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LIFE CYCLE COST PARAMETERS, WHOLE ENGINE LIFE CYCLE

by

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Abstract:

This document describes the most significant parameters which are determining costs in the whole engine life cycle. The parameters are identified and assigned to each particular phase on an engine life cycle which has been identified within Task 2.2.1 of VIVACE project.

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LCC, cost drivers, life cycle phases, definition.

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

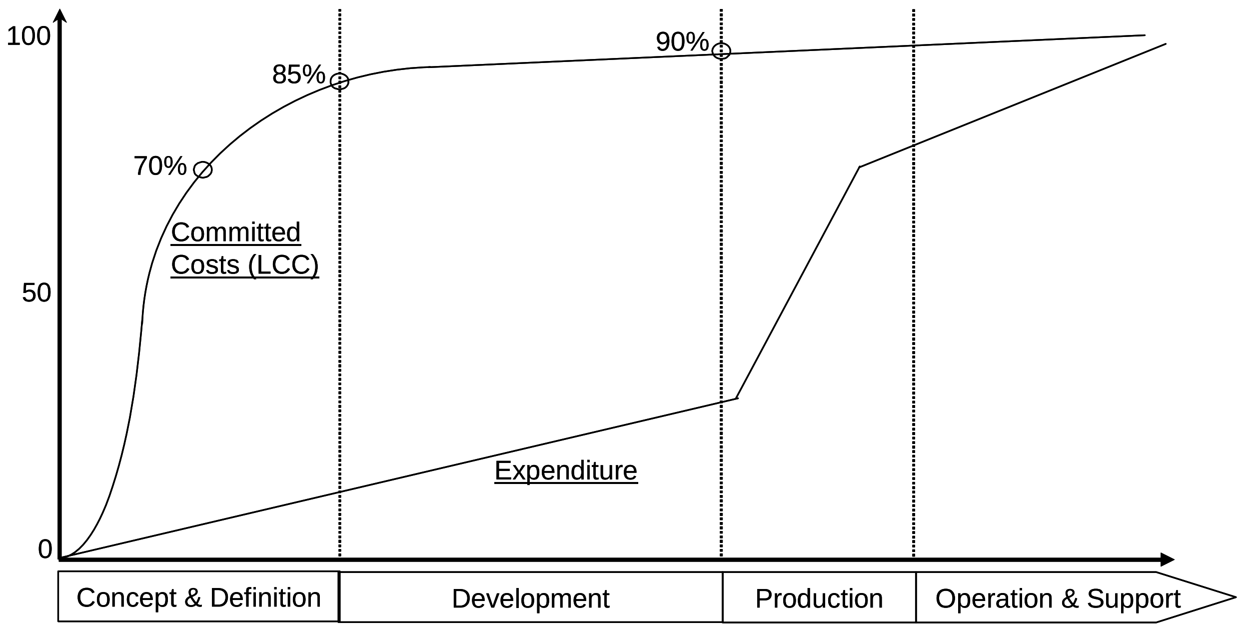
This report is an overview of the work done within WP3.3 in VIVACE. Sub-Task 3.3.3.4 is dealing with LCC cost parameters. The aim of the first of two deliverables during the current period is to identify the most significant cost drivers. This was done for each particular phase on an engine life cycle which has been identified within Task 2.2.1 of VIVACE project. The result should give the chance to contribute to VIVACE HLO. As the parameters are clearly identified the most significant cost drivers are known early in development of a project and corrective actions could be done thereafter.

Task 2.2.1, Generic Life Cycle Cost Nomenclature & Structure, has been the basis for definition of cost drivers. Identified cost elements in Level 3 of that structure have been analysed. The identified cost drivers have been described and assigned to the relevant parameter.

2. INTRODUCTION

Round about 85% to 90% of the total Life Cycle Cost will be committed in a very early phase of the life of a product (before production phase). Therefore it is essential to identify what the main cost drivers are and what can be done to keep them as low as possible.

Having identified the cost drivers, a decision making process could be done to evaluate and select equipment offering the most cost effective solution to meet a defined need.



