MODELS AND PROCEDURES FOR THE ASSESSMENT OF FUTURE MAINTENANCE TECHNOLOGIES FOR NEXT-GENERATION AIRLINERS WITHIN THE FUZZY FRONT END OF THE INNOVATION PROCESS

H. Fromm
EADS Deutschland GmbH - Corporate Research Centre Germany

Abstract

Born from a need to reduce the cost of maintenance in the face of increasing sophistication in aircraft and aircraft systems, the paper presents models and procedures to assess and select future maintenance concepts and technologies for airliners of the next generation. The objective is the validation of innovative technologies and techniques, which provide the means to make the maintenance task more efficient and effective. The selection of the most promising ones is applied already within the early stages of the innovation process, the fuzzy front end, in which the main part of the arising product life cycle costs are predefined. This technology appreciation procedure supports the early preselection of maintenance technologies of interest and the subsequent accompanying cost benefit analysis as decisive help in the process of development to the point of the product. It aims to increase the aircraft operability by increasing the operational reliability and the availability as well as by decreasing the maintenance related costs.

The achieved results are transferred to a currently running European research project [TATEM - Technologies And Techniques for nEw Maintenance Concepts, FP 6, EC contract 502909] for innovative maintenance technologies and concepts of future airliners, in which all relevant enterprises of the branch participate. Based on the knowledge that aircraft maintenance is an expensive endeavour, the project was set up to investigate methods for reducing maintenance costs on both fixed- and rotary-wing aircraft. The objective of the project is to ensure that European aerospace remains competitive in the design, support and operation of current and next-generation aircraft and their systems in the global market. The project results will shape and determine lastingly the concepts and products in the field of maintenance and repair of civilian aircrafts during the next years.

1 Introduction

The strong increase in intensity of competition in many markets, especially in the airline industry, leads to an increasing cost pressure, which is passed to the aircraft manufactures. In this rivalled environment the management of innovation becomes a strategic imperative for the airline industry. But open discussions mainly concern the aeroplane characteristics like the number of seats, range or acquisition cost. Information about the maintenance effort and/or strategies is hardly mentioned, even though the expenses of the aeroplane maintenance hold a large cost saving-potential as they have a big share in the airline's operational cost with up to 20% [1]. For years, innovative companies research for indicators to estimate the success of planned product innovations in advance. Only companies who understand the importance of innovation today can ensure their future success at the market.

The present study is designed to fill this research gap and to scientifically improve the initial situation by analysing the early phases of the innovation process as well as by going against the predominant inadequate structuring.

2 Fundamentals

This chapter describes the basic principles of innovation management, and forms the foundations for the methods of technology assessment discussed later. It shows the link and the importance of the discussed methods to current research in innovation management, beside its undoubtedly practical relevance.

2.1 Innovations

The airline industry has to deal with an increasing cost pressure, caused by a rapid growing low-price airline segment. This cost pressure is passed to the aircraft manufactures, who are also confronted by a strong industry rivalry. In such an environment, the management of innovations is an important core competence of today's aviation companies which must aim for designing their own innovation process effectively and efficiently. Only companies who understand the importance of innovation today can ensure their future success at the market. Accordant to its significance for the company's success, requirements on the management of innovation are high. In particular the management must focus the use and the costs of innovations for the customer.

To fulfil the described requirements, it is necessary to optimize the process of innovation, in regard to its effectiveness and its efficiency.
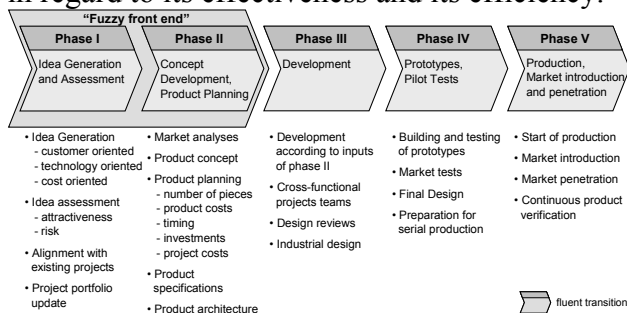

Fig. 1. The stages of the innovation process [3]

There is already some research done in this field; scholars describe different approaches of successful innovations [2]. These clarify the character of innovations as processes, and this distinguishes them from inventions, which refer to a special point in time. One example of a typical five stage innovation process is shown in Fig. 1. Other approaches differ in number and content of the stages. The described method is applied in the so called fuzzy-front-end of innovation, those stages where ideas are generated and evaluated and a first concept of possible future products is developed (phases I and II) [4].
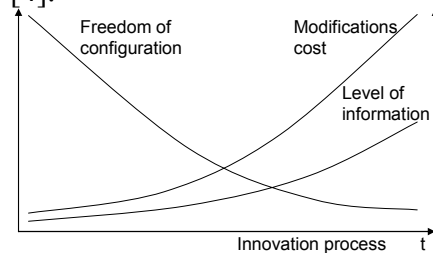

Fig. 2. Influence, costs of change and information during the innovation process [5]

The importance of the early stages for the overall success of an innovation project is caused by the fact that essential characteristic features of the future product become fixed, while at the same moment the expenses for changes of the characteristics are relatively low compared to those of the later phases (cf. Fig. 2). But the assessment of ideas and concepts is difficult because of the low degree of available information in this stage.

