ESTIMATING MODIFICATION EFFORTS FOR NEW AIRCRAFT DEVELOPMENT PROJECTS

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OVERVIEW

The development of a new transportation aircraft leads to a high risk of improvement issues. These improvements which have to be implemented after the typical product development process are in most of the cases cost intensive and not yet planned in the way it could be.

The report focuses on the modification process in European aircraft industry. The approach discusses today's data and past issues in order to propose a forecast method by parametric modelling.

Product maturity is one of the key elements which are highlighted and discussed in order to reveal the potential for future aircraft development projects in an international business world.

1. INTRODUCTION

Today's aircraft programs still reveal a lot of issues where the headline could be "Dreaming of first time right". Major concerns are: far too long lead –times to market, missed business opportunities, failures to match target must costs connected with failures to meet committed delivery dates. The question is: How can the situation be changed and how can we keep ongoing progress in order get a better understanding of the project to be performed considering transparency.

The modification process seems to be a part of the mentioned trouble reasons in some of the recent aircraft programs. In the past it could be recognised that there was a high degree of wasted effort due to not understanding original change requirements or the impact of the change at an early stage in the process. Nevertheless there will be no program without any request for changes which leads to the question how the situation could be analysed and even be forecasted.

Therefore it might be helpful to establish a set of measurable key performance indicators in order to:

- Track the daily business
- Manage the daily business under continuous improvement conditions.

However, the main focus of this report considers the possibility to forecast efforts by learning from the past experience.

This type of approach focuses on today's business on the subject of modification processing and handling.

In order to have an idea about the future modification workload, considering volume and cost, a systematic approach is required. The basis for the foreseen model will be given by parametric modelling. A further result will be the possibility to take the data base for improvement of engineering efficiency by target setting according to the learning curve.

The use of Cost Estimating Relationships (CERs) was a basic breakthrough in cost estimating already many years ago. For the first time, cost analysts saw the promise of being able to estimate relatively quickly and accurately the cost of proposed new systems [1].

Examples for Forecasting KPIs could be based on the experience considering modification proposals (MP) and modifications (MOD) as a function of different business parameters like the number of A/C in service, the age of the A/C fleet or the number of head versions:

- **Based on Volume**
  - MP/MOD development = f(age of A/C fleet)
  - MP/MOD development = f(number of A/C in service)
  - MP/MOD development = f(number of head versions)
- **Based on Cost**
  - MP/MOD development = f(age of A/C fleet)
  - MP/MOD development = f(number of A/C in service)
  - MP/MOD development = f(number of head versions)

Most of the civil aircraft programs don't take into account the real modification efforts to be expected within the product life cycle. The above mentioned examples for possible KPIs give an impression about potential aspects to be analysed in order to find a basis for any cost estimation relation. The specific approach for the subject of modifications is discussed in the following chapter.

2. APPROACH

The key idea for developing an estimating model is based on the parametric approach known from typical cost estimation in the development of complex products. Examples for commercial realisations are available from different corporations [2,3].

The following figure illustrates the process idea behind the approach of estimating modification efforts at least within certain areas.

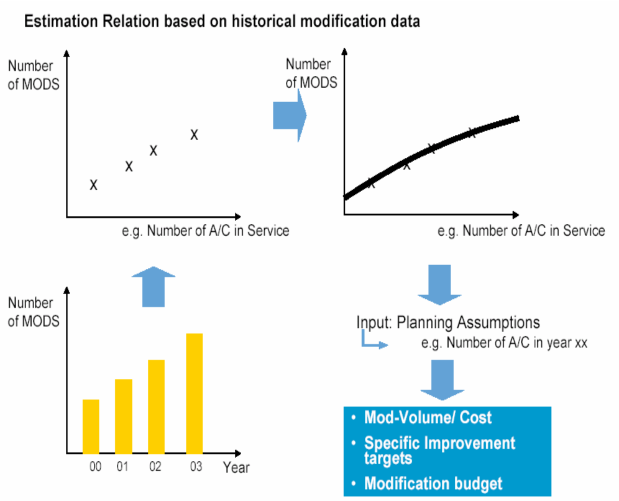

FIG 1. Approach Modification Forecast – Process Example

The process example shows the way a correlation could be derived by taking a data basis coming from the aircraft manufacturer's business experience. The shown fictive correlation is assumed by the input coming from the collected number of modifications within a certain A/C program after entry into service. A regression analysis leads to potential conclusions according to a forecast.