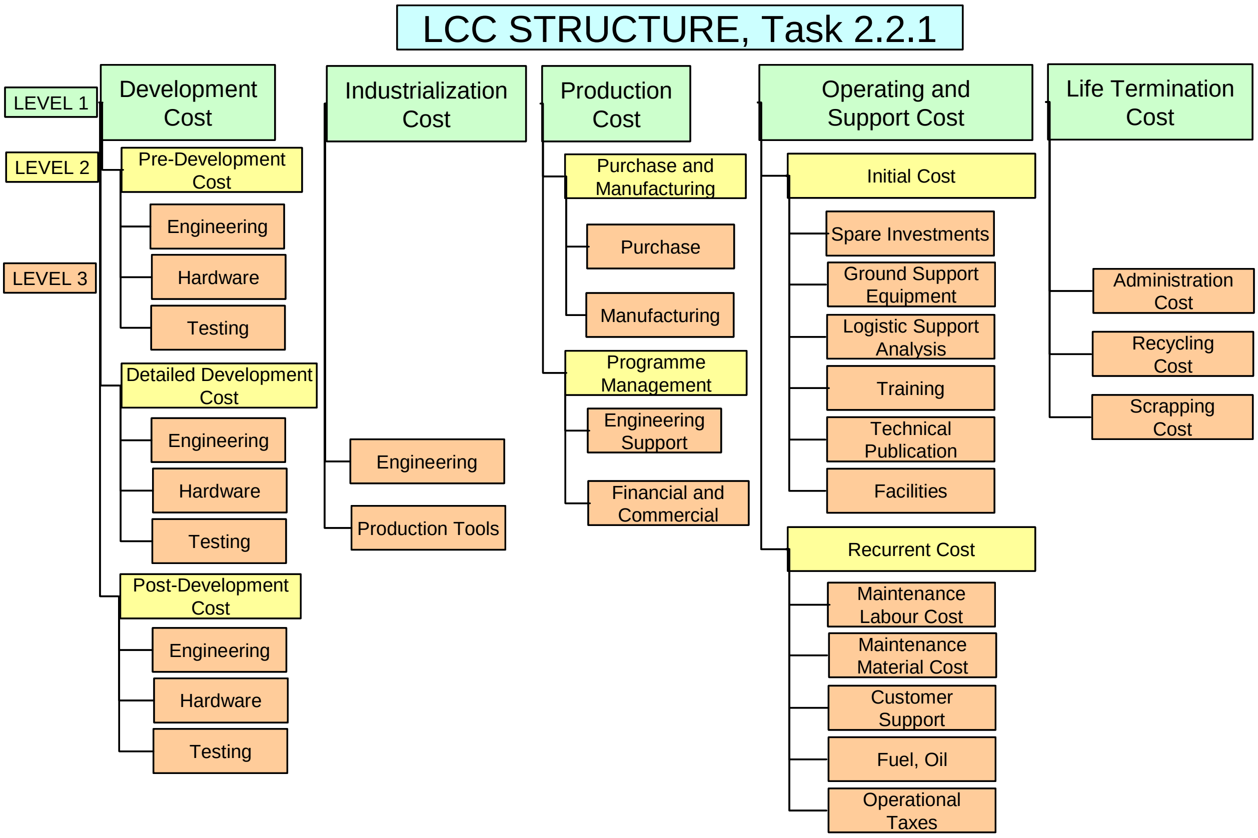
Sample for LCC committed costs vs. expenditure

3. PHASES OF WHOLE ENGINE LIFE CYCLE

The whole engine life cycle is divided into 5 phases. These phases were assigned in
Task 2.2.1 LCC Structure and are there defined under Level 1.

The Level 2 is a more detailed break down to the Level 1 Elements.

The Level 3 details are these elements which had to be analysed and described because of their main cost drivers.



4. WORK CONTEXT

With the first deliverable of Task 2.2.1, the nomenclature and structure of Life Cycle cost were described and agreed. Within this task each of the Level 3 Elements had to be analysed. The five Level 1 Cost Blocks were separated to the contributing companies of the work package. Each of the contributors described the main cost drivers of the Level 3 elements in detail according their companies philosophy. Then a combined session took place where all the cost activities had been discussed. Corrections were incorporated and at least a final agreement had been reached. A full description of all the parameters which cause costs to the Level 3 elements follows thereafter.

4.1. DEVELOPMENT COST; DESCRIPTION OF COST DRIVERS CONTRIBUTION TO LEVEL 3 ELEMENTS.

As the cost drivers are assigned to Level 3 elements, it will happen that some of the elements could appear in more than one Level 3 cost blocks according to where they are generating costs.

Development Cost. (L1)

Pre - Development cost. (L2)

Engineering (L3)

Technology maturity

In this early phase of product development, technology maturity could be relatively low and therefore it has great impact on the cost.

- **Manufacturing Processes**
  A product with low technology maturity could require developing new manufacturing processes to manufacture the hardware for the development phase.
  You also may have more than one concept in this phase which may be requiring different manufacturing processes.
- **Design Processes/Tools**
  A product with low technology maturity may need more work on defining design processes and new or updated development tools, for example applications for calculations, CAD etc which implies higher cost.
- **Product Maturity**
  A new engine development with relatively few “technology leaps” will cause less costs.
- **Material Data**
  New material where you don’t have the material data gives extra cost during the product development.
- **Instrumentation**
  More instrumentation and complex instrumentation bring higher cost.

Project team skill

- **Design Lead**
  High impact on project team skill is the experience level of the design lead (the project manager) higher level of experience brings lower cost.
- **Specialist Competences**
  Higher need of specialist competences leads to higher cost.
- **Partnership maturity**

  New partnerships intend to consume more time – a therefore higher cost

Preliminary requirements

The same requirements as in detailed development, but they are preliminary in this phase and they don't have the same impact on the costs here.