The resources allocation has an outstanding role in the innovation process, as Clark and Wheelwright demonstrate with the innovation funnel [6]. It describes the fact that although lots of ideas for new products and processes are generated, only a few of them reach the development stage and even less are introduced to the market. Therefore, for an efficient allocation of resources, the management is forced to evaluate ideas as early as possible. A selection of the most promising projects has to be made early, so that later activities have to focus their effort on the selected projects.

In spite of the high importance of these early stages for the innovation success, previous research does neither deliver concepts for designing these stages nor methods which support the assessment of the costs of an innovation. Accordingly, two areas for future challenges research are to focus: Design of an efficient organisation of the innovation process and new methods development for early

assessment of technology innovations regarding benefit and total lifecycle costs (LCCs). The paper will help to fill this methodical gap by designing an innovation process for future aeronautical technologies as well as modelling and analysing their maintenance-related costs and benefits in advance to increase the success of future innovations.

2.2 Cost assessment of innovations

Beside the use of an innovation its costs have to be considered. A potential customer will only buy a product if its use exceeds its costs. Relevant are the total costs for the customer. These exceed the costs for the acquisition of a technology, because the operation of a technology is linked with further costs. To calculate the cost/benefit ratio of an innovative technology, the total costs over its whole lifecycle have to be assessed.

But the visibility of these additional costs is limited. Blanchard describes this circumstance with an analogy, an iceberg of which the visible top represents the acquisition cost [7]. The much bigger part of the iceberg is not visible under the water surface; it represents the costs for maintenance, distribution, training, etc. To evaluate new technologies during the innovation process the impact of all of these costs have to be considered.

Target Value	Method	Idea Generation & Assessment	Concept Development, Product Planning	Development	Start of Production & Market introduction
Environment	Scenario-Analysis				
	Portfolio-Analysis				
Customer Benefit / Quality	Conjoint-Analysis				
	QFD				
	Design Review				
	FMEA				
Costs	Target Costing				
	Design to Cost				
	Life Cycle Costing		Methodical Gap		
	Development accomp. Costing				
	Preliminary Costing				
	Project Cost Accounting				
Time	Milestone-Trend-Analysis				
	GANT-Charts				
	Workflow-Management				
Risk	Risk Assessment				
	Prototyping				

Fig. 3. Methods to support the innovation process [8]

Along the innovation process numerous methods are used to support the assessment of innovations. Each method can be used for specific stages of the process and allow the assessment of specific dimensions of the

innovation like the environment, the use for the customer, the costs, timing and risks. Fig. 3 shows the adaptability of the methods for different stages of the innovation process and the dimensions each method evaluates. There is so far no method which supports the assessment of the costs of an innovation during the early stages of the innovation process [8].

Because of the previously described necessity to already evaluate innovations in the early phases of the innovation process, new methods of technology assessment have to be developed. The study described in the next chapter will contribute to the current scientific discussion and help to increase the success of future innovations.

3 Assessment of innovative maintenance concepts

The outlined fundamentals of innovation management and cost assessment provide the basis for the following design of an innovation process for future aeronautical technologies as well as the modelling of their maintenance costs and benefits.

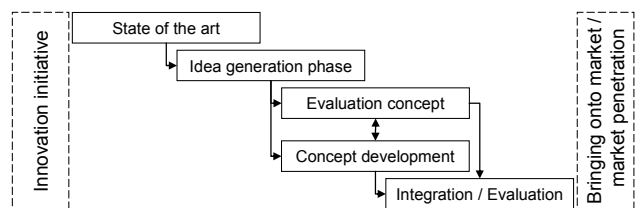## 3.1 Design of the innovation process

Fig. 4. Innovation process

The innovation process is designed according to common theoretical models [9], [10], [11]. The result is a project specific innovation scheme which structures the activities and the effort into five technical process steps (cf. Fig. 4).

