CONTRACT MOVE/C4/2022-62:

"TECHNICAL SUPPORT FOR THE DEPLOYMENT OF ERTMS AND DIGITAL IMPROVEMENTS TO THE SINGLE EUROPEAN RAIL AREA"

DIGITAL AUTOMATIC COUPLING – COST BENEFIT ANALYSIS (INITIAL REPORT)

DEL-T4-01-V0.1

22/12/23

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1. LIST OF ABBREVIATIONS

CAPEX	CAPital EXpenditure
CBA	Cost-Benefit analysis
CCS TSI	Control Command and Signalling Technical Specifications for Interoperability
CEF	Connecting Europe Facility
CINEA	European Climate, Infrastructure and Environment Executive Agency
CNC	Core Network Corridors
CSI	Common Safety Indicators
DAC	Digital Automatic Coupler
DEL	Deliverable
DG MOVE	Department for mobility and transport
EC	European Commission
EDDP	European DAC Delivery Programme enabled
EDP	European Deployment Plan
EEA	European Economic Area
EP Brake	Electro-pneumatic brake
ERA	European Union Agency for Railways
ERTMS	European Rail Traffic Management System
ESC	ETCS System Compatibility
ESIF	European Structural and Investment Funds
ETCS	European Train Control System
EU	European Union
IRR	Internal Rate of Return
IT	Intermodal Traffic
JU	Joint Undertaking

MoM	Minutes of Meeting
MS	Member State
NIP	National Implementation Plan
NSA	National Safety Authority
OB	On-board
OPEX	OPerational EXpenditure
RU	Railway Undertakings
SSMS	Sustainable and Smart Mobility Strategy
SWL	Single Wagon Load
TEN - T	Trans European Transport Networks
TSI	Technical Specifications for Interoperability
TTD	Trackside Train Detection
WP	Work Package

2. EXECUTIVE SUMMARY

2.1. CONTEXT AND OBJECTIVE OF THE STUDY

European rail freight is facing three principal challenges: productivity, quality and rail network capacity.

One of the main causes is how freight trains are operated and handled. Shunting and train preparation are characterised by manual interventions and, generally speaking, rail freight is insufficiently digitalised and automated, which causes inefficiencies and (transport) time losses.

At the same time, the EU's Sustainable and Smart Mobility Strategy specifies the need to increase rail freight with 100% by 2050 to contribute to delivering the European Green Deal.

As building new infrastructure faces a lot of challenges, a significant part of future volumes must be transported on existing infrastructure ("smart capacity"). Train length, loading factor, speed and utilisation rates on the network all have to be improved. Process times in stations and yards have to be significantly shortened. Such progress is only possible through automation, with manual intervention taking place only in case of malfunctions.

In addition, European railway undertakings will have to face, in the next years, a shrinking workforce due to retirement, whilst they currently offer many workplaces with high physical intensity for ground staff. Both staff shortages and the physically challenging nature of coupling operations constrains the future of manual processes in rail freight.

In this context a new technical solution for wagons and locomotives has been proposed by the sector: the "Digital Automatic Coupling" or DAC. DAC enables the rapid mechanical (un)coupling of wagons and locomotives, as well as that of digital communication and energy supply throughout the train. Many perceive DAC as the technology of choice to enable rail freight automation and overcome rail capacity issues, to offer more attractive services to customers, to increase rail freight quality and to decrease operating costs.

This new digital solution will also substantially increase worker's safety by automating manual processes. Better working conditions will improve the attractiveness of the rail sector for workers. Finally, DAC will also be an enabler for the digitalisation of rail freight transport through the development of new digital services.

This will put rail freight into a position to deliver on the European Green Deal, to save transport energy and to create additional value for the European economy.

Yet, the introduction of DAC in European Rail Freight would constitute a major transformation of the European rail system. Beyond the technological and implementation challenges, there are considerable investments required to achieve the migration towards DAC. A complicating factor herein is that costs and benefits can be unequally spread amongst sector players and a gap between the time when costs and benefits occur.

Therefore, before any deployment decision can be taken on political as well as business levels, **a Cost-Benefit Analysis needs to demonstrate the overall positive effects and impacts of a DAC deployment on all concerned stakeholders.**

2.2. METHODOLOGY

The cost benefit analysis is aligned with guidelines from the European Commission, namely the "Guide to cost-benefit analysis of investment projects" (2014) and the Economic Appraisal Vademecum (2021). As stated in the Guide:

"[a] CBA is an analytical tool to be used to appraise an investment decision in order to assess the welfare change attributable to it and, in so doing, the contribution to EU [...] policy objectives. The purpose of CBA is to facilitate a more efficient allocation of resources, demonstrating the convenience for society of a particular intervention rather than possible alternatives."

The DAC CBA applies a 30-year timeline, starting with the first year of investment (2028). This means that costs and benefits will be considered for the period 2028-2057. A social discount rate of 3% is used in the CBA, to convert monetary values in the future to 'present values', so that money flows can be compared over time. The geographical scope covers the EU27, Switzerland, Norway and the United Kingdom[1]. Countries with mainly the 1520mm or 1524mm track gauge are excluded from the analysis in line with current discussions on the implementation scope. The analysis will be extent to Western Balkan countries in a later iteration.

The CBA applies a differential approach, meaning that projections and calculations are prepared for the baseline and investment scenarios separately. The difference between the results of an investment scenario and the baseline scenario provide the impact of the project and its added value. In other words, the DAC CBA includes scenarios with the investment (DAC scenarios), and one scenario without the investment (Baseline scenario).

Determining the baseline scenario is necessary to objectively measure the added value of DAC. In the baseline scenario, European investments and the new legal framework foreseen in the "Sustainable and smart mobility strategy" have been explicitly considered.

The DAC scenarios show the impact of DAC deployment on costs, benefits and development of rail traffic. Several DAC scenarios were developed since there are different levels of DAC that can be implemented and different packages of associated components (higher level of DAC or additional components also represent more features).

Finally, it is important to emphasize that the conclusions of this report should be carefully interpreted, with the following key considerations:

- Some use cases (at least 14 of them) are not considered today, due to a lack of information;
- The life cycle costs of DAC shall be adjusted in the coming year following the development and testing of the product;
- The implementation plan is still under development. Any future update of the CBA shall incorporate updates to the implementation plan. Currently the CBA builds on the initial proposal by EDDP WP3;
- Transport forecast are only partially underpinned by simulations due to the absence of a robust European transport forecast model. Several growth assumptions have therefore been made and corroborated within the EDDP;
- Some of the parameters are based on expert estimates, if no alternative source of information was available during the development of the CBA.
- Further sector feedback is required to better understand the applicability of use cases for specific business segments, such as combined transport. The results of these discussions are likely to have

[1] Countries in the Western Balkan shall be added in a subsequent iteration of the CBA

an impact on the implementation plan and proposed technical solutions, which shall impact the overall results of the CBA.

Notwithstanding the limitations, the CBA brings together the best available data at this point in time and provides a sound insight into the magnitude and direction of the expected impacts. The sensitivity analyses confirm the robustness of the first results. Moreover, the model and parameters have been made publicly available during the development process to ensure maximum scrutiny.

2.3. TRAFFIC FORECAST AND MIGRATION SCENARIO

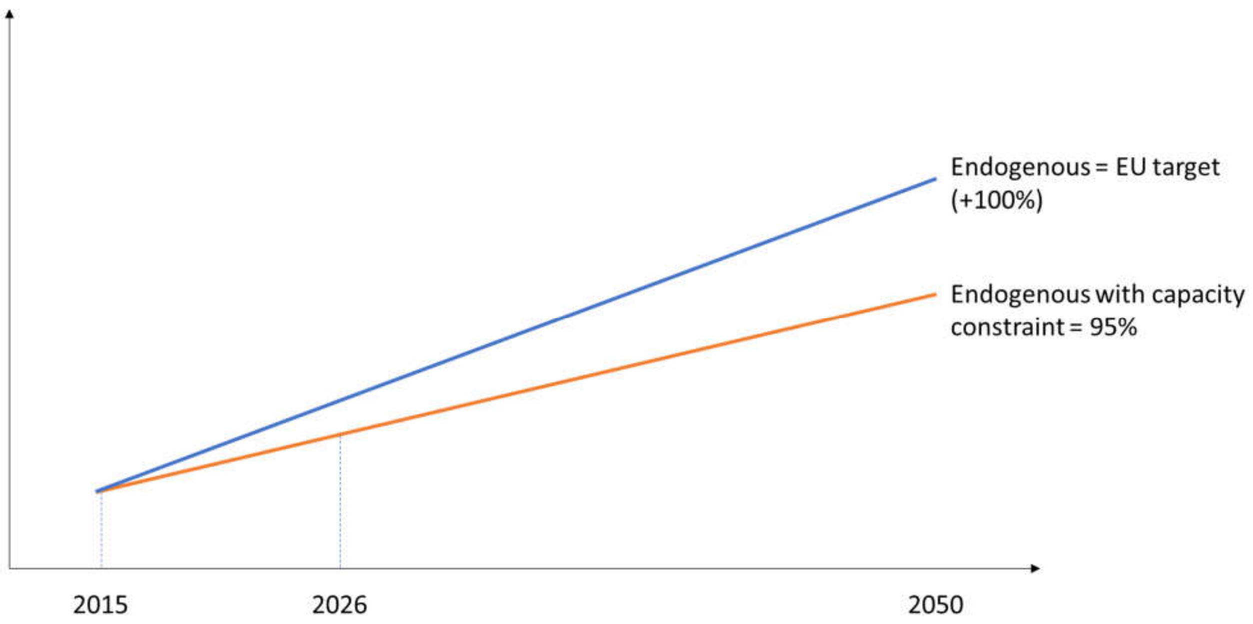
The **traffic forecasts** have considered the measures presented by European Commission in the "Sustainable and Smart Mobility Strategy – putting European transport on track for the future"[2]. The European Commission proposes an ambitious target of a 90% reduction in the transport sector's emissions by 2050. This goal is reflected in terms of composition of the fleet but also in terms of **evolution of the rail freight traffic, which is expected to increase by 50% in 2030 and double by 2050, implying an average annual growth of 2.3%.**

Expert feedback and desk research corroborated the plausibility of the growth rate, assuming that other policy initiatives such as the completion of the TEN-T network are realised.

As DAC is one of the measures foreseen in this strategy, two different scenarios of traffic growth have been considered:

- One without DAC, which would have an impact on the capacity of the network; for this scenario, only 95% of the expected growth would be achieved;
- One with DAC, leading to a doubling of rail freight (only considering the impact of DAC on capacity; the impact of DAC on the productivity system is considered on top)[3]

These two scenarios are presented in the figure below:



[2] SWD(2020) 331 final

[3] See §6.1.2.1 for more explanations on the traffic forecast and the impact of DAC on capacity

Figure 1 – rail freight traffic growth with and without capacity constraint

The fleet **migration plan** distinguishes two types of fleets. **For the core wagon load system** (wagons used in mixed traffic, in often changing compositions, like e. g. single wagon load, representing approximately 210 000 wagons), a 'big-bang' approach is recommended. This entails that, after considerable preparation, the entire CWS fleet shall be converted towards DAC in a two to three weeks period. This approach is expected to minimize the impact of the DAC migration on operations.

In this scenario, the underlying assumption is a big bang retrofit to DAC 2 level, followed by a rapid upgrade to DAC 4 or 5 in the period after the big bang.

For the non-core wagon load system (e.g. block / shuttle trains, representing approximately 250 000 wagons), a gradual retrofit is planned, aligned to the greatest possible extent with maintenance cycles. For this system sufficient capacity in workshops for direct migration to DAC 4 or 5 is considered to exist. Wagons shall be retrofitted to the greatest possible extent to minimise scrapping and parallel DAC / Screw coupling operations. Economically and technically justified exemptions are still being analysed and defined.

Locomotives, finally, shall be fitted with a hybrid coupler and the migration shall follow a stepwise approach, in line with the retrofitting of the wagon fleet.

2.4. COSTS & BENEFITS CONSIDERED

The following costs and benefits have been considered and quantified in the CBA:

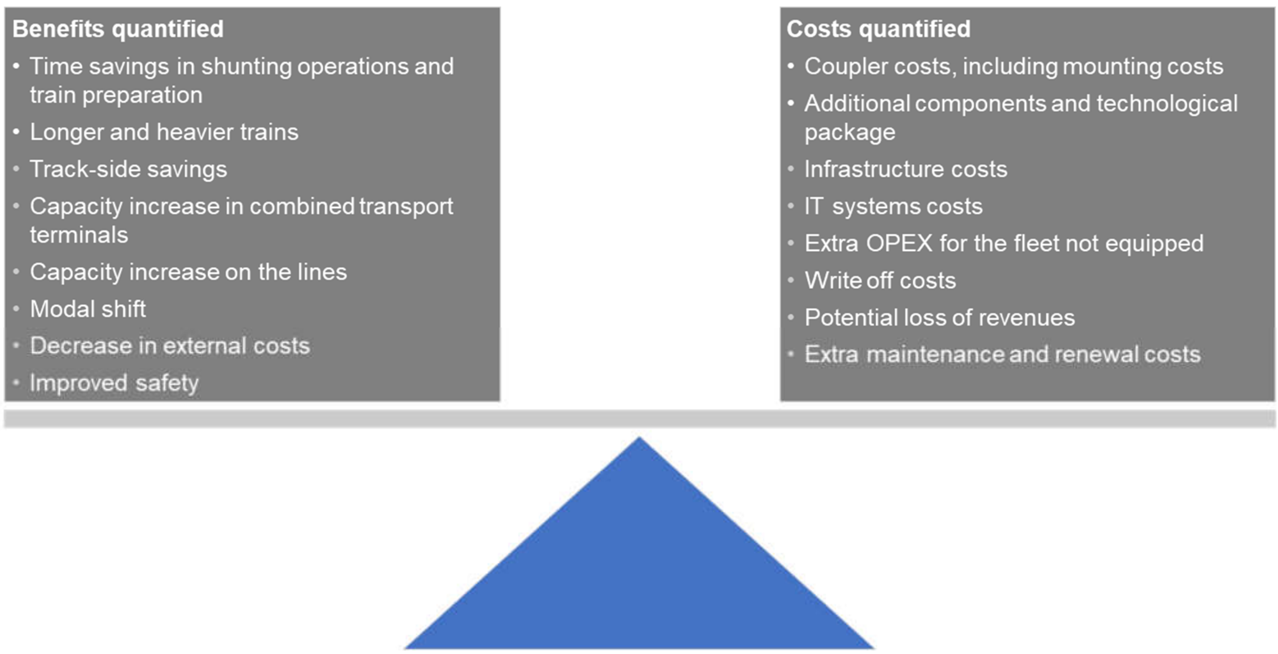


Figure 2 – Costs and benefits considered and quantified in the CBA

Some additional costs and benefits have also been considered, but not quantified at this stage due to:

- A lack of data, like for instance the split between simple and complex retrofit operations for locomotives, or the number of times a train is changing locomotive and requires a new brake test during a trip;
- The need for additional analysis, like for instance for wagon condition / performance, as some alternative solutions already exist and provide similar benefits, but the questions are what would be

the difference of costs between DAC and these solutions, and could DAC bring higher benefits (for instance due to a more reliable power supply);

- Some doubt on the actual existence of a perceived benefit, like for instance on increased payload due to a new wagon design: some stakeholders believe this can happen others believe that wagons will be heavier with DAC. As there is ambiguity amongst sector experts, this benefit has not been considered.

The assessment of the costs and benefits has been based on:

- Studies and existing databases, at EU and national level
- The other work packages from the European DAC Delivery Programme (EDDP)
- Over 20 stakeholders interviewed, sometimes multiple times
- In-depth discussions with the working group of the European DAC Delivery Program dedicated to the topic (21 meetings in the past 2 years, involving on average 25 sector representatives)
- Case studies to validate the calculation done at macro level at company level

Moreover, the first results of the CBA have been shared at the end of 2022 for a sector wide consultation. More than 160 comments have been collected, analysed and addressed.

