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BENCHMARKING OF MAINTENANCE AND SERVICE PROCESSES IN AIR TRAFFIC CONTROL SYSTEMS

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Abstract. A theoretical analysis and benchmark was performed to develop a service model for air traffic control (ATC) systems. Based on a survey of theoretical methods and approaches for ATC maintenance processing in relation to traditional and European harmonised ATC parameters, a structured analysis and evaluation of the problem was performed at an international ATC organisation. The research was performed with parameter-oriented comparison. The results of the research were used in a process maturity assessment and key performance indicator (KPI) system. An ATC-specific maintenance process maturity method based on ISO/IEC Standard 15504 was developed for the process of analysis.

The results can be used to develop an ATC service maintenance model as part of an air transport system model (macro model) and to develop an ATC service model and KPI system (micro model).

Keywords: air traffic control system, maturity assessment, service modelling, KPI system.

1. Introduction

Air transport is one of the most dynamic modes of transport. The traditional organisation of air traffic management (ATM), with strongly defined air corridors and constant monitoring of air traffic by controllers is not enough today. The concept of single European sky (SES) with free flights on the basis of new technology for air traffic systems is actively being discussed in Europe within the framework of the SES programme. The same situation can be observed now in the United States and Canada.

Today we can speak about changes in the focus of ATM from the point of view of standardisation, unification at the international level, etc. ATM procedures and the maintenance and service processes provided by ATC systems are also included in this process of change.

The problems are:

- lack of service characteristics (metrics);
- no common definition or understanding of service-oriented terms or level of service support;
- no definition of ATC end-to-end services;
- no existing ATC service modelling or common ATC service catalogue;
- lack of service-oriented architecture for ATC systems;
- lack of an integrated service approach for ATC.

Figure 1 describes the goal and major steps of the research approach.

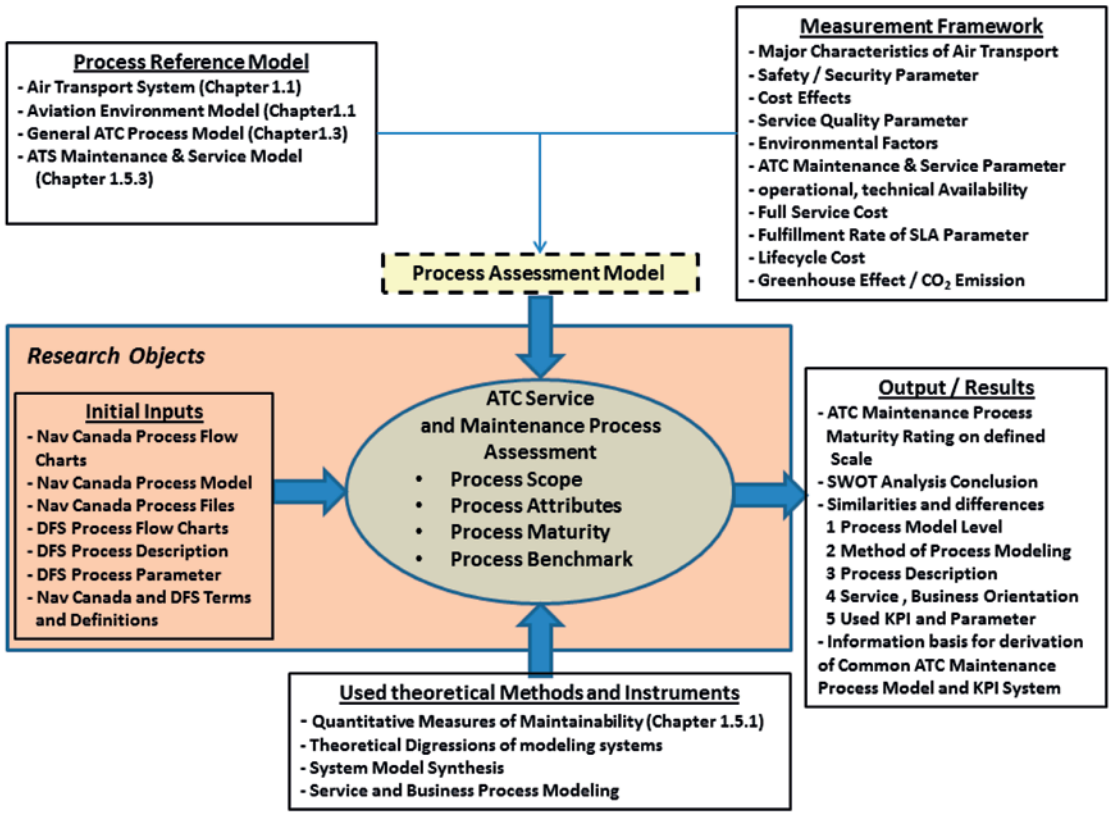

Fig. 1. Approach of ATC maintenance process research

This change in ATM focus requires an analysis of the current situation in this area to define the state of the art and main directions for future research.

