E.02.16-D10-ZeFMaP-Final Report

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Abstract

The final report of the ZeFMaP (Zero Failure Management at maximum Productivity in Safety Critical Control Rooms) project provides a publishable summary of the results. In addition it lists all deliverables, dissemination activities, eligible costs, deviations, bills and lessons learned.

Authoring & Approval

Prepared by - *Authors of the document.*		
Name & Company	Position & Title	Date
[redacted] / SINTEF	Project coordinator / Dr.	16/03/2013
[redacted] / Frequentis	Technical coordinator	18/03/2013

Reviewed by - *Reviewers internal to the project.*		
Name & Company	Position & Title	Date
[redacted] / Frequentis	Project contributor	21/03/2013
[redacted] / SINTEF	Project contributor	21/03/2013

Approved for submission to the SJU by - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
<Name / Company>	<Position / Title>	<DD/MM/YYYY>

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Publishable Summary

The ZeFMaP project investigated if and how process improvement methods and tools coming from other domains can be used in the context of tower control rooms. We have proposed a four step productivity improvement process called ZeFMaP that includes the following:

- Step 1: Modelling the target process into a production workflow and dividing it into "production steps."
- Step 2: Optimizing the "human machine symbiosis" for each step (outside the scope of the project).
- Step 3: Analyses of the decision points and decision content within each of the steps with the aim of optimisation for each decision for the overall process and the improvement of each production step through a feedback loop.
- Step 4: Improvement of the target process through a feedback loop.

The ZeFMaP process was developed in an iterative manner. In the first iteration we surveyed process improvement approaches currently used in other industries and discussed the potential use of those approaches within an ATM setting. We then outlined the ZeFMaP process and applied Step 1 (modelling the target process) on the TWR control room process of the Hamburg airport. An improved version of the TWR workflow was proposed and implemented in the electronic flight strips tool.

In the next iteration we conducted a controlled experiment with five air traffic controllers using replay of recorded traffic samples from Hamburg airport, and the NAVSIM air traffic simulator at the University of Salzburg. The results from the first experiment indicated that the Failure mode, effects and criticality method (FMECA) was of limited usefulness for improving productivity of TWR processes. The scenario that was used in the first experiment was a fairly easy task to perform for the experiment participants and the number of non-optimal decisions appeared to be rather low, indicating that richer data sets are needed when conducting further investigations.
In the last iteration we conducted a second experiment, aimed at collecting richer input data to the ZeFMaP process. In similarity with the first experiment, the second experiment also involved a set of real-time simulation exercises where five air traffic controllers were subject to realistic work scenarios that were played out in real-time using the NAVSIM simulator at the University of Salzburg. During the simulation exercises, the facilitators gathered qualitative and quantitative data, allowing for a detailed analysis and understanding of productivity and safety in the TWR control room. Compared with the first experiment, the second experiment involved a greater number of measured runs and scenarios with higher air traffic loads. The data collected in the second experiment were used to evaluate the usefulness of holistic optimisation and visualization within Step 3 of the ZeFMaP process.

The validity of the applicability of the overall approach (the ZeFMaP process itself) has been proven by implementing Step 1 and Step 3. The benefits achieved by applying Step 1 of the ZeFMaP process were:

- A better understanding of the process and sub-processes which could then be used to discuss alternatives directly with controllers and/or system developers
- The identification of value-adding and non value-adding sub-processes which enables a concentration on value-adding sub-processes
- Selection of key performance areas from the SESAR performance framework that was used for assessment of improvements
- The identification of responsibilities and hand over points showing improvement to potentially reduce the necessary communication and resulting in an optimized HMI
- The identification of decision points which are necessary input for Step 3 of ZeFMaP process

In addition, based on the results gathered within the Step 3 we can recommend the application of workflow process modelling in the ATM domain.

In this regard we proposed and evaluated two tools to improve decision making within the tower control process (the overall process and the sub-processes). To our knowledge both of them introduce new concepts; the first one introduces workflow and performance visualization and the second one introduces holistic optimisation.