2.5. DAC SCENARIOS CONSIDERED

Four different scenarios for DAC have been considered, based on different bundling of DAC with additional components, called "tech packages":

- The **first "tech package"** only considers DAC 4 (automated coupling) and the associated communication system.
- The **second "tech package"** corresponds to DAC 5 (automated coupling and uncoupling).
- The **third "tech package"** considers an automated brake test device on top of tech package 2.
- And finally, the **fourth "tech package"** considers all the components from tech package 3 plus equipment required for automated wagon inspection on the wagon and for automated parking brake. It can be seen as **the upper bond of the potential effect of DAC with the functionalities identified and quantified today**.

2.6. MAIN RESULTS

Overall, all scenarios have a very good result from a societal perspective, with IRR and B/C ratios ranging from 11% to 19% and from 1.9 to 2.8 respectively, as shown in the table below:

Tech package	Start	Duration	Big bang	Variable	Results 2028-2057 *(mEUR)*
1	2028	6	2031	Total benefits (discounted)	29,373
				Total costs (discounted)	14,307
				BC-ratio (discounted)	2.1
				IRR	11%
2	2028	6	2031	Total benefits (discounted)	33,967
				Total costs (discounted)	17,433
				BC-ratio (discounted)	1.9
				IRR	11%
3	2028	6	2031	Total benefits (discounted)	47,012
				Total costs (discounted)	19,428
				BC-ratio (discounted)	2.4
				IRR	15%
4	2028	6	2031	Total benefits (discounted)	66,704
				Total costs (discounted)	23,895
				BC-ratio (discounted)	2.8
				IRR	19%

Table 1 – Main results of the CBA (2028-2057)

The most favourable tech package is the fourth, but there is a high level of uncertainty on the capacity to reduce the time for train inspection as much as proposed in the current CBA (50% of the time required today for train inspection is expected to be saved). Moreover, for a strong decrease in train inspection, additional investments might be required, such as video gates, which could not yet be quantified in the current CBA.

Therefore, **the most robust upper bound to be considered at this iteration of the CBA is the tech package 3**, with automated brake test, which would lead to an IRR of 15% and a B/C ratio of 2.4.

Tech package 1 and 2 have very similar results, as the extra costs associated with DAC 5 (tech package 2) compared to DAC 4 (tech package 1) counterbalance the extra benefits brought by DAC 5 compared to DAC 4 (time saved for uncoupling).

Importantly, in the short term (2028-2037), costs of DAC deployment are higher than the benefits, as shown in the table below:

Tech package	Start	Duration	Big bang	Variable	Results 2028-2037 *(mEUR)*
1	2028	6	2031	Total benefits (discounted)	4,815
				Total costs (discounted)	8,908
				BC-ratio (discounted)	0.5
				IRR	\
2	2028	6	2031	Total benefits (discounted)	5,765
				Total costs (discounted)	10,209
				BC-ratio (discounted)	0.6
				IRR	\
3	2028	6	2031	Total benefits (discounted)	8,439
				Total costs (discounted)	10,928
				BC-ratio (discounted)	0.8
				IRR	\
4	2028	6	2031	Total benefits (discounted)	12,508
				Total costs (discounted)	12,537
				BC-ratio (discounted)	1.0
				IRR	\

Table 2 – Main results of the CBA (2028-2037)

On the cost side, DAC will require an initial (not discounted) investment of €11 bn to €15 bn depending on the technological package considered for equipping around 410.000 freight wagons and 17.000 locos in Europe. Most of these costs will have to be borne by railway undertakings and wagon leasing companies.

On the benefits side, DAC is expected to contribute significantly to the increase of rail freight traffic. 5% are coming from the impact of DAC on improving network capacity, and 2 to 7.5% on the improved performance of rail freight (depending on the tech package considered**). Overall, rail freight traffic is expected to increase by 7 to 12.5% in 2050 compared to the baseline without DAC** (5% coming from increased capacity, the rest coming from improved competitiveness of rail compared to road thanks to DAC). This will also lead to a strong decrease in the external costs of transport, **representing €19 bn to €53 bn (not discounted) between 2028 and 2057 of benefits on air pollution, congestion and greenhouse gases emissions**. Moreover, the overall energy consumption of the transport system is expected to decrease, as rail freight can carry more goods for the same quantity of energy. **DAC will also support the development of a more competitive European industry**, with a more reliable, faster and cheaper transportation system. Shippers are expected to get a net benefit of €11.1 bn to €30.5 bn (not discounted) according to the tech package considered.

In all cases, the **benefit cost ratio** of the CBA is higher than one with **1.9 to 2.8 over 30 years** but **only 0.5 to 1.0 over 10 years**. From a socio-economic perspective, the fourth tech package (DAC5 with automated brake test, sensors for automated wagon inspection) scores highest, but **in terms of assumptions for this report the more robust scenario is the third tech package** (i.e. DAC 5 with automated brake test).

The CBA indicates that the **DAC project is very beneficial from a societal perspective within the total project horizon**. However, railway operators typically apply at a maximum a time window of 10 years for investment decisions. In this period, the CBA shows that the benefit cost ratio does not pass 1, due to the high upfront investment costs and the delayed materialisation of benefits. Moreover, half of the benefits are relative socio-economic benefits that follow from a greater shift from road to rail transport: these benefits will not be fully captured by railway undertakings, wagon leasing companies and ROSCOs. At the same time, **the large societal benefits, provide a strong rationale for public support for DAC.**

In light of substantial ongoing research and testing activities, **the CBA results in this report should be considered preliminary and shall be adjusted based on updated insights**. For the CBA it is critical to gain greater certainty on the final coupler and fitting costs, as well as the detailed implementation plan. Concerning the benefits, a deeper insight needs to be gained into the total number of (shunting) trips and the additional use cases that are enabled by DAC. Further sector feedback is required to better understand the applicability of use cases for specific business segments, such as combined transport. The results of these discussions are likely to have an impact on the implementation plan and proposed technical solutions, which shall impact the overall results of the CBA. Notwithstanding these limitations, the performed sensitivity analyses and expert feedback highlight that these first CBA results provide a robust indication of the possible economic value of deploying DAC in Europe.

3. INTRODUCTION

This document explains the rationale, method and outcomes of the Cost-Benefit Analysis (CBA) for the deployment of Digital Automatic Couplers, or DAC in short. DAC is an innovative solution to automatically couple and decouple wagons in a freight train both physically (the mechanical connection and the air line for braking) and digitally (electrical power and data connection).

DAC is presented as a key enabler to increase efficiency and the digitalisation of rail freight. Moreover, its implementation is considered to provide a unique chance to transform railway operations management. As such, it is often understood to be a prerequisite to significantly increase rail freight's share of the modal split and to achieve the Green Deal objective to double rail freight by 2050.

In particular, the introduction of Digital Automatic Coupling is needed for the purposes of:

- automatic (de)coupling/shunting to reduce costs and process time;
- increasing safety and process reliability;
- enabling ETCS Level 3 as well as Automatic Train Operation (ATO), moving blocks for freight trains;
- increasing capacity of the entire system;
- paving the way to intelligent freight trains;
- enabling heavier and longer freight convoys as the coupler can deal with stronger forces.

The above benefits evidently come at a cost. For DAC to be effective, it needs to be implemented across Europe in a coordinated and feasible manner. The massive roll-out implies a multiple billion Euro investment.

In order to determine whether there is a case for investing in DAC, it is of crucial importance to have a transparent economic analysis that will assess the true value of the programme, as well as credible cost figures associated with its implementation.

To this end a cost-benefit assessment (CBA) was performed. The CBA was developed in close collaboration with numerous sector and Member State representatives. This report, in conjunction with the CBA model, provides a comprehensive overview of the costs and benefits of implementing DAC for the railway sector and Europe as a whole.

This report is structured as follows:

- Section 4 introduces the overall context of the work done on DAC,
- Section 5 presents the methodology used for the analysis,
- In sections 6, 7, 8 and 9, all the assumptions used for the calculations are provided,
- Sections 10, 11 and 12 are presenting the CBA results (main results, sensitivity analysis, allocation of costs & benefits),
- A conclusion is proposed in Section 13, to summarize key findings, evaluate the robustness of the results and suggest areas of improvement for the future.

4. CONTEXT

4.1. WHAT IS THE PROBLEM TO BE SOLVED?

European rail freight is facing three principal challenges: productivity, quality and rail network capacity.

One of the main reasons is how freight trains are operated and handled, especially in shunting and train preparation, requiring a lot of manual / human intervention, creating inefficiencies and (transport) time losses. There is also no common, interoperable technical basis existing for further digitalization and automation of freight trains.

At the same time, EU's Sustainable and Smart Mobility Strategy specifies the need to increase rail freight by 100% by 2050 and to contribute to delivering the European Green Deal.

As building new infrastructure faces a lot of challenges, a significant part of future volumes must be transported on existing infrastructure ("smart capacity"). Train lengths (within given infrastructure limitations), loads, speeds and train density on the network have to be increased. Process times in stations and yards have to be significantly shortened. This acceleration is only possible by automation, with manual intervention taking place only in case of malfunctions.

In addition, European railway undertakings will have to face, in the next years, a shrinking workforce due to retirement, whilst they – currently – only can offer low-attractive workplaces with high physical intensity for ground staff.

4.2. WHAT IS THE SOLUTION PROPOSED?

DAC enables the rapid mechanical (dis)connection of wagons and locos, as well as that of digital communication and energy supply throughout the train. Many perceive DAC as the technology of choice to enable rail freight automation and to overcome rail capacity issues, to offer more attractive services to customers, to increase rail freight quality and to decrease operating costs. DAC is expected to provide an answer to three main challenges for EU rail freight:

Figure 3 – Main drivers of DAC project

This new digital solution will also increase substantially worker's safety by automating manual processes. Better working conditions will improve the attractiveness of the rail sector for workers.

These effects will be implemented via the DAC/Full Digital Freight Train Operations use cases:

Figure 4 – Examples of DAC use cases

This will put rail freight into a position to deliver on the European Green Deal, to save transport energy and to create additional value for our economy.

4.3. WHO DOES WHAT ON DAC?

The DAC technology and its migration were elaborated in the 8 Work Packages of the European DAC Delivery Programme EDDP enabled by Europe's Rail, uniting more than 230 participants (from > 80 companies & 20 countries).

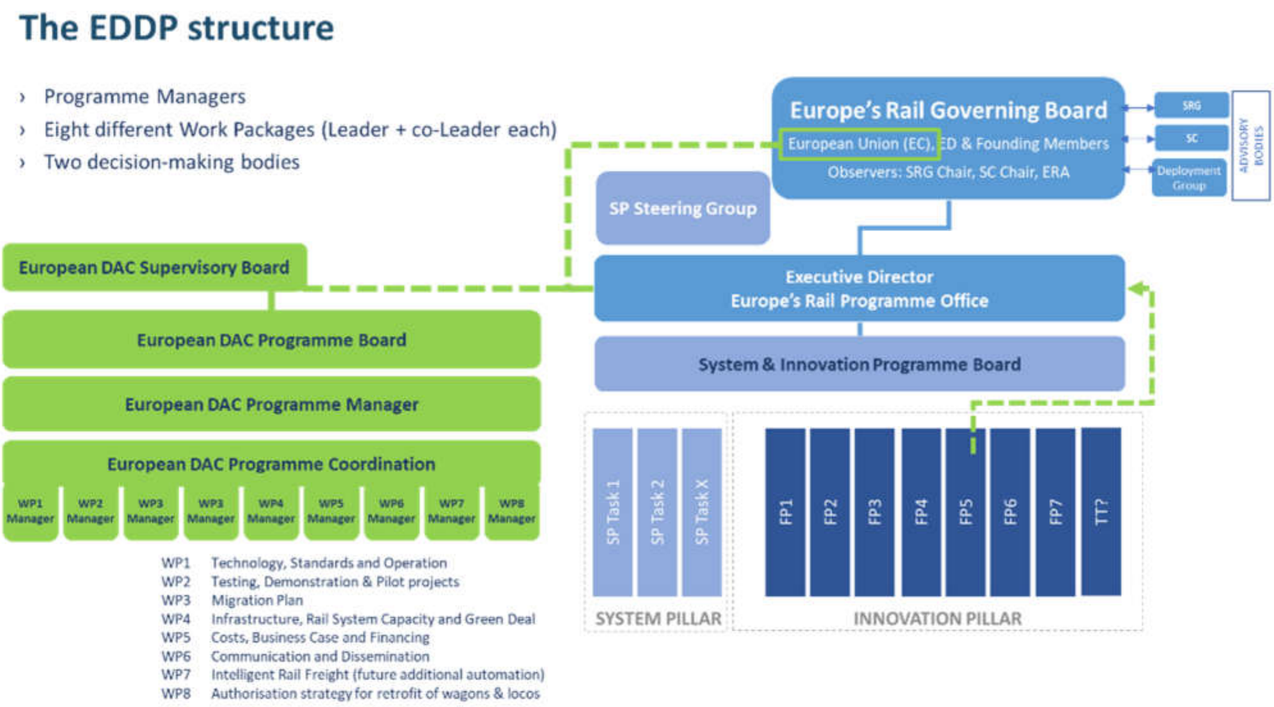


Figure 5 – The EDDP structure

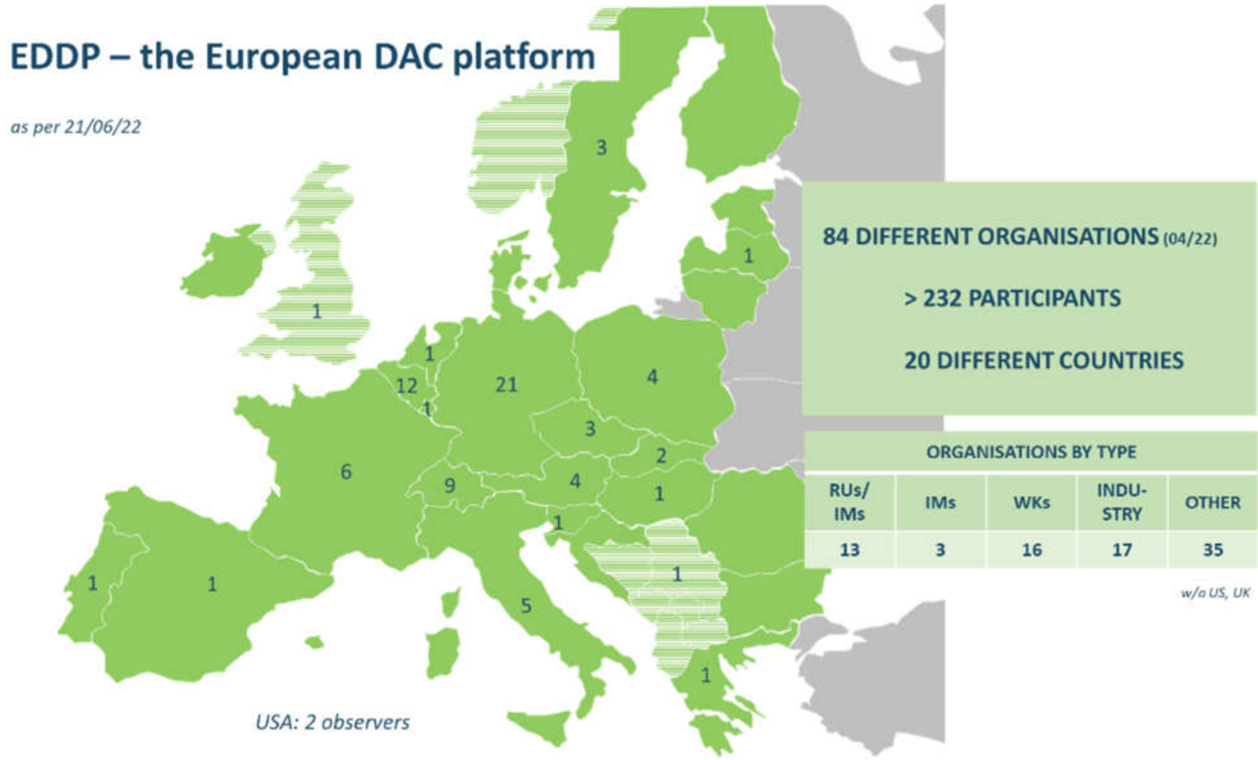


Figure 6 –EDDP structure

The EDDP is a unique forum for the sector to collectively drive the deployment of technological and operational solutions related to the DAC (Digital Automatic Coupler), by means of a focused and inclusive system approach under the umbrella of Europe's Rail.

