Horizon 2020

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Project full title: **Legislative Assessment for Safety Hazard of Fire and Innovations in Ro-ro ship Environment**

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D5.3

Development of cost assessment tool

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Abstract

Alongside the evaluation of technical and operational solutions developed in the project, the economic feasibility of the solutions needs to be evaluated throughout the entire life span. Therefore, the Life Cycle Cost (LCC) methodology has been adapted to assess the characteristics, the pros and cons of each solution for generic ro-ro ship types. Furthermore, the LCC assessment is required as input to calculate the cost-effectiveness in Formal Safety Assessment (FSA*)*. In this deliverable the development of the calculation system is shown, whereas the previous deliverable "D05.2 Cost assessment tool" focuses on the evaluation process of the calculations, their parameters and results.

In order to calculate the LCC, a basic LCC tool developed by CMT during the project will be used. The tool has the capability to calculate the LCC of the solutions. The Key Performance Indicator (KPI) and relational KPIs, which reflect the LCC results in different parameters, have been defined together with the tool users. Furthermore, the tool takes into account varying fuel prices in the future, as the life span can reach beyond ten or twenty years. Besides that, the users are able to know the impact of the solutions on the environment from the external cost value. The calculation of the external cost is extracted after the Life Cycle Assessment (LCA). To understand the impact of the world economy and legislation situation on the LCC, a sensitivity analysis was made available in the tool so the users can understand the impact on the cost if a different scenario might happen in the future.

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Contents

1 Executive summary

The objectives of the LASH FIRE project in this task aim at evaluating and demonstrating the cost-benefit effectivess of individual risk control measures, which can be calculated by the designed assessment tool. In doing so, financial parameters are calculated and a sensitivity analysis is made possible. This deliverable reports on the development of the corresponding cost assessment tool.

Problem definition

One of the objectives of LASH FIRE is to evaluate and demonstrate ship integration feasibility and the costs of developed operational and design risk control measures for all types of ro-ro ships and all types of ro-ro spaces. Therefore, an LCC tool was developed to assess the financial parameter and to allow for sensitivity analysis.

Technical approach

The economic feasibility study of risk control measures will be conducted by LCC methodology where all related costs are included, from investment/production to operation/maintenance and until the end of the life span. The required input parameters and KPIs in the tool were identified from discussion between WP05 and WP04. WP04 focuses on the formal safety assessment, while WP05 works on the integration of the components into the vessel. The tool takes into account varying fuel prices in the future and the external costs that comes from the environmental impact. The data required for the LCC will be collected from ship operators as well as from the Development and Demonstration WPs in the project via a data collector formulated according to the methodology. The tool will be used to calculate the LCC of the selected Risk Control Options (RCO), as input to the cost-effective assessment in the Formal Safety Assessment (FSA).

Results and achievements

As a result of the internal meeting with WP05 – Ship integration and WP04 – Formal Safety Assessment, the LCC modelling approach was defined, including general key performance indicators and four different scenarios. Moreover, several individual KPIs were identified, which will be applied in specific demo-cases only. From this input, a data collector and LCC tool are ready to be used by ship operators and the Development and Demonstration (D&D) WPs in the project. The LCA results will be useful for them to understand the economic impact on the developed solutions and for cost-effective assessment.

Contribution to LASH FIRE objectives

This report will contribute to LASH FIRE objective 2: "LASH FIRE will evaluate and demonstrate ship integration feasibility and cost of developed operational and design risk control measures for all types of ro-ro ships and all types of ro-ro spaces", and LASH FIRE objective 3: "LASH FIRE will provide a technical basis for future revisions of regulations by assessing risk reduction and economic properties of solutions".

Exploitation and implementation

The experiences made within the LASH FIRE project will be used in future LCC assessments. These are directly related to the FSA and may also be used as basis for FSAs in the future, beyond the project. In addition, the LCC tool can be used by the end-users, such as ship operators, suppliers, or shipyard, to assess the economic feasibility of the proposed solutions.

2 List of symbols and abbreviations

CEU	Car Equivalent Unit
D&D	Development and Demonstration
FSA	Formal Safety Assessment
GT	Gross Tonnage
GWP	Global Warming Potential
HFO	Heavy Fuel Oil
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LCPA	Life Cycle Performance Assessment
LM	Lane-Meter/s (unit expressing ro-ro space capacity)
LPP	Length between perpendiculars
LSMGO	Low Sulphur Marine Gas Oil
MGO	Marine Gas Oil
KPI	Key Performance Indicator
PAX	Passengers
RCM	Risk Control Measure
RCO	Risk Control Option (one or several RCMs selected for assessment)
ULSFO	Ultra Low Sulphur Oil
VLSFO	Very Low Sulphur Fuel Oil
WP	Work package

