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Founding Members



Authoring & Approval

Authors of the document

Name/Beneficiary	Position/Title	Date
Damiano Taurino/DBL	Project Coordinator	10/05/2018
Giuseppe Frau/DBL	Project Contributor	10/15/2018

Reviewers internal to the project

Name/Beneficiary	Position/Title	Date
Johan Debattista/MATS	Project Contributor	21/05/2018
Stéphane Conversy/ENAC	Project Contributor	15/05/2018
Mathieu Cousy/ENAC	Project Contributor	15/05/2018

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

Name/Beneficiary	Name/Beneficiary	Name/Beneficiary
Damiano Taurino/DBL	Damiano Taurino/DBL	Damiano Taurino/DBL
Johan Debattista/MATS	Johan Debattista/MATS	Johan Debattista/MATS

Rejected By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date
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TaCo

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

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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 document describes the evaluation strategy and its results obtained mainly during the final stages of the project. The evaluation strategy is strictly connected to the user-centred design process and as such it has been translated into an iterative process that culminated in the final evaluation.

The final evaluation involved both Malta International Airport (MIA) air traffic controllers and external stakeholders coming from the airport domain during two distinct workshops. The conduction and results of these workshops are described in this document. Since the low TRL envisaged by TaCo, a qualitative approach was employed for both the end-users and the external stakeholder feedback.

Results show positive feedback from end-users as well as from external stakeholders. The introduction of automation strategies as the main support for handling the operations was considered beneficial and additional promising strategies were identified during the evaluation. Furthermore, such strategies were not only perceived as a support for optimization, but more in general, as an assistant for coping with specific situations.

Feedback on the DSSL tools pointed to the employment of such concept in offline mode, namely for planning the behaviour of the system considering known or plausible restrictions that are going to be in place during the time of the operations. Such logics would be then available during the actual management of the traffic, provided that the action plans can always be overridden by the controllers.

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1 Introduction

1.1 Purpose and scope of this document

This document describes the evaluation strategy and results of the overall TaCo concept and its final prototype. The concept itself and the implemented prototype are described in [1],[2] and [3]. The evaluation was an iterative process that involved MIA air traffic controllers from the early stages of the project and culminated in two final evaluation activities dedicated to end-users and external stakeholders.

The opinions expressed herein reflect the author's view only. Under no circumstances shall the SESAR Joint Undertaking be responsible for any use that may be made of the information contained herein.

1.2 Relationship with other deliverables

D5.1 reports on the evaluation process and results. A great part of the evaluation regards the TaCo prototype tool and its functions described in D4.1 D4.2 and D3.1 [1][2][3]

Operational needs and use cases are described in D2.1 and were used as drivers for guiding the evaluation.

1.3 Structure of this document

Chapter 1 introduces the document

Chapter 2 describes the evaluation strategy adopted during the TaCo project

Chapter 3 describes the final evaluation with the end users

Chapter 4 describes the feedback from the external stakeholders

Chapter 5 contains the conclusions and future directions

1.4 List of Acronyms

ANSP	Air Navigation Service Provider
ATCO	Air Traffic Control Officer
ATM	Air Traffic Management
ATZ	Aerodrome Traffic Zone
CA	Consortium Agreement
CPDLC	Controller Pilot Data Link Communication
CTR	Control Zone
HMI	Human Machine Interface
DMAN	Departure MANager
DoA	Description of Action
DSGL	Domain Specific Graphical Language
EASA	European Aviation Safety Agency
EC	European Commission
FPL	Flight Plan
GA	Grant Agreement
GMC	Ground Movement Controller
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
KPA	Key Performance Area
KPI	Key Performance Indicator

LMML	Malta International Airport
LOA	Letter of Agreement
MATS	Malta Air Traffic Services
MDI	Minimum Departure Interval
MIA	Malta International Airport
MLS	Microwave Landing System
MRO	Maintenance, Repair and Overhaul
SAR	Search and Rescue
SESAR	Single European Sky ATM Research
SID	Standard Instrument Departure
SJU	SESAR Joint Undertaking
STRS	Standard Taxi Routing Schemes
TBS	Time Based Separation
UCD	User Centred Design
WP	Work Package

2. Evaluation strategy

This chapter describes the overall methodology for the evaluation of the TaCo concept.

The evaluation methodology is strictly influenced by the design process used during the whole project. TaCo has adopted a User Centred Design process engaging the users from the early stages of the activities.

“HCD is “an approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques”[4]

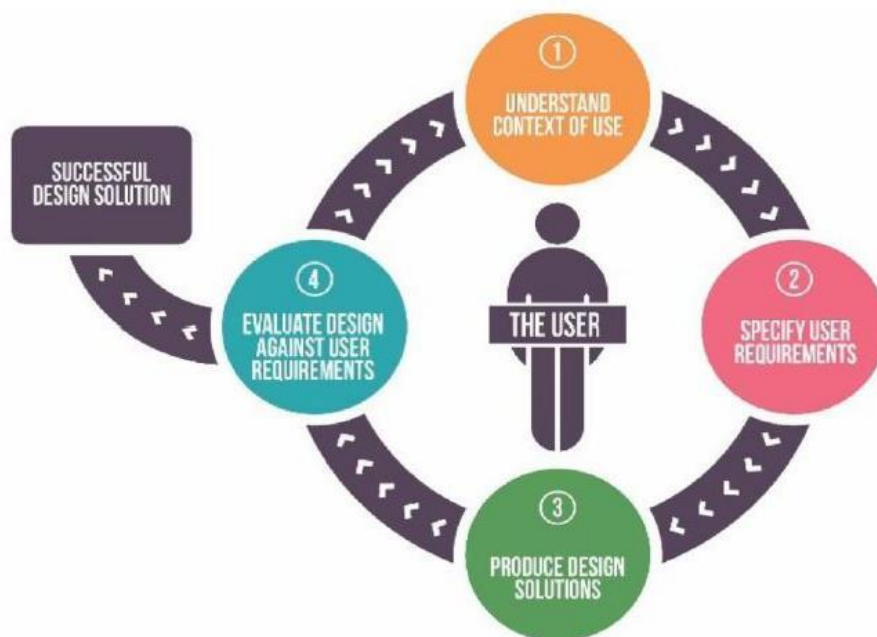


Figure 1 - User Centred Design Process

Figure 1 shows the phases and the flows of a typical user centred design process. Such process is based on 6 design principles:

- The design is based upon an explicit understanding of users, tasks and environments.
- Users are involved throughout design and development.
- The design is driven and refined by user-centred evaluation.
- The process is iterative.