The CBA analysis was one of the tasks of the work package 5 (WP5). Other work packages also provided critical inputs for the CBA:

- Work package 1 provided some case studies on the potential impact of DAC on the railway system;
- Work packages 2 and 3 provided an assessment of the life cycle cost of DAC, and a migration scenario;
- Work package 4 and 6 provided some inputs on the capacity, modal shift and externalities;
- Work package 7 provided some inputs on the cost of additional components required to achieve the main functionalities detailed in this report.

Current situation to be added

4.4. WHY A COST-BENEFIT ANALYSIS?

The introduction of a DAC in European Rail Freight would constitute a major transformation of the European rail system, require considerable investments and allow, over time, considerable benefits.

Before any deployment decision can be taken (on political as well as business level), **a Cost-Benefit Analysis needs to demonstrate the overall positive effects and impacts of a DAC deployment on all concerned stakeholders.**

5. OVERALL APPROACH

5.1. CBA METHODOLOGY

The cost benefit analysis is aligned with guidelines from European Commission: "Guide to cost-benefit analysis of investment projects" from December 2014 and with the Economic Appraisal Vademecum 2021-2027.

"CBA is an analytical tool to be used to appraise an investment decision in order to assess the welfare change attributable to it and, in so doing, the contribution to EU […] policy objectives. The purpose of CBA is to facilitate a more efficient allocation of resources, demonstrating the convenience for society of a particular intervention rather than possible alternatives."

The method used here for the CBA is the differential approach. It consists in preparing the projections and calculations for the base and investment scenarios separately. The difference between the results of an investment scenario and the base scenario describes the impact of the project and its added value. Hence, the DAC CBA has considered several scenarios: scenarios with the investment (DAC scenarios), and one scenario without the investment (Baseline scenario).

5.1.1. BASELINE SCENARIO

The baseline scenario shows the traffic development in the event of DAC not being implemented in comparison to the DAC-implementation scenarios. It has the same assumptions regarding other issues which remain common for both scenarios. Determining the base scenario is necessary to objectively measure what added value will be provided by Digital Automatic Coupling. In the baseline scenario, the investments and the new legal framework foreseen in the "Sustainable and smart mobility strategy" have been considered.

5.1.2. DAC SCENARIOS

The DAC scenarios show the impact of DAC deployment on costs, benefits and development of rail traffic. Several DAC scenarios will be developed since there are different levels of DAC that can be implemented and different packages of associated components (higher level of DAC or additional components also represent more features).

5.1.3. CBA TIMELINE AND SOCIAL DISCOUNT RATE

The DAC CBA is built on a 30-year timeline, starting with the first year of investment (2028), as per the standard recommendation for rail projects[4] assessments. This means that costs and benefits will be considered for the period 2028-2057.

Moreover, as stated in the "Better regulation" toolbox 2021, *"Individuals have time preferences, i.e., the availability of EUR 1 now is worth more than EUR 1 in the future. This can be explained as money can be invested today to generate a higher value tomorrow, there is inflation, or one will be dead in some future. To capture this phenomenon one can use a discount factor. If an individual invests EUR 1 now to have some*

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[4] EU "Guide to the cost-benefit analysis for investment projects" https://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf

revenues in 5 years and wants to be compensated for the fact that this individual is not buying any good or service today with this EUR 1. This compensation is measured by a discount factor. A ***discount factor*** *is a numerical factor used to* ***convert monetary values in the future to 'present values'****, so that money flows can be compared over time. It measures the present value of one euro received in year t. It relates to the complementary concepts of interest rate, rate of return, opportunity cost of a project, or cost of capital. In practice, discounting is using an appropriate interest rate back-to-front."*

As the CBA is done in real terms, the **social discount rate used for this analysis is set at 3%**, as recommended by the "Better regulation" toolbox 2021 and the "Economic Appraisal Vademecum 2021-2027".

5.1.4. GEOGRAPHICAL SCOPE

The geographical scope considered in the CBA is the EU27 + Switzerland + Norway + United Kingdom. Countries with 1520mm / 1524mm gauge are excluded from the analysis in line with current discussions on the implementation scope.

5.2. ANALYTICAL FRAMEWORK OF THE CBA

The analytical framework of the CBA is described in the figure below:

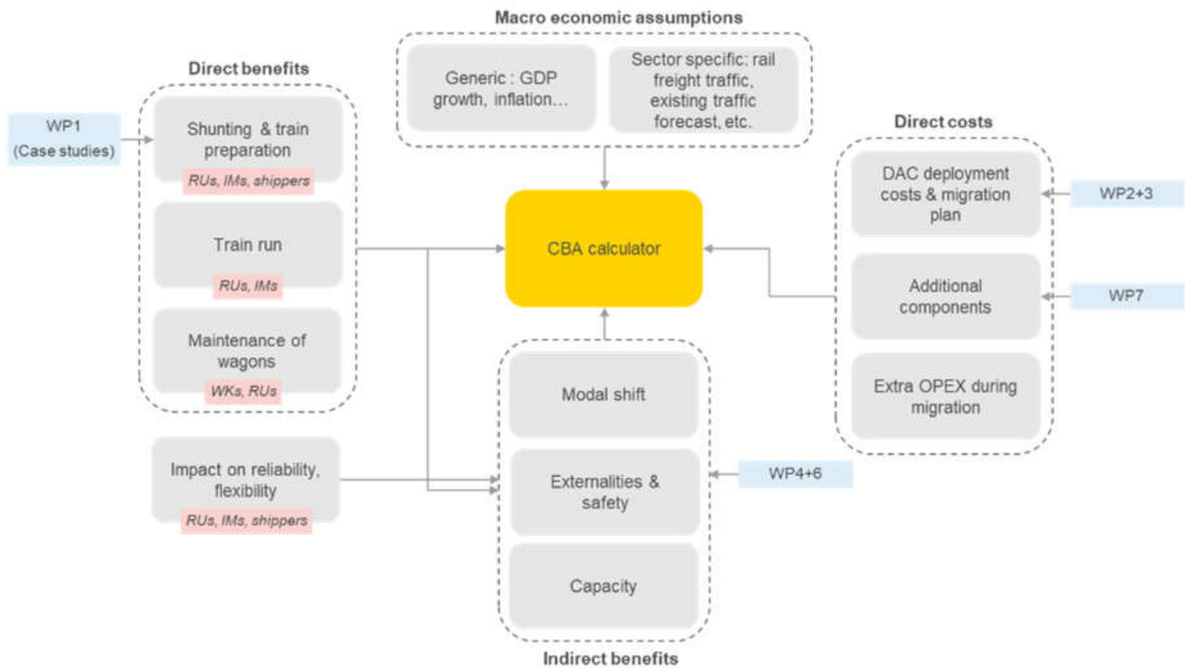

Figure 7 - Analysis Framework[5]

[5] WP1, WP2, WP3, WP4 and WP7 represent the other work packages of the EDDP

There are four main categories of inputs in the CBA:

- **Macro-economic assumptions**, which will give us the potential growth of freight flows to be carried in Europe per category of good and per mode of transport considering other initiatives (such as the deployment of all projects identified on the nine Core Network Corridors)
- **Direct costs**, which include the CAPEX of DAC and additional components, but also the impact of the deployment phase on the OPEX of Railway Undertakings
- **Direct benefits**, such as the time saved in train operations
- **Indirect benefits**, such as modal shift, the potential increase of capacity on the network, etc.

Each of the aspects (i.e. direct benefits, indirect benefits etc.) will be addressed separately in the following sections of the report.

5.3. DAC RELATED FUNCTIONALITIES

The potential impact of DAC, associated with different additional components, has been translated into DAC functionalities. When possible, each functionality has been quantified and then translated into direct costs, direct benefits or indirect benefits. Some functionalities could only be assessed in a qualitative way.

The list of functionalities and associates additional components is presented in the table below:

#	Functionality (DAC/automation use case)	Basis	Additional automation component
1	Automated coupling + manual uncoupling	DAC*	-
2	Automatic brake test & calculation of braking capacity	DAC*	Automatic braking test device
3	Recording of train composition + abandon of rear signal	DAC*	-
4	Heavier trains & longer trains (within existing infra limitations)	DAC*	-
5	Increased payload	DAC*	(elimination of buffers, modified new vehicle design)
6	Train integrity (enabling moving block operations)	DAC*	Train integrity system (+ ETCS level 3)
7	Increased speed via improved longitudinal forces	DAC*	-
8	Increased speed via better braking performance	DAC*	Electro-pneumatic brake

9	Wagon condition/performance info (incl. derailment detection)	DAC*	Wagon telematics
10	Telematics for customers	DAC*	Wagon telematics
11	Automated parking brake	DAC*	Automated parking brake system
12	Automatic uncoupling (remote)	DAC*	Actuator + automated parking brake system
13	Automated technical wagon inspection	DAC*	Wagon telematics + video gate + infra check points
14	Longer trains up to 1500m	DAC*	(infrastructural adaptations +) ep-brake/distributed power

** including key additional components required to reap the basic benefits of DAC, namely "communication backbone", "train composition detection", "draining valve for auxiliary air tanks" and "automated air valve"*

Table 3 - DAC Functionalities

5.4. DATA SOURCES

Three main sources of information have been used in the analysis:

- Studies and existing database, at EU and national level
- The other work packages from the European DAC Delivery Programme (EDDP)
- #20 stakeholders interviewed, sometimes multiple times

The source of information which has been used for each assumption is specified in the § below.

5.5. VALIDATION OF THE RESULTS

5.5.1. INVOLVEMENT OF THE SECTOR

The work on the CBA has been done in close cooperation with the sector, with 21 meetings with the railway industry through Work Package 5 in order to discuss the methodology and the assumptions used.

Moreover, a sector wide consultation has been launched at the end of 2022, which collected more than 160 comments from 25 different stakeholders, with a decent geographical representativeness, but for eastern Europe unfortunately:

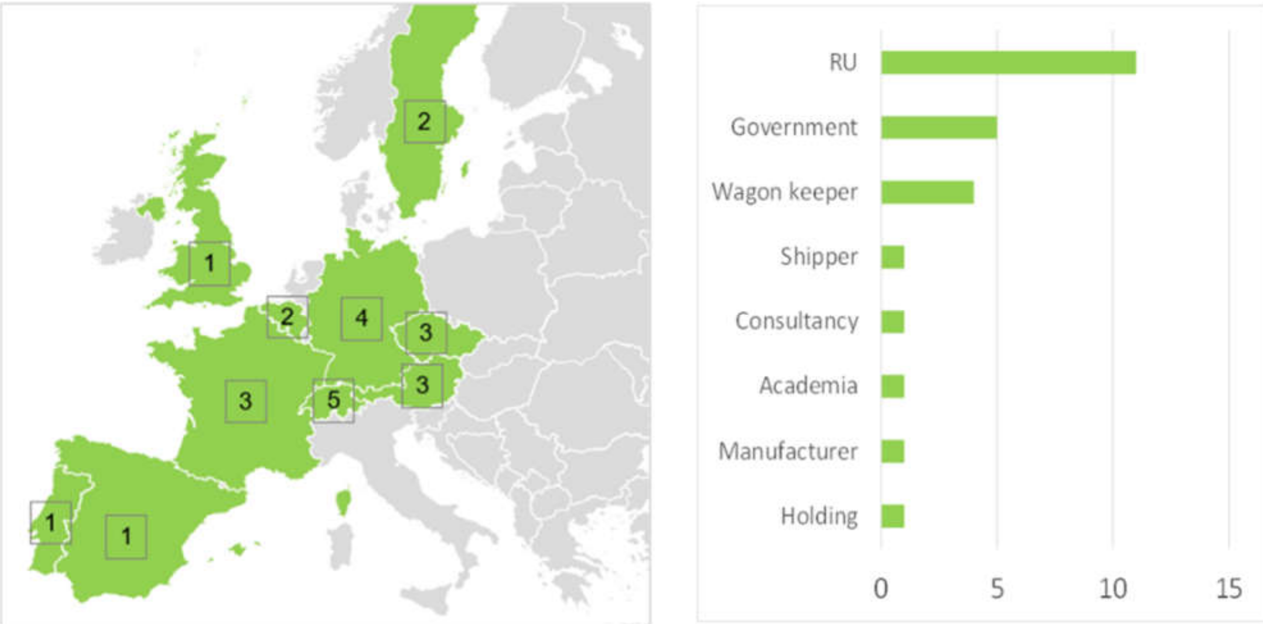

Figure 8 - Type and location of stakeholders who provided feedback during consultation

In the end, a significant part of the comments received were taken into account, either through a modification of the CBA, or through clarifications which were brought forward to the sector. **This report is also an answer to this consultation**, as some stakeholders were requesting more detailed information on the assumptions used.

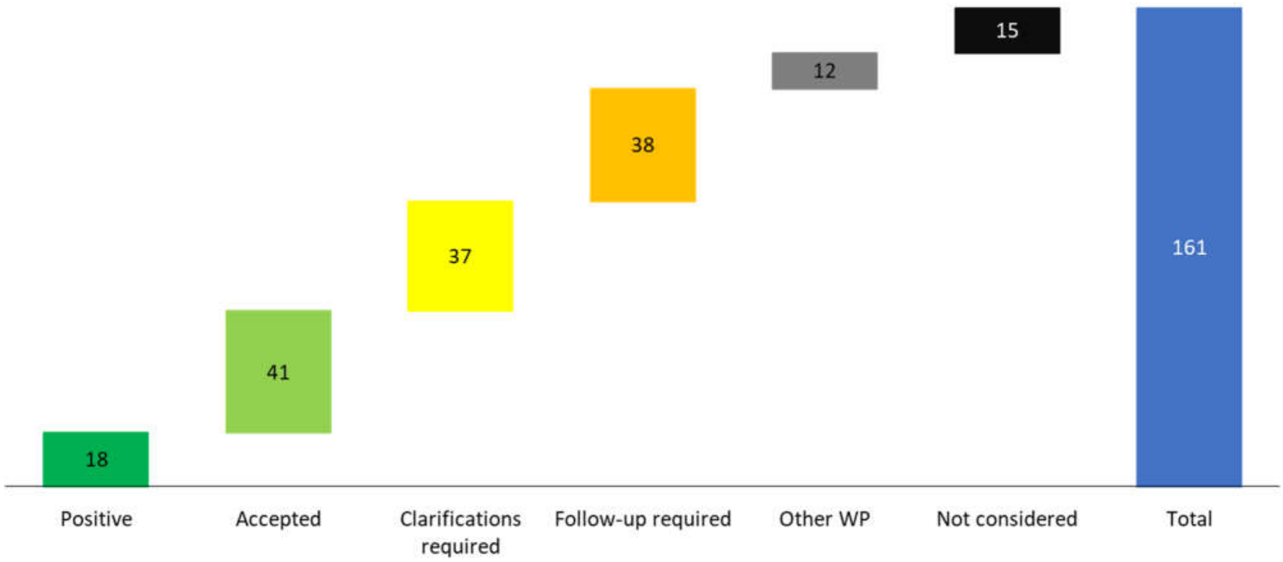

Figure 9 – Distribution of the comments received during the consultation

5.5.2. CASE STUDIES

Case studies have also been used for the validation of the results of the CBA. Indeed, the CBA is a macro-economic exercise, but it is also very important to check whether the overall results are consistent with what will happen for a single stakeholder. Therefore, 4 case studies have been developed, using two different approaches:

- The first approach consists in analysing in detail the process of a stakeholder, to check whether the benefits expected from DAC will actually materialize;
- The second approach consists in using the CBA tool and replace the EU values with the specific values of a stakeholder, and check if the results are consistent with its expectations.

The stakeholders involved in the case studies were:

- 2 shippers from 2 different industries
- 1 wagon keeper
- 1 integrated company (infrastructure manager & railway undertaking)

The findings of these case studies have been used to fine tune the parameters used in the DAC CBA.