A common way of handling is then the interpolation for the expected future program situation. Therefore planning assumptions like the number of A/C per year taking the order situation and the production rate into account are the input for the potential cost estimation relation. The output is supposed to generate the expected volume of modifications or on a monetary basis the cost for modifications. Furthermore the results can be taken for setting specific improvement targets or setting the modification budget for the future project.

However, it is mandatory to have a closer look into the modification process before any kind of prosperous generic model is discussed due to the different modifications and changes which can be influenced more or less by the program responsible.

3. MODIFICATION BASICS

The modification process usually is built up into certain steps starting with the initialization and ending with the implementation of a change. The representative process is shown in figure 2.

In order to come to any kind of assumption for estimating modification efforts it is necessary to analyse the initialisation phase. The figure hints at the point that changes are initialised by the A/C programs. However, the real initiative might come from outside of the A/C developing company and it seems to be impossible to take the active part of introducing requests for changes.

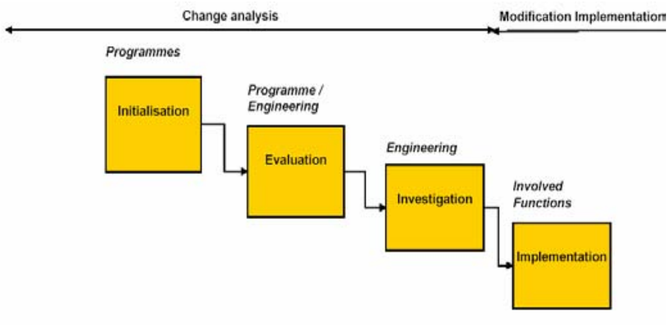

FIG 2. Modification process

For structuring the types of requests for changes it might be helpful to differentiate on a top level into requests for changes and request for customisation like it is introduced in figure 3.

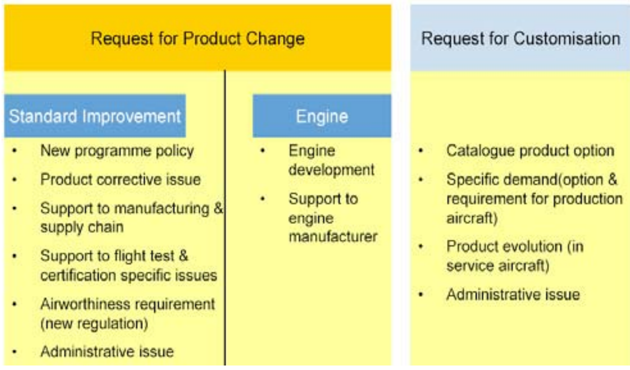

FIG 3. Classification of modifications

The items belonging to standard improvement are based on the future programme policy of the manufacturer for future products and on product evolution considering the existing types. In case of problems experienced on in-service A/C, defects experienced during A/C delivery or any criteria like quality defects, not-right-first-time issues it is handled as product corrective issues. The support to manufacturing & supply chain contains manufacturer improvement or supply chain improvement. Support to flight test and certification specific issues cover modifications in the context of certification campaigns to demonstrate the adequacy of the customised A/C, its systems and its procedures for an operation environment. The issues under airworthiness requirement contain changes which are exclusively due to new airworthiness authorities or certification regulations affecting the standard product. Often a further classification is given by administrative issues covering investigations which are not directly related to a particular program but aiming at developing the harmonisation of directives, procedures or standards.

Due to the fact that the engine of an A/C covers round about 30% of the value and usually is under the main responsibility of the engine manufacturer, changes will be followed up under such a specific category.