- The design addresses the whole user experience.
- The design team includes multidisciplinary skills and perspectives.

The UCD is by definition an iterative process tailored around the user in order to elicit and acquire information useful for the production of design solutions. Such solutions are then finalized when the user requirements are satisfied. The evaluation methodology, as a consequence, needs to take into account the iterative essence of the process. To face this, TaCo methodology was built upon the following pillars:

User engagement and co-design: taking advantage of the presence of MATS in the consortium, it was possible to reach and directly involve the ATCOs in the early design phases. This allowed to smooth the first stages of context understanding and user requirements specification.

Work scenarios: the context of the operations (i.e. MIA environment) was specified directly with and by the users during the first workshop in Toulouse. The shape of the context description was a set of so called “work scenarios” or “use cases” (see deliverable D2.1 Automated Airport for more details) describing the current and most meaningful situations representing a potentially difficult task that could be supported by the automation. Work scenarios represent a hybrid asset containing both the context description and the user needs.

Design scenarios: based on the information collected through the work scenarios, a set of so called “*design scenarios*” was produced introducing potential support solution that TaCo could provide to the controllers. Design scenarios were produced again through a co-design process with the controllers who expressed their ideas on the solutions in a second workshop in Malta. Both the work and design scenarios were generated using paper mockups containing the airport representation and reproducing typical situations for the controllers (see deliverables D4.1 and D4.2 for more details on design scenarios).

Final evaluation: A subset of the design scenarios was then translated and implemented into the TaCo prototype that was evaluated at the end of the project during a dedicated workshop in Malta. The remaining chapters of this deliverable contain the approach and results of the final evaluation with the users and the feedbacks collected from external stakeholders.



Figure 2 - Work Scenario production

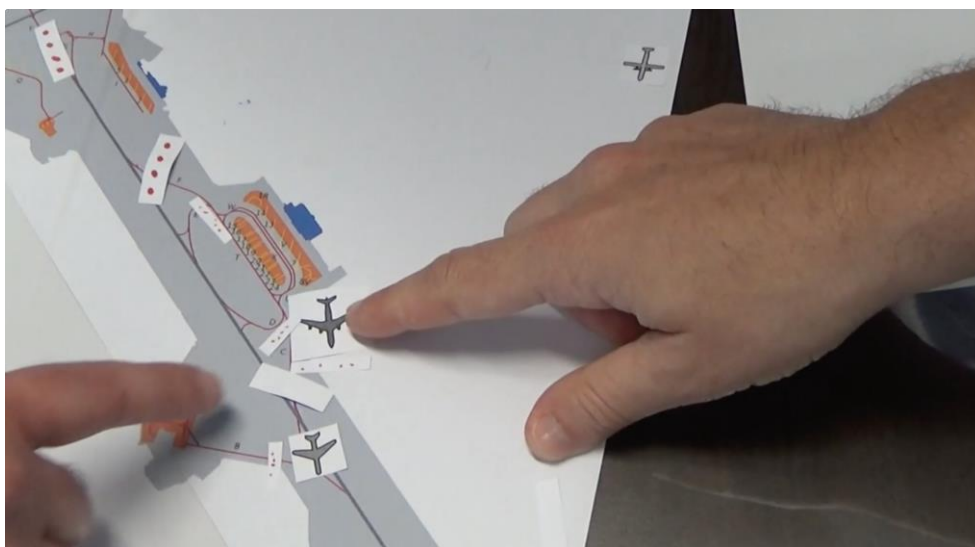


Figure 3 - Design Scenarios production



As already mentioned, the design and evaluation processes constantly involved MATS ATCOs and operational experts. The following table reports the characteristics of the participants involved during the project.

Age	Years of experience	Roles covered
46	27	Snr Head Tower
55	30	Snr Head ACC
46	22	Snr Head Tower
57	32	ATCO – Tower, Radar and ACC
27	7	ATCO – Tower

3. Final evaluation with users

This chapter is structured in two main sections: first it describes the evaluation strategy applied to assess the TaCo concept and its prototype. Finally, it illustrates the results gathered during such evaluation.

3.1 Evaluation strategy

The final evaluation addressed TaCo's main components aiming at collecting qualitative results on their acceptance, suitability and potential issues regarding their introduction and usage. Therefore, for each of the TaCo features the following objectives were pursued

- TaCo automation strategies: investigating with MIA controllers to what extent the designed automation strategies can support their work during nominal situations and identifying the main problems during transitioning towards non-nominal circumstances (see [3])
- DSGI tools for enabling the user-programming: understanding how controllers can benefit from user programming both during and before the operations (see [1][2])

3.2 Evaluation dimensions and methods

Each of the topics mentioned above contributed to the overall assessment and were evaluated against the following dimensions:

- Acceptance of the concept by the controllers
- Suitability of the concept (does the TaCo concept really addresses the operational needs, the complexities and the traffic characteristics of the target case study?)
- Usability of the proposed implementation
- Potential safety issues

Participants were involved by mean of two kind of exercises:

- Demo Exercises: participants observe a live demo where TaCo partners explain the context, the environment, user interface and tools available and use the TaCo prototype to manage a specific situation

Supervised Exercises: participants can interact with the TaCo prototype under the close supervision of the TaCo team and simple demonstrative tasks can be accomplished

3.3 Data collection

The following table reports the data collection means for each of the investigated dimensions

Dimension	Data Collection Means
Acceptance	Semi-Structured Interviews / Debriefings
Suitability	Semi-Structured Interviews / Debriefings
Usability	Debriefings / Expert Based Analysis
Safety	Semi structured Interviews / Debriefings

Table 1 - Data collection means

Debriefings and semi-structured interviews were guided by the TaCo project partners in order to cover all the areas described in the previous sections. During such activities the following questions were investigated by the team:

Benefits/obstacles for the adoption of TaCo

- Possible benefits when using TaCo in this use case:
 - Do you foresee benefits in using the global optimization HMI?
 - Do you foresee benefits in using the user programming tools?
 - Which programming tool would help the most?
- Potential obstacles in the adoption of TaCo in this use case:
 - Do you foresee obstacles in using the global optimization HMI?
 - Do you foresee obstacles in using the user programming tools?
- Potential safety issues related to the use of TaCo in nominal/non-nominal/emergency conditions
- Do you see issues when scaling to different conditions (e.g. different traffic conditions)?