3.2 Technical approach of cost benefit analysis

Within this process the concept & methodology on how to approach the cost benefit analysis is developed as a means for decision support. For

a capital investment decision the classical cost benefit analysis (CBA) compares additional costs of an investment with its expanded benefit. To measure the cost and benefit of a new technology it is useful to compare one future use case against a reference, the current use case. Fig. 5 drafts the process steps or tasks between a conjoint initial and final state of the current scenario and the future one. To ensure that the future scenario is more profitable than the current one, the applied resources (e.g. man-hours, material, etc.), process steps or the occurrence should be less than in the current scenario.
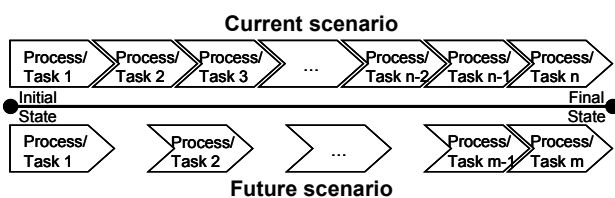

Current scenario

Future scenario

Fig. 5. Comparison of future against current scenario (schematised)

But the CBA tool does not value future technologies directly; it assesses them indirectly by evaluation of different maintenance use cases and scenarios in which the technologies are applied. A use case combines and structures different scenarios dealing with different technologies and/or maintenance concepts. A scenario includes all (maintenance) tasks from an initial unknown failure status to a final known repair status. Tab. 1 gives an example of how an innovative technology can change the process steps and tasks in the future.

Today	Tomorrow
• pilot detects anomaly	• system detects anomaly
• logs this	• in-flight diagnosis
• *aircraft lands*	• data / information transmitted to the ground
• ground crew read the maintenance log	
• then ground crew must diagnose anomaly	• further analysis on ground if required
• then prepare to take action	• system identifies and collates tasks, tools, parts
• collate relevant manuals, tools, parts etc.	• *aircraft lands*
• undertake work	• undertake work

Tab. 1. Changed future process steps due to innovative technologies (example)

Furthermore, the scope of the CBA is to evaluate the impact of future technologies on those LCC elements only, which change as a

result of changed maintenance actions. These cost elements are defined as maintenance-related cost (MrC).

The overall process of cost benefit analysis consists of the CBA model and the calculating tool using input from the use case descriptions as well as the reference model of aircraft and airline profiles to get operational concepts-driven parameters into the model and to enable a comparative cost benefit analysis (cf. Fig. 6).
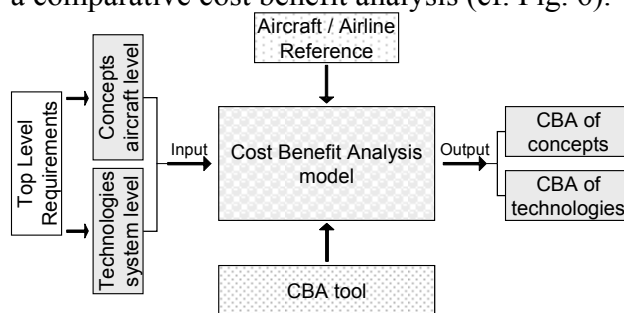

Fig. 6. Overall process of CBA using CBA tool and reference aircraft /airline model

3.3 Costs related to maintenance actions

The study focuses on the assessment of future maintenance technologies within use cases. Therefore, it evaluates those cost elements of the operator's "cost of ownership", which are affected by maintenance actions, especially when maintenance actions change. These cost elements are defined as maintenance-related cost in the following.
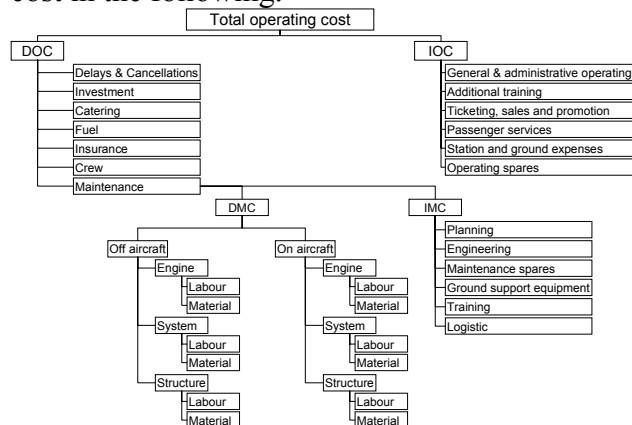

Fig. 7. Cost chapters of the total operating cost

Airline total operating costs are divided into Direct Operating Costs (DOC) and Indirect Operating Costs (IOC). DOC are cost that can be allocated to the aircraft whereas IOC are

caused more generally by running the airlines business.

