

Assessment of impact of Degree of Automation on Human Roles: The Experts' Analysis

**R. Casar, A. Arranz,
B. Escribano**
Isdefe
racasar@isdefe.es

**A. Grosskreutz,
R. Garcia**
CRIDA
argroskreutz@crida.es

R. Suikat, M. Jipp
DLR
Reiner.Suikat@dlr.de

**G.D.R. Zon, M.
Joosse**
NLR
Rolf.Zon@nlr.nl

ABSTRACT

This paper describes the results of the two assessments performed to evaluate the impact of increasing levels of automation (LoA) on Human Factors aspects and the impact on their responsibilities and interactions. This activity has been developed within the "Assessment of Degree of Automation on Human Roles" (ADAHR) project inside the framework of SESAR Work Package E.

These assessments have been carried out in two environments, "Airspace Organization and Management" and "Airport Operations Centre", using the performance of role-based games in two steps: a preparative "Paper Based" gaming session followed by a complementary "Hardware Based" gaming session on hardware platform.

The results of these two exercises have been gathered from the participation of experts in the different games. They will be presented by environment and taking into account the roles involved in each environment. Aspects such as trust in the system, situational awareness, confidence and performance were addressed.

Author Keywords

Gaming; Human Factors, Automation, ATM

ACM Classification Keywords

Human Factors. Automation, Assessment

General Terms

Human Factors; ATM

INTRODUCTION

The Air Traffic Management (ATM) will go for important changes to improve the current performance and operation which has been demonstrated to be insufficient to address the current and future issues. The modernization of the ATM systems foresees an increase in the level of automation as part of the solution to the main problems that ATM is facing nowadays. Thus the impact of the automation and new technologies on the human operator is

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critical to ensure the successfulness of the implementation and deployment of those systems. Automated systems must be compatible with human capabilities and the development of effective and usable automated ATM systems requires Human Factors input throughout the design life cycle, from concept formulation, through detailed design, to implementation and operation.

At this point, the goal of ADAHR project is enlarging the knowledge about the impact of automation on human roles, aiming at investigating how the automation impacts on the interactions and situational awareness among several actors with different interests (e.g. airspace users and air navigator service providers) and focusing on the long-term phase.

The necessary level of automation for 2020 in a SESAR environment is studied in the SJU programme, but this level of automation is expected to be higher in the ATM environment after the SESAR development phase. Therefore the performed assessments embrace three different time horizons: 2020, which will be the starting point used as reference to carry out a comparison between the different timeframes, 2035 and 2050. It is assumed that the Levels of Automation will increase over the time and the baseline scenario, which is the 2020 timeframe, will be the expected situation when improvements of SESAR development phase are in operation.

Since a complete assessment of all ATM roles could not be performed, within the ADAHR project, the boundaries were set out to assess a suite of roles in two different environments: "Airspace Organization and Management" and "Airport Operations Centre". The focus of the analysis were put on the Demand and Capacity Balance (DCB) processes arisen when imbalances are produced by abnormal situations such as bad weather or an special event such as the final of a football match during which lots of passengers needed to be transported in a short timeframe.

The expected results of these assessments are obtained from three different sources: An Expert's judgment by each of the environments, a statistical analysis performed by students in the Airport Operations Environment and a global assessment independent of the environment. This paper is focused on the presentation of the results from the experts' assessment.

GAMING AS ASSESSMENT TECHNIQUE

Human-In-the-Loop (HIL) Gaming technique are “serious games”, designed for a specific purpose other than pure entertainment. These games are played with persons (mostly, experts) acting as actors and allow the exploration of concepts and definition of roles and processes in a structured way focusing the players’ attention on the information flow and responsibilities associated to the processes.

This technique has proven to be excellent to explore the situation awareness and the human-human and human-machine interactions in automated environments [1, 2, 3].

This was the rationale behind the selection of gaming technique to perform the assessment on impact of automation on human operators. A combination of two types of gaming techniques, (Paper-based gaming and Platform-based gaming), were utilised because experience in ATM assessment has proved that this combination of role-based games provides a good quality assessment of the process involved in the concept under test as shown in [2, 3]. More details about the methodology can be found in [1].