Request for customisation contains the sub-classification where e.g. the option development, the suggestion for customisation or offers for retrofit modifications are placed.

The experience shows that the dominant business drivers for modifications are by volume and cost: customisation, new development and product corrective issues. Of secondary relevance are airworthiness, support manufacturing & supply chain and others. Round about half of the workload for modification issues can be seen under internal influence. Customisation is supposed to be honoured by the customer and under financial viewpoints it is obviously to be seen as no further budgetary problem.

The workload generated by standard A/C changes is described in the following figure.

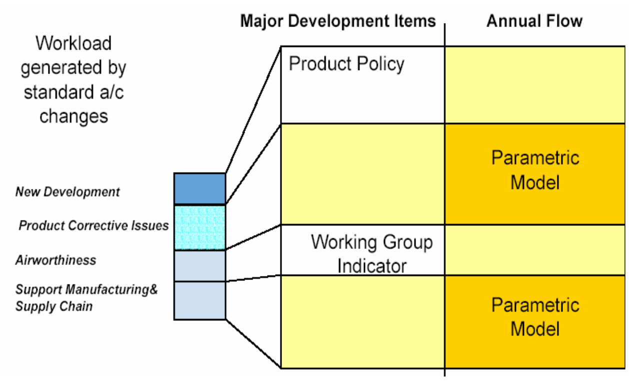

FIG 4. Modification workload

It can be distinguished between major development items and the annual flow. Major development items are covering typically issues out of range considering the parametric approach due to the fact that these modifications are either driven by additional new developments or by new regulations. New development items should be captured and implemented in the product policy and at the end to be found in the general business case. On the other hand major development items are forced by the airworthiness authorities. The early indication of modification volumes could be handled by the so called working group indicator. This means that the clear recommendation is to be involved in the regulation process as soon as possible to get an idea about future demands by capturing weak signals. The way this can be practised is the participation within the different working groups closely connected to the authorities.

The annual flow refers to the part which is supposed to be analysed by parametric modelling. In order to generate an idea for developing a business model for estimating modification efforts, a pilot analysis has been performed in the area of product corrective issues and support manufacturing.

4. BUSINESS MODEL: GENERAL PRINCIPLES

To keep a potential business model, as illustrated in figure four as simple as possible, general principles can be defined as the following ones:

The PURPOSE of the model is to generate a parametric model for forecasting modification effort and target setting considering the operational planning.

The CONSTRAINTS are the number of accessible data and the extrapolation based on past issues.

INPUTS are historical data on the basis of volume on the one hand and on cost on the other hand:

- Modification proposals (MP) or Modifications (MOD) by head of version and A/C type over the product life cycle after entry into service.
- MP or MOD origin according to classification described in chapter three.

OUTPUTS are:

- Forecast for modification effort
- Volume to be produced
- Assumptions for budget on future modification
- Visibility for expected workload
- Baseline for target setting on the issue of engineering budgets

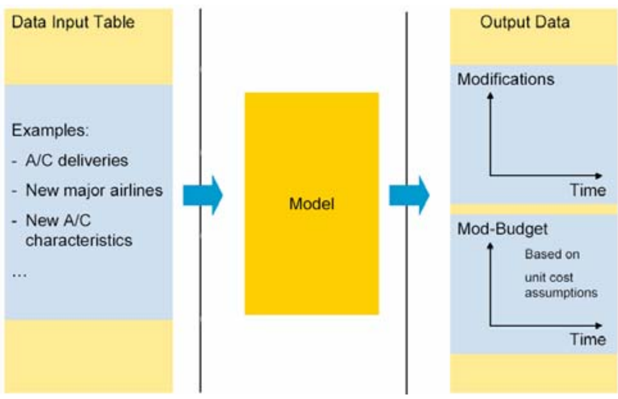

FIG 5. Business model principles

To give an idea about the realisation of the development of such a model a representative example will be taken in chapter five in compliance with the classification described above. A typical sub-class belonging to product corrective issues is covered by major in service problems representing one of the most interesting parts for improvement and transparency.