Hardware (L3)

Manufacturing

- **Material Choice**

  The material choice has great impact on costs, since different material differ very much in cost.
- **Forging / Casting**

  Both forging/casting and the tools for it are very expensive. The design of the component has large impact on these costs. This is especially due to the use of "soft tools" for casting during product development.
- **Number of parts/part numbers/processes/sequences**

  Number of part numbers: more different part numbers mean shorter series in production which raise the cost. More standardized parts (fewer part numbers) will decrease the cost.
- **Complexity**
  More complex leads to higher design cost.
- **Tools & Fixtures**

  Need for *more* tools and fixtures increases cost.
  More *different types* of tools and fixtures lead to higher cost.
  More *new* tools and fixtures bring higher tool engineering cost.

Product Maturity

The product maturity has impact on hardware costs; a new type of product will probably have higher need of new tools, test of new materials and manufacturing processes which will bring higher costs.

Instrumentation

More instrumentation and complex instrumentation bring higher cost.

Testing (L3)

Technology gap

Test methodology : a technology gap could mean that you don't have any specified method for testing and verifying your product, and then you have to begin with developing these verification methods which brings high cost to the programme.
Test rig construction/adaptation: the more rig construction and/or adaptation of existing rigs – the higher cost. Especially when you have to construct a new rig, the cost is of course very high!

Test rig & Labour cost

The primary cost for testing is the cost/rent of the test rig including the personnel resources.

Component/engine Complexity/Product Maturity

A more complex product may need more testing which means higher cost.
A less mature product may need more testing, both for ensuring that the test is "enough" and because you may retest if the test doesn't show what you expected.

Fuel prices

Higher fuel prices automatically bring higher cost.

Required testing procedures & amount

There are many regulations on required testing procedures and amount of testing, which has high influence on the cost.

Development Cost. (L1)

Detailed - Development cost. (L2)

Engineering (L3)

Engine / component complexity

- Number of interfaces.
  Higher numbers of interfaces, or otherwise complex components, need more development engineering time which brings higher cost.
- **Requirements** :
- **Timing of requirements specification.**
  The later in the programme the requirements/specification on the product is "fixed" the higher the cost. If you make changes in the requirement during the development phase, you may have to recalculate/reconstruct components, which will cause higher cost.
- **Load data reliability.**
  It's very important that you can trust the load data, because if you have changes in the load data later in the product development phase, it could cause high cost to recalculate/reconstruct components.

- **Environment**
  Environmental impact on the engine: requirements in environment impact on the cost, higher requirements usually lead to higher cost. By "environment" it is meant pressure, temperature, external environment, etc.
  Engine impact on environment: environmental requirements on the product, for example requirements on recycling and pollution have influence on the cost. More requirements, higher cost.
- **Life/Damage tolerance and fatigue**
  Higher requirement on life / damage tolerance and fatigue limit – higher development cost, since it affects both design and material choice
- **Strength/ Structural integrity**
  Higher demands on strength and structural integrity brings higher cost. (There are two requirements to fulfill: "Limit" demands that you must not have any permanent deformations at a specified load, and "Ultimate" means that you may have permanent deformations at a higher specified load but the deformation mustn't have effect on the function so you can fulfill a safe flight and change the deformed part after the flight.)
- **Weight**
  Lower weight leads to higher cost since it affects both design and material choice.
- **Thrust / performance**
  Higher thrust/performance leads to higher cost
- **Reliability**
  Higher reliability brings higher cost.
- **Maintainability**
  Higher requirements for maintainability increases cost.
- **Mission profile (Flight leg**)
  Requirements of more cycles per flight hour leads to higher cost.
  More complex mission also leads to higher cost.
- **Target cost for production**
  ("Manufacturability", "Recurring cost objective")
  Target cost for the manufacturing of the product is often a requirement for the product development and raises the development cost (with the aim to lower the production/manufacturing cost).

Project team skill

- **Design lead**
  High impact on project team skill is the experience level of the design lead (the project manager), higher level of experience brings lower cost.
- **Specialist Competences**
  Higher need of specialist competences leads to higher cost. Also dependencies on specialist competence could lead to "bottle neck"-effect in resources and delay the development which normally brings higher cost.
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Technology maturity
In the detailed development phase technology maturity is higher and therefore

shouldn't be expected to impact as much on the cost as it did in the pre-development phase.

- **Manufacturing Processes**
  Need of new manufacturing processes brings higher cost.
- **Design Processes/Tools**
  Need of new design processes and development tools increases cost.
- **Product Maturity.**
  Designing a new product of an "already well known type" brings lower cost.
- **Material Data**
  New material where you don't have the material data gives extra cost during the product development.
- **Instrumentation.**
  More instrumentation need means higher cost. *New type* of instrumentation leads to more development engineering time which implies higher cost.
- **Number of partners**
  More partners mean more need of communication, travels for meetings, exchange of material, different languages, etc, which means higher development cost. This is one of the aspects of the VIVACE project to lower these costs through the improvement focus on the Virtual Enterprise.