Our results indicate that workflow and performance visualization can be a useful aid to facilitate learning in TWR control rooms. We believe that the tool will be useful for analysis and improvement of the decision making process. It can also be used by the controllers for self-assessment of their performance at the end of a working day or for training of ATCO students, particularly in the sessions following training simulations. To increase the usefulness of the visualization tool, future versions should provide additional functionality for listening to the communication between ATCOs, and between ATCOs and pilots.

For further optimisation we propose an integrated approach to departure management and surface routing in airports. Our results show that the integrated approach covers calculations and trade-offs probably outside of human capability when handling Hamburg airport in simulated scenarios. The decrease in average taxi time was between 33% and 36% while punctuality improved from 57% to 67%. The model needs to be completed with more detailed real-world constraints. We need to incorporate the ability to maintain stable solutions in a dynamic environment. We also want to extend our model to fully include arrival management. Such developments would lead to a decision support tool covering both planning and real time support. Finally, this optimisation technology can also be developed to become a part of learning tool for controllers that will provide a comparison with their decisions and the most optimal ones.

Furthermore, our results show that active operational use of optimisation tools provides a number of direct economic savings together with greater flexibility, efficiency, overview and safety of the planning effort. The ZeFMaP project's experience with the overall process and the associated tools form a solid basis for our conclusions. However, there are several issues that were not addressed within the project. Future work includes investigating whether additional tools can be useful within the ZeFMaP process. An investigation on how other ATM processes can benefit from the ZeFMaP approach is also highly relevant.

The interaction between Step 2 and Step 3 in the ZeFMaP process can be further investigated. Some dedicated variables or parameters in a heuristic algorithm can be tuned by input from human experience, analysis and judgment. On the other hand, the performance of ATCOs might be improved when an automated decision support tool is used.

1 Introduction

1.1 Purpose of the document

The purpose of this document is to:

- Summarise the technical results and conclusions of the project (Publishable Summary);
- Provide a complete overview of all deliverables;
- Provide a complete overview of all dissemination activities (past and in progress). Where appropriate, provide feedback from presentations. Describe exploitation plans.
- Provide a complete overview of the billing status, eligible costs, planned and actual effort (incl. an explanation of the discrepancies).
- Analyse the lessons learnt at project level.

1.2 Intended readership

This document is intended to be used by:

- ZeFMaP project members including project manager and core team members.
- Representatives of EUROCONTROL and SJU responsible for reviewing and advising the project.
- Other researchers working on similar research projects.

1.3 Inputs from other projects

This project draws its methodological base from relevant work and findings of the FP6 project Episode 3 [1] and the European Operational Concept Validation Methodology (E-OCVM) [2]. Thus, it is in line with both the ATM Performance Indicators [3] and the general performance measurement framework set out in D2 of SESAR [4].

1.4 Glossary of terms

N/A

2 Technical Project Deliverables

Management deliverables such as progress reports, gate report or this final report need not be included.

Number	Title	Short Description	Approval status
D2.1	Evaluation strategy	Describes overall evaluation strategy (goals, methods, planned studies)	approved
D1.1	ZeFMaP Process	Results from the first phase of our work on productivity improvement (hypothesis, tools to be used, modeling of the process)	approved
D2.2	Evaluation plan and results Phase 1	Experiment design and material for the first experiment	approved
M2.1	Evaluation UoS	Subcontracting of UoS; preparation and execution of the simulation	approved
M2.2	Preliminary results - Experiment 1	Results from the first experiment; This document is an updated version og D2.2	approved
D1.2	ZeFMaP Process Final	Results from the second phase of our work on productivity improvement (tools, process improvement, results of the hypothesis testing)	submitted
D2.3	Evaluation plan and results Phase 2	Experimental design, experimental material and the preliminary results from the second experiment	submitted

Table 1 - List of Project Deliverables

3 Dissemination Activities

3.1 Presentations/publications at ATM conferences/journals

In Schaefer, Dirk (ed) Proceedings of the SESAR Innovation Days (2012) EUROCONTROL. ISBN 978-2-87497-024-5. Usefulness of FMECA for improvement of productivity of TWR process, Langlo, J.A., Aslak Wegner Eide, A.W., Karahasanović, A., Hansson, A., Swendgaard, H.E., Andersen, B., Zeh, T., Kind, S., Rokitansky, K-H., Gräupl, T. This paper presents the results from the first experiment we conducted.