5. REPRESENTATIVE EXAMPLE: MATURITY APPROACH

Product corrective issues are closely linked to the maturity of a product to be developed and manufactured which comes to the initial statement of the dream that subjects should be handled first-time-right. The experience in project management says that especially the early project phases are the most important phases in order to come up with products of a high degree of maturity [4, 5]. Concepts have been established especially in aerospace business to take care of the requirements along the product life cycle for achieving a high level of maturity when introducing new technologies and features into future projects.

Nevertheless reality reveals that there exists no development program without product corrective issues which can last not least be reflected by major in service problems. Experiences hint to the fact that round about 80% of major in service problems result in modifications. For that reason it seems to be of interest to follow up the mentioned events as an example for the above stated idea of developing a business model.

When taking the number of major in service problems as a function of product maturity linked to product life cycle a certain characteristic can be obtained. There is a clear relation between the introduction of new technology or at least product complexity and the evolving number of modifications.

The following diagrams based on real figures are qualitatively showing the described effects.

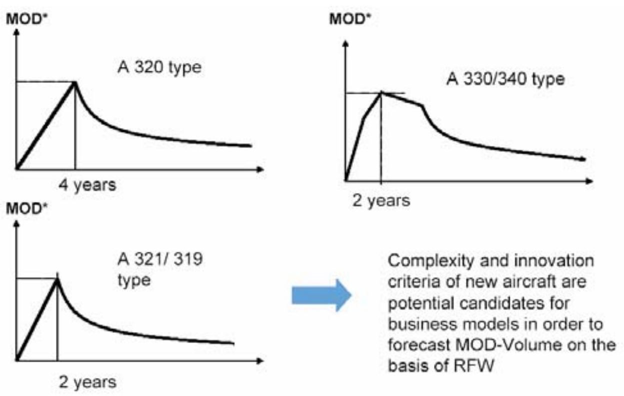

FIG 6. Modifications* along the product life cycle

Figure six shows the representative graphs for different A/C types and the modifications resulting from major in service problems (MOD*) and its development after entry into service. Independent on the number of modifications it can be seen that a peak will be reached after a certain period of time which is related to the degree of product complexity.

It can be argued that the introduction of new technologies leads to a definite degree of complexity which is followed by the modification effort. The example of the introduction of new technologies in the 80s, when Airbus introduced the A320 (Fig. 7) leads to higher modification effort and usually takes more time to overcome the peak due to potential maturity aspects. The technologies involved are many, including advanced aerodynamic design, which saves fuel, the extensive use of composite materials, which saves structural weight and reduces fuel burn, a fly-by-wire control system, which saves weight, complexity and reduces maintenance costs and a Centralised Fault Display System which makes troubleshooting faster and reduces unnecessary component removal.

FIG 7. A320 family technology highlights [6]

The examples of the different types of aircraft programs and derivatives validate the general approach to take a database linked to the classification of modifications/changes described in chapter three. Nevertheless it is necessary to differentiate between the root causes of modifications in order to increase the accuracy of any kind of estimation model. In the presented example a degree of complexity containing technology features etc. could be proposed for further investigations.

6. CONCLUSION

In general the estimation of modification efforts is possible. However, it has to be differentiated according to the accuracy of forecast data. The classification of different modifications clearly leads to areas which are almost out of influence and difficult to capture. For one of the critical issues like upcoming regulations a different approach has been proposed.

Especially modifications caused by maturity reasons are linked to classifications like product corrective issues. These classifications are predestined for the establishment of CER in modification management.

The following pre-requisites have to be given:

- Access to historical data under the defined criteria in order to evaluate the expected correlations.
- Available data have to be categorised under the aspects of classification and e.g. complexity.

The expected benefits are:

- In case of having a close relation between fixed parameters and the available historical data the development of a parametrical model should be realised.
- The model then will give the possibility of forecasting future modification efforts on the basis of volume and cost.
- Higher planning accuracy
- Target setting for process improvement linked to the limitation of allocated resources

7. LITERATURE

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