3 Introduction

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When new solutions or services wish to be used, the assessment is not only limited to the technical and operational feasibility but also to the cost and even further to the environmental impact. For the cost assessment, the evaluation should not only rely on the purchasing cost, but also the delivery, installation, operation, maintenance, and end of life costs. Based on the EU directive 2014/24/EU, "Life Cycle Cost (LCC) shall to the extent relevant cover parts or all of the following costs over the life cycle of a product, service or works:

a) costs, borne by the contracting authority or other users, such as:
   - costs relating to the acquisition,
   - costs of use, such as consumption of energy and other resources,
   - maintenance costs,
   - end of life costs, such as collection and recycling costs.
b) costs imputed to environmental externalities linked to the product, service or works during its life cycle, provided their monetary value can be determined and verified; such costs may include the cost of emissions of greenhouse gases and of other pollutant emissions and other climate change mitigation costs."

The LCC assessment brings awareness for the users to understand the real cost of the ownership of the products or services. Besides that, it could lead to guide the users to pick the best solution which provides less energy, investment, and operation cost.

In LASH FIRE, the LCC tool was done to assess the solutions proposed by Development and Demonstration (D&D) WPs when integrated into three different generic ships with two different cases, newbuilding and existing ship. All the cost components related to the solutions will be given by D&D WPs and all the costs related to the integration of the new solutions in the ships will be given by ship operators. The LCC assessment results from the tool become the input for the cost-effective assessment in WP04. The cost assessment work flow to develop the tool is explained in chapter 3.1. The modelling and the Key Performance Indicator (KPI) for LCC calculations in the tool are described in chapter 4 while all the cost components in the tool are described in chapter 5. Furthermore, all the forecasted values for fuel cost and the external cost used in the tool are described in chapter 6. In chapter 7, a sensitivity analysis is described. The sensitivity analysis is available in the tool so the users can understand the impact on the cost in a different economy and legislation situation that might occur in the future.

3.1 Cost assessment workflow

As explained before, the LCC assessment is an important study to understand the economic feasibility of the solutions proposed in LASH FIRE. Therefore, the LCC should be performed by involving the information of the solutions and the integration process into the generic ship. All the information related to the purchasing of the equipment, equipment's energy consumption, and maintenance cost of the solution need to be provided by D&D WPs (WP06-WP11). The cost information related to the installation, integration of the solution, and the revenue during the operation need to be provided by WP05. Figure 1 showing the workflow which consists of the input, the process, and the output. For providing the input, the data collector is available to be filled by the Ship Operators, shipyards and ship designers (WP05) and the D&D's (WP06-WP11). This consists of the cost components of single and multiple systems and the cost of integration into the ship. The procedure to fill the data collector is available in Deliverable D5.2. Besides the cost from the solutions and the integration, the assessment will also consider the other cost such as external cost and the benefit & societal costs. The external cost is coming from the output of the Life Cycle Assessment (LCA) in WP05. For the benefit and societal cost, the input will come from risk assessment of risk control measures (RCM) that will be done by WP04 with support from WP05.

After getting input for the data collector, the LCC of the solution can be calculated by using LCC tool prepared by CMT, the procedure to use the LCC is available in Deliverable D5.2. The results from the tool are the LCC, external costs, and LCC/RCO that important as the input for cost-effective assessment in WP04.