Handover assessment

- In case TaCo would stop working. Given the information you got/are getting:
 - Describe how the system is supporting the handover to you
 - Counter on the user programming HMI
 - Unsolved constraint(s) in the global HMI
 - Make a guess on how much time you would need to come back to full control
 - Environmental conditions that may have an impact on the handover (meteo, traffic, runways configuration)

User experience

- Usability of the tool

- Look&feel of the HMI
- Suitability of visual representation of aircraft, runways, etc.
- Easiness of comprehension and use of the visual programming language (like the “&” operator, the “stop bars”, “no enter area”, etc.)

3.4 Results

This section describes the results collected during the final evaluation with the ATCOs. At the current maturity level of TaCo, it was possible to qualitatively investigate the new concept with the controllers. The demonstrative sessions (or exercises) had the aim to explain the main features of TaCo in a semi-interactive way, however it was not possible to propose and replay specific traffic scenarios in a real-time simulation fashion. Within this context, it was possible to acquire two kinds of results, namely:

- Operational support results: these results were derived by mapping the operational use cases with the TaCo concept. It is clear that the TaCo prototype could not entirely support the set of operational use cases but it was sufficient to let the controllers answer the following question *“Given this operational scenario, what kind of supports would you envisage from TaCo?”*
- Transversal results: these results emerged from controllers’ observations about the current status of the prototype and could be directly mapped with the dimensions identified in section 3.3.

3.4.1 Operational Support Results

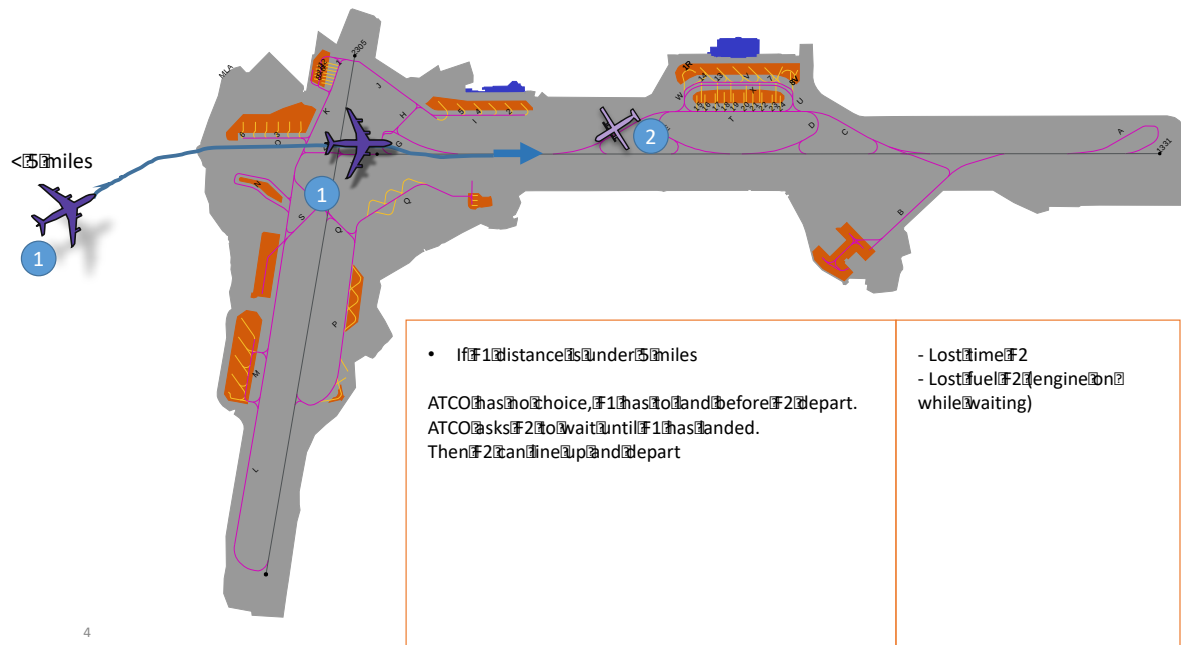
This section shows the results related to the operational use cases described in deliverable 2.1 section 4.2. For each explored use case, the most suitable tools of TaCo were identified together with

- Possible changes to the current features of TaCo
- Additional features not yet existing but compatible with the TaCo concept

The use cases are here reported for the readers’ convenience and followed by the related results

Use Case 1 – Runway 13 – one arrival and one departure

This use case describes the parameters ATCOs consider and their actions, when choosing which flight from a departing one and an arriving one should use the runway first. Depending on the remaining time before landing, the ATCOs may choose to schedule a departure to avoid any delay.