Data communication maturity
Information exchange between partners and suppliers often requires data communication, and low data communication maturity at one or more of the companies involved means higher costs. This applies especially for the company with the lower data maturity.

Hardware (L3)

Manufacturing

- **Material Choice**
  The material choice has great impact on costs, since different material differ very much in cost.
- **Forging/Casting**
  Both forging/casting and the tools for it are very expensive. The design of the component has large impact on these costs. This is especially due to the use of "soft tools" for casting during product development.
- **Number of parts/ part numbers/processes/sequences.**
  Number of part numbers: more different part numbers mean shorter series in production, which raises the cost. More standardized parts (fewer part numbers) will decrease the cost.
- **Complexity.**
  More complex product means higher design cost.

Tools & Fixtures

Need for *more* tools and fixtures increases cost.
More *different types* of tools and fixtures lead to higher cost.
More *new* tools and fixtures bring higher tool engineering cost.

In the detailed development phase, the cost for Tools & Fixtures ought to be lower than in the pre-development phase, since you probably have procured most of the equipment during that phase.

Instrumentation

More instrumentation and complex instrumentation bring higher cost.
The practical instrumentation work for testing is about the same as in the pre-development phase, but the equipment for instrumentation is mostly procured already in the pre-development phase.

Product Maturity

The product maturity has impact on hardware costs; a new type of product will probably have higher need of new tools, test of new materials and manufacturing processes which will bring higher costs.

Supplier Relation Maturity

Where there is risk for market monopoly regarding to suppliers, the cost could increase severely.

Testing (L3)

Test rig & Labour cost

The primary cost for testing is the cost/rent of the test rig including the personnel resources.

Technology gap

A technology gap could mean that you don't have any specified method for testing and verifying your product, and then you have to begin with developing these verification methods, which brings high cost to the programme.

In the detailed development phase the need for Test rig construction/adaptation ought to be lower than in the pre-development phase, since you probably have fulfilled most of the need in the pre-development phase.

Component/engine complexity/Product Maturity

A more complex product may need more testing which means higher cost.
A less mature product may need more testing, both for ensuring that the test is "enough" and because you may retest if the test doesn't show what you expected.

Fuel prices

Higher fuel prices automatically mean higher cost.

Required testing procedures & amount

There are many regulations on required testing procedures and amount of testing, which has high influence on the cost.

Geographical location

If you don't have the test rigs at the same location as the developers/analysis experts, it brings travel expenses.

Development Cost. (L1)

Post - Development cost. (L2)

Engineering (L3)

Frozen/fixed interface

Most impact on development cost after certification is all the "frozen" interfaces that limit your work very much. Your degree of freedom for re-engineering could be very low which makes this factor the most influencing on post certificate engineering.

Requirements:

- **Load data reliability.**
  It's very important that you can trust the load data, because if you have changes in the load data later in the product development phase it could cause high cost to recalculate/reconstruct components.
- **Environment**
  Environmental impact on the engine: requirements in environment impacts on the cost, higher requirements usually lead to higher cost. By environment we mean pressure, temperature, external environment etc.
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- **Maintainability**
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- **Mission profile (Flight leg**)
  More cycles per flight hour brings higher cost.
  More complex mission also leads to higher cost.

- **Target cost for production**
  ("Manufacturability", "Recurring cost objective")
  Target cost for the manufacturing of the product is often a requirement for the product development and raises the development cost (with the aim to lower the production/manufacturing cost)

Technology maturity

In the post development phase, technology maturity is high and therefore should have less impact on the cost than in the pre-development phase.

- **Manufacturing Processes**
  Need of new manufacturing processes leads to higher cost.
- **Design Processes/Tools**
  Need of new design processes and development tool increases cost.
- **Product Maturity.**
  Designing a new product of an "already well known type" brings lower cost.
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  New material where you don't have the material data gives extra cost during the product development.
- **Instrumentation.**
  More instrumentation need means higher cost. *New type* of instrumentation leads to more development engineering time which implies higher cost.

Engine / component Complexity

Higher number of interfaces, or otherwise complex components, needs more development engineering time which brings higher cost.

Project team skill

- **Design Lead**
  High impact on project team skill is the experience level of the design lead (the project manager), higher level of experience results in lower cost.
- **Specialist Competences**
  Higher need of specialist competences means higher cost. Also dependencies on specialist competence could lead to "bottle neck"-effect in resources and delay the development which normally brings higher cost.

Program maturity

- **Number of partners**
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Component/engine Complexity/Product Maturity
A more complex product may need more testing which means higher cost.
A less mature product may need more testing, both for ensuring that the test is "enough" and because you may retest if the test doesn't show what you expected.

Fuel prices.
Higher fuel prices bring higher cost.

4.2. INDUSTRIALIZATION COST; DESCRIPTION OF COST DRIVERS CONTRIBUTION TO LEVEL 3 ELEMENTS.

Industrialization Cost (L1)

Engineering (L3)

Related to the total cost there are no cost drivers in that area.