2. Theoretical process for performing analysis

ATC providers have been selected based on criteria described in figure 2. It is important to select a mix of different ATC providers according to form of organisation, size of company, property relationship, etc. because of the goal to get common informational feedback at the international level. The selection has been performed at the following steps in the process:

- selection of ATC service organisation and qualified contact;
- development and analysis of questionnaires;
- performance of telephone interviews;
- personal visits and interviews.

The questionnaire method is simple and needs little effort. The information can be formed based on the following structure:

1. Introduction.
2. Methodology of survey.
3. Research objects.
4. Analysis of:
   - maintenance process;
   - standardisation level;
   - process and service modelling.
5. Organisational purposes.
6. Individual feedback.

Handling the process via e-mail is easy and low cost. Based on the open questions, the answerer is able to provide more open answers and has space to provide open-ended feedback and experience. The use of a questionnaire also has also disadvantages, however, like the risk of questions being misunderstood, no response, or incomplete responses. It is therefore very important to have a network of people who are able to provide access to specialists. To reduce these disadvantages, it was decided to perform additional different telephone interviews and personal visits. Based on the interviews, it is possible to get more direct answers, non-verbal information, and personal experiences in the form of personal discussion. A specific catalogue of criteria and evaluation structure was developed for the analysis. It was used for the evaluation of the questionnaire and interview information and to review the documentation of ATC providers (Tab. 1).

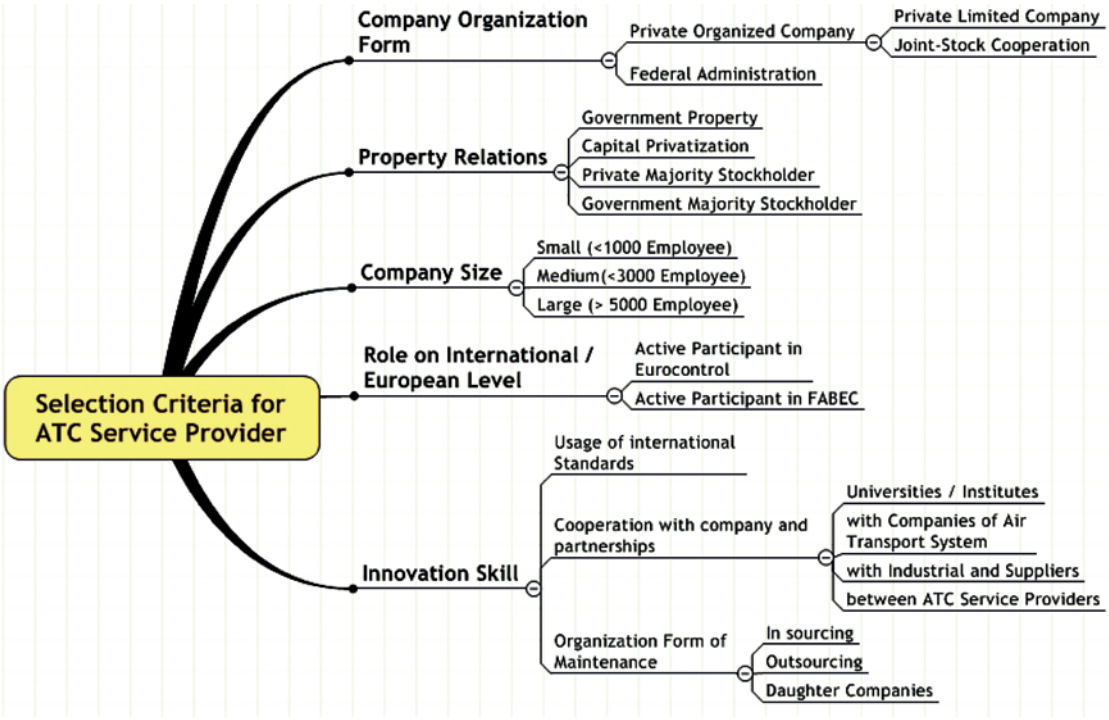

Fig. 2. Set of selection criteria for ATC service providers

Table 1. Overview of ATC service provider analysis

Criteria	LGS Latvia	FAA USA	NAV Canada	NATS UK	LVF Sweden	DFS Germany	TTC Germany
Delivery of Information	Questionnaire Interview	Questionnaire Documentation	Documentation Interview	-	-	Questionnaire Documentation Interview	Questionnaire Documentation Interview
Legal Status	Private	Public	Private	Private	Public	Private	Private
Property Relation	State Owner	Gov. Administration	State Owner	Private-State Owner		State Owner	State Owner
Company Size	Small	Large	Medium	Large	Medium	Large	Small
FAB Member	NEFAB	No	No	FAB UK-IR	NEFAB	FABEC	No

The evaluation is based on the following methods:

- on descriptive methods, with analysis and evaluation in verbal form;
- on binary evaluation methods, which in general give information about the existence or non-existence of required criteria (yes or no) and the related maturity level analysis and measurement (MLAM) derivation; this method is used specifically to analyse and evaluate of different levels of processes and standardisation.