Paper-based games are performed using basic office material. They are basically board games where the rules are designed according to the processes and roles interactions to be studied/ clarified. Hardware-based games are basically performed in the same way as the paper-based ones, but the means/tool used to play is a hardware platform. They use and complement the results obtained from paper-based games with the following benefits:

- the platform contributes to execute the exercises in a more realistic context, imitating the real environment and showing the information as they will be in the real life. Some examples are shown in the figures 1 and 2.
- platform results are more reliable and accurate. The players used to assess them more realistic than the ones obtained in paper-based.
- the performance analysis is easier,
- and for this project, there is a strong link with automation and human roles.

Concretely for the assessment carried out in ADAHR, the combination of both techniques allowed the definition and exploration of roles and their responsibilities and the interaction of these roles within an automated environment:

- the paper-based games produced high-level and preliminary outcomes to support the platform/s configuration and they served as training about the technique and the scenarios to be analyzed.
- the hardware-based games consolidated the results and allowed to have enough data to provide the results with statistical significance.

The platforms used in the hardware-based games were:

- CHILL (Collaborative Human-In-The-Loop Laboratory) to analyse the “Airspace Organization and Management” environment, henceforth Environment 1. CHILL is a versatile collaborative ATM validation platform in which different categories of actors can work together to efficiently manage traffic demand and capacity, exchange ATM data and share information in support of a collaborative ATFM planning process. Next figure shows on example of the type of information displayed.

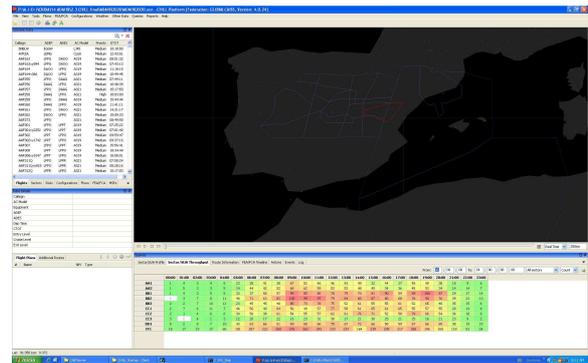


Figure 1. CHILL Platform-based Game screen shot

- ACCES (Airport operations and Control Centre Simulator) to analyse the “Airport Operation Centre” environment, henceforth Environment 2. ACCES provide several operator working positions as well as a means to provide a common overview of the situation to the operators. This platform has a flexible infrastructure with up to ten operator working positions as well as a large power wall to show a situation overview to all operators. Next figure shows the physical layout of the ACCES platform:



Figure 2: APOC simulator ACCES - Layout

APPROACH OF THE ASSESSMENT

The assessments performed were focused on the achievement of the following objectives:

- Identification of mechanisms that enhance the trust of the human actors in automation.
- Analysis of the impact of automation in the interaction between human actors.

- Analysis of the impact of automation on the new roles and responsibilities foreseen by the levels of automation addressed, especially in terms on workload and situational awareness.
- Analysis of the tools supporting the ATM human actors' duties

In order to reach these objectives, the first stage was the definition of the new roles and responsibilities of human operators for the two environments, starting from the SESAR definitions of human roles in 2020 and the expected technical capabilities of automation [4]. Next, the scenarios were defined for the two different environments and for three future automation levels (corresponding to a situation around approximately 2020, 2035 and 2050) [5]. The design of the different exercises through the development of different games was planned and reported [6,7,8,9], the impact of the automation described in the scenarios on human roles is assessed through the execution of the designed games and afterwards the outputs were analyzed and reported [10,11]. The process is envisioned in the Figure 3.

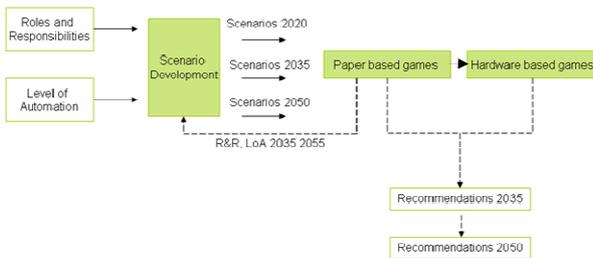


Figure 3: Process flow followed to carry out the ADAHR assessments

To analyze the impact of automation on human roles the following metrics were taken into account: Trust and confidence, Workload, Performance, Situational Awareness and Teamwork.

Given limited number of participants the assessment performed by the experts does not allow a statistical analysis of the data obtained from the questionnaires. Due to this and to enrich the nature of the results of the project, the performance of an additional platform-based gaming sessions focused on Environment 2 were planned to feed the assessment with statistical data which give more value to the analysis of the results. The participants to these gaming sessions were students or people with no real experience in these processes.