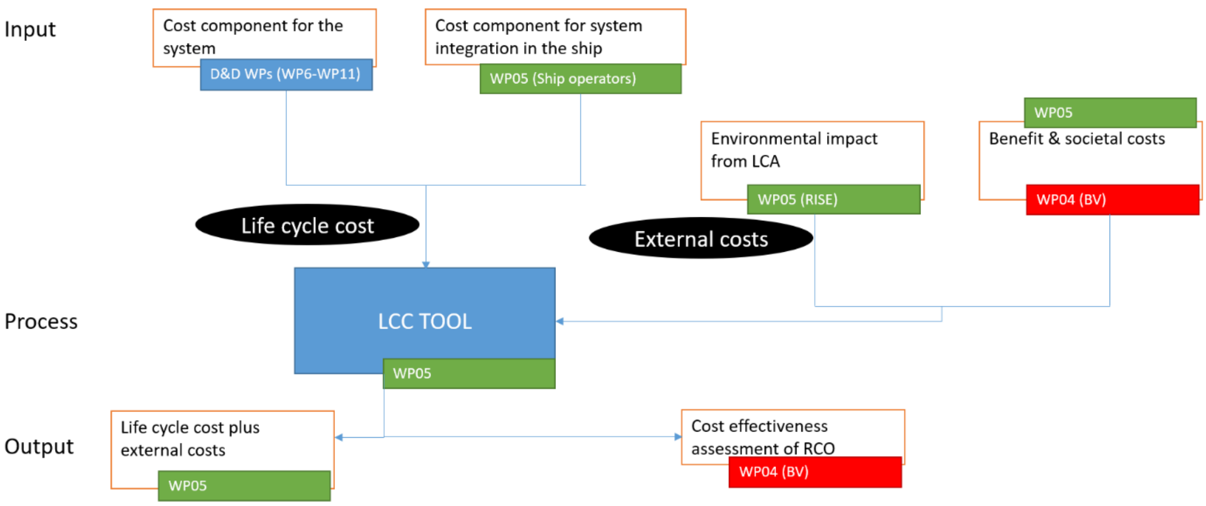

Figure 1. General LCC Workflow

The detailed LCC assessment execution can be seen in Figure 2. Once the data collector has been filled by D&D WPs and ship operators, shipyards and ship designers in WP05, then the responsible partner in task T05.8, T05.9, and T05.10 will review the inputs. If the inputs are sufficient, then the LCC assessment can be performed using LCC tool. After that assessment, WP05 with D&D WPs support need to write the internal report as listed in Table 1. TEMP05.3 is used as the template to write these internal reports. The internal reports then will be reviewed by the evaluators.

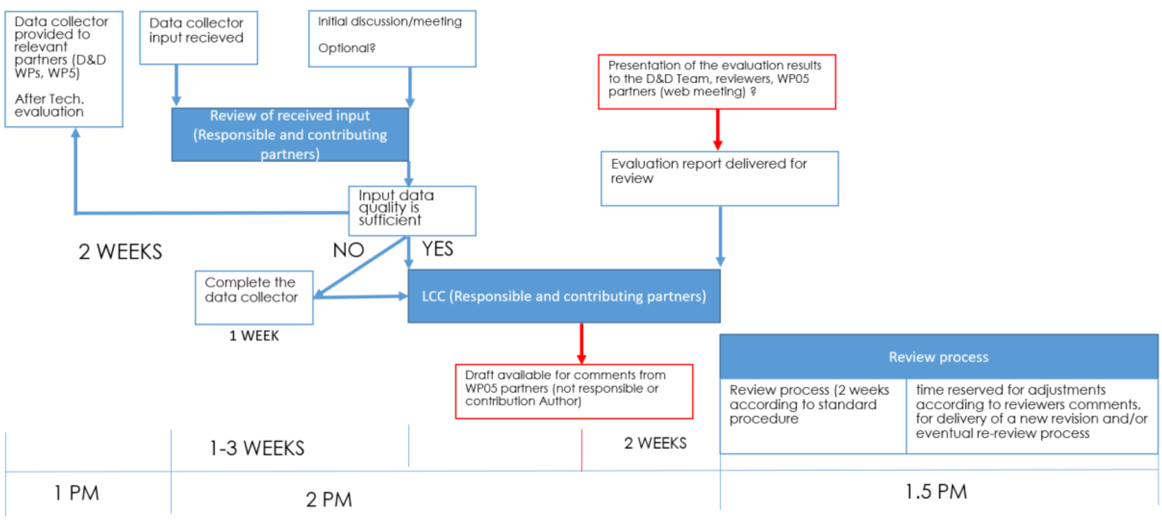

Figure 2. Detailed LCC Workflow

As the development of the LCC tool and the reports of the cost assessment are related to other reports in different WPs, the relation among the report is shown in Figure 3. Each cost assessment report will be used by WP04 as the input for the cost-effectiveness assessment deliverable.