Direct operating costs are a result of flight operations such as fuel, crew, maintenance, insurance, and depreciation costs. Indirect Operating Costs are those costs not considered to be DOC but contributing to the overall operating costs of the aircraft, including such costs as general administration and finance, passenger service, marketing, and aircraft and passenger handling services [12]. The IOC cannot be accurately approximated because they vary widely with each purchaser of the aircraft.

Maintenance Costs as part of the DOC are made up by Indirect Maintenance Costs (IMC, also known as burden maintenance) and Direct Maintenance Costs (DMC). Indirect maintenance costs are the maintenance labour and material costs not considered to be DMC but which contribute to the overall maintenance program costs through overhead operation, administration, engineering, record keeping, supervision, tooling, test equipment, facilities, etc. Direct maintenance costs are the maintenance labour and material costs directly expended in performing maintenance on an item or aircraft [12]. To cover the different origins DMC is split into two categories: On-Aircraft and Off-Aircraft DMC. So the origin of DMC is the labour and material costs caused by aircraft systems, engines and structures on a scheduled and unscheduled basis to keep the aircraft in an operational state.

Due to the complexity of the cost of ownership, the CBA does not include the whole cost of ownership elements but considers the "Maintenance-related Cost" (MrC) elements only in order to evaluate the global impact of the proposed use cases on aircraft maintenance. The scope of the CBA is to focus on those costs elements, which can change as a result of modified maintenance actions due to new technologies.

3.4   Maintenance cost model

The CBA model is designed to assess the impact of MrC elements from current to future maintenance use cases in order to compare them

independently and measure their benefits. The model describes each MrC chapter and provides a mathematical algorithm with needed parameters. The model is composed of two parts. One part is the quantitative model for DMC calculation. It contains mathematical algorithms for estimating MrC elements on the basis of parameters. The other part of the model is the qualitative one. It is made up of mainly qualitative models/algorithms to measure the impact of Indirect Operating Costs. Depending on the availability of data in a use case, a specific cost chapter will be calculated with the quantitative or qualitative model. Because the costs incurred at different points in time, they have to be compared at one point of time. For this purpose the reference date t_0 is defined.

The on aircraft DMC, equation (1), are the summation of the on aircraft labour and material costs for engine, structure and system. The algorithm to assess for example the DMC for labour workforce on aircraft for engine maintenance ($C_{On,Engine,Lab}$, in US\$/block hour) is part of the individual costs model "Labour (Engine)" which describes the costs of the maintenance task workload & its frequency.

$$DMC_{On} = C_{On,Engine,Lab} + C_{On,Engine,Mat} + C_{On,Struct,Lab} + C_{On,Struct,Mat} + C_{On,Syst,Lab} + C_{On,Syst,Mat} \qquad (1)$$

$$C_{On,Engine,Lab} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} r_{skill_j,MH} \cdot \dfrac{t_{task_i,MH}}{Eff_{skill_j}}}{\sum_{k=1}^{o} t_{bl_k}}$$

with i=task, j=skill level, k=flights per year

The qualitative costs models are assessed just like the quantitative models, if exact data for the parameter is available. Otherwise (and that concerns most of the cases) the figures for the parameters have to be estimated. For these estimations different statistical approximation methods are used. In the worst case, even estimated data is not available. In this case of missing data a probabilistic estimation is not applicable, so that the study works out a trend estimation.

Since many real parameter values and costs data for cost and benefit evaluation will not be available, these data are estimated. A possibility for costs analysis is an approximation with a tool for probabilistic cost estimation. The quality of the results depends on the quality of estimated parameter values. The tool enables the

cost estimator to work with uncertain cost information using probabilistic mathematics. The uncertain information is derived by triangular distributions (Fig. 8).
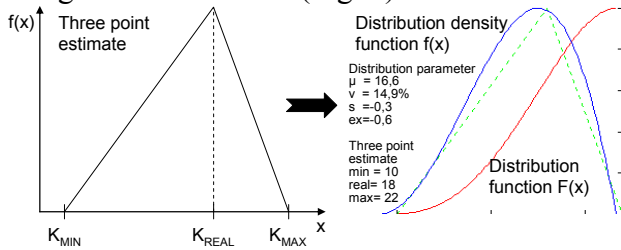

Fig. 8. Three point estimate, distribution function F(x) and distribution density function f(x)

