks (see D2.2, Section 1.1 and [23]).
- *adherence of the functioning of automation to the mental model of the user.* When automation fails, operators must engage into a Knowledge-based type of behaviour, as opposed to Skills

or Rules-based, that is typical a nominal situation. This implies that operators gather information, make sense of it, understand the causes and consequences and counter-act appropriately, leading to a substantial increase of his/her cognitive workload. An important aspect of this problem-solving activity for the operator is to have in mind the right conceptual model of the automation, together with a correct understanding of the status of the whole system (see D2.2, Section 1.1).

The problem of designing a suitable handover strategy between humans and system falls into a wider problem, namely the *out of the loop performance* problem, studied from the very first introductions of automation [25][26][27][28] in professional environments.

The out of the loop performance problem is a major potential consequence of automation that arises when system fails and operations are required to be managed again by the human operator. More specifically operators working with automated solutions were found to have lower ability to detect system errors and recover system failures compared to the operators manually performing the same tasks.

As Endsley [29] points out, the out of the loop performance can be linked with two major factors, namely the loss of manual skills, and the loss of situational awareness by the operator. While the former can be considered mainly a training requirement and a marginal factor for the focus of TaCo, the latter has greater implications for the project. In the same work, Endsley, shows how low situation awareness corresponded with out of the loop performance decrement when a failure of the automated system occurred. The incidence of the situation awareness is also broken down into several components, namely vigilance and complacency problems, shift from active to passive information processing, change in the feedback provided to the operator. Such components act on the human system collaboration on different levels (e.g. choosing an appropriate level of automation, defining suitable tasks and feedback, etc. [23]) and it is advisable for TaCo to consider all these aspects when designing the handover strategy.

Within the framework of TaCo, the handover problem may be modelled in four phases, not necessarily time-consequent, but somehow interlaced and interdependent:

- Monitoring: in this phase the automated system, which is executing some high-level strategy instructed by the human operator, continuously monitors some indicators about its own "goodness" at respecting certain parameters. These parameters may be related to the strategy itself (e.g. ability to keep delay below a certain threshold) or to other global indicators or events (e.g. potential conflicts on a taxiway);
- Detection: in this phase the system processes data coming from the monitoring and takes decisions about its own ability to perform sufficiently good (i.e. parameters within certain thresholds). The capability to early detect unfavourable configurations and/or events is an important property of the system, so effective prediction strategies should be considered and included;
- Resolution: once the systems has detected a situation that is not able to manage, the actual handover to the human is activated. In this sensitive phase, the system and the human has to

negotiate which tasks should be taken by the human and which tasks the system may hold (e.g. handover the control of an aircraft to the human, while another aircraft may remain under control of the automation);

- Information presentation: the handover process includes the timely selection and presentation of the right information to the user, with the aim to enhance visibility and to support the formulation of a suitable mental model (e.g. a timely identification and suitable representation on the HMI of which aircraft the system is leaving to the human).

The next stages of TaCo, starting with the collaborative design workshop, will focus on the identification and analysis of the key information for the design of a suitable handover: the parameters and indicators for the monitoring phase and associated thresholds; events and system configurations that need a human recovery intervention; negotiation strategies and protocols for the handover; quantity, quality and representation of the information associated to the handover process.

Obviously, the concrete design of handover strategies will depend on the selected automation strategies and their implementation, i.e. every automation tool will have its own specific handover strategies and associated design measures. Anyway, a common approach to the handover problem will drive the design of adequate solutions: end users will be involved since the very beginning of the process and the four phases model introduced above will be the framework for the analysis and assessment of handover issues and solutions.