The outputs of the execution of the games were collected through: observations and notes wrote down by the management team during the execution of the games, questionnaires filled in by the actors and notes taken during the debriefing session after the run of each game.

The execution of the different gaming sessions was consecutively performed: Firstly the sessions of the

environment 1 (paper-based and afterwards platform-based) and finally the sessions of the environment 2 (also paper-based and afterwards platform-based). This allowed to applying the lessons learnt from each session to the subsequent ones, improving the quality of the results obtained and the time implied in the preparation and execution of the exercises. Following figure shows the schedule of the gaming exercises:

| Id | Nombre de tareas | tn 1, 2012 | | | tn 3, 2012 | | | tn 1, 2012 | | |
|----|---|------------|-------|-------|------------|-------|-----|------------|-------|-------|
| | | nov | ene | mar | may | jul | sep | nov | ene | mar |
| 1 | ADAHR Gaming Sessions | | | | | | | | | |
| 2 | Environment 1 Games | | | | | | | | | |
| 3 | Pape Games Preparation | | 02/01 | | | 18/04 | | | | |
| 4 | PaperGames Execution (Madrid) | | | | | 18/04 | | 20/04 | | |
| 5 | Platform Games Preparation | | | 01/02 | | | | 26/06 | | |
| 6 | Platform Games Execution (Madrid) | | | | | | | 26/06 | | 28/06 |
| 7 | Environment 2 Games | | | | | | | | | |
| 8 | Paper Games Preparation | | | | 01/05 | | | | 17/10 | |
| 9 | Paper Games Execution (Madrid) | | | | | | | 18/10 | | 19/10 |
| 10 | Platform GamesPreparation | | | | 02/07 | | | | | 18/01 |
| 11 | Platform Games Execution (Braunschweig) | | | | | | | 12/12 | 13/12 | |
| 12 | Platform Games Execution-Students | | | | | | | 21/01 | | 22/02 |

Figure 4: Gaming sessions planning

Following section deals with the description of the environments under study, through the description of the scenarios and their roles. This will facilitate the understanding of the results putting the reader in the same context as the players who were in charge of the assessment.

ENVIRONMENTS DESCRIPTION

Airspace organization and management (Environment 1)

The scenarios of the environment 1 feature the impact of a non-severe capacity shortfall due to bad weather forecast. The bad weather is expected to be over Madrid impacting the capacity of Madrid-Barajas airport and the Madrid Air traffic Control Centre (ACC). This happens during Madrid's high season, when unexpected events may disrupt operations and the agreed service level may fail to be met. The scenario encompasses the whole process from the detection of the imbalance until the approval of a solution to be implemented.

More specifically, it consists of the following core processes:

- Build/Refine Reference Traffic Demand;
- Detect Airspace Demand Capacity Imbalance;
- Select/refine/Elaborate a demand and capacity balancing (DCB) Solution at Network Level;
- Assess Network Impact of the DCB Solution;
- Start user driven prioritization process (UDPP) on shared business trajectories (SBTs).

Environment 1 Roles

The following roles will take part in the scenarios of the Environment 1:

- Regional Network manager (RNM);
- Local Traffic Manager (LTM);

- Airport collaborative decision making (CDM) Manager
- Airspace Manager

The detailed list of responsibilities of these roles is provided in detailed in [6,7]

Environment 1 Scenarios

The 2020 scenario was used as the baseline. It is assumed that SESAR is in place and that airspace users express their preferences which are reflected in the priority level of a flight. The DCB tools are automated to provide a complete set of solution/action alternatives on demand, which do not completely solve the situation, but simplify it. These solutions take the priority of a flight into account.

In 2035 scenario the demand and capacity balancing tools are automated to provide a ranked list of solutions/action alternatives on demand, which completely solve the situation, and have different cost of solution indexes. The cost of solution index takes into consideration the business needs of the different actors and the airlines. This scenario had two different runs with different location and impact of the storm.

In 2050 scenario the demand and capacity balancing tools are automated to identify and solve demand capacity issues and try to optimize capacity usage. They provide the solution that best fits the pre-agreed parameters reflecting the business needs of the different actors and airlines, and an equity parameter taking into account previous penalizations. This solution has to be approved by the actors. The 2050 scenario had two different runs with different location and impact of the storm.

Airport Operation Centre (Environment 2)

The scenario designed for the games is based on a special event taking place at a European airport with high demand. Such special event is a football match, the Champions League final, which faces a British and a Spanish team. This will implicate an airport demand increase due to special flights chartered for the occasion.