The MLAM will be a major method.

In reference to research tasks, a specific maturity level analysis and measurement method for provision of ATC maintenance services should be developed. The results for each ATC Provider analysed were summarised in a specific SWOT analysis and descriptive part. It should be mentioned that NATS and LVF were not able to deliver the required information due to the amount of time needed. The analysis is structured as a four-step approach.

Step 1. Structuring information about ATC maintenance processes based on a set of criteria.

Step 2. Rating/assessing utilisation by theoretical methods.

Step 3. Comparing and evaluating the key performance indicator system (KPI) implemented.

Step 4. Assessing the maturity of ATC processes based on the principle of ISO/ IEC 15504 (ISO/IEC 15504-1:2004 2004a, b, c, d, e).

The research goal is to evaluate the ATC organisations from different aspects. It should be mentioned that all the methods used are qualifying methods based on defined attributes in reference to the ISO/IEC 15504 standard. The ISO/IEC 15504 concept was transformed to ATC evaluation specifics and KPIs. The research contains all detailed information such as selection parameter, catalogue of criteria for analysis, conspectus of interviews, SWOT analysis, and detailed conclusions. Due to the limits of this article, the results can be only summarised.

Step 1: results of analysis of ATC maintenance process

LGS, Latvia (Golosov 2010)

- The maintenance process follows a strong practical orientation and is system-oriented;
- Maintenance guidelines and procedures are described textually at the system level. Maintenance is technical system–oriented;
- The maintenance process is certified by the national authority and by the ISO 2001 standard;
- Usual technical metrics are collected manually.

FAA, the United States of America (Walker 2010; US Department… 2007a, 2007b, 2009)

- Documents have a top-down approach, starting from general maintenance philosophy to maintenance guidelines to detailed system-related maintenance handbooks;
- Based on the best practice level;
- Maintenance is system/subsystem/equipment-oriented and includes logistics support;
- The FAA uses national standards and definitions that do not conform to ITIL standards.;
- Metrics reflect technical parameters.

NAV Canada, Canada (NAV CANADA 2010, 2009a, b)

- Maintenance is strongly process oriented. Technical operation and maintenance is not only technical system oriented, but also includes quality, safety management, finance and training processes;
- Maintenance also includes logistics support;
- Definitions of services are only fractional. The ITIL standard is partly implemented in the technical operation of NAV Canada;
- Maintenance is strongly practical and orientated on national and ISO standards;
- The service level is only mentioned. A special SLA process has not been designed;
- Usual technical, finance and other management metrics are defined and reported.

DFS, Germany (Dussoy 2010 ; DFS Deutsche 2009a, b; Kundler 2010)

- Maintenance is process and service oriented. Services and end-to-end services are partly defined implemented;
- The maintenance description and process flow charts are based on best practices. Process or service modelling is not available; processes are not simulated;
- The maintenance process is described via a standard structure by process overview and process flow chart, including textual description;
- Service level management is implemented and in practical use;
- The service levels are differentiated into various levels and sub-levels not conforming to market and ITIL understanding;
- The maintenance process conforms to ISO, national and SES II standards. The maintenance process includes quality, safety management, finance, and training processes;
- The maintenance process also includes logistics and calibration services.

TTC, Germany (Koch 2010)

- TTC is a specialised company delivering ATC services at the air traffic control towers of regional airports and is working in a specific low-cost market segment;
- TTC exclusively uses DFS technical support and maintenance infrastructure and has adapted DFS processes. TTC is able to generate synergies and to purchase technical support and maintenance services from an ATC service provider (DFS);
- The impact of TTC on DFS and their process landscape is low;
- Due to this sourcing strategy, TTC and DFS have the same standardised level of processes and services; TTC does not have its own maintenance process or technical services.

Step 2: use of scientific methods, models and ISO standards

Tables 2 and 3 present a comparison of the use of theoretical methods and instruments based on the theoretical research of methods.

The ordinal rating scale defined below is used to express the levels of achievement of the process attributes in accordance with International Standard ISO/IEC 15504-2.