5.6. LIMITATIONS AND INTERPRETATIONS

This CBA integrates all available information at 23/08/2023

- It is NOT a completed CBA, as the work of other work packages which are used as an input for the CBA are not finalised yet. Some open points and data need to be reviewed, complemented and validated (which will take place in EDDP, as up to now);
- Information was typically fragmented and incomplete. Despite continuous efforts, data quality can be improved;
- The transport forecast is partially based on a policy goal: the doubling of rail freight by 2050. It presumes an average annual growth of ~2.3%. Important factor to properly interpret results;
- The CBA does provide an insight into the direction and magnitude of what DAC implies for the rail sector.

Key points to be integrated and/or considered qualitatively:

14 use cases (e.g. derailment detection) have not been assessed.
Nor have their associated component costs been considered due to data gaps.

Time savings and conversion factors – values depend on how successfully the railway system as a whole adapts to DAC.
A topic of ongoing discussions.

Update cost assessment of final DAC design
Update assessment of coupler costs

Update implementation cost assessment based on final implementation plan, including e.g. staff training costs

Final assessment of DAC maintenance
Final assessment of DAC reliability

Final assessment administrative and possible authorisation costs

6. TRAFFIC FORECAST & MIGRATION SCENARIOS

6.1. TRAFFIC ASSUMPTIONS

At this point in time, there is no single transport forecast modelling tool that provides sufficiently robust insights into transport demand and supply in Europe until 2057. As such, several sources were consulted and assumptions applied. This chapter shall explain how this has been done and which data have been selected. Particularly, it will lay out how:

- A baseline for 2019, split per market segment and considering traffic in t x km, in train x km and in number of trips has been developed
- And how this baseline has been used in:
  - A scenario which considers the effect of DAC on the capacity of the network
  - A scenario which does not consider the effect of DAC on the capacity of the network (capacity constraint)

6.1.1. TRAFFIC IN 2019

The current situation in the rail freight sector is analysed to better develop and assess transport forecasts.

Information on tonnes-kilometres and tonnes were obtained from Eurostat and national statistical offices. Where large differences were found, meetings with national stakeholders were organised to identify the cause and agree on the most robust value. Values for 2019 were selected as they were believed to be more representative than values from 2020 (which were impacted by COVID 19).

Information on the number of trips was obtained from the group of railway regulators (IRG-rail) and cross-checked against national publications, which were obtained for 12 countries. Interactions with sector stakeholders helped us to determine the most plausible trip counts for all countries in scope. Having said that, there are substantial differences between countries in how trip statistics are codified and shared with data collectors. Some countries include trips between and on service facilities, whereas others apply a more narrow definition of traffic on the main network. The more conservative estimates were used as there were more reliable numbers using this interpretation. It does imply that we suspect that the number of considered trips could be increased if an accurate view could be developed on the number of trips in service facilities (i.e. which also includes some large port areas).

As the benefits are different for each production system, the statistics needed to be disaggregated by production system. Many national and European publications were consulted to approximate the share of each segment in terms of tonnes-kilometres. To derive the total number of trips per production system one cannot simply take that share of the estimated total trip count. The reason is that the average weight and distance travelled of Block / Intermodal Trains (IT) / Single Wagon Load (SWL) trains differs. For example, generally more SWL train are needed to achieve the same tonnes-km performance as with Block trains[6].

Interview data and several consultative iterations in WP5 helped to more accurately identify the numbers for each production system. The results for 2019 are summarized in the figure below:

[6] ERA (2022) DAC CBA Model

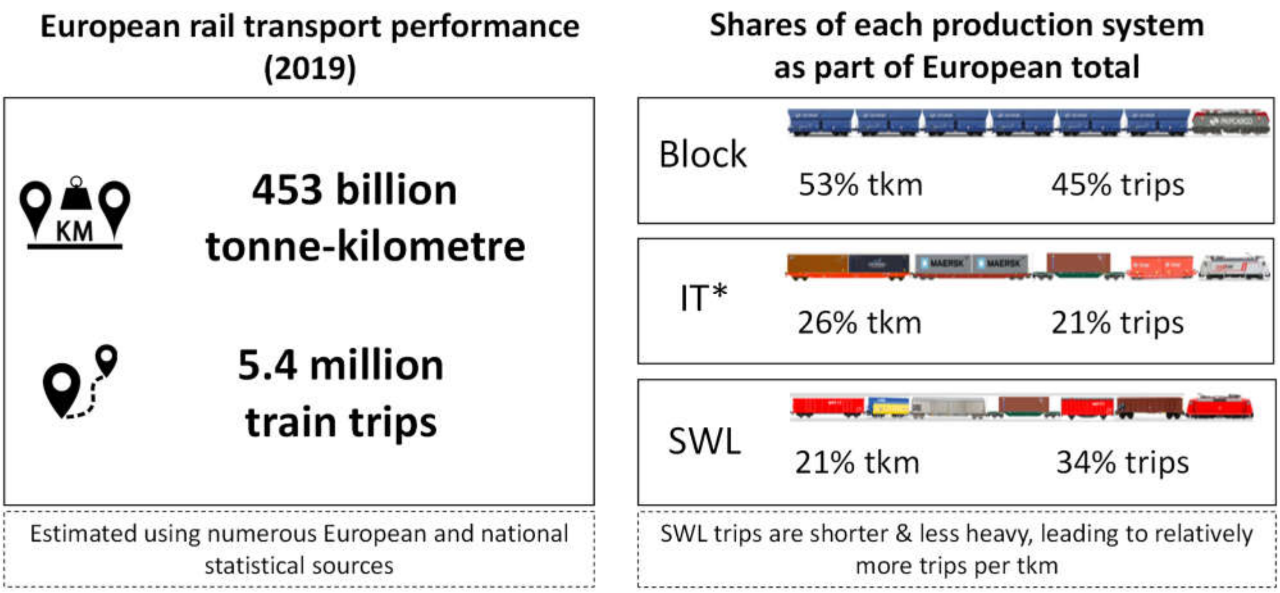

Figure 10 – European rail freight traffic in 2019 (in total and per production system)

These results have then been disaggregated at the national level for train trips, tonnes-km and tonnes. Train trips were subsequently categorised as domestic, international or transit trips using Eurostat data. This categorisation of trips is important to adequately assign certain benefits (e.g. transit trips do not need to be considered to determine the total time savings at sites).

The results for the train trips is shown in the figure below:

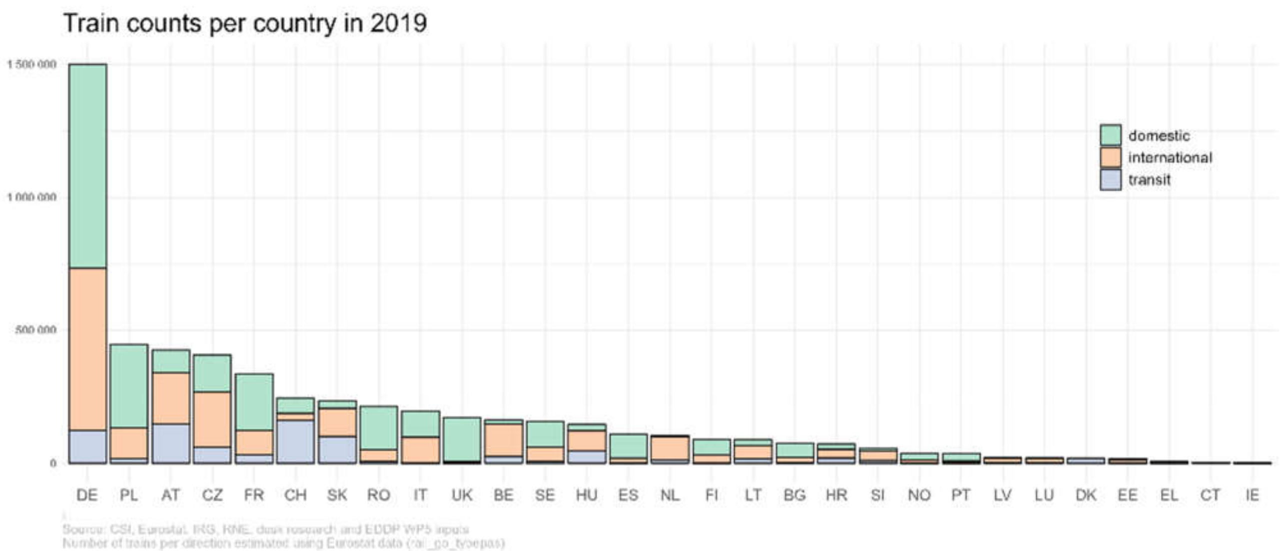

Figure 11 – Train counts in 2019 per country

6.1.2. TRAFFIC FORECAST

As indicated, there was no transport model at our disposal that could satisfy all data needs. Moreover, considering that the project has a European scope, aligning assumptions with those for other large-scale European transport CBAs is imperative to facilitate comparisons. Therefore, it was decided to draw upon multiple European sources of information to define the potential growth of rail freight until 2057.

First of all, it is important to remind that rail freight traffic has been stagnating in the past years, leading to a decrease of its modal share:

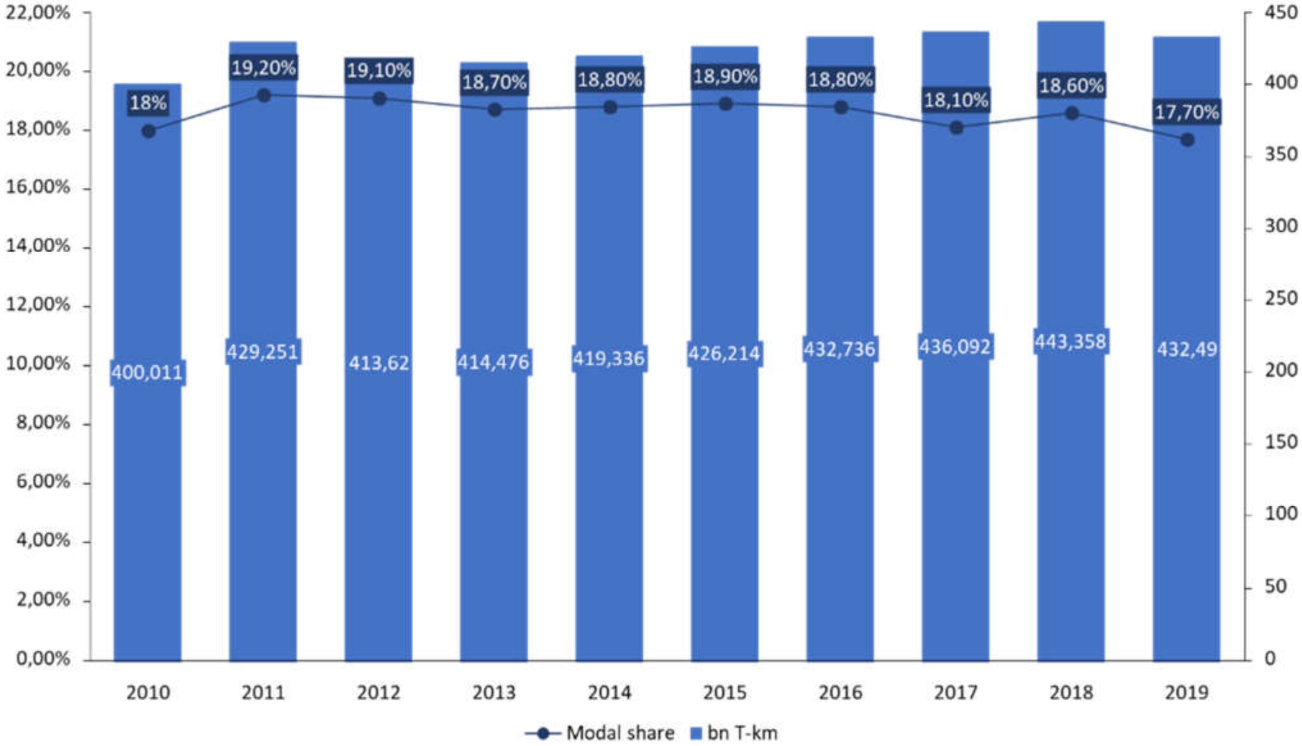

Figure 12 – Rail freight transport in Europe (2010-2019, Eurostat)[7]

Road is still the dominant mode of transport, with a market share of 75% on t-km. Moreover, prior to the COVID-19 pandemic, the sector was expected to continue growing, with a projected increase of 40% by 2030 and around 80% by 2050[8]. Even though road transport is making strong progress in decreasing its external costs, the trend is clearly not aligned with the EU ambition to reduce the transport sector's emissions by 90% in 2050, as stated in the EU Green Deal and the "Sustainable and Smart Mobility Strategy" (SSMS)[9].

Therefore, the SSMS is proposing for some important policy measures which are expected to change the current trend, including:

- Revision of the Rail Freight Corridor Regulation;
- Review of the regulatory framework for intermodal transport, including the Combined Transport Directive;

[7] Belgium and Greece have been excluded from the calculation as the data are not available for the whole period for these 2 countries

[8] EUI, 2022

[9] SWD(2020) 331 final

- Issue guidelines for operators and platforms on informing users about the carbon footprint of their deliveries and on offering sustainable delivery choices;
- The implementation of the 'polluter pays' and 'user pays' principles in all transport modes;
- The completion of the TEN-T network.

These measures are expected to lead to an increase by 50% in 2030 of rail freight transport and a doubling by 2050 versus the 2015 figures.

These values have been cross-checked with several sources:

- the traffic forecast of OECD/ITF transport outlook[10], which foresees a tripling of rail freight by 2050
- the commitment of the European Rail Freight CEOs from the Community of European Railway and Infrastructure Companies (CER) and the International Union of Railways (UIC): "30 by 2030" commitment (a rail modal share of 30% by 2030), which is considered today as "an absolute and necessary minimum"[11]
- The forecast for specific market segment, like for instance for intermodal transport[12]

Based on all the sources of information analysed, the target associated with the policy measures listed in the SSMS strategy were deemed reasonable and have been used in the CBA.

Moreover, it should be noted that one of the measures of the SSMS is linked with **'The deployment of new technologies such as digital coupling and automation'.** The communication does not specify the extent to which DAC, or any other initiative, contributes to achieve the goals. In line with the above, the effect of DAC on the capacity of the network and growth is deemed integral to achieving green deal objectives (see below for more explanations). Therefore, two traffic scenarios have been considered:

- A scenario which is considering the effect of DAC on the capacity of the network. This scenario enables the doubling of rail freight traffic, and is presented in §6.1.2.1 below.
- A scenario which is not considering the effect of DAC on the capacity of the network (capacity constraint). This scenario is limiting the growth of rail freight, and is presented in §6.1.2.1 below.

6.1.2.1. Traffic forecast – DAC implementation and capacity constraints

As explained in the introduction, it is considered that the growth of rail freight can only be achieved if the capacity of the network is increased, by means of the expected investments in the TEN-T network, but also considering the effect of DAC on capacity.

DAC is seen as a key enabler of train integrity monitoring for rail freight operations, which is a pre-requisite to deploy ETCS level 3, leading to potentially significant capacity increase, as stated in the "Report on capacity/productivity gains, modal shift potential, market opportunities and quantification of external effects"[13]:

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[10] OECD (2021) Freight transport: Bold action can decarbonise movement of goods [Available at: https://www.oecd-ilibrary.org/sites/0c13b23d-en/index.html?itemId=/content/component/0c13b23d-en#section-d1e22595]

[11] https://www.cer.be/media/press-releases/european-rail-freight-ceos-reaffirm-ambition-30-percent-modal-share-by-2030

[12] UIRR (2022) ZCCT Roadmap study [Available at https://www.uirr.com/en/component/downloads/downloads/1741.html]

[13] DELIVERABLE 7.1, "Report on capacity/productivity gains, modal shift potential, market opportunities and quantification of external effects", project "DACcelerate"

"In fact, train integrity represents the main important aspect to be considered for the introduction of ETCS level 3. Train integrity must be ensured to guarantee safety of the system."