The reception of the extra flight plans and the search for a solution to the capacity problem takes place during the day of operations, several hours before the match start. More specifically, it consists of the following core processes:

- Detect Airport Demand/Capacity Imbalance
- Select/Refine/Elaborate a Demand Capacity Balancing (DCB) Solution at airport level

Environment 2 Roles

- Airport Agent
- Major Airline Agent
- Charter Airline Agent

The detailed list of responsibilities of these roles are detailed in [8,9]

Environment 2 Scenarios

The 2020 scenario is used as baseline to compare the other two scenarios, 2035 and 2050. The LoA is supposed to be the lowest and then the most similar to current one. For this scenario each actor will have a different what-if tool to assess the solutions. The information shared to all actors will be limited. For this timeframe coordination and communication between actors acquire greater importance.

In 2035 scenario, the system creates and proposes a set of possible solutions based on KPIs such as punctuality or throughput, but not on the cost models of the actors, which are still confidential for each of them only. Then each actor will select his/her own solution and they will have to agree a common solution for all actors involved in the process.

In 2050 scenario, System Wide Information Management (SWIM) is assumed to be fully implemented and all actors share all the information in real time, so communication required between them is limited. The level of automation for this scenario is the highest and the system knows the cost model of all the stakeholders, so that it looks for the solution with the highest total profit for the whole operation. This scenario will assess the acceptance of the solution proposed by the system, which is supposed to be the best globally speaking. Agents will have to accept or reject the solution proposed by the system.

For this environment, different runs are planned to minimize the order's effects of the execution of the scenarios (in environment 1, the order was 2020-2035-2050), then nine runs were planned and the variants of this scenario were:

- Scenario 1: a set of additional charter flights is announced in the morning of the day of the match, resulting in a heavy overload of the airport, as the available parking capacity is not sufficient for all flights without creating additional parking space by closing a runway.
- Scenario 2: a heavy storm is forecast for the peak arrival traffic period, resulting in increased separation for arriving flights and hence in a reduction of the runway capacity.
- Scenario 3: the airport announces a planned closure (for maintenance) of one of the runways during the peak traffic hour. The closure may be moved in time by some margin.

In all three cases is the task of the stakeholders to make the best possible use of the available resources and to conduct the traffic as efficiently as possible.

PLAYERS

The actors who performed the different roles were all males and they had a great deal of experience in ATM. They had different nationalities (British, Italian, Romanian, German and Spanish).

None of them had experience with gaming technique previously to these assessments. Although one of them participated in all gaming sessions (performing just one role in each environment).

RESULTS

This section aims at presenting the main results obtained in each of the two environments from the gaming exercises performed by ATM experts. More details can be found in the report documents [10, 11] and they will serve as input for the conclusions report to be issued on April 2013.

A general consideration to take into account for both assessments is that UDPP process was not performed because of the lack of experts availability and also because the UDPP process definition is still not very mature to be assessed. This process is too much complex to be slightly studied and other initiatives within SESAR are exclusively dedicated to its study.

Results on Airspace Organization and Management (Environment 1)

The study of this environment was performed in two different gaming sessions, one using paper-based games and another one using platform-based games

The paper-based sessions resulted in two-fold outputs:

- Feedback for the design and configuration of the platform-based games
- Qualitative results related to the ADAHR objectives assessment.

The main outputs of the paper-based gaming sessions to the platform-based gaming sessions were:

- Refinement of the processes involved in the different timeframes, and the actions performed by each actor: the experts pointed out some actions or processes that should be changed or improved to be more realistic and adapted to a future real scenario.
- Improvement on the definition of the level of automation that should be in place in each year: the experts considered the levels of automation, based upon their current experience, proposed for 2020 and 2035 very low;
- Improvement on the definition of the solutions to be provided by the automation: the experts commented the information that they experienced as missing in order to have sufficient confidence on the system and to facilitate their operation (for example, the solutions that system proposed in 2035 timeframe were not considered realistic conforming to the expected LoA for this timeframe).
- Initial awareness of the expected outcomes from the simulation: At the beginning of the gaming sessions, the experts were informed about the objectives of the project. After the execution of the different game runs and after they filled in the corresponding questionnaires, they

deeply knew the objectives of the exercise and the assessment to be done, in terms of questions and metrics to be evaluated.

- Initial knowledge by the expert participants on the scope of the simulation: The paper-based gaming sessions in this environment were the first experience of the players with the gaming technique and also with the scenarios. This served as training on the general performance of a game and, even more important, on the processes and responsibilities of the roles that they performed.