For the determination of the distribution, three parameters needed are to be estimated: the minimum (K_{MIN}), the likely / almost certain (K_{REAL}) and the maximum (K_{MAX}) value. The developing of the values is linear and can be divided in three sections with the following equations [13]:

for $K_{MIN} \leq x \leq K_{REAL}$: (2)
$$f(x) = \frac{2 \cdot (x - K_{MIN})}{(K_{MAX} - K_{MIN}) \cdot (K_{REAL} - K_{MIN})}$$

for $K_{REAL} < x \leq K_{MAX}$: (3)
$$f(x) = \frac{2 \cdot (K_{MAX} - x)}{(K_{MAX} - K_{MIN}) \cdot (K_{MAX} - K_{REAL})}$$

for $x < K_{MIN}$ and $x > K_{MAX}$: $f(x) = 0$ (4)

These data enable to calculate the expectation value (μ), variance (v), skewness (s) and kurtosis (ex). The expectation value μ (equation (5)) of the three point estimate is calculated using the arithmetical means of the three influencing variables:

$$\mu = \frac{(K_{MIN} + K_{REAL} + K_{MAX})}{3}$$ (5)

The variance σ² is calculated as follows:

$$\sigma^2 = \frac{(K_{MAX} - K_{MIN})^2 + (K_{REAL} - K_{MIN}) \cdot (K_{REAL} - K_{MAX})}{18}$$ (6)

The estimated distributions can be linked with other distributions resulting in another beta distribution. Beside determining expected costs there is the possibility to display chances and risks within a sensitivity analysis. In spite of the partially quite high uncertainties regarding the

cost on task level, the range to forecast total cost on system level is relatively exact. Thus, the aggregation of probabilistic data results in an increase of the accuracy of the output [14]. This is due to the stochastic consolidation effect and is shown by distributions with lower variances in Fig. 9.
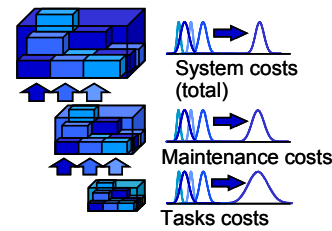

Fig. 9. Consolidation effect - increase of the accuracy

3.4.1 Model input: Operational parameters
Main input to the cost benefit model is the data of the different use cases. Each use case is analysed to identify whether it affects a certain cost chapter of the operating cost or not. For the affected ones, the cost amount, which arises in a certain use case, must be assessed. In this context, the specific characteristics of different fixed wing and rotary wing aircraft types and airline strategies have to be considered in order to estimate the MrC adequately. A specific use case could be profitable for a certain a/c type, e.g. a short range flying a/c, but unprofitable for a long range one. The discrepancy regarding maintenance costs for helicopter and aircraft can be even more severe. For the CBA a representative set of reference aircrafts is modelled to get operational-concepts-driven parameters into the CBA. Relevant model parameters are captured in a multidimensional database. The CBA model accesses these specific operational parameters depending on the use case. These operational parameters are divided into:
- Technical parameters
- Operating company specific parameters

The technical parameter model contains specific fixed wing and rotary wing a/c parameters. Relevant concrete attributes define certain baseline aircrafts as well as airliners' profiles. The parameters and their values as well as its units for each different aircraft type (short/medium/long range, helicopter) are stored

in the database described above. For each aircraft type (e.g. A310 or A300, Single aisle, Long range, A380) the values of the parameters are given individually as well as in average.

The operating company specific parameter model determines which influence the airlines' strategy has regarding the maintenance actions and costs. Therefore specific airline profiles are modelled and defined by typical airline fleet and costs parameters stored in the database.

Different airlines in the world follow different strategies, i.e.:

- Premium: Lufthansa, Air France, …
- Charter: Condor, HLX, …
- Low budget: Ryan air, Easy Jet, …
- Cargo: DHL, TNT, UPS, FedEx, …
- Smaller airlines: Aeroflot, Lauda Air, …
- Regional airlines: Airlinair, Eurowings...

Each of the different airline strategies is attributed with different characteristic operational parameters. A Premium airline e.g. provides fewer seats (i.e. higher passenger comfort) in an aircraft than a low budget airline.

The relational database combines the different airline strategies with the airline specific parameters. In addition the operating company specific parameters are linked to the technical parameters characterising different aircraft types. This parameter linkage is necessary input to the CBA model: If a certain use case is for example designed for a premium airline using long range aircrafts, the database only links the corresponding parameters and provides a set of certain parameters to the CBA model. The CBA model accesses the parameters defined by this constellation and estimates the MrC and benefit of that certain scenario. This procedure enables the cost assessment of each single use case for a certain aircraft type used by a specific airline.

3.4.2 Model output

This chapter describes the concept for the results presentation and performance visualisation of different use cases.