Production Tools (L3)

Tooling – Investment – Flight Test Engines - Maintenance

The costs within Production Tooling are mainly driven by Tooling, Investment and Flight Test Engines. The cost drivers with Tooling are to manufacture, refurbish and maintain them. On investment there will be a machine invest, investment on Test Stand and others.
The costs on Flight Test Engines are driven their manufacturing and their refurbishment and at least the quantity of test engines necessary for the programme.

4.3. PRODUCTION COST; DESCRIPTION OF COST DRIVERS CONTRIBUTION TO LEVEL 3 ELEMENTS.

Production Cost (L1)

Purchase and Manufacturing (L2)

Purchase (L3)

Manufacturing (L3)

There is no difference on main cost drivers between Purchase and Manufacturing. The difference is the source where the part is manufactured. The demand on material and architecture is driven by requirements on the product, on performance and on legal requirements.

Product

The **size** as well as the **configuration** heavily influences the production costs of the engine.

Very important is the **fleet size** because the learner has one of the major inputs on manufacturing cost.

The **weight** of a new engine has to be lower than the state of the art engines as the weight has much influence on operating costs. But lower weight means special material or technologies which will increase production of the product.

Performance

Required performance affects especially thrust, temperature and pressure. To bear the stress on the parts and to reach the claimed quality standards are lot of cost influencing activities and have to be considered. These could be e.g. precious material due to high temperature; Coating on airfoils or expensive cooled airfoils.

Legal Regulations

The main focus is onto Noise of the engine and Gas emission.

Production Cost (L1)

Programme Management (L2)

Engineering Support (L3)

Cost effective activities are mainly due to changes and deviations during manufacturing process. This means preparing and updating engine build standard master parts list and doing all necessary activities with regard to modification procedures. A great variety of part numbers, because of modifications, will lead to substantial logistic effort.

Financial & Commercial (L3)

In general in that area there are not those big cost drivers with regard to overall generated costs.

There is only one occasion where more work has to be done and that is when the project is a government order. In that case, the customer requires to have very detailed cost information.

4.4. OPERATING & SUPPORT COST; DESCRIPTION OF COST DRIVERS CONTRIBUTION TO LEVEL 3 ELEMENTS.

The main cost drivers are ranked from the most influence to the less ones within the relevant Level 3 Data Element. As the cost drivers are assigned to Level 3 elements it will happen that some of the elements could appear in more than one Level 3 cost blocks but in a different ranking according generating costs in that area.

Operating & Support Cost (L1)

Initial Cost (L2)

Spares investments (L3)

Mission profile

Spares are sized up by taking into account the projected Shop Visit Rate. A high severity of the missions will increase this SVR and spares investment will be higher.

Production technology complexity

A high technology complexity in production of engine parts will of course lead high spares cost.

Projected Reliability

This is the reliability of the engine which is projected during its development. A low reliability will increase SVR. So a low projected reliability leads to have high spare investments.

Maintenance areas repartition

A higher number of sites increase the maintenance organization complexity. It leads to have bigger spare investments.

Fleet size

A bigger fleet increases the overall cost but makes the cost per engine decrease.

Ground support equipment (L3)

Maintenance areas repartition

A higher number of sites increase the maintenance organization complexity, and so it influences cost.

Technology gap

This gap leads to a renewing of the Ground Support Equipment. A bigger gap will increase cost.

Geographical area

The country in which the engine support is done will influence cost. Equipment prices are different from a country to another.

Projected Reliability

The Ground Support Equipment is sized by taking into account the projected SVR. A low reliability will increase SVR and thus influence cost.

Fleet size

A bigger fleet increases the overall cost but makes the cost per engine decrease.

Mission profile

A high mission severity will increase the SVR and GSE cost will be higher.

Logistic support analysis (L3)

Mission profile

A higher severity of a mission increases the Shop Visit Rate. Taking this severity into account for the logistic support analysis will influence cost.

Calculation capability

High calculation capabilities contribute to shorten analyses. It will decrease cost.

Projected Reliability

Logistic support analyses are made from engine reliability characteristics. So, projected reliability will influence initial cost.

Maintenance areas repartition

A high number of sites increases the maintenance organization complexity, and thus lead to increase logistic support analysis cost.

Technology gap

A big technology gap will lead to complicate logistic support analyses and so will increase cost.

Geographical area

The country in which the logistic support analysis is done will influence cost.

Fleet size

A bigger fleet will increase the overall logistic support analysis cost but makes LSA cost per engine decrease.

Staff skills

These skills to make analyses could decrease cost, but increase in the same way labour cost. So staff skills influences logistic support analysis cost.

Training (L3)

Technology gap

New technologies in the engine lead to renew trainings and to train trainers. Trainings will be more difficult to follow and be longer. A big technology gap increases training cost.

Geographical area

Training has to be adapted to the country where the maintenance is done. There could be some translation problems, culture differences. Specifics training documents could have to be done. So, geographical area influences training cost.