0 Not rated;

N Not achieved; little or no evidence of criteria being assessed, 0 to 15%;

P Partially achieved, >15% to 50%;

L Largely achieved; there is evidence of a structured systematic approach and significant achievements, and defined attributes are implemented, monitored and controlled in process being assessed, >50% to 85%;

F Fully achieved; there is complete evidence of a systematic approach, and all defined attributes are implemented, monitored and controlled in the process >85% to 100% achievement.

The general fulfilment of the theoretical methods and instruments and the main qualitative differences between ATC organisations are marked in tables by colour.

Step 3: evaluation of KPI system on quantitative methods

Comparative analysis of the data shows that only NAV Canada and DFS use detailed metrics (Tab. 4). There is no common understanding of the KPI system in different organisations. Service-oriented indicators are not used in ATC organisations (ISO… 2005; ISO / IEC… 2011; ISO… 2008).

Table 2. Utilisation of methods and instruments at ATC organisations

Theoretical Methods/Instruments	LGS	FAA	NAV Canada	DFS	TCC
Economic Indicator Models	N	N	N	N	N
COBIT 2000 Systematic	N	N	N	N	N
Mathematical Decision Making	N	N	N	N	0
Decision Priority Matrix Model	N	N	N	N	0
Input Output Model	N	P	F	F	0
Data Process Model	N	N	P	L	0
Structured Process Description	N	L	F	F	0
Process Flow Model	N	N	F	F	0
Business Modelling	N	N	P	P	0
Service Modelling	N	N	P	L	0
Process Model Simulation	N	N	N	N	0
Mathematical Time State System	N	N	N	N	0
Graph Theory	N	N	P	P	0
Process Maturity Evaluation	N	N	P	P	0
ISO Standard 9000:2005	F	N	F	F	N
ISO Standard 20000-1	N	N	N	N	N
ITIL de-facto Standard	N	N	P	P	N

Table 3. Comparison of metrics used by ATC organisations

Air Transport System Metrics	**LGS Metrics System**	**FAA Metrics System**	**NAV Canada Metrics System**	**DFS Metrics System**	**TTC Metrics System**
Safety Security $W_{ATCpart}$ (1)	Safety Coefficients	N/A	N/A	N_{STU}	N/A
Cost Effects R_{ATCfee} (2) $R_{ATCEnrouteFee}$ (4) $t_{NationalUnitRate}$ (5) $E_{RouteExtensions}$ (6)	N/A	N/A	N/A	Cost Performance Index Productiveness Resource Capacity	N/A
Technical Quality of Service $A_{operational}$ (8) $A_{technical}$ (9) T_{MTTS}	P_{outage} Availability - technical Reliability $T_{operationOutages}$ $N_{outages}$ $N_{ControllerCompliants}$ Robustness	Trend Analysis Key Performance Parameter	N/A	Availability - technical - operational Availability Index Operational Service Availability Reaction Time Recovery Time	N/A
Environmental Factors $R_{RouteExtensions}$ (11)	N/A	N/A	N/A	N/A	N/A

Table 4. Process capability matrix of maturity of ATC maintenance and service process

Process Capability Matrix of Maturity of ATC Maintenance and Service Process			
Maturity Assessment Criteria's on ISO/IEC 15540-4			**ATC Specific Derivation of Process Attributes**
COBIT Maturity Level	**Rating Fulfilment**	**General Process Attributes**	**Process Attributes**
ML 0 Incomplete			**Service process is not implemented, not defined or not realised**
ML 1 Performed			**Processes mostly defined and implemented**
	L or F	Process Performance	PA 1.1. Service processes are defined and main processes are completely defined PA 1.2. Process landscape exists
ML 2 Managed			**Processes are completely implemented and managed**
	F	Process Performance	PA 2.1. Process KPI and metrics are identified PA 2.2. Process performance is defined and monitored PA 2.3. Process resources, roles and tasks are identified and available
	L or F	Management Performance	PA 2.4. Process KPI and metrics are identified PA 2.5. Process performance is defined and monitored PA 2.6. Process interfaces are identified and managed
	L or F	Work Product Management	PA 2.7. Process requirements and metrics are defined PA 2.8. Documentation and controlling process requirements are identified PA 2.9. Inputs and outputs are managed and reviewed based on requirements
ML 3 Established			**Processes are implemented, managed, controlled on the basis of defined requirements and metrics**
	L or F	Process Definition	PA 3.1. All resources and environment are available PA 3.2. Human resources and capacities are defined PA 3.3. Employees have been proved to be competent and are educated and regularly tested PA 3.4. Data are collected and analysed for effectiveness and suitability
	L or F	Process Deployment	PA 3.5. Process is implemented on standard processes PA 3.6. Partial level of automation and tool support is implemented
ML 4 Predictable			**Process operates based on given parameters, metrics and requirements; maintenance process operates inside of given KPIs**
	L or F	Process Measurement	PA 4.1. Process includes business / service processes and aspects PA 4.2. Process is regularly measured on technical, process and business metrics PA 4.3. Measurement objectives, processes and frequency are defined PA 4.4. Performance correlates with business requirements PA 4.5. Process is analysed with use of metrics PA 4.6. Process deployment is in accordance with process performance
	L or F	Process Control	PA 4.7. Process analysis and control are defined and implemented PA 4.8. Process KPIs contain defined control limits for proactive management PA 4.9. Regular corrective tasks are defined, documented and realised PA 4.10. Dynamic control system with indication of operation has been established
ML 5 Optimising			**Maintenance process is continuously approved and the PDCA cycle is realised and contains all technical, business and service aspects.**
	L or F	Process Innovation	PA 5.1. Process improvement actively takes place and supports all business requirements PA 5.2. Process improvement is actively used for dynamic process performance and the establishment of different process performance levels based on required service levels PA 5.3. Regular process and data analysis is performed in correlation with existing market standards, best practice and benchmarks PA 5.4. Processes are regularly improved based on new technologies
	L or F	Process Optimisation	PA 5.6. Is under control of regular change and problem management process PA 5.7. All changes in process made based on quantitative parameters PA 5.8. Process is completely controlled by defined maintenance process metrics and is completely business and service oriented