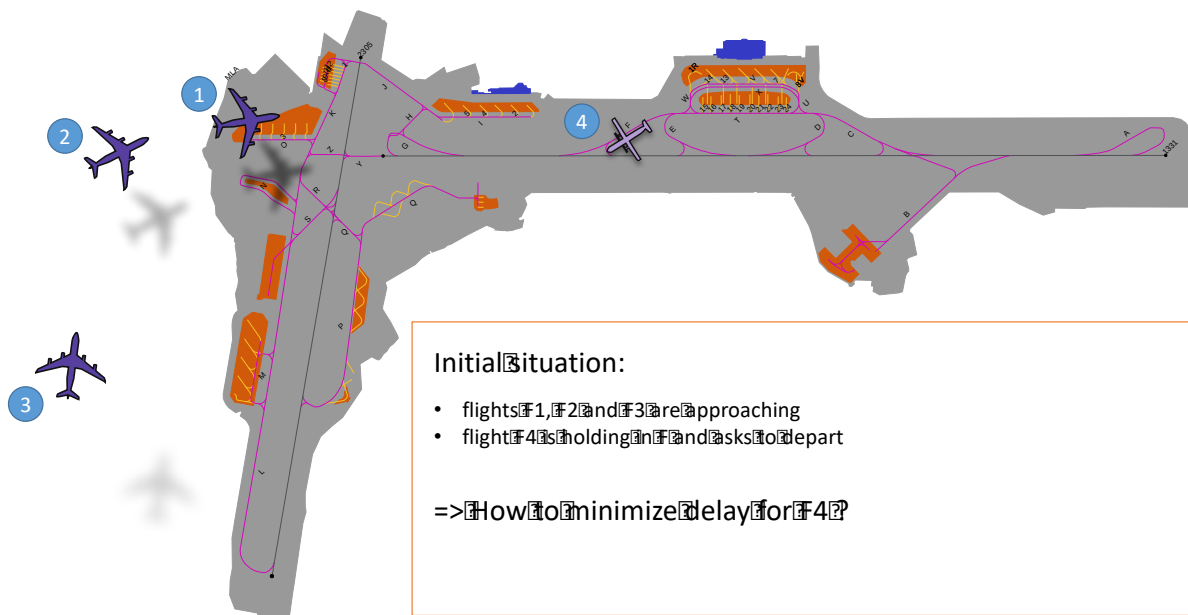


The main challenge introduced by this situation is related to the decision regarding what flights should be prioritized and which ones, on the other side would be “penalized” in terms of delay and fuel consumption. From the controllers’ perspective, this scenario can easily be solved through the usage of the automation strategies, in particular by using a fuel reduction optimisation or a runway usage one. In fact, by timely specifying one of the strategies, the departing flight would have been instructed coherently from the engine start to the waiting point. Additionally, two other functions were considered potentially useful:

- The introduction of an automation strategy related to the prioritization or grouping of specific flight categories
- The usage of DSGI support to specify a sort of pre-safety net similar to the stop-bar scenario (see deliverable 4.2) but with no automatic clearances for the departing aircraft

Use Case 2 – Runway 13 – multiple arrivals and one departure

This use case describes the parameters ATCOs consider and their actions, when inserting a departure into a flow of arrivals. Depending on the remaining time before landing, the ATCO may choose to slow down or lengthen the trajectory of an arriving flight to get an empty slot for the departing flight, and thus minimize delays.



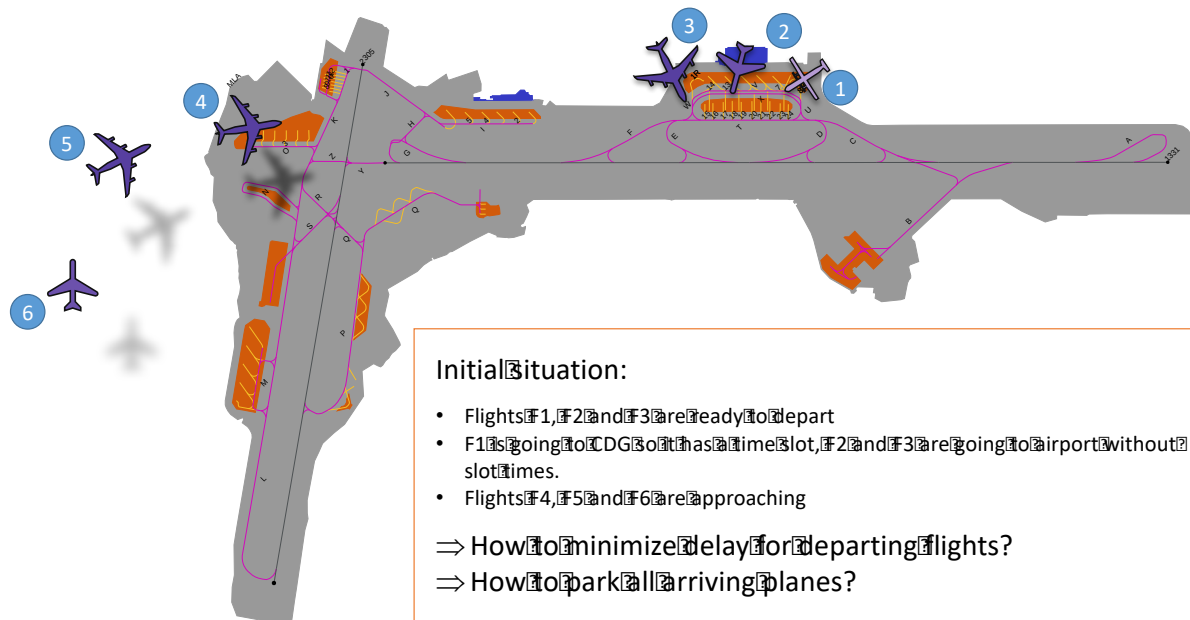
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Similarly to the first use case, the usage of the TaCo automation strategies was considered a suitable support for managing the traffic. In particular, the “runway usage” optimisation was considered a good-to-have strategy to obtain a first sequence of actions (for example, the system can propose to first land all the inbound traffic and only then to clear the last flight to take off) provided that this sequence can be edited by the controller, for example to insert the departing flight before the last inbound. This aspect emerged in several points of the evaluation and it should be considered a key driver in the design of a system supporting the TaCo concept: controllers want to be in control, and should always have the possibility to tune (or even discard) what was proposed by the system. Even though one of the TaCo objectives is to transfer and to use part of the controllers’ knowledge and skills to the machine, it is unlikely that all the peculiarities of the environment will be taken into account to produce the solution.

Generally speaking, TaCo should not aim to produce the perfect solution but rather a good enough solution that can be then easily tuned by the controller. Based on that tuning, TaCo should be intelligent enough to learn and propose a better solution for a similar situation.