These outcomes were translated into a refined set of requirements for the hardware platform [7], refined validation scenarios, and better background for the participants.

Environment 1 Overall results

The results of the paper-based gaming sessions suggested that actors felt more comfortable with the 2050 environment than with the intermediate 2035 level, (based on the answers to the questionnaires and also taking into account the comments of the experts during the debriefing and during the execution of the games). The results of the platform-based gaming sessions seemed to confirm this, but in the end; they pointed out the need to remain in control over the situation. This assessment could be explained because although they requested that the system proposed more solutions in order to have more options, they did not understand the rationale behind them.

In fact, one of the conclusions to define the more trustable Level of Automation for the participants is that it would be interesting to see the results of the students gaming sessions which are assumed to be more prone to accept computerized automation than experienced participants which may be more set in their way of operating.

Herewith, there is a brief description of the most remarkable aspects found during the different timeframes of the Environment 1.

About 2020 timeframe, the scenario related to 2020 timeframe was the first one to be performed and it was used as training for the actors.

Discussion about processes and use of tools took place during these sessions.

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About 2035 timeframe, in one of the runs the Airport CDM Manager and LTM solved the situation in parallel which resulted in some technical problems when implementing the solution because the LTM was working with old information and Airport CDM Manager did not understand the need of waiting for another player to find a solution. The actors felt more comfortable than in 2020 timeframe but they could not indicate if it was because now they knew the system better or because the automation solves the whole situation.

One interesting issue took place in this timeframe: the RNM decided to use the solution that delayed the flights by minus of few minutes (mainly minus of five minutes delay) but without including the transatlantic flights, because after a long flight having even a small delay could provoke bad blood. The actors questioned whether or not human kindness would be lost.

About 2050 timeframe, the actors were told that there was a conference where all the parties in the ATM/airport reviewed the performance of the network in the previous season, and agreed the performances of the next season. During the 2050 debriefings, they said that the related parameters should include the different preferences (mainly cost was mentioned and fuel/lack of fuel by 2050).

One of the main discussions was about the need to clearly know the limits of the ATM network. The situation was that the small network effect produced an overload of two flights in one sector over Europe. The RNM approved the solution because the overload was very low, (and he knew that sector capacity is above the official one to allow the controllers to deal with this type of situations), and the related solution cost was the best one. The APOC indicated that he was talking about current capacity definition, and probably in 2050 the capacity was the real limit or very close to it. The flexibility of the human compared to the machine was discussed.

Environment 1 Metrics assessment

The assessment on the impact of automation on human roles is based on qualitative results coming from the comments of the experts and also based on the analysis of some metrics assessed in the questionnaires. To do this, the outputs of the questionnaires were used to assess the metrics:

Role of automation – the participants rated that the level of automation was adequate to perform the activities and they positively assessed the substitution of human tasks for the performance of their activities although the 2050 timeframe was slightly considered the best one.

Acceptance – The participants accepted the increasing levels of automation. The participants agreed that given the level of traffic in the 2035 and 2050 exercises, a high level of automation was required to be able to undertake the work, but the LTM felt more comfortable with the level of automation in 2035, where he had to review the solution and had several options available to him. The RNM showed a slight preference for the 2050 situation but he still wanted to be able to review the solution, checking that everything is ok.

Active Involvement of humans – The participants perceived a decrease in the activity of the human involvement in the tasks but they did not experience it as inconvenient for their performance.

Confidence and self-efficiency – Their perception on the execution of their tasks resulted positive and they felt confident with the solution given by the system. This data was according to the low rates on the degree of frustration in their performance, being the 2020 situation the most frustrating.

Situational Awareness – the participants did state that their situational awareness was sufficient for the given LoA and traffic density of that year. The LTM felt that the 2035 situation as the best one and the RNM is the role which rated lower their situational awareness. The CDM Airport Manager similarly rated their situational awareness.

Trust in the system–It was seen that the level of trust is maintained as the level of automation increased. Feelings of system reliability, accuracy, usefulness and confidence increased over the periods of time. However, the RNM did state that he would have liked to be able to perform a final "check" on the solution before accepting it.

Teamwork –The participants found that the system did help them out more as the LoA increased, but that the interactions between participants decreased. The LTM did mention that the chat function worked well as a means of communication what he was doing to the other team members and was appropriate since the activities occurred during the planning phase of flight, not execution, so that there was no time pressure.