Usually, the impact of an investment on capacity can be assessed the following way in a CBA:

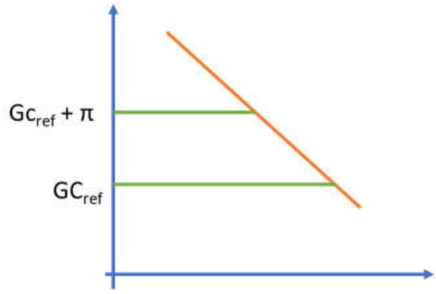


Figure 13 – Theoretical impact of a capacity constraint on traffic

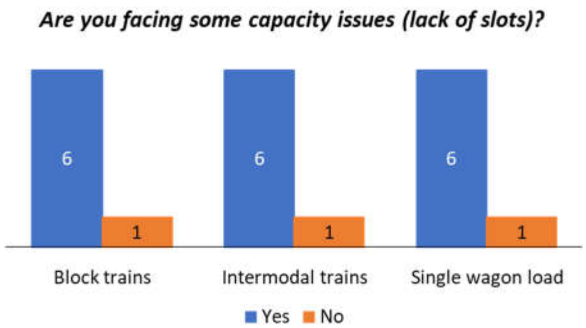
In the figure above:

- GCref represents the generalized cost in the reference scenario with no capacity constraint
- GCref + π represents the generalized cost with the capacity constraints, which can be seen as an extra cost (π)
- π is usually assessed using a traffic modelling tool

As indicated before, there is no modelling tool available at EU level to assess the value of π. Therefore, it was decided to assess the traffic which could be reached without DAC considering the extra capacity which could be achieved with DAC + ETCS level 3. For the latter, two inputs have been used:

- The results of the study carried out by EDDP work package 6, which demonstrated that a theoretical capacity increase of 30% could be achieved under certain circumstances.
- A survey with railway operators, carried out in September 2022, to check whether there was unsatisfied demand, and therefore if this extra capacity would actually be used by rail freight. Two questions were asked for each market segment (block trains, intermodal, single wagon load):
    - Is there a capacity issue?
    - If yes, could you assess the unsatisfied demand?

  7 answers could be collected. Answers are shown in the figures below:



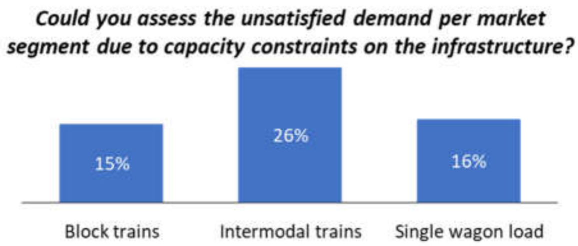


Figure 14 – Survey on capacity issues for rail freight operators – September 2022[14]

Acknowledging the results and limitations of the survey and the theoretical analysis carried out by WP6, it was considered that only 95% of the traffic growth of the "Sustainable and smart mobility strategy" could be achieved without DAC.

The logic is the following:

- DAC is a key component of the 'Sustainable and smart mobility strategy' goal to double rail freight by 2050. DAC shall not only improve the efficiency of rail freight operations, but shall also create additional capacity
- The maximum theoretical capacity increase is 30% (based on WP6)
- Considering the limitations of this assessment, a conservative value of only half of this capacity increase is proposed (15%)
- The benefits of this extra capacity can only be partially assigned to DAC (as this capacity increase also depends on ETCS level 3 deployment) and the share which will be used by rail freight is only part of it (as capacity increase could also be used by passenger trains). This assumption was set at 1/3, **leading to a very conservative value of 5% of rail freight traffic increase in 2050 that is attributed to the higher capacity created thanks to DAC**

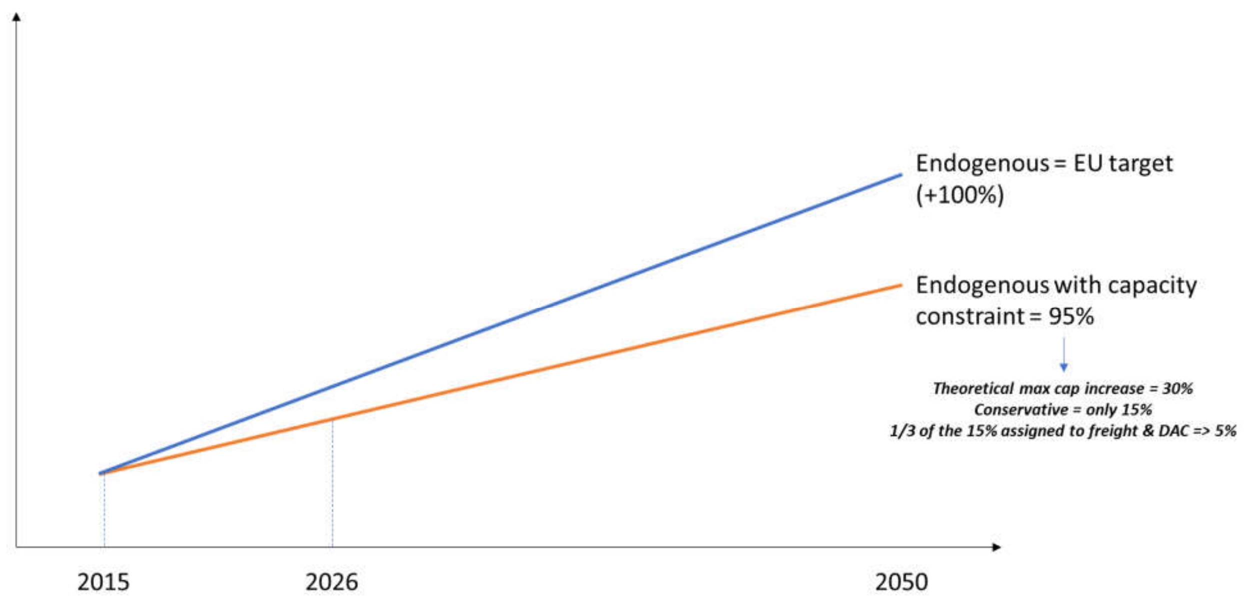


Figure 15 – rail freight traffic growth with and without capacity constraint

6.1.2.2. Traffic forecast – Growth by segment

[14] The only negative answer to the question "Are you facing some capacity issues (lack of slots)?" is coming from an infrastructure manager

The OECD/ITF transport outlook[15] was used to develop a better understanding of the forecasted outlook of block, intermodal and SWL. The OECD traffic forecast includes three distinct scenarios depending on the level of ambition of future carbon policies and recovery of rail freight transport over the coming decades. The scenarios are named **Recovery**, **Reshape** and **Reshape+**.

The definition of policies within these scenarios was based on 1) inputs from experts in the form of a policy scenario survey disseminated to policy experts from all regions of the world in early 2020, 2) ITF research[16,17,18] and 3) from ITF workshops held for projects under the ITF Decarbonisation Initiative in 2020[19,20]. All three scenarios include the same baseline economic assumptions to reflect the impact of the Covid-19 pandemic: a five-year delay in GDP and trade projections compared to pre-Covid-19 levels.

In the **Recovery** scenario, freight transport in the coming decade is shaped by pre-pandemic thinking in terms of policies, investment priorities and technologies. Governments prioritise established economic activities to accelerate the recovery. The main objective is the return to a pre-pandemic "normal".

In the **Reshape** scenario, the impacts of COVID-19 on freight transport also gradually disappear by 2030, as under Recover. Reshape differs in that policymakers set ambitious climate goals and implement stringent policies in their pursuit. Also, these more ambitious policies are put in place worldwide, not only regionally.

In the **Reshape+** scenario, positive decarbonisation trends from the pandemic are locked in through policies that lead to permanent change. As in the other two scenarios, the negative impacts of Covid-19 on freight transport are overcome by 2030. As in the Reshape scenario, governments set ambitious decarbonisation targets and implement policies that can deliver them. By aligning economic stimuli with climate and equity objectives, they leverage economic recovery for environmental and social sustainability[21].

The resulting traffic forecasts across the analysed production networks and different scenarios for 2060 is shown in Figure 16.

The forecast that was identified as the closest fit to the EU Green Deal was the Reshape Scenario. The growth per production system in the Reshape scenario was then considered under the assumption of a doubling of total rail freight transport in line with the CBA forecast figures. Subsequently, these numbers were broken down according to each production system conditioned by market forces affecting the distribution between them in the future.

[15] OECD (2021) Freight transport: Bold action can decarbonise movement of goods [Available at: https://www.oecd-ilibrary.org/sites/0c13b23d-en/index.html?itemId=/content/component/0c13b23d-en#section-d1e22595]
[16] ITF (2018), Decarbonising Maritime Transport Pathways to zero-carbon shipping by 2035
[17] ITF (2018), Towards Road Freight Decarbonisation Trends, Measures and Policies,
[18] ITF (2019), Enhancing Connectivity and Freight in Central Asia
[19] ITF (2019), Modelling International Transport and Related CO2 - Expert Workshops
[20] ITF (2020), Setting Scenarios for Non-Urban Transport and Related CO2 Measures - Workshop Summary
[21] OECD (2021) Freight transport: Bold action can decarbonise movement of goods [Available at: https://www.oecd-ilibrary.org/sites/0c13b23d-en/index.html?itemId=/content/component/0c13b23d-en#section-d1e22595]

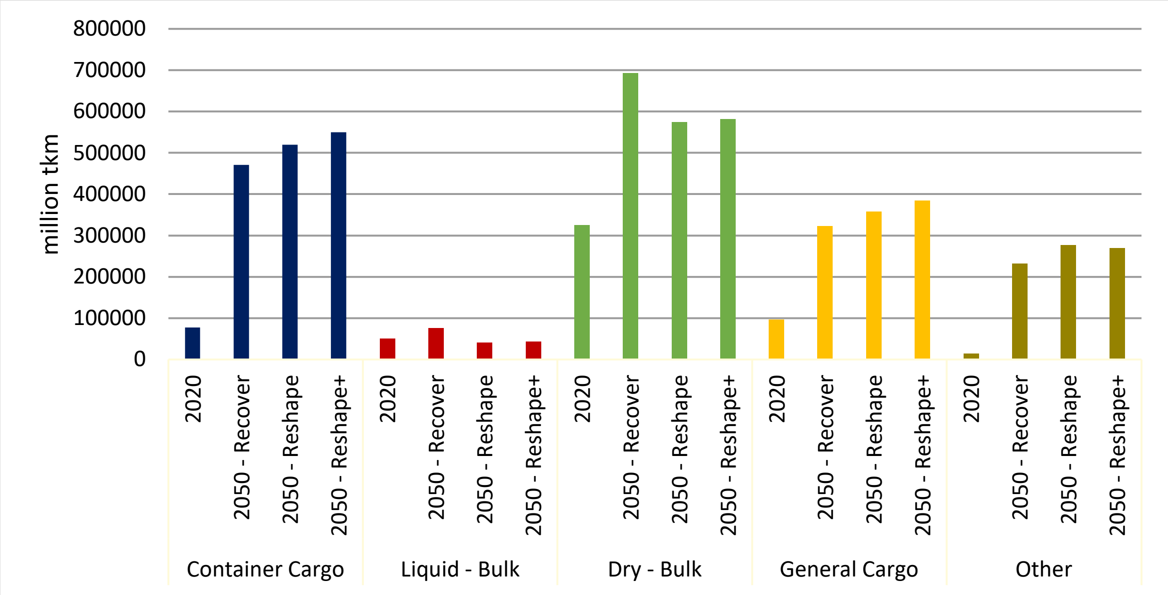


Figure 16 - OECD Forecast for 2050 for each production network and different scenarios

Through expert judgement the traffic volumes per cargo type were converted to the segments that are under consideration by this CBA (i.e. Block, Intermodal and SWL). The applied conversion percentages are shown in Table 4.

	Container	General	Bulk - Dry	Bulk - Liquid	Other
Block		15%	70%	70%	
Intermodal	85%	15%	10%	5%	60%
SWL	15%	70%	20%	25%	40%
Total	*100%*	*100%*	*100%*	*100%*	*100%*

Table 4 - Mapping of cargo types across the three market segments

After the conversion the traffic growth figures per market segment were obtained, as shown in Table 5.

Market segment	Overall Growth (%)
Block	+43%
IT	+218%
SWL	+126%
Total	~ +100%

Table 5 - EU growth percentages based on EU Green Deal ambitions and OECD Reshape scenario[22]

[22] ERA (2022) DAC CBA Model

Total growth until 2050 per segment and their respective market share in 2020, 2030 and 2050 is summarized in the figure below:

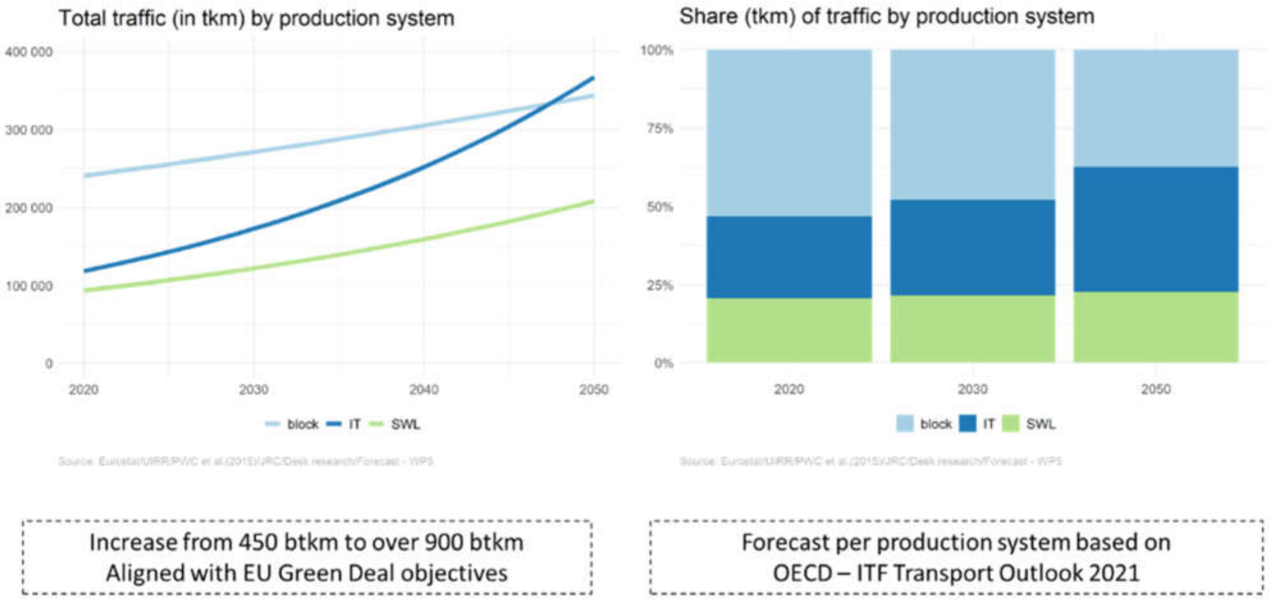


Figure 17 - Traffic forecast per production system [23]

The same annual growth rates have been applied for the period 2051-2057.

6.1.2.3. Traffic forecast – Modal shift thanks to DAC

Beyond the two trajectories presented above, modal shift thanks to DAC has also been considered in the CBA. This modal shift achieved through:

- A drop in the price for rail freight, thanks to a DAC-enabled decrease in operating costs;
- An improved performance of rail freight transport, which allow it to compete for markets which are not accessible today.

The assumptions on modal shift are presented in the section 9 below.

6.2. MIGRATION SCENARIOS

Another important input for the CBA is the migration scenario which is going to be used for the deployment of DAC. Two parameters have to be considered for this:

- The size of the fleet which has to be equipped (both wagons and locomotives)
- The path for the migration

All the figures presented below are coming from the work of EDDP work package 3 on DAC migration.