Use Case 3 – Runway 13 – multiple arrivals and multiple departures

This use case describes the parameters ATCOs consider and their actions, when inserting multiple departures into a flow of arrivals. One departing flight goes to CDG and has a time slot to respect. The objectives of the ATCOs are to minimize delay for departing flights, and make room in aprons to handle the arriving flights.



When facing more complex situations like in the present use case, the need of more elaborated logics that could be used side by side with the strategy aroused. This scenario provided multiple sources of complexity that were combined with the environment constraints. In particular, beyond the decisions related to the safety and efficiency of the movements, controllers had to face a problem of space in the main airport apron. In such situations, as already mentioned, the mere usage of an automation strategy is not sufficient. A solution identified with the controllers is the automation authoring through the DSSL tools. More in details, it should be possible to automatically apply specific automation strategies based on the number of aircraft in the main apron. Such rules should be prepared offline as the time to author the automation is not compatible with the real-time management of the movements. However, some parameters of the rules like the specific thresholds can be defined tactically. Figure 4 below shows the way TaCo support such feature: the purple area was sketched around the main apron and it is attached to a counter function that, in turn, feeds the logic for the automation strategy selection.



Figure 4 - Automation authoring for strategy usage based on main apron congestion

It appears that in more complex situations, a support of pre-set logics defined through the DSGL tools can provide benefit to controller workflows as the complexity of the situation is reduced toward the recognition that a specific set of rules can be applied in that moment.

3.4.2 Transversal Results

Unified interface (usability, suitability)

The global strategy interface and the ground interface are not necessarily dedicated to different ATCOs. The specific configuration of the interface is likely to depend on the complexity and size of the airport. *"In Malta it's probably going to be the same person and it would make sense to have a single unified interface"*

Overall good quality of interface (usability, suitability)

ATCOs who participated to the final evaluation expressed an overall positive feedback regarding the look and feel and usability of the interface. In particular, they were able to recognize the functions of TaCo and their effect on the airport operations after a brief introduction by the team.

"I like the interface, it looks very clear"

Risk of visual clutter and information overload (acceptance, usability, safety)

During the evaluation sessions, ATCOs reported several times the concern of working with cluttered interfaces that could prevent them from recognizing alerts, or potentially risk situations. As TaCo introduces new elements of control (e.g. logic operators in the DSGL tools, gauges etc.) it is important, for moving to more mature stages of TaCo to carefully take this aspect into consideration when designing the interface.

"When DMAN understands that the constraints cannot be met, it should highlight it. But keep the information simple (e.g. on the DMAN)"

Authoring automation (suitability, acceptance, usability)

The feedback from ATCOs revealed, as expected, that authoring the automation and defining its behaviour is an activity with different levels of complexity depending on what aspects of the operations are impacted by the rules.

"There is a set of rules that should always be there because they always apply, but other things you cannot foresee them, and need to be specified the day of operation, for example closed taxiways, closed parts of the airport, temporary restrictions on type of aircraft etc."

DSGL was considered beneficial for offline programming, planning and configuring the airport environment and having TaCo ready for the moment of the operation. Pre-set of rules, behaviours etc. can be then presented to the ATCOs who can decide whether to apply them, modify or simply discard.

"if the ATCO knows a taxiway will be closed for maintenance, he can reprogram specific automation"

Connection between global interface and DSGL (suitability, usability)

The less evident connection between the TaCo tools seems to be the matching between the global strategies/optimization part and the DSGL functionalities. This was due to the fact that not all the DSGL functionalities were implemented. Further cases of connections between DSGL and optimization strategies should be explored.

Additional strategies (suitability, acceptance, safety)

A strategy for grouping/clustering same vortex category aircraft can be useful (you line up all the heavy and then all the medium instead of putting heavy-medium-heavy-medium-heavy-medium). This suggests that automation strategies shouldn't only represent an optimization supports but operational modes to be used in specific circumstances. Strategy implementation were considered a valid support by the controllers.

Controllers want to be in control (acceptance, safety)

ATCOs repeatedly stated their preference toward a system that allows them to modify, override, discard planned actions.

"We always want to be in control"

"The confirmation tool in the DSGL family is my favorite tool"

Even when the system provides good results when applying a strategy, there always be specific situations that require fine tuning of the actions. The sequence of the AMAN/DMAN represented a good source of such cases: controller reported how, for example, it has no effect to delay crew only flights coming from maintenance even when they are ready to take-off, to give priority to other flights.

"Flight like this needs more checks since they have been maintained, so the checks take longer, moreover they are crew only flights"

Grouping critical information (safety, usability, suitability)

ATCOs need to know where to look for specific information.

"I don't want the alarms to be all spread in the screen, I need to have a place where I look to find if alarms went off. Like an alarm box."

This aspect was also related to the risk of visual clutter in the interface but it was explicitly pointed out by the ATCOs for the critical information such as the alarms.

Importance of voice communication for critical stages (safety)

In ATCOs team it is necessary to make actions and plans explicit. Having all silently automated would introduce some risks of decreasing team situation awareness. As a result, there are a set of more important actions that need to be declared explicitly. The voice communication, in this context, works as a mean of common awareness and double check in the team. This emerged during the usage of the DSGL for implementing automatic stop-bars: in this design scenario, stop-bars were handled automatically by TaCo following the logic pre-defined through the DSGL tool (i.e. when first flight frees the area, then the second flight is cleared to enter runway) and instructing the flight through CPLC.

ATCOs were asked: *"What if there was a button and no talk for stop-bar? by CPDLC?"*

"No, voice is important for situation awareness, for everybody, pilots and ATCOs alike"

4. Feedback from external stakeholders

TaCo organised a final dissemination event at the International Airport of Malta in April 2018. The main objective of the event was to share the project results with all the potential users and stakeholders including airport operators and ANSPs. Nonetheless, scientific results have been also presented to raise interest and feedbacks from the scientific community. The final dissemination event of TaCo was organised the day before SESAR-ACI Europe workshop that took place at the same

Agenda

The event has been thought as a full day workshop. In order to better fit the needs of the participants, the morning session has been oriented more on scientific outcomes of the project, while the afternoon session has been designed to better fit the operational needs and the benefits coming by the use of TaCo in a real airport environment. In Appendix 1 the full agenda of the event is reported.