Workload – The workload was acceptable for the given automation and traffic density of that year, although there was a difference per participant in the amount of decrease in workload as the LoA increased. It was suggested that since the automation is solving all the local DCB conflicts, the role of LTM approval of the solution could be incorporated into the duties of the RNM.

Needs of possible future support tools – Since the general becomes more and more accustomed to communicating textually (IM, SMS/texting, etc.), the acceptance of this mode of communication in a DCB planning environment will increase and could be taken advantage of. Other needs revolved around the visualization of the solution and the actor's ability to see what had been implemented, if they so desired. Some proposals for improvements were:

- Ability to show multiple scenario data: it was recommended that future DCB systems aiming at this LoA incorporate means for the actors to visualize the scenarios being proposed for implementation and the changes involved.
- The rules used by the tools to calculate the best/optimal solution should be known by all the participants..

Environment 1 Lessons learnt

As result of the performance of these gaming sessions the following conclusions about their preparation and execution

were done to take into account in next environment assessment:

- The combination of both gaming techniques is very suitable to perform this type of assessment: The platform offered the realism that players needed to perform a complete assessment and the paper-based sessions supported the familiarisation with the concept and the configuration of the platform to concentrate the assessment on the most important and interesting issues.
- Training is crucial for getting high confidence on the results. The training time must be even excessively planned to get that participants feel comfortable with the platform or tool operations and they can be focused on the concept or issue to be assessed.
- It is recommended that the participants are the same in both paper and platform exercises and that they assume the same roles. So they acquired the experience in the gaming technique and the knowledge about the scenarios allowing them to focus on the evaluation of the objectives of the simulation.
- Changing roles in the same scenario has been demonstrated to NOT work out in a proper manner. When not many runs are scheduled to be done, it is better to maintain the same roles to facilitate the familiarisation with the technique and the concept.
- The order effects (2020 - 2035 - 2050) should be taken into consideration for any future games of this nature. There was a feeling that learning and other positive carry-over effects would be stronger than negative effects such as fatigue which would lead to results which were positively biased for the later scenarios.

Results on Airport Organization Centre (Environment 2)

Similarly to the Environment 1, the analysis was performed in two different gaming sessions, one using paper-based games and another one using platform-based games

The difference with the environment 1 is that the qualitative results of the gaming sessions carried out by Experts will be complemented with the statistical analysis of the data obtained from the performance of the students gaming session. The analysis of these results is still on-going at the moment in which this paper is being developed.

Taking advantage of the lessons learnt from the Environment 1 gaming sessions, following aspects were considered:

- the execution of several runs per timeframe (3 per each timeframe) was planned to minimize the order effects of the different scenarios.
- the same actors participated in both gaming sessions.
- the actors assumed the same roles

- Training was carefully planned and the performance of the game was simplified to avoid the need to have a lot of knowledge about the interaction with the tool.

The paper-based sessions resulted also in two-fold outputs:

- Feedback for the design and configuration of the platform-based games
- Qualitative results related to the ADAHR objectives assessment.

The main outputs of the paper-based gaming sessions to the platform-based gaming sessions were:

- The solution to cancel a regular scheduled flight in favour of additional charter flight was considered as totally unacceptable: The scenario and cost model were modified such that cancellations of scheduled flights were not necessary to achieve an acceptable solution.
- The ground handler role was missed by the participants: providing a separate ground handler role was however not an option for the platform-based gaming, as this would change the team. Furthermore the ACCES platform did not include the capabilities to manage the ground handler aspects sufficiently.
- The actors found the system provided solutions not to be sufficiently transparent, i.e. they could not see the rationale behind them: this effect was considered as a limitation of the paper-based gaming; so the platform-based gaming will give the actors more options to explore and evaluate the proposed solutions.

Environment 2 Overall results

From the global analysis of the paper-based a platform-based gaming sessions, the main aspects about the impact of automation on the Environment 2 roles were:

- The personal opinion regarding automation and whether automation results in an optimal solution affected the average rating given by the actor. The rating over time of the actors was comparable.
- The actors stated it was not clear who was responsible for the final decision.
- The trust in the automation over time remained the same, but more insight in the reasoning of the tool is needed to trust and understand the solution provided by the tool.
- There was a comment about the importance of the involvement of the end-user of the system into all phases of the systems lifecycle, (design, development and testing). This was considered as crucial for the trust in the systems and the confidence on the performance: *"I have to image that although I don't know the logical implementation of my requirements in the tool, it should comply with all of them since I assume that the system has been developed and tested by myself and the rest of the stakeholders since the very beginning of its lifecycle"*

- The ratings by the two Airlines are often comparable while the Airport ratings' somewhat differ. Broadly the Airport Agent assesses more positively the impact of the LoA on his own role than the Airline Agents.