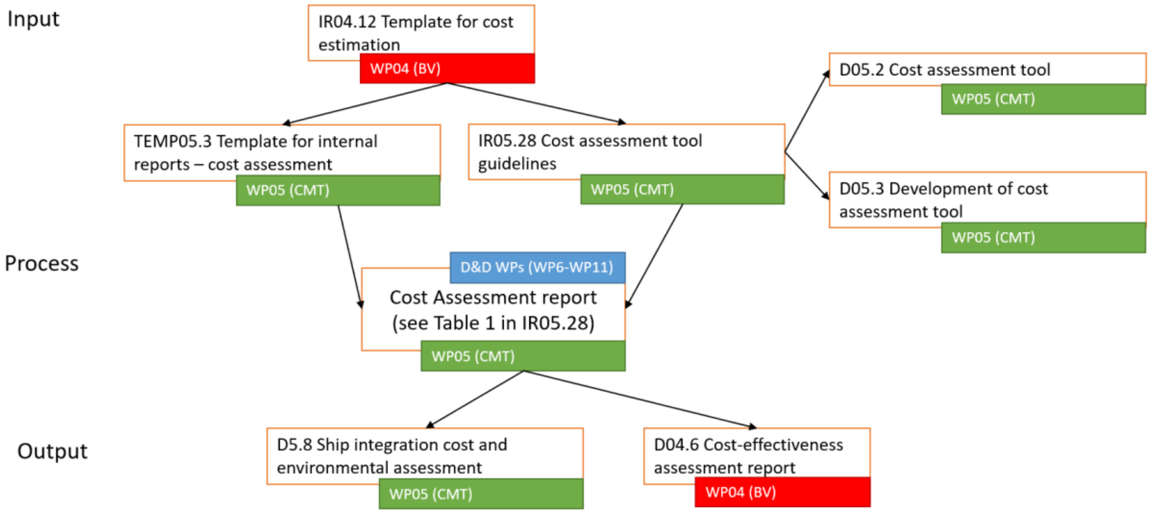

Figure 3. Reports relation for LCC assessment

4 Key Performance Indicators (KPIs)

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4.1 Cost Assessment KPIs

The solutions provided in LASH FIRE are validated from the economic feasibility KPIs estimated in the LCC study. The LCC KPIs to be estimated in the project are:

- Life Cycle Cost
- Investment cost
- Operation cost
- Maintenance Cost
- End of life cost
- External costs.

All the costs are presented as the marginal cost which means it shows the different cost between using and not using the solution or the added cost by using the new solution as regards as the reference case. The life cycle costs are presented as present values, therefore an actual discount rate is needed. Following the FIRESAFE II study, in LASH FIRE the LCC will use 3.5% as the value of the actual discount rate for years 1-30 and 3.0% starting from year 31 [1]. The present value of LCC for each cost element (investment cost, operation cost, maintenance cost, end of life cost) can be calculated using below formula:

$$C_p = \frac{C_n}{(1+(i-p))^n}$$

C_p = Current costs associated with the cost factor

C_n = Cost incurred after n years

n = Number of years

p = Inflation rate

i = Interest rate

$i - p$ = actual discount rate, 3.5% & 3%

After that, the LCC for the lifetime can be calculated using the formula

$$LCC = C_i + \sum_{0}^{N} \frac{C_o}{(1+(i-p))^n} + \sum_{0}^{n} \frac{C_m}{(1+(i-p))^n} + C_e$$

N = The lifetime

C_i = Investment or production cost

C_o = Operation cost

C_m = Maintenance cost

C_e = End of life cost

The end-of-life cost can occur if the recycling process requires additional cost. However, if after the end of the usage the solution can be resaled, then additional revenue will reduce the LCC value.

Since some solutions were anticipated to have important environmental impacts, a Life Cycle Assessment (LCA) will also be performed in this project for selected solutions [6-D *(Effective and efficient manual firefighting);* 10-B (Fixed fire-extinguishing systems for weather*)].* Environmental impact during the overall life cycle can be translated into economic value through external cost. The cost from the environmental impact generally is not carried by the user but by other parties that received the impact. Therefore, in the future, there will be a strategy to internalise the external cost to compensate for the impact. Knowing the external cost is also useful as part of a decision-making process for the transport users before using the solution.

Besides assessing the external cost of the developed solutions, LASH FIRE project also doing risk assessment where the Potential Loss of Cargo (PLC) and Potential Loss of Ship (PLS) of risk control measures (RCM), i.e. costs saved by reducing cargo and ship losses throught the implementation of a risk control measure, will be calculated. The value between the RCM and reference solution will be compared to see the economic benefit along the ship's lifetime. The benefit value will not be included in total LCC, however, it will be shown to assess the cost-benefit assessment in the FSA study. The information about the benefit values will be available in the WP04 report.

4.2 Relational KPIs

In order to understand the impact of LCC KPIs on the specific parameters that have normally been used in the ship, all the LCC KPIs result will be converted to one generic unit. The process can be called as relational KPIs. For Ro-Ro cargo, Ro-Pax, and Vehicle carrier the units that are normally used are Gross Tonnage (GT), Lane-Meter (LM), Length between perpendiculars (LPP), Passenger capacity (PAX) and Car Equivalent Unit (CEU). LM is the unit of Ro-Ro space while CEU for vehicle carrier. After the database construction and statistical analysis study in WP04, it has been decided that lane-meter or car equivalent unit will be used as a unit of ro-ro space-year. Therefore, the relational KPIs for the project are:

- Life Cycle Cost/LM or Life Cycle Cost/CEU
- Investment cost/LM or Investment cost/CEU
- Operation cost/LM or Operation cost/CEU
- Maintenance Cost/LM or Maintenance Cost/CEU
- End of life cost/LM or End of life cost/CEU
- External costs/LM or External costs/CEU

5 Methodology for life cycle cost

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In the LASH FIRE project, the LCC assessment involves three different phases of the ship, the investment/production phase, operational phase, and end of life phase. The cost component that is listed in each phase is coming from several inputs. The first input comes from the LCC assessment in the previous CMT's LCC projects such as Leanship, RAMSSES, Joules. The second input comes from the requirements of the cost-effective assessment in WP04. The last input comes from the ship operator and shipyard and ship designers representatives in WP05, representing the cost components for specific ship types. In LASH FIRE the LCC assessment will be done for three different generic ships (Ro-Ro cargo, Ro-Pax, Vehicle carrier) for two different cases, newbuilding and existing ship. Through the statistical analysis study in WP04, the expected lifetime for the risk assessment, LCC, and LCA for the three different generic ships are defined in Table 1.