The output of the CBA model is used to aid technology assessment and validation. In other words: The information sent out from the CBA model points out which use case is more

beneficial than another. This builds the basis for analysing which technology is more advantageous than another. So the model supports the decision which profitable maintenance process and/or technology to investigate in further and which not to follow up.
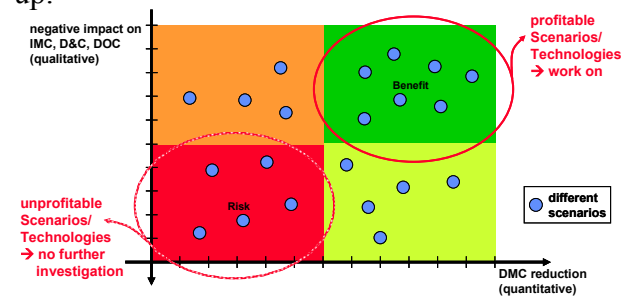

Fig. 10. Risk-benefit portfolio

To visualise a first interim solution, i.e. the ranking of profitable use cases, a risk-benefit portfolio is conceivable (cf. Fig. 10). It compares the DMC reduction feasibility with the negative impact on MrC in order to cluster profitable scenarios. This portfolio enables the analyst to cluster profitable use cases to investigate in further (quadrant top right) and unprofitable ones (quadrant down left).
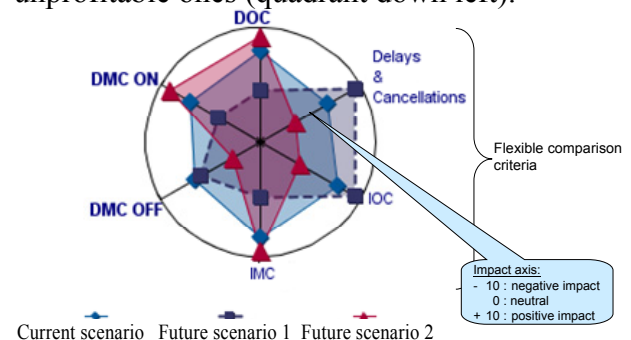

Fig. 11. Scenarios selection approach – radar to summarize CBA results on different costs performances

Another way of illustrating the CBA results of the scenarios selection approach is the radar type presentation (cf. Fig. 11). It enables the analyst to display costs performances of different use cases flexibly by different comparison criteria (e.g. costs chapters).

4 Technology assessment and selection tool

The assessment of the use cases shall be carried out by a tool, which supports the previously

defined CBA model. The resulting cost benefit analysis tool will provide metrics for the impact of the technologies validated in the work packages on the maintenance process.

4.1 Tool requirements

The tool shall support the cost benefit analysis model. The requirements determine the demands placed on the CBA tool. They form the basis for the CBA tool selection process. For the definition of the tool requirements following topics are investigated:

- the requirements capturing from different partners and their activities related to the cost benefit analysis
- the definition of global objectives (cost reduction, usability, reliability improvement etc.) of the cost benefit analysis derived from the global project goals and current and future maintenance scenarios
- the investigation of existing cost benefit models, tools and approaches

The investigation results in a list of requirements, which can be divided as follows:

- Top level requirements which are linked to global project objective, process, etc.
  - Support of the entire CBA process
  - Appropriateness for the needed tasks
  - The tool shall contain the models and algorithms to support the concept and methodology for assessment
- Functional requirements which are linked to the main CBA functions
  - Data import possibilities of different maintenance concepts, aircraft, airline, economic parameters, etc.
  - Calculation of maintenance related cost by using sensitivity analysis, statistical and probabilistic methods as well as mathematical algorithms
  - Saving of analysis results
  - Capability to export the results of the CBA analysis into different formats
- Interface requirements
- Technical requirements
- Costs requirements

4.2 Tool design

The CBA tool is designed for the usage on at least Windows low range terminals. Furthermore, the operating system has to be Windows 98, ME, NT, XP or any future version. The uncertainties and probabilistic distributions are modelled with a software system which incorporates methods for analysing risk intensive situations, @Risk.
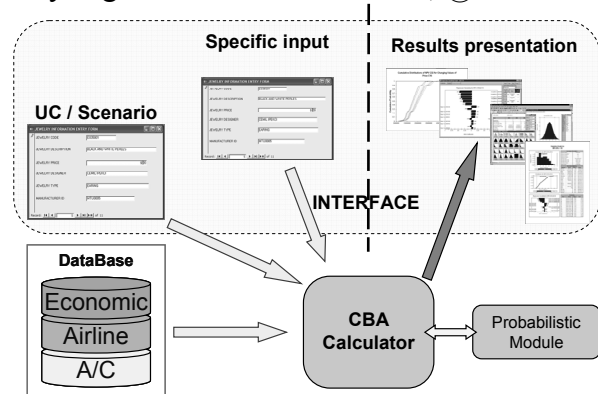