Step 4: process maturity assessment for the ATC maintenance process

The process maturity assessment is based on the principles of ISO/IEC Standa rd 1504 (ISO/IEC 15504-1:2004 2004b, c, d; Golosov 2010). These processes were adapted to ATC purposes. Note that only NAV Canada and DFS were able to deliver a detailed process description and process flow charts. The following process maturity assessment is therefore based only on the ATC process models supplied by NAV Canada and DFS. The scope of the assessment is defined by the following parameters:

- assess the objectives of the maintenance process;
- assess the maintenance process modelling;
- assess the maintenance process from business and management aspects;
- assess the methods of the flow process chart;
- assess the defined of KPI parameter of process control;
- provide a qualified ATC process rating.

ISO/IES standard 15504 helps to give a structured approach to the assessment process, which is modified for ATC maintenance. In addition, the maturity assessment provides the possibility to perform improvements and set objective benchmarks for ATC service providers. For that a specific ATC parameter set was developed. In the following figure, the different assessment steps and process adaptation are described. In addition, the figure also illustrates the major framework and characteristics. The following process criteria can be derived for the ATC maintenance and service model from these normative components of process assessment.

The assessment activities are tailored and redesigned to the ATC specifics. The following table reflects these adaptations and describes the ATC specifics developed.

3. Results of process maturity assessment of ATC organisation

NAV Canada

The maintenance process was evaluated by review of the documents and process description provided (NAV CANADA… 2010, 2009a, b). In general the NAV Canada maintenance process is performed according to detailed process flow charts on UML and is divided into defined process bundles. These bundles are broken down to detailed processes. The maintenance process of NAV Canada is described and tailored into 44 different processes and flow charts. The detailed process is described by a standard approach:

- description via process flow charts;
- each process flow chart is described by the following textual description via table 5.

This kind of process flow description gives an overview of the detailed maintenance process. Each process flow is described in detail by a number of detailed processes. Several times the mentioned additional textual description is empty (Work Instruction Listings, Mitigation, Hazards). The quality of metric definition and business requirements is also sometimes insufficient. In general, the type of process presentation gives a professional overview combined with needed management information. Analysis of the NAV Canada maintenance process is illustrated in figure 3. Process modelling focuses on process flow charts and descriptions, without real modelling or process simulation. A general lack of process modelling is found in the lack of process performance metrics. Process KPIs are in general not defined. The different process bundles and detailed processes are developed on the same standard level. The process flow chart description sometimes from the point of view of quality is different. Some flow charts are described superficially (Technical Operation Accounts Payable Invoice Process, Technical Operations Capital Project Approval Process), and other flow charts describe the processes in great detail (Competency Process, Contract Services/ Maintenance and Space); the level of detail is not homogeneous. In reference to the ISO/IEC assessment chart, it is not possible to define a clearly reached level for the process maturity profile. The fact is that the NAV Canada maintenance process completely fulfils the requirements of maturity level ML1 and mostly fulfils parts of ML2. In level ML2, the main lack of process modelling is missing process metrics and performance measurements. The process attributes reach an overall standard level that is presented in figure 3. The figure presents the degree of fulfilment for each defined maturity level.