Table 1. Ship expected lifetime (Years)

	Ro-Pax	Ro-Ro cargo	Vehicle carrier
Newbuilding	43	40	29
Existing ships	23	23	17

Depending on the availability of cost data, the cost component listed in the data collector and LCC tool might be too detail or too general. Therefore, the users are able to add and modify the cost component according to their need. Moreover, to estimate the cost, the best assumption from experience or benchmark the similar technology can be used. However, for the transparency purpose of the cost assessment, the users are obliged to put the reference on the source or the assumption when defining the cost. In a research project, sometimes it is hard to estimate the actual cost that will occur, especially during operation. Therefore, for this LCC assessment, if the cost inputs are coming from assumptions or benchmarking from similar solutions, the partners need to provide their best estimations and give the explanations for assumptions.

5.1 Production phase

All the cost related to the production of the solution and integration of the solution to the ship will be considered as the investment cost. The data about the investment cost comes from D&D WPs and the ship operators and shipyard and ship designer representatives in WP05. D&D WPs will provide the information about the equipment cost for the new solution, and the ship operator will provide the information on the equipment cost for the reference solution. Furthermore, ship operators will provide information about the cost to integrate the solution into the ship, which can include the transport cost, assembly cost, etc. If the solution provided by D&D WPs doesn't require the cost to purchase equipment, the cost might still appear for modification the ship according to the new solution. The general investment phase model in LASH FIRE contains the following investment cost breakdown:

- Purchasing cost: The equipment or software cost
- Insurance cost: The insurance for the purchased equipment or software
- Integration design & validation cost: The cost to integrate and validate the solution into newbuilding or existing ship design
- Road transporter cost: The cost to transport the equipment until the port

- Ship transporter cost: The cost to transport the equipment to the sea
- Assembly/Installation cost: The cost to assemble the solution to the ship, including the equipment and system assembly or installation.
- Commissioning cost: The cost that occurs to test and review if the equipment or the system are working according to the standard
- Document, certification, and other administration costs: The cost related to the administration or certification
- Loss of hire costs: The loss that might occur if any activities related to the integration of the solution disturb the operation plan
- Operator training cost: The cost to train the ship crews to use the new solution
- Other costs: Other costs that occur during production or integration of the solution

5.2 Operational phase

During the operation phase, the costs that might occurs are the fuel or energy cost, other operation costs, and maintenance cost. In addition to the cost, during the operation, the ship operator also gains income. Normally the fuel cost is the most significant cost during operation. Therefore, the D&D WPs should provide the information if the new solution will affect the energy consumption onboard the ship and the source of the energy, either is coming from an auxiliary engine or an emergency engine. After knowing the energy consumption of the solution, the mass of the fuel for the diesel engine will be calculated using below formula.

$$M_{fuel}\,(t) = \sum_{n}^{1}\left(\frac{P_{mech}[kW]}{\eta_{mech}} + \frac{P_{el}[kW]}{\eta_{el}} + \frac{P_{therm}[kW]}{\eta_{therm}}\right) x \left(\frac{SFOC\left[\frac{g}{kWh}\right] x\ 42.700\left[\frac{kJ}{kg}\right] x\ \Delta t_p[h]}{1.000.000\ x\ LHV\left[\frac{kJ}{kg}\right]}\right)$$

n = Number of units

P = Mechanical, electrical, or thermal power requested

η = Efficiency

$SFOC$ = Specific fuel oil consumption

Δt_p = Length of the phase for calculation

LHV = Lower heat value of the fuel

As the operation time of the ship can reach beyond ten or even thirty years, therefore the fuel price projection until 2050 will be used in the tool. The explanation of the fuel price projection will be explained in chapter 6.1.

Besides the fuel costs, the other operating costs on the ship are listed below. These costs varying from being personnel costs, insurance costs, maintenance costs etc. Moreover, to understand the real cost of the solution, it is also important to know the repair period of the solution and the cost associate to repair activities. If the solution gives additional revenue during the operation, then the operating cost can be reduced.