In Schaefer, Dirk (ed) Proceedings of the SESAR Innovation Days (2011) EUROCONTROL. ISBN 978-2-87497-024-5., Theodor Zeh, Volker Grantz, Stephan Kind, Robert Rubenser, Amela Karahasanović, Bjørn Andersen, Lisbeth Hansson, Jan Alexander Langlo & Hans Erik Swengaard, Zero Failure Management at Maximum Productivity in Safety Critical Control Room. This paper presents the overall approach of the ZeFMaP project.

Grantz, Volker; Zeh, Ted; Karahasanovic, Amela.

Optimierte Arbeitsleistung in Kontrollzentralen der Flugsicherung. I: Fortschrittliche Anzeigesysteme für die Fahrzeug- und Prozessführung. 54. Fachausschusssitzung Anthropotechnik der Deutschen Gesellschaft für Luft- und Raumfahrt, DGLR, Koblenz. DGLR-Bericht 2012 ISBN 978-3-932182-77-8. s. 205-218. This paper presents the ZeFMaP process

The presentations listed bellow describes the ZeFMaP approach and its possible role in the ATM context.

ATC Global, Amsterdam, 7.3.2102, Ted Zeh, Integrated Controller Working Position, THE enabler for collaborative ATM

5th iCWP Club meeting Vienna, 21.03.2012, Ted Zeh, ZeFMaP: Productivity in ATM

Hans Erik S Swengaard, 12.6.2012, Brussels, Zero Failure Management at Maximum Productivity in Safety Critical Control Room, Presentation at the WP E information days

Grantz, V., Zeh, T., Karahasanovic, A., A process to achieve an optimized performance in safety-critical control rooms; in preparation – the paper will be extended by the results from the second experiment and sumbitted to a journal or a conference.

Generally feedback received was very positive. The community appriciated the novelty and the usefulness of the approach and recognised a need for the tools we presented. Good collaboration between industry and research institutes was also appretiated.

3.2 Presentations/publications at other conferences/journals

Hansson, Lisbeth; Andersen, Bjørn; Langlo, Jan Alexander; Karahasanovic, Amela; Zeh, Theodor.

Measuring Team Quality as a Means for Improving productivity in Air Traffic Management (ATM). I: 11th International Probabilistic Safety Assessment and Management Conference and the Annual European Safety and Reliability Conference 2012, 25-29 June 2012, Helsinki, Finland. Curran Associates, Inc. 2012 ISBN 978-1-62276-436-5. s. 5112-5121. The paper presents the results from the first experiment related to team collaboration.

Dag Kjenstad, Carlo Mannino, Patrick Schittekat, Morten Smedsrud, Integrated Surface and Departure Management at Airports by Optimisation, ICMSAO'13, the 5th international conference on modeling, simulation and applied optimisation. April 28-30, Hammamet, TUNISIA. The paper presents holistic optimisation.

3.3 Demonstrations

N/A

3.4 Exploitation plans

3.4.1 Frequentis exploitation plans

For Frequentis the most interesting finding is the possible change of the mind-set throughout the various actors in the ATM world. The approach put forward by the ZeFMaP projects represents a new way of thinking about air traffic control. It places system-wide productivity on one level with safety and distances itself from mere failure prevention and analysis. The first reaction of the audience is rejection or confusion. On the second thought we realise a change of mind-set and a tendency to agreement. So it is expected that the introduced approach will have a positive effect in the following areas:

- The first positive effect is to be seen in relation to air traffic control itself: knowledge of zero-fault principles from other domains and their implementation in air traffic control centres has a large influence on the way of thinking and will thus likely lead to a reconsideration of existing processes initiating the request for new tools.
- The second effect is to be seen over a long period of time and refers to the construction of an efficient and permanent process of improvement, supported also by prospective self-learning systems.
- The third effect is the resulting demand for new algorithms supporting the global aspect of the single decision. This can result in new product lines.