Participants

Participants have been invited by the consortium members among their contacts and extending the invitation to the participants to the following SESAR-ACI Europe workshop. The announcement of the event has been put on the website as well, in order to collect subscriptions by the visitors. A table with the list of participants is shown below. It can be seen that a wide range of stakeholders has been reached (airport operators, ANSPs, airlines, industry, research), in accordance with the dissemination objectives defined in the Communication and dissemination plan.

Name	Organization	Type of stakeholder
Damiano Taurino	Deep Blue	Consortium member
Duarte Gouveia	ACI-EUROPE	Airports association
Jason Gauci	University of Malta	Research/Academia
Dirk Schaefer	EUROCONTROL	ATM intergovernmental organisation
Federico Petrocchi	Enav	Air Navigation Service Provider

Jaroslav Niewinski	PANSA	Air Navigation Service Provider
Roberto Weger	SITTI	Systems manufacturer
Martin Dalmas	Malta International Airport	Airport operator
Noel Friggieri	Malta International Airport	Airport operator
Luca Crecco	SESAR JU	Project officer
Mr. Maximilian Hartwig	Flughafen Muenchen GmbH / Munich Airport	Airport operator
Sara Bagassi	University of Bologna	Research/Academia
Krzysztof Kalaman	PANSA	Air Navigation Service Provider
Anne Bruss	Fraport AG	Airport operator
Valerio Cappellazzo	EUROCONTROL	ATM intergovernmental organisation
Kurt Eschbacher	University of Salzburg	Research/Academia
Sebastian Hentrich	Fraport AG Operational Planning	Airport operator
Steve Burchill	SBworkdesign Ltd	SME/Industry
Daniel Liebhart	ETF	Air Traffic Controllers trade unions
Jennifer Sykes	Heathrow airport	Airport operator
Roland Guraly	Slot Consulting Ltd.	SME/Industry
Michele Altieri	ATCEUC	Air Traffic Controllers trade unions
Francesco Modafferi	ATCEUC	Air Traffic Controllers trade unions
Kari Osterberg	Finnish Meteorological Institute	Meteo Service provider
Vojin Tomic	University of Belgrade, Faculty of Transport and Traffic Engineering	Research/Academia
Zeljko Gojko	ATCEUC – CATCU	Air Traffic Controllers trade unions

Giuseppe PILLIRONE	Air France	Airline
Trevor Darmanin	Malta Flying	Aviation Training organisation
Ana Ferreira	Deep Blue	MOTO project
Giuseppe Frau	Deep Blue	Consortium member
Mathieu Cousy	ENAC	Consortium member
Stephane Conversy	ENAC	Consortium member
Joe Degiorgio	MATS	Consortium member

Figure 5: participants to TaCo final dissemination event

Workshop activities

The morning session focused on the scientific outcomes of the project. In particular, the presentations introduced the user programming techniques, the innovative approach and algorithms used to define and compute automation strategies and the user centred process used to design the solutions.



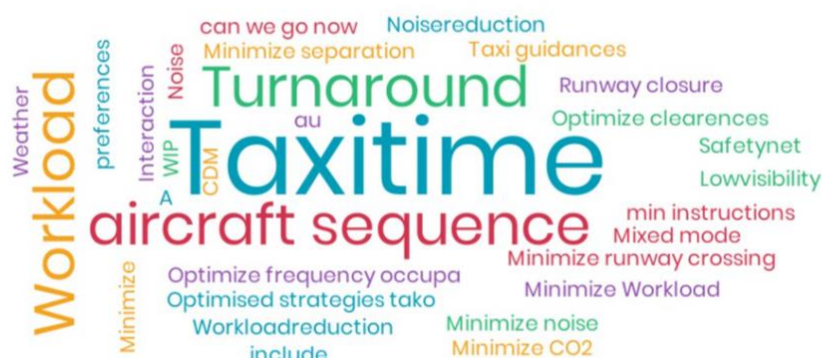
Figure 6: one of the presentations in the morning session of TaCo final workshop

At the end of the morning session, a brainstorming has been done with the participants. Due to the high number of participants and to time limitations, the consortium decided to support this activity by means of an interactive application¹ able to collect live feedbacks by the users during a discussion. In Appendix 1 the outcomes of this session are reported. In general, the feedback by the audience was good in terms of acceptability and overall quality of the proposed solutions. The optimisation of runway usage has been ranked as the most promising optimisation strategy among the ones already implemented, as well as minimizing taxi time and reducing controller's workload were proposed as possible strategies to be further investigated.

The following figures show the main results obtained during the workshop with the external stakeholders.

What other optimization strategies would you suggest for airport movements?

Mentimeter



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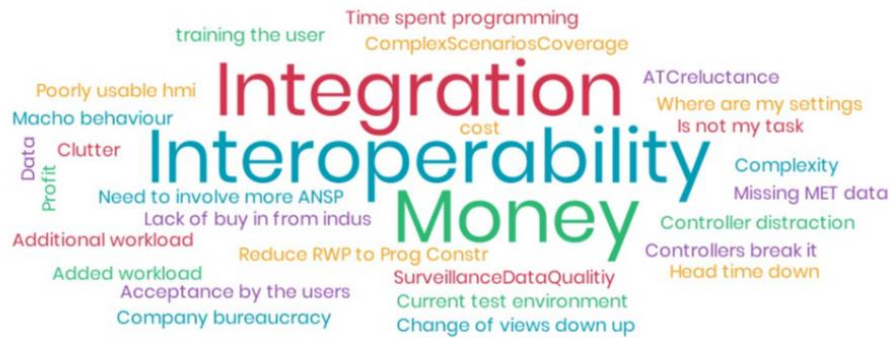
Figure 7 - Optimization strategies suggested during the workshop

Participants were asked to specify beneficial optimization strategies that were not implemented in TaCo. Among the keywords in the picture, bigger words represent the ones having a higher number of votes. It has to be noted however that the same concept/strategy expressed with slightly different wording would appear as a different keyword: for example, a strategy regarding workload optimization was specified by several people in different ways.