- Operator cost: The cost that occurs if the solution needs to be operated by the crew, including the maintenance and repair process per year
- Insurance, taxes, and other fee costs: Insurance (P&I) cost, taxes and other administrative costs that occur by using the solution during operation per year
- Loss of cargo or loss of revenue: The loss that might occur if the solution reduces the cargo capacity per year
- Additional cargo or revenue: The revenue that might occur if the solution increases the cargo capacity per year
- Annual system maintenance cost: The cost that occurs for the solution's maintenance per year
- Loss due to vessel downtime during maintenance: The loss that might occur if any activities related to the maintenance activities disturb the operation plan
- Spare part cost: The cost that occurs to replace the part(s) of the solution
- Service repair cost: The service cost that occurs to replace the part(s) of the solution
- Loss due to vessel downtime during repair: The loss that might occur if any activities related to the repair activities disturb the operation plan
- Periodic inspection and certification cost: The cost that occurs to do period inspection and certification of the solution

5.3 End of life

After the end of the operation phase, the ship comes to its end of life. There are several possibilities that could happen to the ship or solution. The first possibility is to sale it, the resale value can be considered as additional revenue. The second possibility is to recycle it, normally this activity will add an additional cost. The last one is to resale some parts and recycles the others. The tool user has deliberation to decide which case that they will choose. However, knowing the information at the end of life is quite difficult, sometimes such information is not always available. Therefore, for cost-effective assessment, the information about LCC will be excluded. However, for LCC assessment the user can put the end-of-life cost to analyse the cost from one solution to another.

5.4 External cost

During the production, operation, and end of life phases, all the emission and the environmental footprint will be assessed using the Life Cycle Assessment (LCA). The LCA study will be performed for both actions by RISE, action 6-D on ”Effective and efficient manual firefighting and action 10-B on” fixed fire-extinguishing systems for weather” . The guideline for LCA study can be found in D5.5. The information about the environmental impact then will be transformed into economical value as the external costs. The external cost values are using the information from the EU external handbook [2]. For example, the cost of climate change cost or Global Warming Potential (GWP), air pollution, and water pollution. For GWP, the value (central) that will be used for the calculation can be seen in Table 2.

Table 2. GWP cost in Eur/tCO_2 equivalent [2]

	Low	Central	High
Short-and-medium-run (up to 2030)	43	40	29
Long run (from 2040 to 2060)	23	23	17

For air pollution cost, every EU country has its value to charge on every particle produce during transport activities. However, for this calculation, the total and average cost per vehicle and country are being used. Table 3 shows the cost of maritime emissions in different areas.

Table 3. Air pollution cost in Eur/Kg emission [2]

Eur/Kg	NH_3	NMVOC	SO_2	NO_x	$PM_{2,5}$	PM_{10}
Atlantic	0.0	0.4	3.5	3.8	7.2	4.1
Baltic	0.0	1.0	6.9	7.9	18.3	10.4
Black Sea	0.0	0.2	11.1	7.8	30.0	17.1
Mediterranean	0.0	0.5	9.2	3.0	24.6	14.0
North Sea	0.0	2.3	10.5	10.7	34.4	19.7

6 Cost assessment scenarios

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6.1 Fuel cost

Currently, convention fuels such as Heavy Fuel Oil (HFO) and Marine Gas Oil (MGO) are still widely used as fuel for the diesel engine in ships. However, alternative fuels with low sulphur such as Very Low Sulphur Fuel Oil (VLSFO), Ultra Low Sulphur Oil (ULSFO), and Low Sulphur Marine Gas Oil (LSMGO) started becoming an alternative of the conventional fuels. As the price of the fuels is fluctuating, therefore in the LCC assessment, the study will include the forecast price of each fuel types in the calculation.

Table 4. List of fuels in LASH FIRE for LCC assessment

NAME	DESCRIPTION
HFO	Heavy Fuel Oil low quality (low-quality HFO similar to IFO380 with S = 3,5 %)
VLSFO	Max 0.5% Sulfur fuel
LSMGO	Max 0.10% Sulfur Distillate
MGO	Unless otherwise specified, a Max 1.50% Sulfur
ULSFO	Ultra-Low Sulphur Heavy Fuel Oil (ULSHFO similar to RMD80 with heavily reduced sulphur content, S = 0.1 %)

6.1.1 Fuel price 2021

The fuel price for 2021 was collected from the Rotterdam bunker price [3]. The Intermediate Fuel Oil (IFO) 380 was used as a reference for the blend of HFO and distillates. Figure 4 shows the trend of fuel prices from mid-2020 until early 2021.

Figure 4. The trend of the fuel price from 2020-2021. [3]

The fuel prices in the Rotterdam bunker are in the USD. In LASH FIRE project, all the price in USD were converted into Euro using currency forecasting in mid-2021 [4], with 1 USD equal to 0.867 Euro. The calculated fuel prices in Euro for 2021 can be seen in Table 5. The mid-price will be used base case of LCC assessment.