Fig. 12. Technical design of CBA tool

Fig. 12 illustrates the technical design of the CBA tool. Input to the CBA calculator is the use case/scenario data via a graphical user interface (GUI), as well as a database with aircraft, airline and economic data. Further, the calculator is linked to a probabilistic module. The output is processed via another GUI and can be analysed upon different aims.
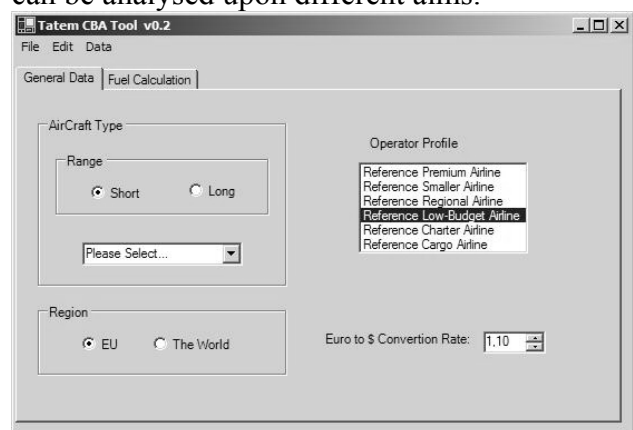

Fig. 13. GUI of CBA tool (screenshot)

A GUI screenshot of the beta version is given in Fig. 13, which shows the general data tab and its selection possibilities of different aircraft types, scenario regions and operator profiles.

5 Application

Born from a need to reduce the cost of maintenance to the point where it can reduce airline operating costs by 50 percent in the face of increasing sophistication in aircraft and aircraft systems, the European research project TATEM started in March 2004 to investigate 'Technologies And Techniques for nEw Maintenance Concepts' [1]. The 40 million Euro, four-year project was created by the European Union under its Sixth Framework Program, and brings together a consortium of 58 contractors from 12 countries across Europe, Israel and Australia. Based on the knowledge that aircraft maintenance is an expensive endeavour that can account for as much as 20% of an airline's direct operating costs, the project was set up to investigate methods for reducing maintenance costs on both fixed- and rotary-wing aircraft. The objective of the project is to ensure that European aerospace remains competitive in the design, support and operation of current and next-generation aircraft and their systems in the global market. This objective is realised by validating technologies and techniques, which can be used to transfer unscheduled maintenance to scheduled maintenance and provide the means to make the maintenance task more efficient and effective. The TATEM project researches maintenance philosophies, technologies, and techniques to develop new approaches for maintaining aircraft structures, avionics, utilities and undercarriages, and engines. The program will investigate all aspects of on-aircraft and off-aircraft maintenance issues. Its task is to evaluate: maintenance-free avionics; signal-processing techniques; novel onboard sensor technology; diagnostics methods; prognostics methods; decision-support techniques; and human interface technologies.

To assess the performance of the project against this objective, a specific CBA will be undertaken which will both translate these high level objectives into specific targets for the technologies and provide a means of measuring the results.

5.1 Innovation process

The innovation process described in chapter 2.1 is upgraded to the TATEM project needs. To structure the effort of the several project partners, the work is divided into seven technical and two organisational work packages (WP) (cf. Fig. 14).
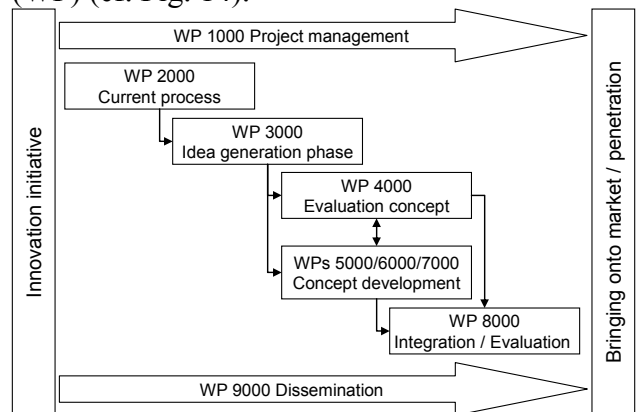

Fig. 14. Innovation process in TATEM project

The two accompanying WPs, the Project management (WP1000) and the Dissemination (WP9000) guide the entire innovation process. The innovation initiative phase and the bringing onto market phase are not directly part of the project but shown for the sake of completeness.