Table 5. Textual description of process flow chart

Business Requirements	Inputs	Outputs	References	Work Instruction	Listings	Hazards
Risks	Mitigation	Records	Metrics	Likelihood	Technical Operation Information	

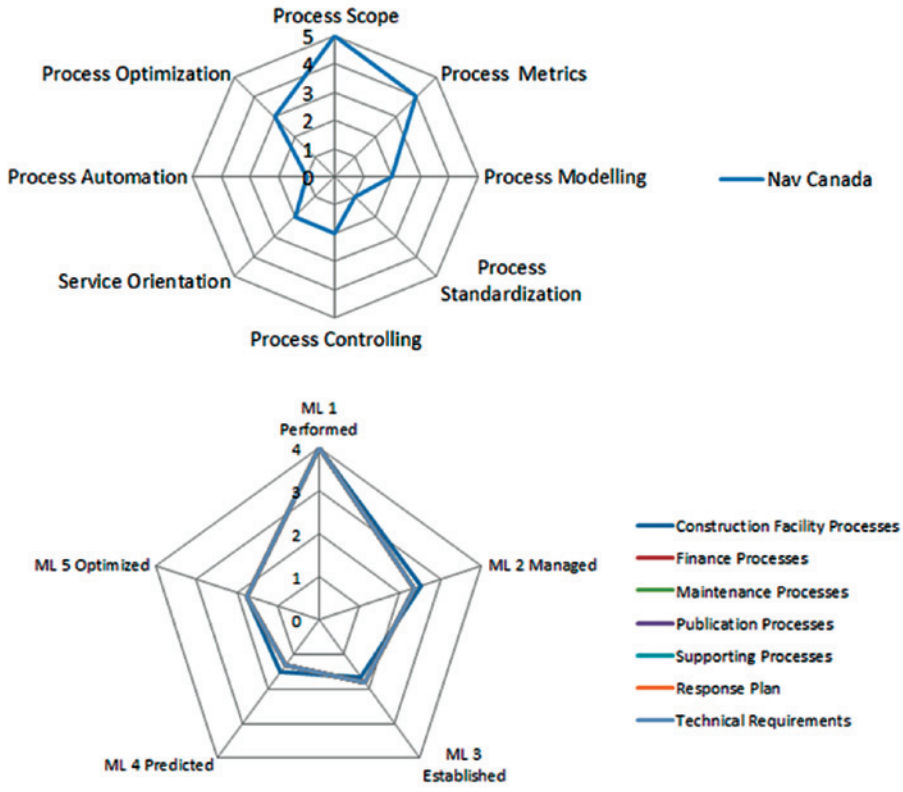

Fig. 3. NAV Canada ATC maintenance process maturity assessments. Since the process types marked by various colours mentioned on the right side of the ML diagram overlap, only the construction facility and technical requirement processes are differentiated

DFS ACC Bremen

The DFS maintenance process for ACC Bremen was assessed based on the delivered process description documents delivered, the interview, and additional management documents (Dussoy 2010; DFS Deutsche… 2009a, b; Kundler 2010). The DFS maintenance process is different from NAV Canada. DFS starts modelling its maintenance process generally as an overview. Starting from this process overview, the DFS is modelled into the next level of detail. The number of maintenance processes is not as high as it is at NAV Canada. Process modelling is therefore more complex. The models are based on flow process chart with *unified modelling language*. Figure 3 presents the level of process modelling attributes reached. Differently from NAV Canada, the input/output, process interfaces, customers, external suppliers, and partners are defined in general for the DFS process landscape. The process and product metrics are also defined. The process landscape describes the main maintenance process components, including references of entry and exit points to other processes. Each detailed process is illuminated by a process flow chart and includes a textual description in structured table form. This descriptive table relates all steps of the process in detail, including roles and responsibilities, applicable documents, and documents needed for approval. The quality of metric definitions is not specific and not in detail corresponding to the related process step. The combination of process flow chart and structured description gives sophisticated information about the related maintenance process. Management information about business requirements, work instructions, hazards, risks and likelihoods are missing completely. Due to the higher level of process complexity, the handling of the process flow chart is not as sufficient as NAV Canada. In comparison with the process maturity level, Figure 4 shows the degree of ML fulfilment. The level of description is homogeneous and has the same standard throughout the entire process description. The same problem, that in reference to the ISO/IEC it is not possible to define a clearly reached level of process maturity, was observed for DFS. DFS reached in general the same level as NAV Canada, but in some cases the DFS process modelling partially reaches higher maturity fragments. The DFS maintenance process completely fulfils the requirements of maturity level ML1 and largely fulfils parts of ML 2. The processes of modelling, performance and control at DFS are more successful.