Table 5. Fuel price for 2021

(Eur/Tonne)	Low price	Mid-Price	High price
HFO	208,1	261,0	347,2
VLSFO	247,1	326,4	438,3
LSMGO	267,0	354,6	473,8
MGO	264,4	361,1	478,6
ULSFO	226,3	311,3	427,4

6.1.2 Fuel price projection until 2050

Future HFO, VLSFO, LSMGO, MGO, and ULSFO price will be calculated using a forecasted formula developed in the JOULES project [5]. Based on the JOULES project, the fuel projection of those fuels has a strong connection to the Brent crude oil price. The assumption based on the Energy Information Administration (EIA) world energy outlook data in 2014.

Table 6. Price projection factor from JOULES project [5]

Name of Fuel	Price projection factor
HFO	0,83*Brent Price
MGO	1,29*Brent Price
VLSFO	1,25*HFO
ULSFO	0.92*LSMGO

For LASH FIRE project, the fuel prices are using the Brent crude oil price from EIA annual energy outlook 2021 [6].

Table 7. Price projection factor from JOULES project [5]

	2030			**2040**			**2050**		
(USD/barrel)	Low price	Mid-Price	High Price	Low price	Mid-Price	High Price	Low price	Mid-Price	High Price
Brent Crude oil	37	73	136	43	87	155	48	95	173

The unit USD/barrel then transformed into Eur/t by using the assumption as below. The fuel prices projection until 2050 can be seen in Table 8. Mid-price will be used for LCC assessment. For the fuel price beyond 2050, as EIA did not publish yet their fuel projection above that year, the price in 2050 will be used for calculation.

$$1\ barrel = 158{,}987\ L$$

$$Crude\ oil\ density = 0{,}8334\ kg/L$$

$$1\ barrel = 158{,}987\ L * 0{,}8334 \frac{kg}{L} = 132{,}5\ kg = 0{,}1325\ t$$

Table 8. Fuel price projection until 2050

	2030			2040			2050		
(Eur/t)	Low price	Mid-Price	High Price	Low price	Mid-Price	High Price	Low price	Mid-Price	High Price
HFO	200,9	396,5	738,6	233,5	472,5	841,8	260,7	515,9	939,6
VLSFO	251,2	495,6	923,3	291,9	590,6	1052,3	325,9	644,9	1174,5
LSMGO	314,7	621,0	1156,9	365,8	740,1	1318,5	408,3	808,1	1471,6
MGO	312,3	616,2	1148,0	363,0	734,4	1308,4	405,2	801,9	1460,3
ULSFO	289,6	571,3	1064,3	336,5	680,9	1213,0	375,6	743,5	1353,9

7 Sensitivity Analysis

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To understand the impact of the world economy and legislation situation on the LCC, a sensitivity analysis is available in the tool so the users can understand the impact of the cost from a different situation that might happen in the future. For this project, the reference from DNV GL is being used to do sensitivity analysis. In the DNV GL Shipping 2020 report, DNV GL introduced four different scenario models that represent the economic growth and the legislation condition related to the external cost from the emission in the future.