Technical publication (L3)

Publication standard

Publications can be done under different standards. The most frequently used standard is S1000D and if a partner uses a different publication standard it will increase the cost for the partner who will have to adapt their publications to the new standard.

Technology gap

Many new technologies in the engine lead to make more detailed publication and publications in bigger quantity. A big technology gap will increase technical publication cost.

Facilities (L3)

Maintenance areas repartition

Very logically, a high number of sites increases facilities cost.

Fleet size

A large fleet will need larger facilities. So, the fleet size will influence facilities cost.

Technology gap

New technologies in the engine or in the maintenance of the engine can lead to adapt existing facilities or to build new ones. Higher will be the gap higher will be the facilities cost.

Geographical area

The country in which engine support is done will influence cost. Facilities cost is different and environmental norms could be also different.

Recurrent Cost (L2)

Maintenance Labour cost (L3)

LLP life time

Life Limited Parts are engine critical parts. Their failures can cause an engine lost. Reaching LLP life time causes a shop visit.

Lower will be the LLP life time, higher will be the SVR or the number of removals during a Shop Visit and thus, higher will be the maintenance labour cost.

Programme maturity

The maintenance cost of a type of engine decreases during the programme life, because of improvements done along its duration. This cost stabilizes when the engine is mature.

Staff skills

These skills to make engine support could decrease cost, but increase in the same way labour cost. So staff skills will influence labour cost.

Assembly technology complexity

The complexity to assembly and disassembly the engine influences the duration of the maintenance operations and also labour skills needed. So this complexity can decrease or increase labour cost.

EGT margin

The Exhaust Gas Temperature is a good indicator of the engine condition. It is quantified comparing to an EGT limit, which gives the EGT margin.

Exceeding this limit causes a shop visit. So, the EGT margin influences the SVR, which directly influences maintenance labour cost.

MTBR

The Mean Time Between Removals of an engine indicates the quantity of work of labour. Higher is the MTBR, higher is the labour cost.

Stub life

The stub life is the remaining life of an LLP, when it is removed of the engine.

A long stub life shows that many maintenance tasks are done at the same moment, so it decreases cost. But it shows also that an LLP is changed a long time before the end of its determined lifetime, which tends to increase cost.

Flight leg

The flight leg of an aircraft is the medium duration of its flights. Lower is the flight leg, higher is the SVR and higher is the cost.

Derate

The derate is the difference between the maximal possible thrust of an engine and the real thrust in flight. The bigger the derate of an engine is, lower are the stresses on the engine, and so lower is the SVR, lower is the maintenance labour cost.

Engine aging

The maintenance cost of an engine decreases, stabilizes and finally increases during its life. This cost stabilizes when the engine is mature.

Air temperature

A high or a low air temperature increases stresses on the engine, decreasing the EGT margin and increasing the SVR. Air temperature influences the maintenance labour cost.

Air humidity

Humidity could damage engine components. A very high humidity leads to increase maintenance labour cost.

Maintenance organization

The organization of the maintenance influences labour organization, e.g. the LLP removals planning which influences the SVR and the number of removals during an SV. So the maintenance organization influences labour cost.

Geographical area

The country in which the engine support is done will influence cost. The labour cost is different from a country to another.

Maintenance material cost (L3)

Rise in prices

Of course material prices influence directly maintenance material cost.

LLP life time

Reaching LLP life time causes a shop visit. Lower will be the LLP life time, higher will be the SVR and the number of removals in an SV, and thus higher the maintenance material cost.

Programme maturity

The maintenance cost of a type of engine decreases during the programme life, because of improvements done along its duration. This cost stabilizes when the engine is mature.

EGT margin

Exceeding the EGT limit causes a shop visit. So, the EGT margin influences the SVR, which directly influences maintenance material cost.

MTBR

The Mean Time Between Removals of an engine indicates the quantity of maintenance operations and thus the need in material. Lower is the MTBR, higher is the maintenance material cost.

Flight leg

The heavy stress and temperature which affect the engine parts mainly on start and landing happen more often in the life of an engine with a short flight leg. So lower is the flight leg, higher is the SVR or the number of maintenance operations in a Shop Visit higher is the cost.

Stub life

A long stub life causes that an LLP is changed before the end of its determined lifetime. So it increases maintenance material cost, by increasing the number of LLP removals.

Derate

Bigger is the derate, lower are the stresses on the engine, and so lower is the SVR, lower is the maintenance material cost.

Engine aging

The maintenance cost of an engine decreases, stabilizes and finally increases during its life. This cost stabilizes when the engine is mature.

Air temperature

A high or a low air temperature increases stresses on the engine, decreasing the EGT margin and increasing the SVR or the number of operations in a Shop Visit. Air temperature influences the maintenance material cost.

Air humidity

Humidity could damage engine components. A very high humidity increases cost maintenance labour cost.

Staff skills

High staff skills avoid maintenance operation mistakes or consumables waste. So it will decrease maintenance material cost.