6 References

[1] SESAR, http://www.sesarju.eu/solutions
[2] SESAR, SESAR 2020 Multi-annual Work Programme, http://ec.europa.eu/research/participants/data/ref/h2020/other/wp/jtis/h2020-wp-multi-annual-sesar-ju_en.pdf
[3] ATM Masterplan, https://www.atmmasterplan.eu/exec/overview/performance-ambition
[4] ICAO, Doc 4444 ATM/501 Air Traffic Management, 2001
[5] Eurocontrol Experimental Centre, CONTROL TOWER OPERATIONS: ROLES DESCRIPTION - EEC Note No. 09/2006
[6] ICAO, Doc 9426-AN/924 Air Traffic Services Planning Manual, 1984
[7] Bergé, 2005, Initial EMMA Air-Ground Operational Service and Environmental Description (OSED Initial), Document No. D1.3.1, Eurocontrol
[8] TaCo Grant Agreement, May 2016.
[9] TaCo Consortium Agreement, February 2016.
[10] TaCo Kick Off Meeting Final minutes, 2016
[11] MoTa project - D1.2 - Modern Taxiing Techniques Dynamic Models
[12] MoTa project - D1.3 - Simulation Platform
[13] MoTa project - D2.2 - Functional HMI1
[14] MoTa project - D4.2 - AMAS Opt ATC use case adaptation FINAL
[15] Simić, Tatjana Krstić, and Obrad Babić. "Airport traffic complexity and environment efficiency metrics for evaluation of ATM measures." Journal of Air Transport Management 42 (2015): 260-271.
[16] Chaboud, T., Hunter, R., Hustache, J.C., Mahlich, S., Tullett, P., 2000. Air Traffic Complexity: Potential Impacts on Workload and Costs. EEC, Bretigny, France.
[17] Clean Sky J.U, 2014. Annual Implementation Plan 2014. CS-GB-2013-13-12 doc8a AIP 2014.
[18] Djokic, J., Lorenz, B., Fricke, H., 2010. Air traffic control complexity as workload driver. Transp. Res. Part C Emerg. Technol. 18 (6), 930e936.
[19] Mogford, R.H., Guttman, J.A., Morrow, S.L., Kopardekar, P., 1995. The Complexity Construct in Air Traffic Control: a Review and Synthesis of the Literature. FAA, Atlantic City, USA.
[20] Z. K. Chua, M. Causse, F. André, and M. Cousy, "Modulating Workload for Air Traffic Controllers during Airport Ground Operations," in Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 2015.
[21] Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2000). A model of types and levels of human interaction with automation. IEEE Transactions on Systems, Man, and Cybernetics – Part A: Systems and Humans, 30, 286–297.
[22] Endsley, M.R. & Kaber, D.B. (1999). Level of automation effects on performance, situation awareness and workload in a dynamic control task. Ergonomics, 42, 462-492.

[23] Save, L. Feuerberg, B. (2012) Designing Human-Automation Interaction: a new level of Automation Taxonomy. In De Waard, D. et al (Eds.) (2012), Human Factors: a view from an integrative perspective. http://www.hfes-europe.org/human-factors-view-integrative-perspective
[24] SESAR Joint Undertaking (2013). Guidelines for Addressing HP Automation Issues. P16.5.1 Deliverable 04
[25] Billings, Charles E. "Human-centered aircraft automation: A concept and guidelines." (1991).
[26] Moray, Neville. "Monitoring behaviour and supervisory control." (1986)
[27] Wickens, C. D. (1992). Engineering psychology and human performance (2nd ed.). New York: HarperCollins
[28] Wiener, Earl L. Cockpit automation: In need of a philosophy. No. 851956. SAE Technical Paper, 1985.
[29] Endsley, Mica R., and Esin O. Kiris. "The out-of-the-loop performance problem and level of control in automation." Human Factors: The Journal of the Human Factors and Ergonomics Society 37.2 (1995): 381-394