The most remarkable aspects found during the different timeframes of the Environment 2 are detailed in the following paragraphs.

About the 2020 scenario, the actors were still in command using a tool to calculate the benefits of the solution, they were not very familiar with the tool and finding an optimal solution took a lot of time in comparison with the real life. The actors commented the need of more training with the tool to have more confidence on the results. In fact, they experienced the training curve with the system over the runs of each timeframe. In addition to this the actors stated several times the big effort and time spent in negotiation: *“At the end of the day I lost money as the airport agent had to ultimately make a final decision. We worked at nine different solutions and in the end, my business lost out. There was nothing I could do to resolve it”*.

During the paper-based games the players made the following comments:

- some information about the airport was crucial for decision making processes, (e.g. location and alternative airports)
- the possibility of swapping slots seemed not to be feasible, maybe the auction slots resulted more possible.
- the airport has more confidence in the information provided by the Major Airline than Charter one. This confidence is based on the familiarity and the knowledge of the Major Airline's systems

About the 2035 timeframe, although the actors had less influence on the possible options (defined by the system) than in the 2020-timeframe and a lower situational awareness, they were still in command as they could choose an alternative. The actors felt responsible and the confidence and self-efficacy was rated higher than in the other time-frames. The Airport Agent felt that the information provided by the system was correct and that he could access to the information that he needed: *“Solutions are presented in a desired and clear way. It is easy to choose within the three options with the rest of participants, and if one needs further details, the tools present a lot of additional information”*.

During the paper-based games the players made the following comments:

- It is assumed that in 2035 the use of shared i4D business trajectories will be widely extended, meaning that somehow airlines will have to negotiate directly (without the intervention of the airport), both airline representatives considered that the behavioural change is even as important as the change in systems and procedures.

- For Charter Airline, the optimisation of global KPI will be less important than maximizing their profit. This may not be the case for the Major Airline.

About the 2050 scenario, the actors were not convinced the system provided the optimal solution and; as the actors had no possibility to check or optimize the provided solution, they felt powerless and without control over their job and very low situational awareness. One of the actors defined as a “the leap of faith “, the acceptance of the solutions that a high-automated system can provide.

The paper-based gaming sessions provided some feedback about the information which should be shared and known by all the actors. The actors playing as airlines pointed out that only global number should be shared. The information related to the Airport should however be shared by all partners due to the importance to take decisions.

Environment 2 Metrics assessment

Similarly to Environment 1, the assessment on the impact of automation on human roles is based on qualitative results coming from the comments of the experts and also based on the analysis of some metrics. To do this, the outputs of the questionnaires were used. Below the analysis of these metrics is described:

Role of automation – there is an overall increase in the positive role of automation over the time. However the participants assessed more adequate the levels of automation in 2035 and 2050. There are some differences between the roles:

- the Airport Agent assumed that in general, the levels of automation assumed for all timeframes were very adequate in comparison with the Airline Agents.
- the Major Airline considered the adequacy of the level of automation in 2020 very low.

Active Involvement of humans – The participants perceived a decrease in the activity of the human involvement in the tasks but they did not state any negative comment about this issue.

Confidence and self-efficacy – the participants did state that their confidence and self-efficiency was better in 2035 timeframe. The 2050 scenario was the worst one evaluated by the players in terms of confidence and self-efficiency. Globally the Airport Agent felt more confident and efficient in comparison with the Airline Agents.

Situational Awareness – this indicator was differently perceived by the actors. The Airport Agent was the actor who considered better the situation awareness, he rated as good indeed. The best time frame for him was the 2035. The Airline Agents experienced a decrease in their situational awareness in time, highlighting the low situational awareness that Charter Airline declared in 2050

Trust in the system – the trust in the systems remained stable during all timeframes and no differences over time

were stated for all actors. Again was the Airport Agent which declared to have a high trust on the system. However the Airline Agents were uncertain for all timeframes.

SUITABILITY OF THE RESULTS

In spite of none expert has experience in the gaming technique, no scepticism with respect to the technique was observed in none of the environments. Figures 5 and 6 show the pre and post-gaming opinion about the suitability of the Gaming Technique for these types of assessments and the confidence on the results produced.