6.2.1. SIZE OF THE FLEET IN EUROPE

6.2.1.1. Wagons

[23] ERA (2022) DAC CBA Model

The total size of the fleet which is expected to be impacted by DAC deployment is estimated at 460 000 wagons., split in two categories:

- wagons belonging to the core wagon load system, representing 210 000 wagons. These wagons are used in mixed traffic, in often changing compositions (e. g. single wagon load)
- wagons not belonging to the core wagon load system: wagons in relatively stable compositions (e.g. block/shuttle trains)

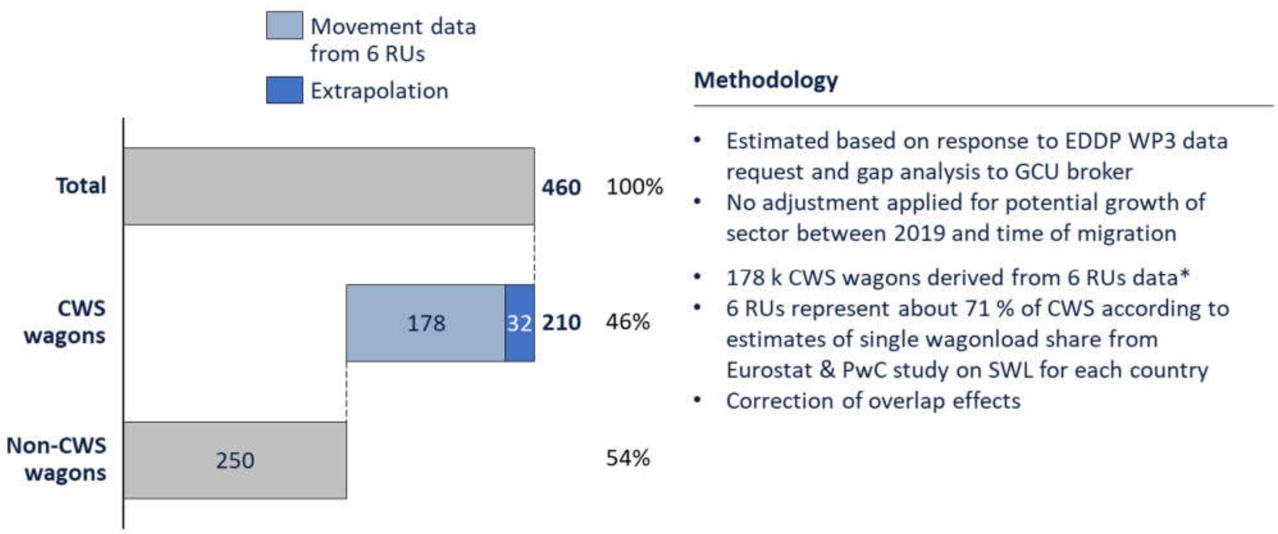


Figure 18 – size of the fleet of wagons affected by DAC deployment in Europe

It is noted that the current number of wagons registered in the European Vehicle Register is over 600 000. EDDP WP3 reasoned, based on wagon fleet analyses and expert inputs, that a large number of wagons is indeed registered, but does not perform any substantial transport operations. Therefore, the total wagon fleet in scope was deemed to be 460 000 wagons.

6.2.1.2. Locomotives

The European fleet of locomotives used in freight transport is shown in the figure below:

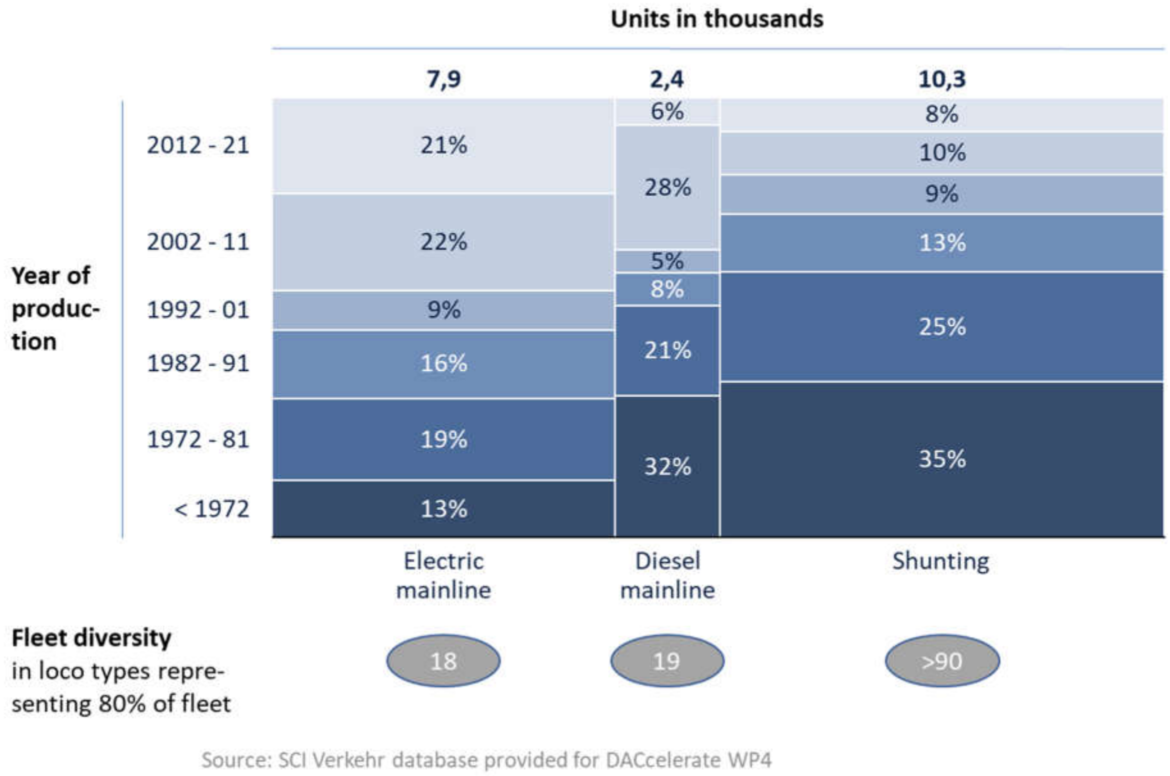


Figure 19 – size of the fleet of locomotives affected by DAC deployment in Europe

6.2.2. MIGRATION

6.2.2.1. Migration - wagons

For the wagons, the migration strategy depends on the type of fleet considered.

For the CWS (representing approximately 210 000 wagons), a 'big-bang' approach has been privileged. After careful preparation, a very short period (2-3 weeks) will be dedicated to convert the entire CWS fleet towards DAC[24]. This is expected to minimize the loss of operations.

In this scenario, the underlying assumption is a big bang retrofit to DAC 2 level, followed by a rapid upgrade to DAC 5 in a very short period after big bang. The success in technology and authorisation process development in the ER JU Flagship Project 5 might change this scenario to a direct DAC 5 migration in big bang, which currently cannot be guaranteed.

For the non-CWS (representing approximately 250 000 wagons), a gradual retrofit is foreseen, aligned to the greatest extent with maintenance cycles. Direct migration to DAC 5 is assumed in the model due to sufficient time in workshops for DAC 5 installation and authorisation.

Wagons shall be retrofitted to the greatest possible extent to minimise scrapping and dual operations. Economically / technically justified exceptions need to be analysed and defined.

[24] As the whole fleet of the CWS is equipped in a very short period of time, this strategy has been called 'big-bang'

The current overall DAC migration strategy is summarized in the figures below:

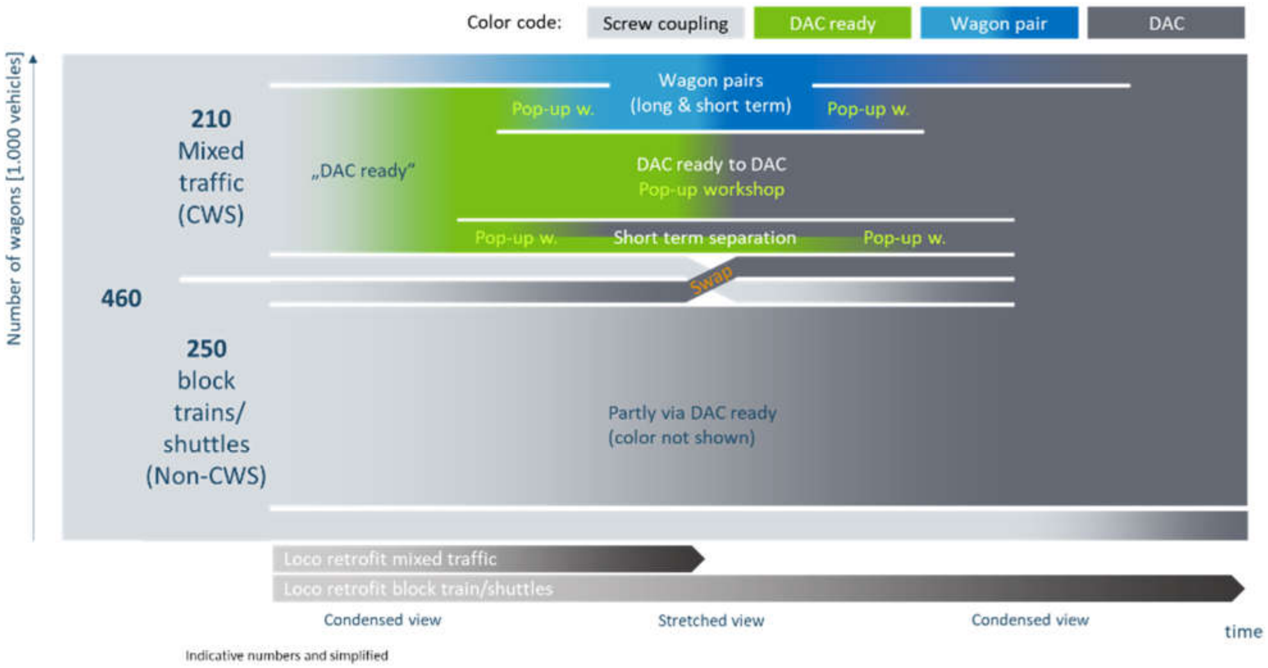


Figure 20 – DAC migration strategy

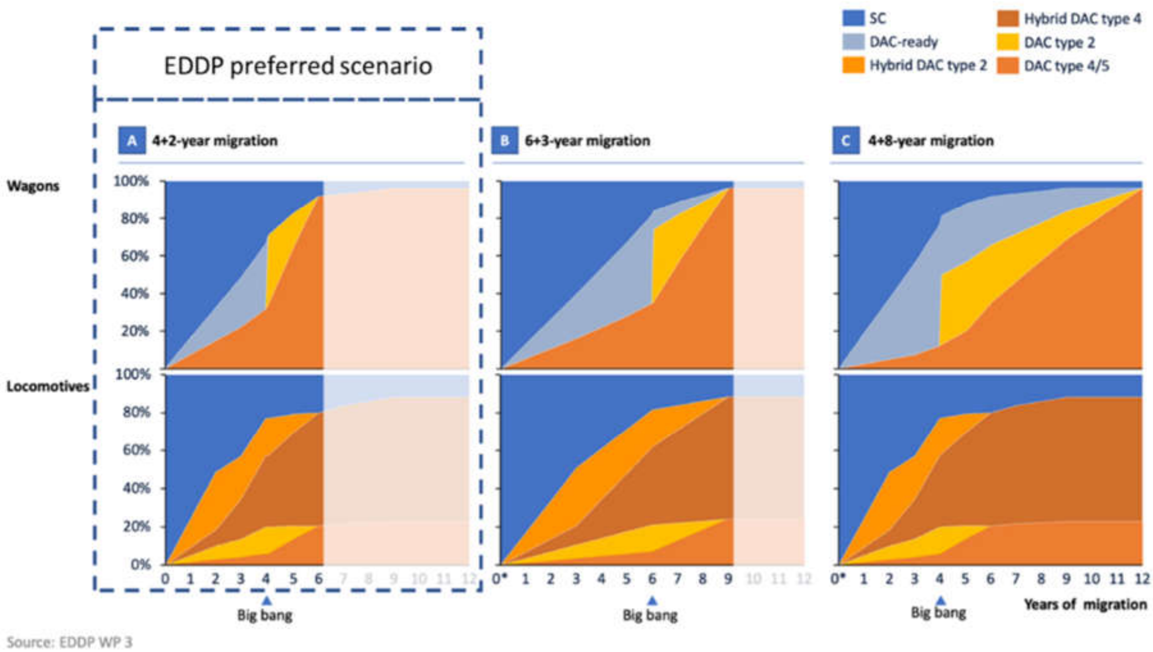


Figure 21 – DAC migration strategy – fleet structure by coupler mode

6.2.2.2. Migration - locomotives

The migration scenario used for locomotives is spread over 6 years (2028-2033), with 2000 locomotives equipped / year, but in 2031 where 3 500 locomotives are expected to be equipped.

On top of that, 250 locomotives are expected to be equipped annually (starting in 2028) through the “normal” renewal of the fleet.

7. DIRECT COSTS

The costs considered in the analysis are the listed below:

- The cost of the couplers and the cost of mounting the couplers (CAPEX)
- The cost of the additional components required to deliver all the targeted functionalities. These additional components are bundled into technical packages in order to present a range of potential impacts for DAC (CAPEX)
- The infrastructure and IT costs (CAPEX)
- One-off costs associated with DAC deployment (OPEX)
- Recurring costs after DAC deployment (OPEX)

Corresponding assumptions are presented in the following paragraphs.

7.1. COUPLER COSTS

The coupler costs include:

- The cost of the DAC itself;
- But also the costs of mounting the DAC on a wagon / a locomotive, which is covering:
  - The cost of adapting existing workshops or the cost of new workshops (like pop-up workshops)
  - The staff costs (including training)
  - The storage and logistic costs associated with DAC deployment

Cost assumptions are coming from other EDDP work packages.

For **wagons belonging to the CWS,** the following costs have been considered :

- The first step will be to prepare the wagon to facilitate the mounting of DAC during the big bang ('DAC ready' retrofit). Two different costs have been introduced in the CBA:
  - The cost of a basic retrofit, estimated at 1000 € / coupler
  - The cost of a complex retrofit, estimated at 1500 € / coupler
- Then, wagons are equipped with DAC 2 during the big bang. A cost of 5000 € / coupler has been used in the CBA. As a reminder, 2 couplers are required per wagon and per locomotive (one on each side). Moreover, a cost of mounting the coupler on the wagon has been taken into consideration. This cost is differentiated according to the level of complexity of the operation (390 € / unit for a basic retrofit, 2000 € / unit for a complex retrofit). On top of that, an extra cost of 200 € / wagon for administrative & authorisation has been considered.
- Finally, the DAC 2 is replaced with a DAC 4/5, with the same unit price (5000 €), and considering the same mounting cost as presented above (390 € / unit for a basic retrofit, 2000 € / unit for a complex retrofit), and also the same administrative and authorisation cost (200 € / wagon).

As there is no assessment yet on the number of wagons which have to go through a complex retrofit, the assumption taken was to use the cost of a basic retrofit for all wagons of the CWS.

For the deployment of DAC on wagons **not** belonging to the CWS, the only costs to be considered are:

- The cost of the DAC 4/5 coupler (5000 € / unit)
- The cost of mounting the coupler (390 € / unit for a basic retrofit, 2000 € / unit for a complex retrofit)
- The administrative and authorization cost (200 € / wagon)

As for wagons belonging to the CWS, as there is no assessment yet on the number of wagons from the non-CWS which have to go through a complex retrofit, the assumption taken was to use the cost of a basic retrofit for all wagons of the non-CWS.