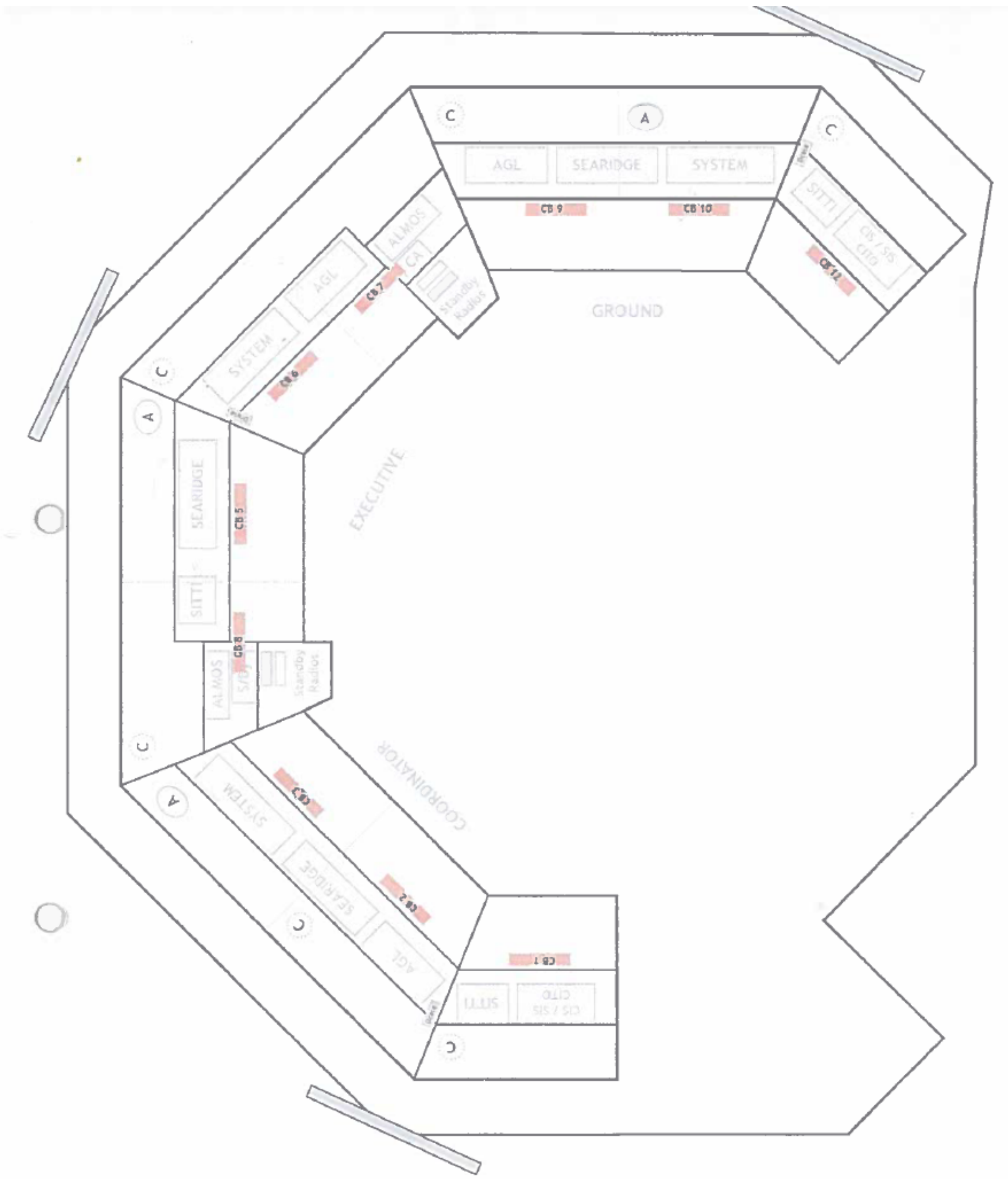
Annex A

The following charts are taken from the Aeronautical Information Package (AIP) Malta.