This change not only affects potential customers but also needs a different way of understanding ATM processes on the developers' and project managers' side. In the end it can result in the new and better products mentioned above to increase the support of the controller in order to optimize system-wide performance.

As the project has shown the positive effect of performing a value stream analysis, Frequentis will continue to use this method in customer projects to increase the understanding of the controller tasks and workflow. The value stream analysis has proven to be a tool which can easily improve the performance just by optimizing the workflow to fit the value adding processes of a control room and potentially provide more automatisms for non-value adding processes which are although required to support the business processes. The changed mind-set is a pre-requisite for this.

Additionally Frequentis will more and more introduce this optimisation approach within the projects and thus within the resulting products.

In detail the following aspects will be further developed within the future in Frequentis:

- Following step 1 of the ZeFMaP process to increase the understanding of the production process by performing a user task - and value stream analysis which results in an optimized process through the elimination or automation of non-value adding process steps. This generates room for new products and tools.
- Optimisation of the holistic human-machine symbiosis based on the knowledge gained by the step 1 of the ZeFMaP project
- Usage and further development of the optimisation algorithm introduced within the ZeFMaP project within the workflow tools of Frequentis.

In summary it can be said that for Frequentis the ZeFMaP project has proven that looking at the productivity aspect can bring substantial benefits for a customer and opens new areas for potential applications and/or functions to be introduced in the future.

3.4.2 SINTEF exploitation plans

For SINTEF as a research institute the value of a project is in: i) developing technologies that enable a continuation of leading edge research projects, ii) establishing good contacts with industrial partners that might give insight and work on new industrial problems, and iii) ability to provide research-based teaching and training to its industrial and academic partners

Within the ZeFMaP project SINTEF had possibility to advance its ATM research and collaboration, not only with the consortium partners, but also with relevant national industry. The project resulted in several project proposals. The project also contributed to the teaching at BSc and MSc level at the Department of Informatics, University of Oslo.

The ZeFMaP project has demonstrated that holistic optimisation technology can handle the complexity and associated enormous amount of variables needed for decision making in the control tower. Moreover, its ability to produce optimized decision support within very short response intervals (order of seconds) brings optimism for further development into a complete and implementable technology.

Currently, the power of optimisation technology is not used to its full extent. One of the main reasons is that before the ZeFMaP project, optimisation technology was developed to support only parts of the controllers' decision process, and not a "complete" segment of the business trajectory. However, for the first time, a smart integration based on holistic optimisation of the control tower decisions is implemented. This has improved the whole control process from the moment an aircraft it lands until it take-off (gate-to-gate aspect).

SINTEF will continue to promote the ZeFMaP productivity process and the benefits of holistic optimisation technology. The ZeFMaP productivity process, when increasingly more adopted, will most likely create a change in the productivity mind-set within the ATM community. This change is needed for implementation and the ATCOs ability bring the best effects out of decision support based on holistic optimisation technology in the day-to-day operations.

The ZeFMaP productivity process, when introduced, provides also an evaluation platform for continuous improvement of the human-optimisation technology interaction. This aspect is vital in order to utilize the potential of optimisation and to overcome some known pitfalls of using decision support. For example, decision processes need to be redesigned such that controllers remain actively engaged and do not rely solely on optimisation technology. The redesign should aim for more utilization of human creativity, experience and judgment into performance based operations. We will aim for new projects were this human-optimisation technology interaction will be increasingly studied.