For the **deployment of DAC on locomotives**, the costs considered are:

- The cost of the DAC 4/5 coupler (10 000 € / unit)
- The cost of mounting the couplers (20 000 € / loc for a basic retrofit, 40 000 € / loc for a complex retrofit)
- The administrative and authorization cost (200 € / loc)

The corresponding costs are shown in the figure below:

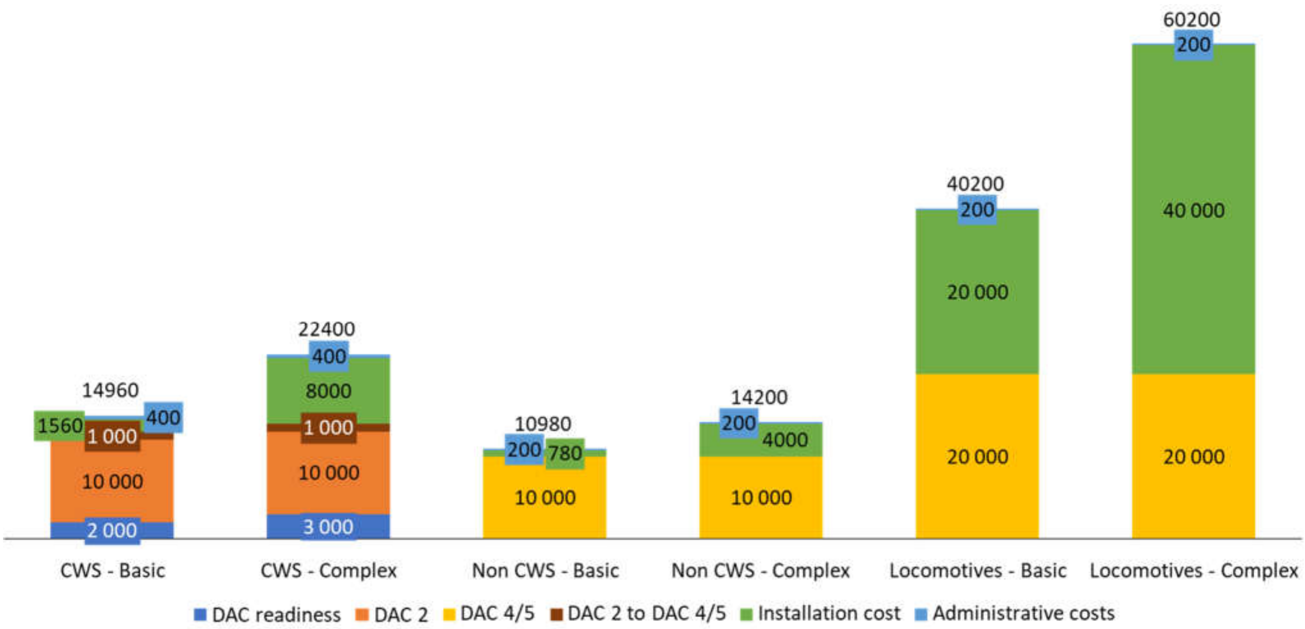


Figure 22 – DAC retrofitting costs

Moreover, an extra cost for **new wagons and locomotives** equipped with DAC (compared with the cost of a wagon / locomotive equipped with screw couplers) has also been considered: 3 500 € / wagon and 8 000 €/ locomotive.

The life expectancy of a digital coupler is supposed to be at least 30 years.

7.2. ADDITIONAL COMPONENTS AND TECHNOLOGICAL PACKAGES

DAC is one of the key enabler of the digitalization of rail freight transport. As explained in §5.3 above, multiple new functionalities can be developed thanks to DAC and additional components. But of course, these additional components have a cost, which has been taken into account in the CBA.

With the tool developed it is possible to test all the combinations of additional components. Nevertheless, for the clarity of the report, additional components have been bundled in "technological packages", with the objective to represent the widest range of possibilities offered by DAC:

Components / tech packages	Tech package 1	Tech package 2	Tech package 3	Tech package 4
DAC 4	X	X	X	X
Communication backbone	X	X	X	X
Train composition detection	X	X	X	X
Draining valve for auxiliary air tanks	X	X	X	X
Automated air valve	X	X	X	X
DAC 5		X	X	X
Automated brake test			X	X
Automated technical wagon inspection				X
Automated parking brake				X
Tail light (control device)				X

Table 6 – Technological packages used in the DAC CBA

The **first "tech package"** only considers DAC 4 and the associated communication system.

The **second "tech package"** corresponds to DAC 5.

The **third "tech package"** considers an automated brake test device on top of tech package 2.

And finally, the **fourth "tech package"** considers all the components from tech package 3 plus equipment required for automated wagon inspection on the wagon and for automated parking brake. It can be seen as **the upper bond of the potential effect of DAC with the functionalities identified and quantified today**. Unfortunately, the identification of the additional components (and corresponding costs) to deliver an automated wagon inspection is still on-going; therefore, the costs associated with tech package 4 might be underestimated.

Corresponding costs, coming from other EDDP work packages, are detailed below:

Component	Cost € / wagon
Communication backbone	3 970 €
Train integrity and train composition determination	875 €
Automated venting device	370 €
Automatic uncoupling (type 5) actuator	1 880€
Automatic braking test device	1 575 €
Automated parking brake system	2 350 €
Wagon telematics	1 175 €

Table 7 – Cost of the additional components used in the DAC CBA

The life duration of these additional components is equal to 12 years.

7.3. INFRASTRUCTURE COSTS

The infrastructure managers will have to change their buffer stops in Europe in order to accommodate the new digital couplers. A unit cost of 5 000 € / buffer has been used in the CBA. The total number of stops at EU + CH + NO + UK level has been estimated from the number of buffer stops in Germany and Austria (only known values), using the length of lines / country.

The total number of buffer stops in geographical scope is estimated at approximately 83 000. In a simplified approach, all buffers are changed in 2028 in the CBA. The life duration of a buffer is supposed to be equal to 30 years.

7.4. IT SYSTEMS COSTS

As explained above, DAC is an enabler for new ways to operate in rail freight but also for new digital services. But to cope with the new possibilities, IT systems will have to be modernized and upgraded.

A lump sum of 600 M€ has been considered in 2028 for this IT investment. There is no replacement cost foreseen in the future for this investment: it is considered that IT maintenance costs are also required without DAC, and that this investment would not generate significant extra maintenance costs compared to the scenario without DAC.

7.5. ONE OFF COSTS

Two types of costs have been considered here:

- The extra OPEX for the fleet which is not going to be equipped with DAC (because it would be too complex, or because some wagons or locomotives are too old and their remaining life expectancy does not justify to equip them with DAC)
- The loss of revenues during migration

As explained in §42 above, other costs like the costs of adapting existing workshops or the costs of the staff for mounting the couplers are already considered in the coupler costs (CAPEX).

7.5.1. EXTRA OPEX FOR THE FLEET NOT EQUIPPED

Another extra cost of €5000/wagon for wagons and locomotives[25] which are **not going to be equipped** with DAC has also been considered, as there will be some extra cost to **keep on operating** those wagons and locomotives:

- Cost to isolate the screw couplers wagons from the rest of the fleet
- Transportation costs to bring those wagons in the right location
- Loss of economic value of wagons due to limited scope of operations

Finally, a unit cost of 5 000 € / wagon and 50 000 € / locomotive[26] for **scrapping wagons and locomotives** which would be too expensive to retrofit or to redirect has also been considered.

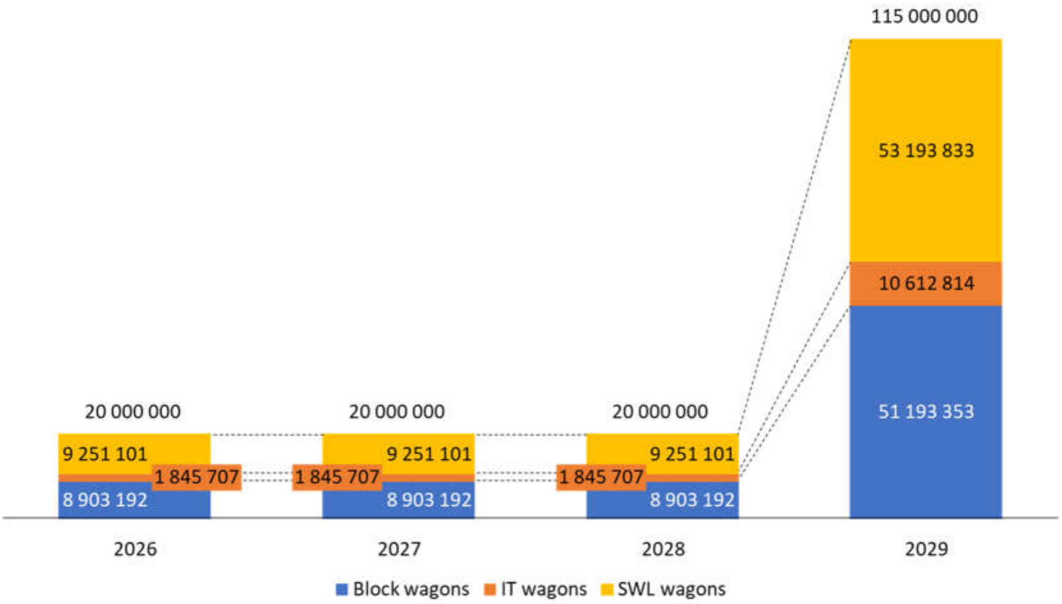


Figure 23 – Extra OPEX for the fleet not equipped

[25] In the current CBA, this value is not used for the locomotives as the number of locomotives not equipped and which continue operating has not been assessed.

[26] In the current CBA, this value is not used for the locomotives as the number of locomotives not equipped and which continue operating has not been assessed.

7.5.2. POTENTIAL LOSS OF REVENUES

The very crude assumption is that if SWL system is longer than 4 weeks out of operations, the entire SWL business comes to a standstill (customers change permanently to e.g. road transport). The table below shows the potential loss of revenues for each year of parallel operations:

Total	Block	IT	SWL	Total
Share tkm (WP5)	53%	26%	21%	/
Revenue (est. bnEUR from RMMS 2018)	8.6	4.2	3.4	**16.25**
Loss due to too long retrofit period (WP3)	0%	0%	100%	/
Revenue loss (bnEUR)	0	0	3.4	**3.4**

Table 8 – Potential loss of revenues due to parallel operations

Recovery loss of revenue (after implementation is completed) can be assumed to be 30% of temporary revenue loss for the double of the implementation duration. However, it is assumed that the implementation strategy will prevent such a situation from occurring.

7.6. RECURRING COSTS

The last costs considered in the CBA are the costs linked to the maintenance of the new equipment. **This is estimated at 300 € / year / wagon and locomotive equipped** (source: EDDP work packages)**.**

8. DIRECT BENEFITS

The DAC deployment will enable new functionalities for rail freight transport but also on the EU rail network. Multiple benefits are expected, ranging from improvements in shunting operations to shortened periods of wagons being stationary in the marshalling yards.

This section presents a list of potential direct benefits (i) derived from the DAC impact on functionalities (see section 5.3 for the list of functionalities explored) and (ii) identified during the development of the CBA. Three main processes where DAC functionalities will potentially bring direct benefits have been identified: shunting and train preparation, wagon maintenance and design, and train run. Moreover, DAC could also generate savings in infrastructure investments and maintenance.

This section discusses the expected benefits from DAC for each of these topics.

8.1. SHUNTING OPERATIONS AND TRAIN PREPARATION (FUNCTIONALITIES 1-3 & 11-13)

The improvements with regards to shunting operations and train preparation are induced by 6 functionalities of the DAC technology:

- Functionality 1: Automated coupling + manual uncoupling
- Functionality 2: Automatic brake test & calculation of braking capacity
- Functionality 3: Recording of wagon order + dismissal of rear signal
- Functionality 11: Automated parking brake
- Functionality 12: Automatic uncoupling (remote)
- Functionality 13: Automated technical wagon inspection

To calculate cost savings and capacity increase due to time reductions induced by the functionalities, a spreadsheet form was circulated as part of the survey in order to collect data on the time it takes for each sub-process today. This was then used for estimations of time savings as a percentage of overall operation time. The blank template for this input is shown in Annex 1. In total, 9 organizations contributed, located across Europe, representing approximately 30 to 55% of total European rail freight (depending on market segment):

Figure 24 – Geographical representativeness of the survey[27]

8.1.1. TOTAL TIME IN BASELINE SCENARIO FOR THE SAMPLE

Corresponding times extracted from interviews are presented in the figures below for customer & departure sidings, big and small marshalling yards and combined transport terminals:

[27] There are more than 9 dots as some companies are operating in several countries.

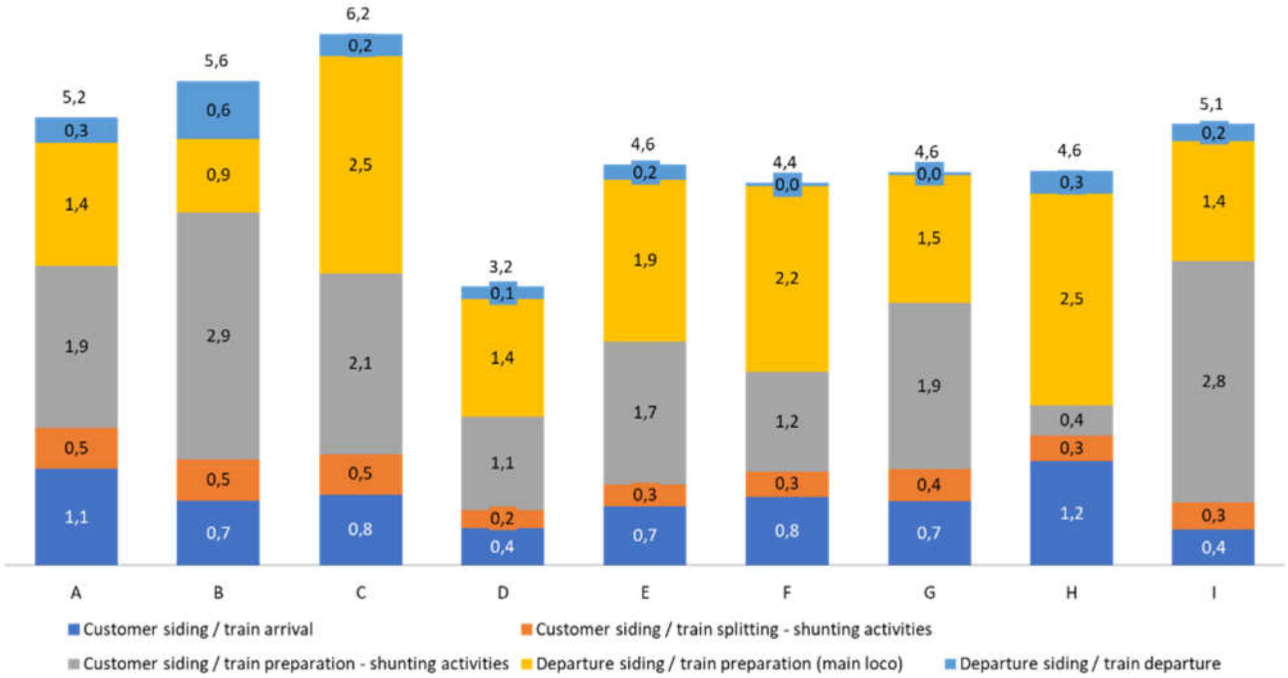


Figure 25 – Total time in the baseline scenario for customer sidings and departure sidings