Malta International Airport - Aerodrome

Malta International Airport – Apron 9

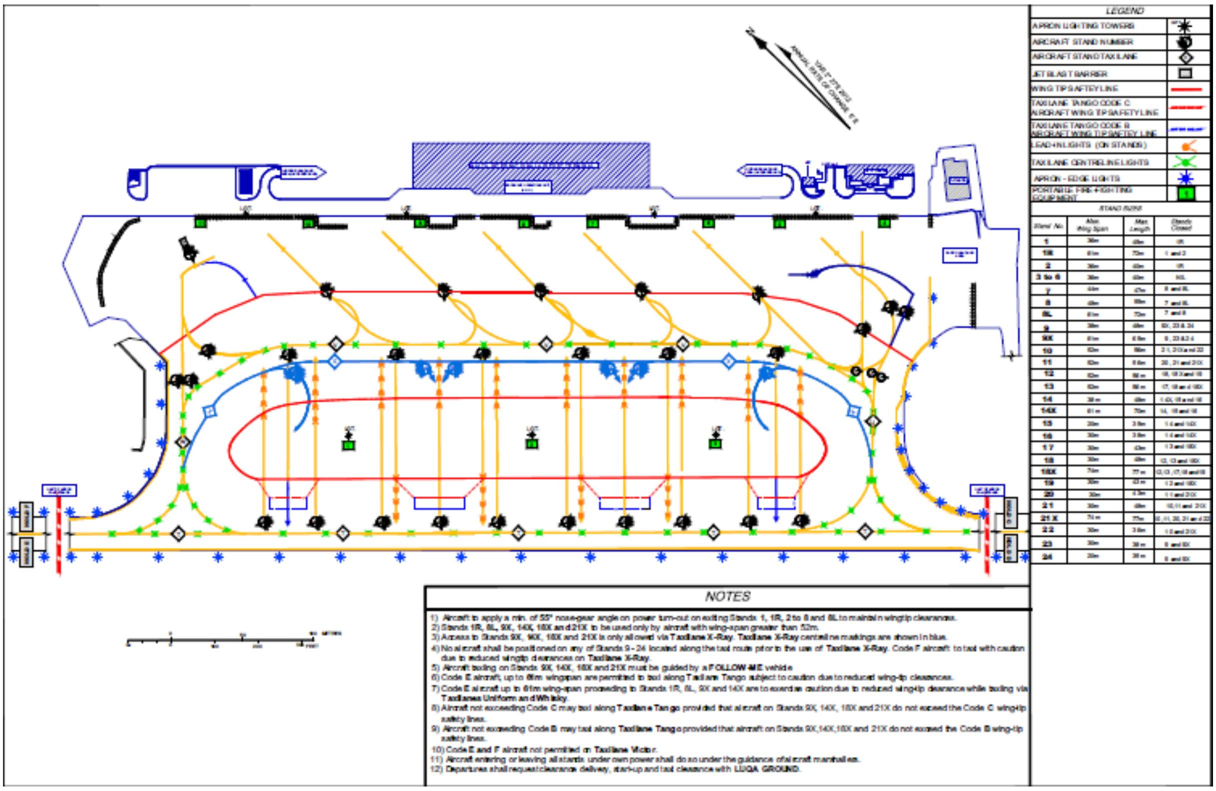
Annex B



Luqa Aerodrome Control Tower layout

Annex C

Here the limitations and procedures in place for Apron 9 of the International Airport of Malta are presented.



Taxilane T

a) Taxilane T is restricted to Code E aircraft with wingspan up to 61m. Aircraft with wing span greater than 61m can taxi unrestricted on taxilane T only when the outer stands along the taxi route are vacant.
b) Aircraft not exceeding Code C (maximum wingspan 36m) can taxi on taxilane T provided that aircraft on stands 9X, 14X, 18X and 21X do not infringe the Code C wingtip safety line.
c) Aircraft not exceeding Code B (maximum wingspan 24m) can taxi on taxilane T provided that aircraft on stands 9X, 14X, 18X and 21X do not infringe the Code B wingtip safety line.
d) On completion of the Follow – Me service for aircraft proceeding to stands 9X, 14X, 18X and 21X the following information shall be communicated by MIA to the CORD:
FOLLOW-ME COMPLETED –
TAXILANE TANGO AVAILABLE TO CODE C AIRCRAFT