Customer support (L3)

Fleet size

Of course a bigger fleet leads to increase customer support needs and by the way customer support cost.

Reliability

Low engine reliability will lead the airliner to ask for more support, and thus increase customer support cost.

MTBR

The engine Mean Time Between Removal indicates engine reliability. A big MTBR indicates a high reliability and leads to decrease customer support cost.

Fleet technical skills

If the airliner technical staff has good technical skills, he will less ask for support. As a consequence, high fleet technical skills lead to decrease customer support cost.

Technology gap

A big gap in engine technology could increase technical problems for airliners due to new technologies they are not used to and questions from airliners to engine manufacturer. It will increase engineering support and field service work, and so increase customer support cost.

Support staff skills

The skills of the engine manufacturer customer support staff lead to solve quickly airliner's problems. Higher are these skills, lower is customer support cost.

Programme maturity

The customer support cost of a type of engine decreases during the programme life, thanks to improvements done along its duration and to customer's engine knowledge improvements. Moreover, airliners and manufacturer support staff get used to work together and the work gets more efficient. More mature is the programme, lower are the customer support cost.

Fuel, Oil (L3)

Fuel price

Fuel price is of course the main cost driver of this cost element.

Fuel efficiency

A fuel efficient engine consumes less fuel than another. Very logically, more fuel efficient is an engine; higher will be cost due to taxes.

Severity of use

A severe use of an engine implies many frequent changes in engine loads. It will increase fuel and oil consumption.

EGT margin

EGT margin is a good indicator of engine condition. An engine with a low EGT margin contains hotter components and thus has big oil and fuel consumption.

Flight Leg

The higher fuel and oil consumption is during the take off, the climb and the landing. With a small flight leg the proportion of crusade is low. So smaller is the flight leg, higher is the fuel and oil consumption.

Derate

Higher is the engine thrust, higher is the fuel and oil consumption. And, as the derate is the difference between the maximal possible thrust of an engine and the real thrust in flight, lower is the derate; higher is the fuel and oil consumption.

Operational taxes (L3)

Noise

Noisier is an engine, higher are cost due to taxes.

Polluting gas emission

More polluting is an engine, higher are cost due to taxes.

Flight geographical area

Noise and polluting gas emission norms depend on countries. A country with severe norms leads to increase cost.

Fuel quality

A bad quality fuel increases polluting gas emission. Better is the fuel quality; lower is the cost due to taxes.

Severity of use

A severe use of an engine implies many frequent changes in engine loads. It will increase noise and pollution gas emission and thus cost due to taxes.

Derate

Noise and gas emission depend on engine used thrust. Lower is the derate, higher is the thrust and noisier and more polluting is the engine.

EGT margin

EGT margin is a good indicator of engine condition. An engine with a low EGT margin has big fuel consumption and thus a high polluting gas emission.

4.5. LIFE TERMINATION COST; DESCRIPTION OF COST DRIVERS CONTRIBUTION TO LEVEL 3 ELEMENTS.

Life Termination Cost (1)

Administration Cost (3)

This cost element has to be recognised, but not as a cost driver.

Recycling Cost (3)

On the recycling cost especially **the type of material** is deciding and the **country** where the company is based who recycles the material.

Scrapping Cost (3)

This cost element has to be recognised, but not as a cost driver.

5. CONCLUSION, RECOMMENDATION & GLOSSARY

5.1. CONCLUSION

The work done described in the first deliverable (D3.3.3_2) of Sub - Task 3.3.3.4 shows a very detailed description of all the costs that could occur during the whole life cycle of an engine. This is the basis to analyse and rank the main cost drivers in the second deliverable (D3.3.3_5). These two deliverables (D3.3.3._ 2 and D3.3.3._5) will then transferred back to WP2.2 and will form the basis for Task2.2.2

5.2. RECOMMENDATION

The next work to be done is to analyze the identified cost drivers and rank them according their main input to the cost elements. These results give us the opportunity to identify the main cost relevant elements and activities. A decision making process could be done to evaluate and select equipment offering the most cost effective solution to meet a defined need. A contribution to VIVACE HLO can be achieved. This will be worked out in the second phase of Sub - Task 3.3.3.4 (D3.3.3_5).

5.3. GLOSSARY

WP – Work Package

LCC - Life Cycle Cost

HLO – High Level Objectives

L1 – Life Cycle Cost Elements Level 1

L2 – Life Cycle Cost Elements Level 2

L3 – Life Cycle Cost Elements Level 3

CAD - Computer Aided Design

Soft tool - A temporary tool for casting, which is used during product development and is only possible to use for about 10 pieces maximum

Flight Leg – the amount of hours used during one flight.

SV – Shop Visit

SVR - Shop Visit Rate; Number of Shop Visits of a fleet for 1000 engine flight hours

GSE - Ground Support Equipment

LSA - Logistic Support Analysis; All activities to organize engines support: level of repair analysis, spares modeling and maintenance analysis

S1000D - International Specification for Technical Publications common to ASD and AIA.