¹ Mentimeter, <https://www.mentimeter.com/>

Potential obstacles in the adoption of the TaCo concept

Mentimeter



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Figure 8 - Potential obstacles identified

Among the obstacle against the introduction of TaCo participants mainly specified reasons related to money, integration, and interoperability with the existing systems.

Potential safety issues in the adoption of the TaCo concept

Mentimeter



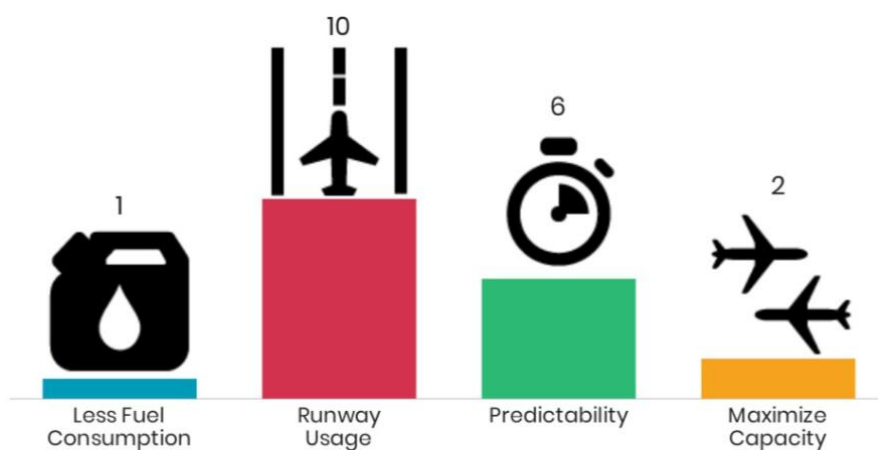
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Figure 9 - Potential safety issues identified

Safety issues related to the introduction of TaCo were asked separately as the importance of the topic. A number of well-known issues related to the introduction of highly automated systems was specified by the participants, for example “human in the loop”, “misuse”, “loss of situation awareness”.

In your opinion, what is the most promising optimization strategy in TaCo

Mentimeter



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Figure 10 - Most promising optimization strategy

Participants were also asked to select the most promising automation strategy among the one already implemented in the TaCo prototype. Surprisingly, the “less fuel consumption” strategy was the one with less votes.

Overall quality of the prototype's user interface

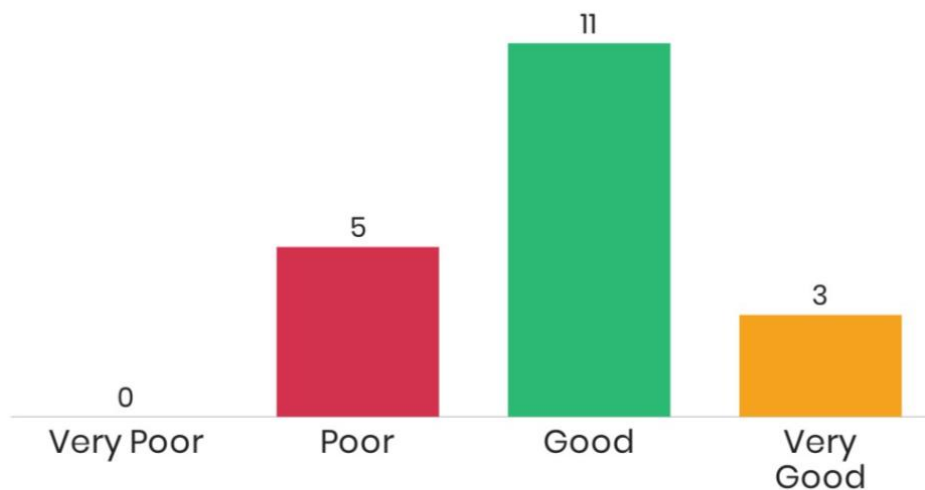


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Figure 11 - Overall quality of the prototype's user interface

The overall quality of the prototype's user interface was rated as good or very good by 14 participants on a total of 19.

It would be easy to adapt TaCo to be used in other airports

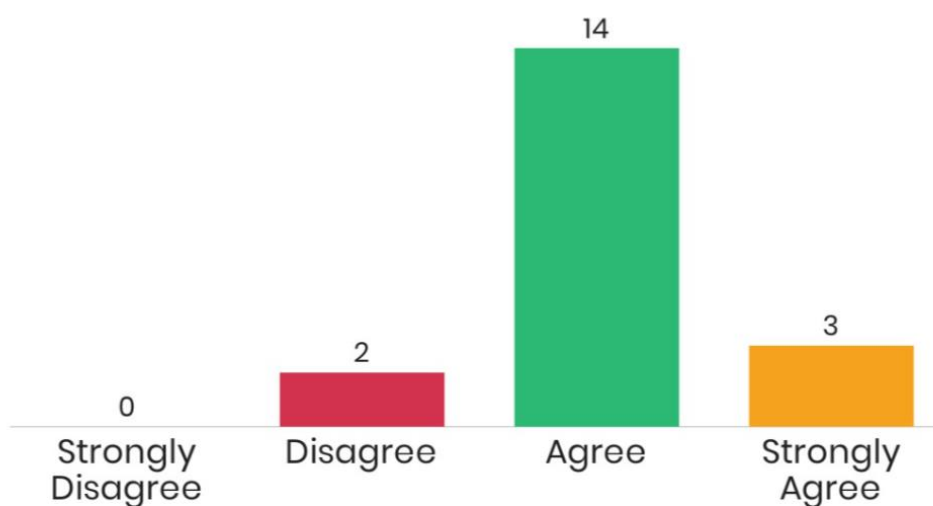


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Figure 12 - Transferability of TaCo on other airports

Finally, participants were asked how difficult would be to transfer the TaCo concept and apply it to other airports. The general feedback show that this would be a feasible process. Further comments during the discussion pointed out that it wouldn't be a "research work" to transfer such concept.