OR
FOLLOW-ME COMPLETED –
TAXILANE TANGO AVAILABLE TO CODE B AIRCRAFT
OR
FOLLOW-ME COMPLETED –
TAXILANE TANGO CLOSED TO AIRCRAFT

Taxilane U

a) Taxilane U is restricted to Code E aircraft with wingspan up to 61m subject to stands 9, 9X and 24 being vacant.

b) When stands 9, 9X or 24 are occupied, taxilane U is restricted to aircraft up to Code D (maximum wingspan 52m).

Taxilane V

a) Taxilane V is restricted to Code D aircraft (maximum wingspan 52m).

Taxilane W

a) Taxilane W is restricted to Code E aircraft with wingspan up to 61m subject to stands 14, 14X and 15 being vacant.

b) When stands 14, 14X or 15 are occupied, taxilane W is restricted to aircraft up to Code D (maximum wingspan 52m).

Taxilane X

a) The centreline of taxilane X is marked in blue.

b) Taxilane X is restricted to Code F aircraft with wingspan up to 74m.

c) Access to stands 9X, 14X, 18X and 21X is only allowed via taxilane X with a Follow-Me vehicle which shall commence from the intersections of the TWY C with TWY D or TWY E with TWY F.

d) Prior to the provision of the Follow – Me service to stands 9X, 14X, 18X and 21X, MIA shall co-ordinate with the CORD to establish the taxi route of the aircraft.

e) When aircraft proceed to stands 14X and 18X via Taxilane W, it is necessary that stands 12 to 19 are vacant. In the event that all the outer stands are vacant (stands 9 to 24), the aircraft can proceed to stands 14X and 18X from any direction via Taxilane T.

f) When aircraft proceed to stands 9X and 21X via Taxilane U, it is necessary that stands 9 to 11 and stands 20 to 24 are vacant. In the event that all the outer stands are vacant (stands 9 to 24), the aircraft can proceed to stands 9X and 21X from any direction via Taxilane T.

g) When an aircraft is being marshalled on stands 9X, 14X, 18X or 21X the marshaller needs to temporarily infringe taxilane T. Therefore the segment of taxilane T abeam these stands should be considered closed to aircraft from the time the aircraft enters taxilane X until the Follow-Me reports that the aircraft is parked and the marshaller is clear from taxilane T.

h) Aircraft on stands 9X, 14X, 18X or 21X will be parked clear of taxilane V.

The table in the next page illustrates the limitations in place for Apron 9.

Stand Number	Maximum Wingspan	Maximum Aircraft Length	Stands Closed
1	36m	45m	1R
1R	61m	72m	1, 2
2	36m	40m	1R
3	36m	40m	NIL
4	36m	40m	NIL
5	36m	40m	NIL
6	36m	40m	NIL
7	44m	47m	8, 8L
8	48m	55m	7, 8L
8L	61m	72m	7, 8
9	38m	48m	9X, 23, 24
9X	61m	70m	9, 23, 24
10	42m	56m	21, 21X, 22
11	52m	56m	20, 21, 21X
12	52m	56m	18, 18X, 19
13	52m	56m	17, 18, 18X
14	38m	48m	14X, 15, 16
14X	61m	70m	14, 15 16
15	20m	35m	14
16	30m	38m	14
17	30m	43m	13
18	30m	48m	12,13
18X	74m	77m	12, 13, 17, 18, 19
19	30m	43m	18
20	30m	43m	11
21	30m	48m	10, 11
21X	74m	77m	10, 11, 20, 21, 22
22	30m	36m	10
23	30m	38m	9
24	20m	35m	9