ASD - AeroSpace and Defence Industries Association of Europe

AIA - Atelier Industriel Aéronautique:
Maintenance Service of the french DGA "Direction Générale de l'Armement"

LLP – Life Limited Part. These are engine parts with a fixed hard life.

LLP life time – this will be expressed in flight cycles.

Flight cycle – each Start / Landing is considered as one flight cycle.

EGT - Exhaust Gas Temperature

EGT Margin - Margin between the measured EGT of an engine and the EGT limit, the EGT margin indicates the engine wear.

MTBR - Mean Time Between Removal.

Stub life – LLP life which will not be consumed due to replace of the part before total hard life is reached. This happens if the rest of the LLP life is not sufficient enough for the next assumed engine cycle to shop visit.

Derate – The portion of thrust which will not be used in operation (take off).

5.4. DESCRIPTION OF COST ELEMENTS FROM D2.2.1_1

Development cost

All the costs linked to design and validation activities.

Pre-development cost

All the costs linked to all the activities for preliminary design of an engine: need analyses, general requirements, global definition and preliminary tests.

- Engineering

All engineering activities for preliminary design: drawings, studies, instrumentation and project management activities.

- Hardware

Hardware needed for pre-development: components for rig testing; test rig adaptation and tools.

- Testing

All activities to test the concepts of engine preliminary design, including instrumentation and results analyses.

Detailed development cost

All the costs linked to all the activities for detailed design of an engine: studies and tests.

- Engineering

All engineering activities for detailed design: drawings, studies, instrumentation and project management activities, engineering support to product support.

- Hardware

Hardware needed for detailed development: components for rig and engine testing; test rig adaptation and tools.

- Testing

All activities for rig testing and engine testing in detailed development phase : modules and engines assembly/disassembly, instrumentation, rig and engine tests and results analyses.

Post-development cost

All the costs linked to all post-certification activities to finish the development of an engine off.

- Engineering

All engineering post-certification activities: modification and updating assessments, project management; instrumentation, engineering support to product support and certification documents update.

- Hardware

Hardware needed for post-certification activities: components for rig and engine testing; test rig adaptation and tools.

- Testing

All activities for rig testing and engine testing in post-development phase: modules and engine assembly / disassembly, instrumentation, rig and engine tests, and results analyses.

Industrialisation cost

All the costs linked to the activities that prepare the production of engines.

Engineering

All engineering industrialisation activities: production process definition, suppliers' validation and machine programming.

Production tools

All activities to design, buy, manufacture or maintain production tools.

Production cost

All the costs linked to all the activities that allow production of engines.

Purchase and manufacturing

All the costs directly linked to all activities for engines manufacturing.

- Purchase

What the engine manufacturer buys to manufacture engine. It includes raw materials, components and equipment purchase. Reception quality control is added.

- Manufacturing

What the engine manufacturer pays to transform purchase into the final engine. It includes components and equipment manufacturing, assembly, quality control, and tests.

Programme management

All the costs linked to the program management to support production.

- Engineering support

Purchase, production and system management.

- Financial and commercial

Financial and commercial activities during production phase: sales contracts, insurance, patents and licences, commercial program activities.

Operating and support cost

All the costs incurred from the initial engine deployment through the end of engine operations. Includes all costs of operating, maintaining, and supporting the engine.

Initial cost

All the costs incurred at the initial engine deployment to allow the engines support.

- Spares investments

Investments in spare accessories, modules and engines for supporting the fleet.

- Ground support equipment

Equipment to support engines: tools, test equipment and transportation containers.

- Logistic support analysis

All activities to organise engines support: level of repair analysis, spares modelling and maintenance analysis.

- Training

Employees training and line operating courses for engine support.

- Technical publication

All publication such as illustrated part catalogues, aircraft and components maintenance publication and maintenance plan to help engine support.

- Facilities

Costs linked to modification of facilities and fulfilment of technical and environmental requirements.

Recurrent cost

All the costs that occur during the engine operational life.

- Maintenance labour cost

  All labour costs to maintain the engine during its operational life.

- Maintenance material cost

  All costs linked to components, LLP and materials needed to maintain the engine during its operational life.

- Customer support

  All support activities provided by the engine manufacturer for the customer, except maintenance. These activities are program management, configuration control, engineering support, field service, and ground support equipment maintenance.

- Fuel, Oil

  Costs linked to engine fuel and oil consumption.

- Operational taxes

  Taxes related to noise and gas emissions paid by the company.

Life termination cost

All the costs that occur at the end of engine operational life. Includes all costs linked with the scrap or the reuse of whole engine, engine components or spares.

Administration cost

Costs linked to the management of the termination phase.

Recycling cost

Costs linked to all recycling activities from dismantle to sale of reusable engine components or from removal to sale of a whole engine.

Scrapping cost

Costs linked to all scrapping activities from dismantle to scrap of a whole engine or of no reusable engine components.