5.2 CBA process

The CBA process is also adapted to the project needs (cf. Fig. 15). Taking into account the top level requirements, all partners' ideas in terms of future maintenance scenarios are gathered in a template in a bottom-up process. Ideas specific to one technical domain (engines, landing gears, structure, systems, ground crew processes) are classified in the category Domain Specific Scenario (DSS). Ideas at aircraft or fleet level or involving several technical domains are classified as an Aircraft Level Scenario (ALS). At the same time as the above bottom-up process, top-level maintenance scenarios called Integrated Aircraft Level Scenarios (IALS) are defined in a top-down process. IALS constitute extreme maintenance scenarios that are characterized as unrealistic or hardly achievable even in the very long term (more than 20 years) as well as illustrating the ultimate that could be achieved in one

maintenance situation. The DSS are consolidated into Use Cases (UC). IALS and UC are the input to the CBA model of WP4000. These IALS and UC raise the need of more specific input data which is delivered by WP 5000, 6000 or 7000 (depending on each IALS / UC) in the form of IALS / UC specific parameters.
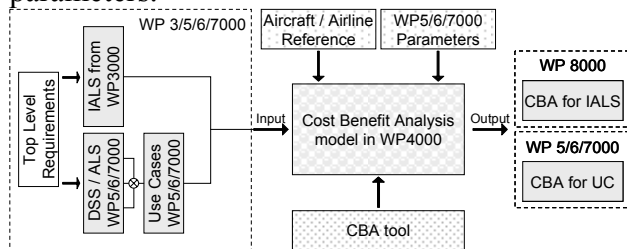

Fig. 15. Overall process of CBA using CBA model, reference aircraft model and input from WPs

The CBA model receives data from the reference aircraft/ airline model to get operational concepts-driven parameters into the CBA and to enable a comparative cost benefit analysis. It contains a representative set of reference aircrafts (short/medium/long range, helicopter) for CBA and captures relevant airline model parameters (costs data for modelling a representative airline profile for reference a/c). WP4000 discovered a high sensitivity to share any costs data from both sides OEMs and Airliners. Subsequently, if real reference data cannot be made available, it will lead to a "virtual" aircraft fleet using estimated model parameters.

Additionally to the use case descriptions different use case specific (cost) data and parameters are mandatory. From a current point of view, this detailed input data needed is not enclosed within each individually delivered use case description. In consequence, WP4000 specifies data input requirements to WP5/6/7000.

6 Outlook

Current research work focuses on the ongoing tool development to support the WP5/6/7000 technology assessment process. The acceptance criteria include the degree of adaptation necessary and the ability to achieve this within the allocated resources. Furthermore, investigations (collection, validation and verification) on certain parameters for the assessment are main tasks.

The scope of the CBA tool is to support the cost benefit analysis, to aid future technology assessment and to evaluate the overall project achievements against the stated objectives.

7 References

[1] TATEM internal report, EC contract 502909

[2] Herstatt C, Verworn B. Innovation process model and their evolution Innovation. in: Probert et alii: *Bringing Technology Management to Board Level,* Palgrave McMillan, 2003

[3] Herstatt C, Verworn B. *The fuzzy front end of innovation.* Arbeitspapier Nr. 4, Technische Universität Hamburg-Harburg, 2002

[4] Cooper R G, Kleinschmidt E J. *Screening new products for potential winners.* Institute of Electrical and Electronics Engineers IEEE engineering management review 22 (1994) 4: 24-30

[5] Hippel E. von. *Wettbewerbsfaktor Zeit, Moderne Industrie.* 1993

[6] Wheelwright St C, Clark K B. Creating project plans to focus product development. in: *Harvard business review,* - Boston, Mass. - 70. 1992, Nr. 2. S. 70 – 82

[7] Blanchard B S. *Logistics Engineering and Management.* Englewood Cliffs, New Jersey: Prentice-Hall Inc., 2004

[8] Neff T. *Front Load Costing - Produktkostenmanagement auf Basis unvollkommener Information.* Wiesbaden 2002

[9] Herstatt C, Verworn B. *Management der frühen Innovationsphasen – Grundlagen - Methoden - Neue Ansätze.* Wiesbaden 2003

[10] Seibert S. *Technisches Management - Innovationsmanagement - Projektmanagement – Qualitätsmanagement.* Stuttgart Leipzig 1998

[11] Vahs D, Burmester R. *Innovationsmanagement: Von der Produktidee zur erfolgreichen Vermarktung.* Stuttgart 2002

[12] Air Transport Association of America: *WATOG – World Airlines Technical Operations Glossary.* 14th edition, Washington DC 1992

[13] Schultz V. *Projektkostenschätzung: Kostenermittlung in frühen Phasen von technischen Auftragsprojekten.* Wiesbaden 1995

[14] Neff T, Kokes M. *Front Load Costing - Produktkostenmanagement auf Basis unvollkommener Information.* DaimlerChrysler Forschung, Technischer Bericht FT2/K-1999-006, Frankfurt/M 1999