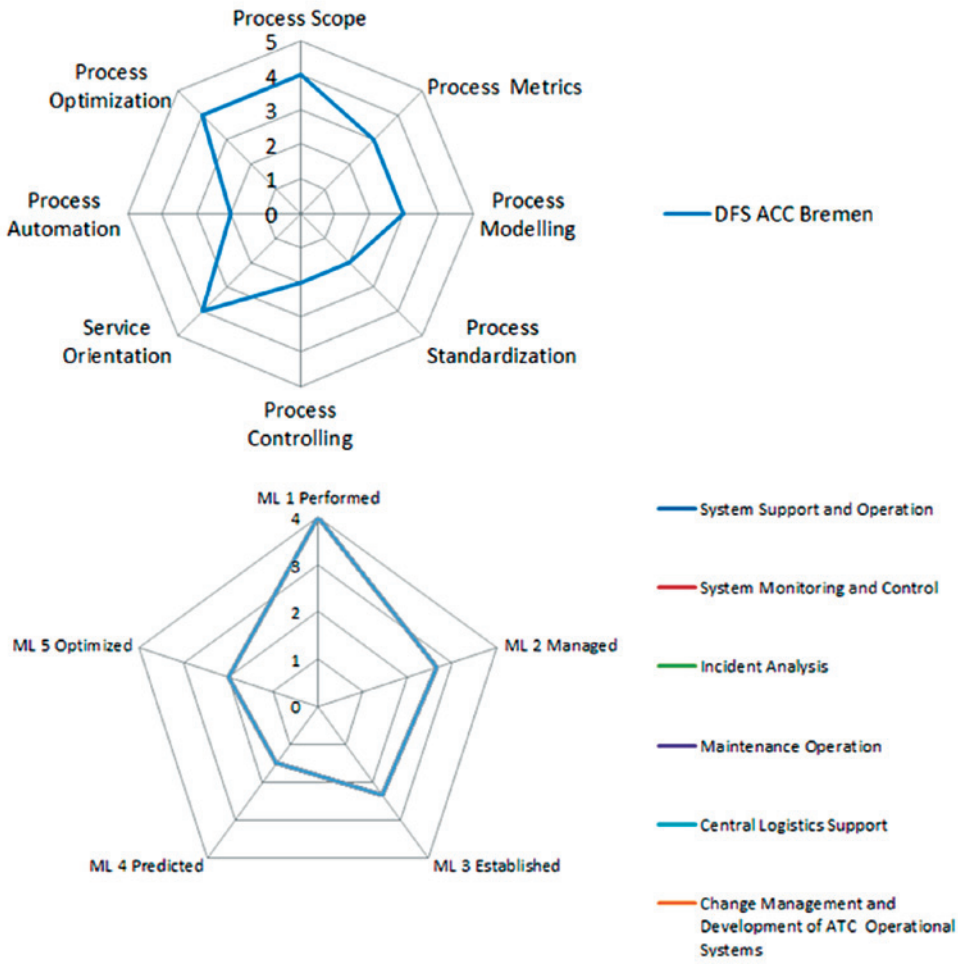

Fig. 4. DFS ATC maintenance process maturity assessments. The process types marked by various colours mentioned on the right side of the ML diagram completely overlap

General comparison of maturity assessment of ATC maintenance process

The method and procedure described in ISO/IEC 15504 is only partly useful, because maturity and quality level reached is different. Figure 5 illustrates the different attainment of ISO maturity levels based on a defined maturity level (ML1–5). Both ATC organisations fulfil the criteria of ML1 and most criteria of ML2. Differences can be observed in ML3 and ML5 only. The levels reached differ only in minor categories.

Process modelling is performed on textual description and process flow charts. Mathematical process methods and simulations are not used. Process content metrics are used. Process performance metrics are not defined; process performance control is not performed. Since the process modelling procedures of NAV Canada and DFS are different, the process description is performed on different levels of detail. NAV Canada has designed a large number of detailed processes that are defined by their own national understandings (service level, system management, product management). International standards like ITIL are used only partly. The process modelling of both NAV Canada and DFS shows that logistics support processes and special calibration services have major priority in the ATC maintenance process model. That is a specific feature that has also been observed by the FAA. Due to ISO 9001:2008 certification, both ATC organisations have implemented a regular optimisation process based on the PCDA cycle. DFS has also implemented a regular company-wide process optimisation programme and a regular benchmarking process. DFS performs ATC operational benchmarks with ACC from other ATC companies.