5. Conclusions

This chapter presents the conclusions regarding the evaluation activities including a discussion about how the TaCo approach changed from the beginning to the end of the project thanks to the gathered results.

In this deliverable the evaluation strategy and the results were described. The evaluation activities were tailored around the User Centred Design (UCD) process: the TaCo project constantly involved the end users from the early stages, adopting co-design techniques where possible to elicit user needs, user requirements and design solutions.

The evaluation culminated in two final workshops for the final assessment of the TaCo concept and the implemented prototype with end users and external stakeholders. Both the groups of participants express positive feedback regarding the evaluated elements.

Future studies should focus on the following aspects:

- the quantitative assessment of the automation strategies in airports of different complexity levels
- further investigating how the DSGT tools for authoring automation can provide benefits during their full life cycle, i.e. from their specification offline to their application during the moment of operations
- stressing and studying the transition from nominal to non-nominal situations and vice-versa in order to identify safety issues and mitigate them with graceful handovers

5.1 TaCo's approach to automation

TaCo's initial vision of human-automation collaboration involved the usage of innovative concepts such as

- the presence of multiple autonomous agents (i.e. aircraft, vehicles etc.) that can be instructed to pursue a specific objective
- the user-programming techniques for
 - defining agents' behaviours and logic during the tactical phase
 - keeping the controllers engaged and in the loop
- the presence of intelligent modules capable of sensing the inability of the system to manage the current situation (or even better, predict this minutes ahead)

- the ability of such modules to recognize what operations are still controllable through the automation and how to gracefully shift back the control toward the human

Thanks to the results gathered along the whole project activities, it was possible to further refine these pillars of the TaCo concept and to adapt and integrate them towards a more mature and suitable concept. While some of the pieces have gone under minor tunings (i.e. the automation strategies were considered a valid support with very small modifications), others shown the need to be redesigned when explored with MATS air traffic controllers. These changes put together resulted in TaCo concept/approach that is here described.

The resulting TaCo approach envisages to cover the entire spectrum of the operations, from the strategic stages to the tactical ones. TaCo stands for "Take Control", and the assumption is that controllers will be facilitated in keeping, taking or releasing the control if they are involved in the definition of the automation logics. This assumption is not different from the one defined at the beginning of the project. The real difference is the time frame envisaged for the definition of the automation logic, the usage of this logic and the support applying them. Put in concrete terms, TaCo approach translates in the following supports

Strategic/pre-tactical phase: (from 1 month to day before operations) during this phase, considering the planned flights and the fixed constraints in the airport environment, TaCo allows to setup the strategies to be used during the operations. This is done using the DSGL tools that can be applied to

- local areas of the airport
- specific flights
- specific times of the day (e.g. during peak hour)
- specific situations (e.g. when more than, see figure Figure 13)



Figure 13 – Programming an automatic change of global strategy with the DSGL according to the number of flights at apron 9

At this point, it is important to highlight that this process is essentially a translation and transfer of knowledge from the controller experience to the rules specified for planning the system behaviour.

The strategic and pre-tactical phase considers different aspects while approaching towards the pre-tactical side: for example, some of the constraints are fixed due to the structure of the environment and can be considered during the initial stages, while others will be known only some days before the operation forcing a re-planning of the logics.

The result of this stage is a set of rules/behaviours/logics linked to the expected traffic picture and that already the known constraints and complexity of the airport. Each of these rules has its own degree of autonomy depending on how it has been defined: for example, a rule stating that "runway usage optimization will be applied when the inbound + outbound traffic overcomes a given threshold" can be applied automatically, while more safety critical behaviours may require the confirmation or the explicit intervention of the controller.

Tactical Phase: during the tactical phase, the rules previously defined are proposed to the controllers depending on the actual situation. As described before, one of the properties defined at strategic level is the degree of autonomy of the behaviours. During this phase, controllers have a tool box of pre-set rules that they can decide to apply, tune or even discard depending on what is happening at the moment.

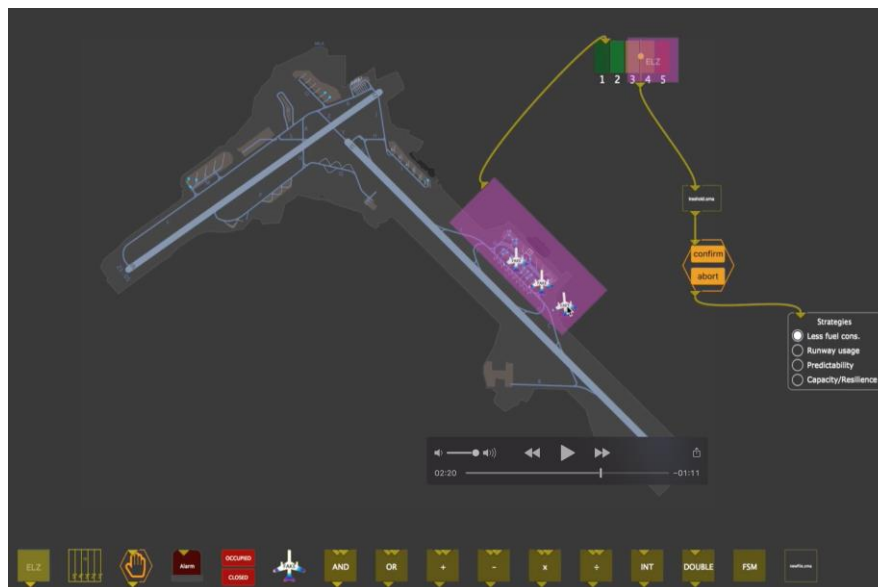


Figure 14 – The user tuned the previous visual program to request an explicit confirmation before the change occurs

Controllers' input at this stage is important not only for safety and human performance reasons: if monitored and tracked, their input also produces a valuable dataset that reveals the actual usage of pre-defined behaviours mapped with the traffic situation and constraints. This can be used as a training-set for supervised models able to propose suitable rules depending on the situation.

References

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