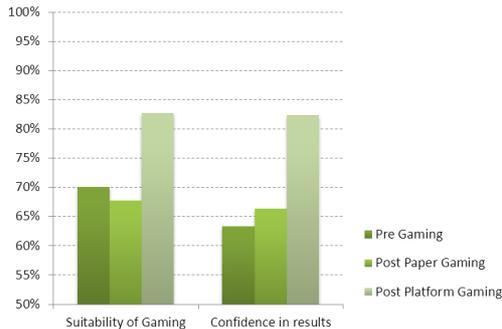


Figure 5. ENV1 Suitability and Confidence of Gaming

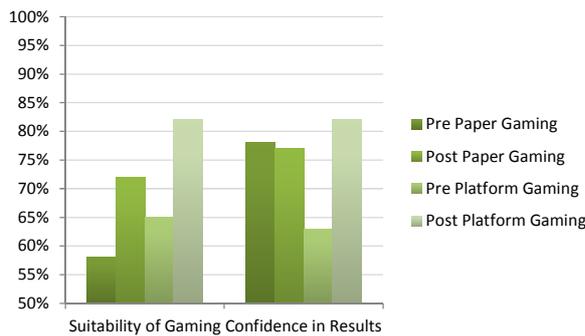


Figure 6. ENV2 Suitability and Confidence of Gaming

It can be seen that the differences between pre and post paper-based gaming opinions are relatively small for both environments. The belief in suitability of Gaming Technique for assessment new concepts decreased slightly for paper-based games. This can be attributed to the fact that these games do not “feel” realistic, as some of the participants remarked. After the platform-based games the opinions were – as expected – considerably more positive, mainly because of the higher degree of reality owing to using a platform. Another positive effect may come from the fact that the same actors as during the paper-based gaming session were participating in the platform-based gaming session, which was considered essential for the overall assessment by all three actors.

This latter fact increases the validity of the results because the actors value positively the performance of the

technique and the usefulness of the results and comments that they pointed out.

CONCLUSION

The impact of increasing LoA on the interaction between human actors and on their roles and responsibilities was assessed for the “Airspace Organization and Management” and “Airport Operation and Centre” environments by consecutive paper-based and platform-based gaming sessions by each environment. The participants in these games were ATM experts.

The paper-based games were used to refine the scenario, to provide the platform-based gaming with the right input and to do a preliminary assessment of the effect of higher levels of automation on the involved ATM actors. The platform-based gaming sessions were completely focused on assessing that effect. The gaming sessions met the expectations and the combination of the paper and platform-based gaming sessions has again demonstrated their suitability for this type of assessments.

Globally, the results of both environments showed that:

- The role of automation was positively perceived over the time.
- The active involvement of humans decreases over the time, as expected. But no claim was performed about this issue.
- The confidence and self-efficiency was positively assessed for all timeframes in Environment 1. However in Environment2 there are more differences between actors and timeframes, being the best perception for the 2035 environment and the Airport Agent role and the worst perception for the 2050 environment and the Major Airline Agent.
- The situational awareness was assessed in line with the confidence and self-efficiency: In environment 1 the situational awareness was sufficiently assessed for all actors in all timeframes, being significantly better for 2035 and the LTM airport. Meanwhile in Environment 2 more differences were found being the most positive assessment for 2035 environment and Airport Agent role. The Airline’s Agents found their situational awareness insufficient and decreasing over time.
- The trust on the system was maintained as the level of automation increased for both environments. In general, the need to have the final decision to apply and accept one solution was requested. This allowed the actors to perceiving the situation under control.

Other remarkable comments were:

- Flexibility is a parameter which is better used by humans than systems and this should be taken into account in the design of the systems giving the chance of interactions between human and machines.

- Importance of the involvement of the end-user in all systems lifecycle, (especially in early stages, design and development and testing), for the trust in the systems when increasing levels of automation.
- Importance of the insight in the reasoning of the system and the training to be performed. This is crucial for the trust and understanding of the solutions provided by those systems when increasing levels of automation.
- The responsibilities must be clearly defined when high-levels of automation are implemented. Sometimes the roles will mainly monitor the situations and it will be the system the provider of solutions without human interaction almost.

These results about the impact of automation on human roles will be further completed with students gaming sessions which will provide results with statistical significance. After this, all these data will be jointly analyzed to provide conclusions and recommendations about the implementation of higher LoA on human roles.

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