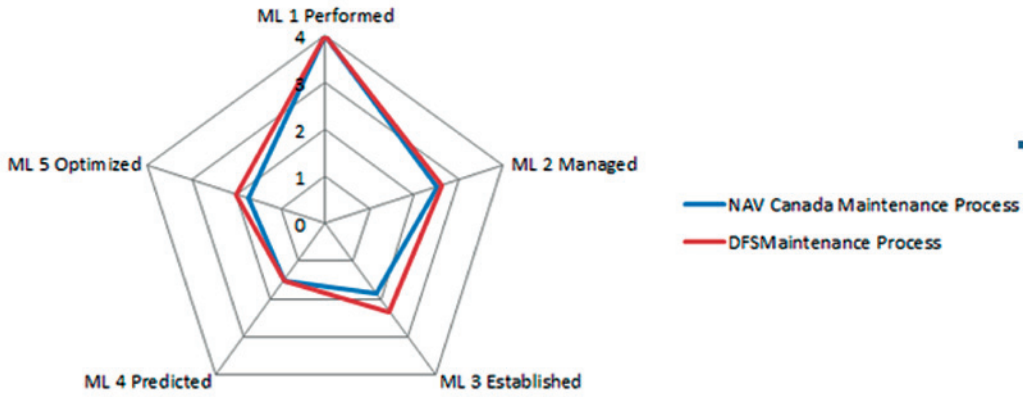

Fig. 5. Maturity level of ATC maintenance process model

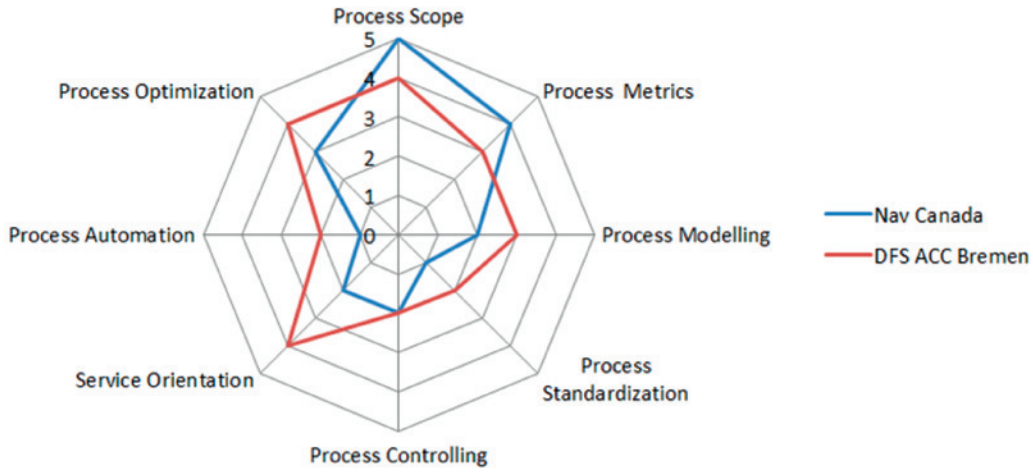

Fig. 6. Process attribute profile

4. Conclusions

The maintenance processes of national ATC organisations are not harmonised at international or European levels. Each national ATC organisation performs the maintenance process by it own rules and experiences. Normally the maintenance process models for ATC systems are best practise processes developed by national experiences and national rules:

- General definitions of terms, processes and services for the ATC technical support services do not exist. ATC providers use different definitions and terms. Thus a *general technical language* does not exist. ATC providers use their own defined terms and have a national characteristic for understanding ATC technical support services and their processes.
- A standard European/international level for ATC technical services are not available.
- Different parameters are defined at a low level only. A set of parameters is defined in different ESARR documents. These parameters reflect only the ATC controller's operational side. A complete sequence of parameter derivation is not given. ATC providers have their own defined parameters for monitoring ATC technical support. These parameters are derived from practice. The relationship between the process of air traffic control and the process of technical support is not described formally.
- A general ATC service and maintenance process model is not available. Guidelines and criteria for developing and designing an ATC service and maintenance process model do not exist either.
- Technical maintenance support should change to a common harmonised technical service orientation. The focus of support should change from technical support to technical service chain support.

With regards to the actual development of ATC functional airspace blocks (FAB), operational and technical support should change from the national level to a multi-national level, because inside of an FAB the ATC processes should be harmonised between different

states and national standards. To develop an ATC technical support service model, it is a prerequisite to build up FABs, because different ATC technical providers for ATC centres or towers operated on a multi-national basis will deliver the different ATC services. Based on the assessment of the ATC maintenance process that was performed, the following major results have been detected.

1. It is necessary to develop a general and complete ATC process model. A top down model for ATM maintenance and service process modelling and their derived ATC process metrics in relation to the specific ATC KPIs.
2. The practical results and conclusions of the four-step approach of ATC maintenance process research by the different ATC organisations will have direct use and impact on the further development of a new harmonised ATC maintenance and service model.

5. Further development and research

A significant increase in the efficiency of ATC as an integrated system can be achieved by building its business model using the principles of QoS (quality of services). For these purposes, the theoretical principles of service-oriented architecture (SOA), concept of ATC service modelling, and definition of semantic, logical, meta and context data models of the service must be developed. The general model with SOA must independent of national specific of ATC systems.

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