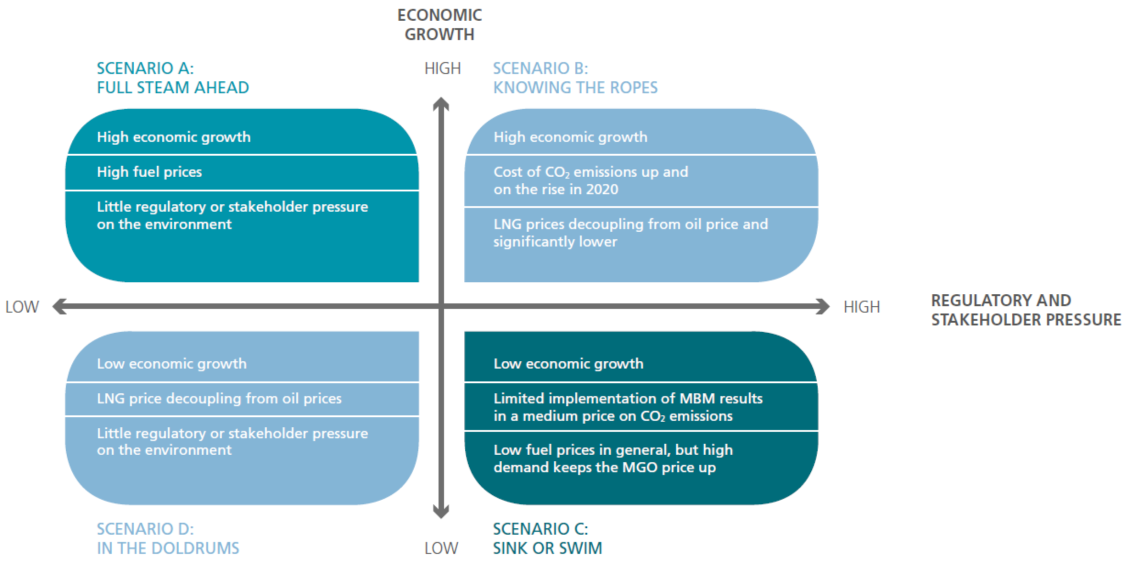

Figure 5. Four different scenarios from DNV GL Shipping 2020 report

The high economic growth represents positive economic development which means increasing demand for resources and energy. For LASH FIRE project, the high economic demand will be represented by the GDP growth. As the changes in the fuel usage will not be significant in this project, therefore the high or low fuel prices will not be considered in the scenarios. For the GDP growth, from the growth data in 1971-2019 [7], it is assumed on the average EU countries growth rate can be up to 2.6%. And if the GDP growth rate is stagnant or in the low economic growth, then the average 0.6% GDP growth will be used in the scenario.

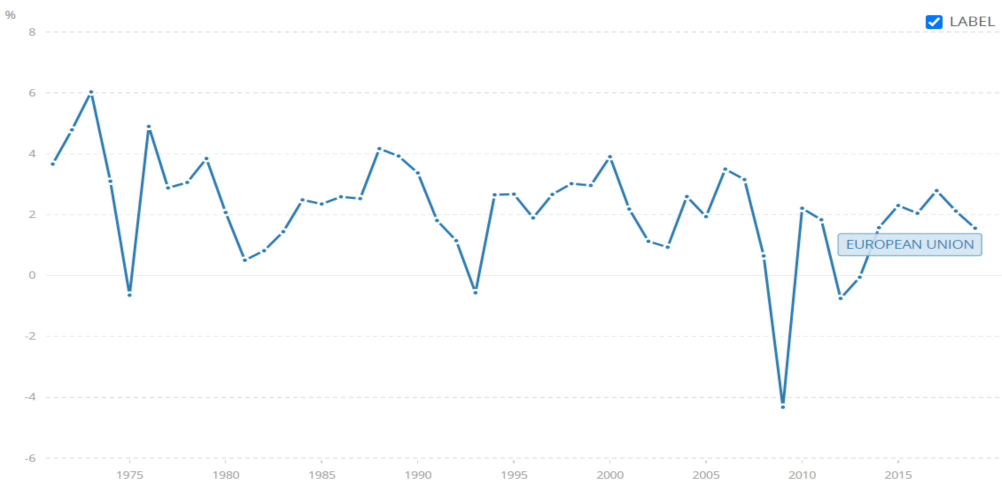

Figure 6. GDP growth from 1971 until 2019 [7]

For regulatory or legislation condition, the external cost from emission will have an impact on the LCC. If the regulation is strict then the external cost should be paid and included in the overall LCC. However, if the regulation is not strict, the external cost does not need to be paid and included as the cost component in LCC.

8 Conclusion

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One of the objectives of LASH FIRE is to evaluate and demonstrate ship integration feasibility and cost of developed operational and design risk control measures for all types of ro-ro ships and all types of ro-ro spaces. Alongside the evaluation of technical and operational solutions developed in the project, the economic feasibility of the solutions needs to be evaluated throughout the entire life span. Therefore, an LCC tool was developed to assess the financial parameter. Furthermore, to understand the impact of the world economy and legislation situation on the LCC, a sensitivity analysis feature was made available in the tool so the users can understand the impact on the cost if a different scenario might happen in the future.

The deliverable provides explanations of the KPIs, methodology, and scenarios used in the LCC tool. Moreover, the report provides a detailed workflow which includes the work process and task for responsible partners.

9 References

[1] J. L. et.all, „FIRESAFE II Containment and Evacuation,“ 2018.

[2] European Comission, „Handbook on the external costs of transport version 2019,“ Brussels, January 2019.

[3] Ship & Bunker, „Roterdam Bunker Prices,“ Ship & Bunker, [Online]. Available: https://shipandbunker.com/prices/emea/nwe/nl-rtm-rotterdam. [Zugriff am March 2021].

[4] „The Economy Forecast Agency,“ [Online]. Available: https://longforecast.com/euro-to-dollar-eur-usd-forecast-2017-2018-2019-2020. [Zugriff am March 2021].

[5] C. Thiem, R. Nagel, J. Ellis, S. Hänninen und A. Lieblich, „Deliverable 21-2: Cost Models and LCa,“ in *JOULES (Joint Operation for Ultra Low Emission Shipping)*, 2017.

[6] Energy Information Administration, „Annual Energy Outlook 2021,“ https://www.eia.gov/outlooks/aeo/pdf/appc.pdf, 2021, p. 1.

[7] „GDP growth (annual%) -European Union,“ [Online]. Available: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?end=2019&locations=EU&start=1971&view=chart.