SINTEF aims at integrating holistic optimisation technology in work flow tools that are currently used in the control tower. To that end, the benefits of the proposed technology will not only be a research tool, but a software component that can be actively used by the controllers. Frequentis, will be a preferred partner to accomplish this. Avinor has already shown interest in further development of this technology and we started preparing project proposal of a follow-up project that will be funded by the Norwegian Research Council.

Optimisation technology as part of a visual learning tool, also developed in ZefMap, is another approach to introduce holistic optimisation in the control tower. Such an off-line learning tool has the advantage that the optimisation model can learn (tuned, increase completeness of the model) from the controllers and vice versa, before it is integrated in day-to-day operations. Avinor was involved in the evaluation of the visualisation technology and is interested in its further development and usage. A project proposal will be submitted to the Norwegian Research Council.

4 Total Eligible Costs

This section is based on the Project Costs Breakdown Forms of the eligible costs incurred by project participants.

Date	Deliverables on Bill	Contribution for Effort	Contribution for Other Costs (specify)	Status
Date of invoice	*List of deliverable numbers*	*Requested contribution for effort*	*Requested contribution for travel, licences, logistics etc.*	*Billed or paid*
09.05.2012	Deliverables D0.0, D0.1, D0.2, D0.3, D1.1 and D2.1	210 492,35 (ECTL contribution 149 831,94)	20 386,75 (ECTL contribution 12 692,46)	162 524,39
27.11.2012	Deliverables D0.0, D0.1, D0.2, D0.3, D1.1 and D2.1	22 261,54 (ECTL contribution 11 251,32)	322,06 (ECTL contribution 40,44)	11 291,80
31.12.2012	Deliverables D0.4, D0.5, D2.2 and M2.2	278 609,09 (ECTL contribution 182 026, 64)	18 985,04 (ECTL contribution 11 620,21)	193 646,86
31.12.2012	Deliverables M2.1	50 000,00 (ECTL contribution 33 921,50)		33 921,50
planed	Deliverables D06, D07, D1.2, D2.3, D0.8	246 960,82 (ECTL contribution 180 767,33)	14 391,89 (ECTL contribution 7 709,11)	188 476,43
GRAND TOTAL		758 564,90	53 844,55	589 860,98

Company	Planned man-days	Actual man-days	Total Cost	Total Contribution	Reason for Deviation
SINTEF	*456*	475,56	*649 634,64*	*487 225,98*	*More costs were needed for travels and similar; these are covered by SINTEF (internal project) and are not presented here. Underlying technology for optimisation was developed outside of the project (SINTEFs internal projects); costs related to its development are not presented here.*
FREQUENTIS	*383*	*360*	*213 470,62*	*106 735,31*	*Changes in hour-price. More efforts were needed than planned; these were paid by FRQ (internal project).*
GRAND TOTAL	839	835,56	863 105,26	593 961,29	

Table 2 Overview of Effort and Costs per project participant

5 Project Lessons Learnt

What worked well?
Small team, close coordination and cooperation
Efficient work share with clear roles & responsibilities
Challenging research questions that inspired across knowledge areas
What should be improved?
Project scope should have been more detailed from the beginning (e.g. the development of the experiment tools was not planned)
The availability of needed resources (in our case controller) should have been better planned
Usage of a common workspace with other SESAR projects (SESAR extranet) would have made things easier, especially to find information for people not directly involved in the project.

Table 3 - Project Lessons Learnt

6 References

Reference to main documentation, delete if not required

[1] EPISODE 3 – Single European Sky Implementation support through Validation. D2.4.1-04a – Influence Diagrams Update – Annex to EP3 Performance Framework, 2009.

[2] Eurocontrol, *European Operational Concept Validation Methodology (E-OCVM) Version 3*, 2010.

[3] ZeFMaP: E.02.16-ZeFMaP-D2.1-Evaluation Strategy.

[4] [1] SESAR Definition Phase – Deliverable 2: Air Transport Framework – The Performance Target. SESAR Consortium. DLM-0607-001-02-00a, December 2006.