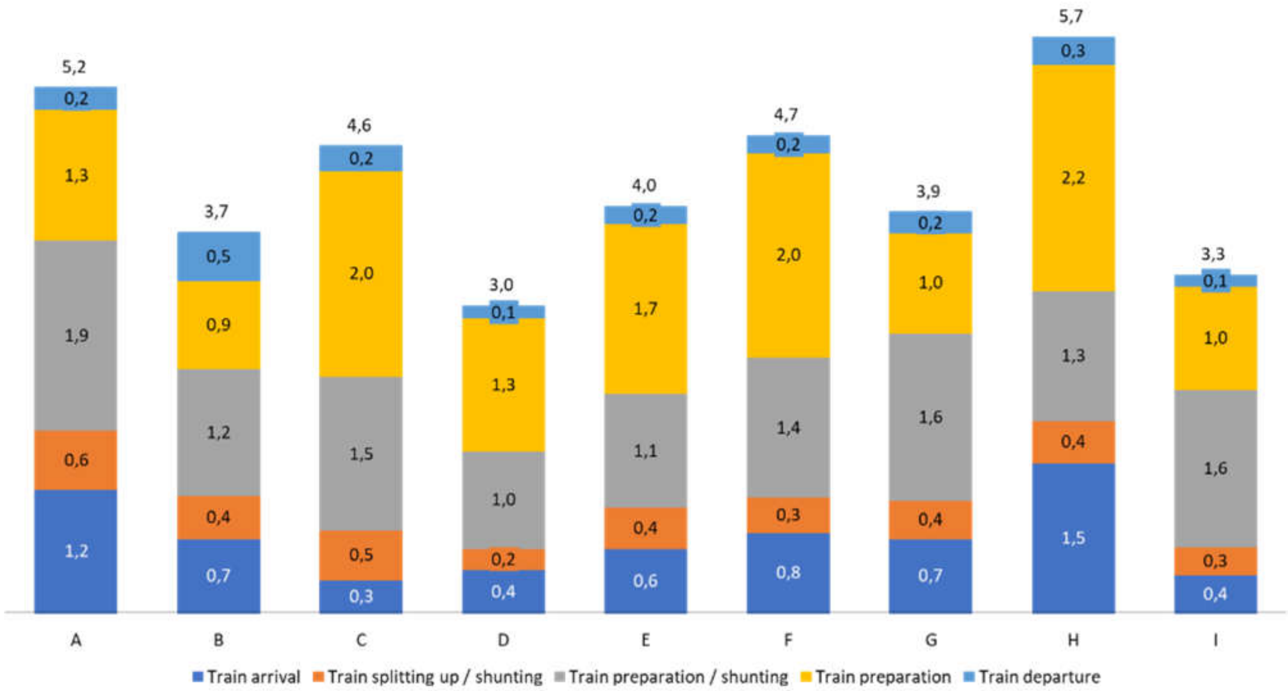


Figure 26 – Total time in the baseline scenario for small marshalling yards

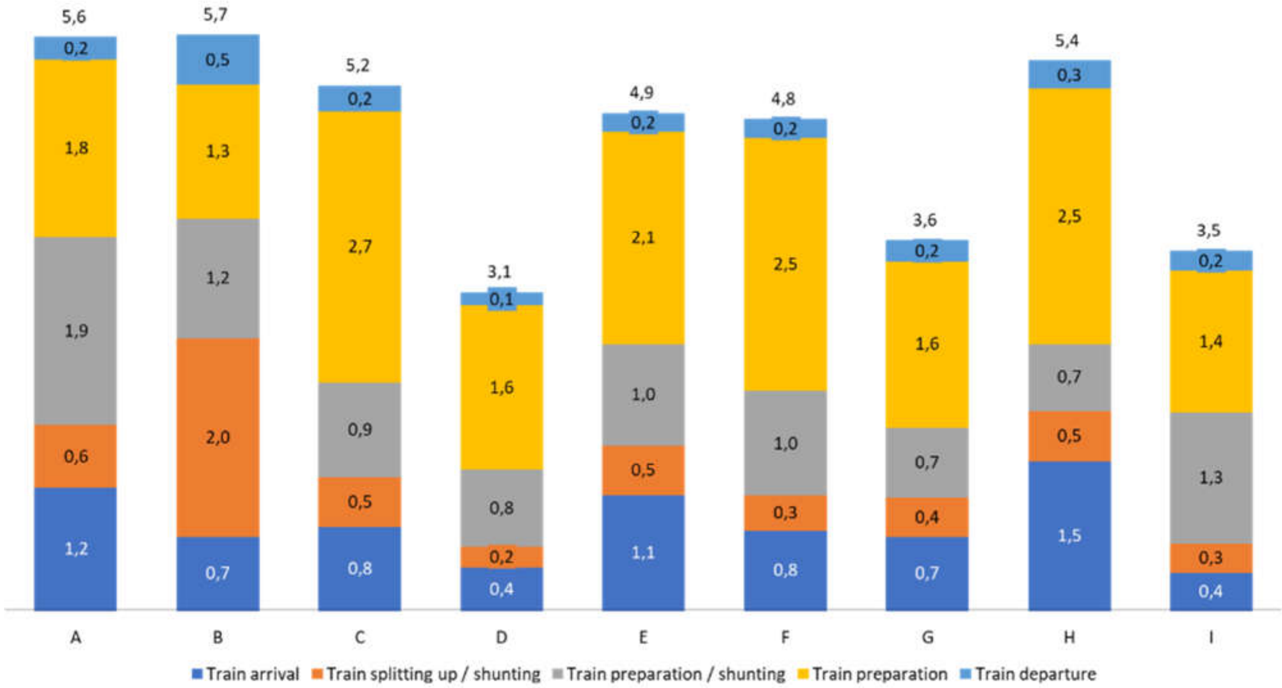


Figure 27 – Total time in the baseline scenario for big marshalling yards

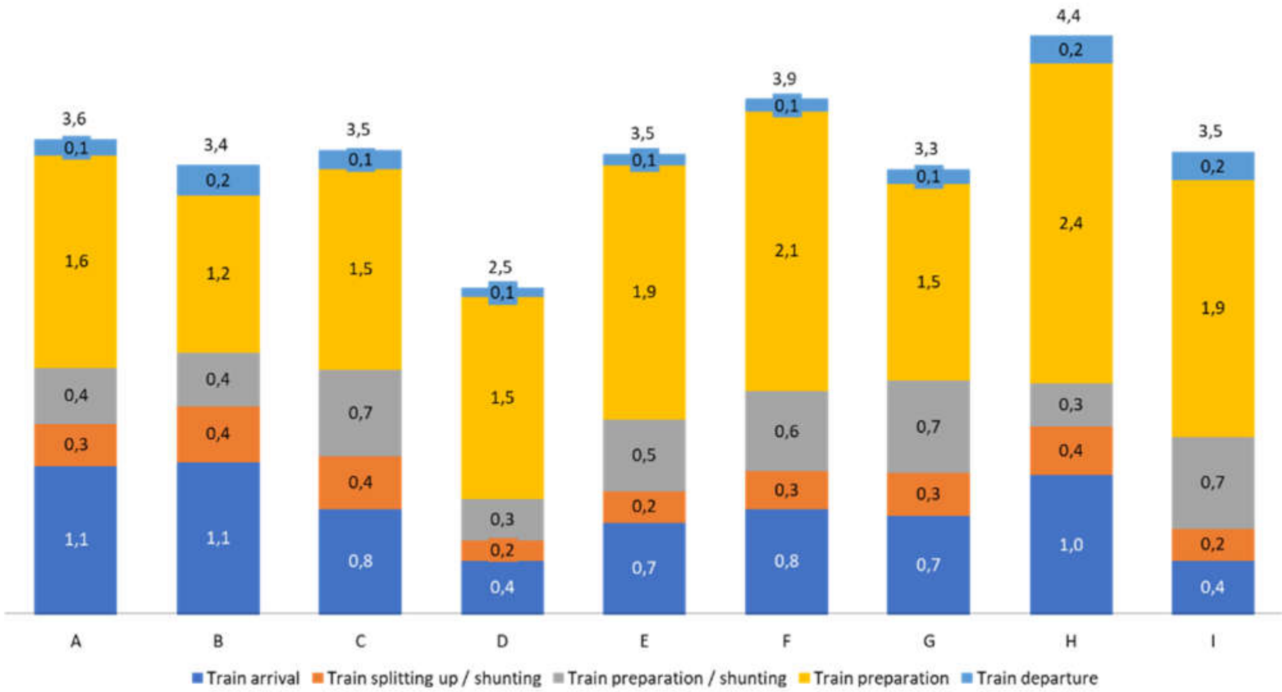


Figure 28 – Total time in the baseline scenario for combined transport terminals

The following comments can be made on the figures above:

- Train preparation, and especially the brake test and wagon inspection, represents a significant part of the total time in yards, sidings or terminals;

- The results vary from one company to another; this is mainly due to the size of the train (number of wagons) and the performance of the operator;
- Big differences can be seen on train arrival: this is due to the fact that in some countries, a train inspection is done at arrival and before departure, whereas in other countries, train inspection is only done before departure;
- Another big difference is on the number of shunting operations, which is much lower for combined transport than for other production systems.

8.1.2. WEIGHTED AVERAGE OF THE TIME PER SYSTEM OF PRODUCTION

Based on the results of the sample above, an average time on site per train and per system of production has been calculated:

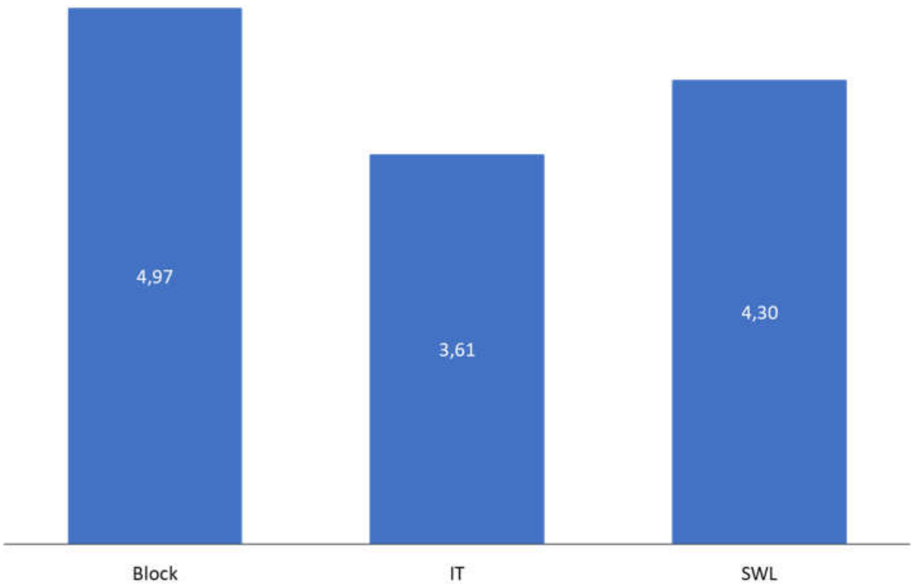


Figure 29 – Average time on site / train in hour, for each system of production

For block train, this average time includes the time in customer siding and the time in departure siding (from the arrival to the departure of the train).

For intermodal transport, this average time includes the time in combined transport terminal (from the arrival to the departure of the train).

For single wagon load, this average time includes the time in marshalling yard (from the arrival to the departure of the train)[28].

[28] This is consistent with how the number of trains is calculated: one train corresponds to one segment of traffic, from one yard to another

8.1.3. TIME BENEFITS FROM DAC AND ADDITIONAL COMPONENTS

The potential benefits of DAC and additional components have been assessed by EDDP experts and reviewed by WP5 for each step of the sub-process of operation in customer sidings, departure sidings, combined transport terminals, small marshalling yards and big marshalling yards.

For DAC and each additional component, the potential benefit is either given through a relative value (% of decrease of the time) or in absolute value (new time). An example of the matrix developed for the calculation (for small marshalling yards) is presented below:

Figure 30 – Example – detailed assumptions on time gains for small marshalling yards

Small Marshalling Yards		DAC 4	DAC 5 actuator	communication system	automated venting device	automated park brake system	automatic brake test device	train integrity / eot system	automated wagon inspection
	train de-initialisation	-	-	0,2	-	-	-	-	-
	arrival notice	-	-	-100%	-	-	-	-	-
	Handover of shipping documents	-	-	-	-	-	-	-	-
	putting safety stop (wagon)	-	-	-	-	-100%	-	-	-
	Uncoupling Loco	-20%	-80%	-	-	-	-	-	-
	train inspection at train arrival	-	-	-	-	-	-	-	-50%
	optional: check/recording train composition	-	-	-100%	-	-	-	-	-
	Couple Shunting Loco	-100%	-	-	-	-	-	-	-
	Remove rear train end signal	-	-	-	-	-	-	-100%	-
	removal of safety stop (wagon)	-	-	-	-	-100%	-	-	-
Train arrival		-	-	-	-	-	-	-	-
	putting safety stop (wagon)	-	-	-	-	-100%	-	-	-
	Uncoupling Shunting Loco	-20%	-80%	-	-	-	-	-	-
	Uncoupling	-20%	-80%	-	-	-	-	-	-
Train splitting up/ shunting in SMY		-	-	-	-	-	-	-	-
	check/recording of wagon list	-	-	-100%	-	-	-	-	-
	Couple Shunting Loco	-100%	-	-	-	-	-	-	-
	Backing mov. of wagons (by shunting loco)	-	-	-	-	-	-	-	-
	Coupling	-100%	-	-	-	-	-	-	-
	Couple Shunting Loco	-100%	-	-	-	-	-	-	-
	simplified brake test within shunting operations - each time you couple a wagon - check if brakes are released	-	-	-	-	-	6,0	-	-
	Uncouple Shunting Loco - shunting mode ends	(0,2)	(0,8)	-	-	-	-	-	-
Train preparation / shunting in SMY		-	-	-	-	-	-	-	-
	Couple Main Line Loco	-100%	-	-	-	-	-	-	-
	full brake test	-	-	-	-	-	8,0	-	-
	train inspection full after coupling	-	-	-	-	-	-	-	-50%
Train preparation		-	-	-	-	-	-	-	-
	Putting train rear end signal	-	-	-	-	-	-	-100%	-
	Handover of shipping documents	-	-	-	-	-	-	-	-
	train initialisation	-	-	0,2	-	-	-	-	-
	removal of safety stop (wagon)	-	-	-	-	-100%	-	-	-
	departure notice in IT system	-	-	-100%	-	-	-	-	-
Train departure									

All the matrix used in the calculation are presented in Annex 2. For automated wagon inspection, a provisional value of 50% has been used, as the potential time gain which could be reach with DAC and additional components (like sensors) has not been assessed yet.

For intermodal transport, an intermediate step has also been introduced in the calculation. Indeed, our discussions with the sector showed that there are two very different ways to operate intermodal trains in Europe today:

- Some operators are only using shuttles, with fixed train composition, and modern terminals with video gates and specific equipment to carry out wagon inspections and brake tests. For this type of operation, the time benefits of DAC are expected to be very small – too small anyway to lead to any savings in operating costs;
- But many operators are still using terminals with limited length of the tracks and no modern equipment, where a technical wagon inspection of the wagons and a full brake test are required before departure. For this type of operation, DAC is expected to lead to a significant decrease in the time to process a train in the terminal, which could be translated into important savings in operating costs.

The share of each type of operation has been estimated using the distribution of the length of the tracks in terminals[29]. The results are shown in the figure below:

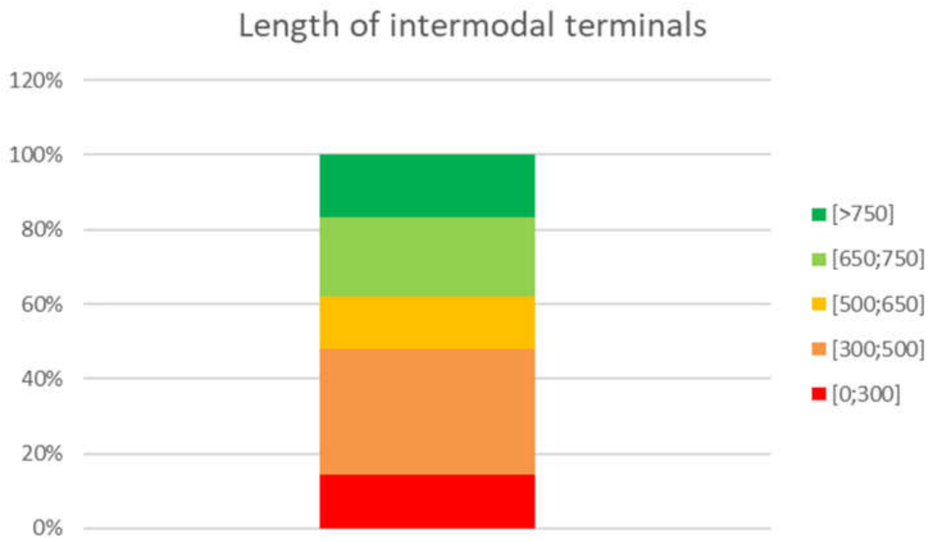


Figure 31 – Distribution of the length of the tracks in intermodal terminals

The terminals with tracks long enough to accommodate shuttle operation (> 650 m as an assumption based on the discussion with the industry) represent 38% of the total number of terminals of the sample. Nevertheless, all these terminals are not equipped with video gates or brake test systems. Therefore, **the market share of operators which would not reap any benefit from DAC operations has been estimated at 20%** (half of the 38% quoted above).

[29] Source: Rail Facility Portal, only for the 345 terminals where this information was available

Then, an average time benefit for intermodal transport has been estimated, using the weighted average between operators with the full time benefit of DAC (80% of the market) and operators with no time benefit (20% of the market).

The final step to assess the total time benefit thanks to DAC was to make the link between functionalities and the components, which is shown in the figure below:

Components / functionalities	F1 : Automated coupling + manual uncoupling	F2 : Automatic brake test & calculation of braking capacity	F3 : Recording of train composition + abandon of rear signal	F11: Automated parking brake	F12: Automatic uncoupling (remote)	F13: Automated technical wagon inspection
DAC 4	X					
Communication backbone	X		X			
Train composition detection			X			
Draining valve for auxiliary air tanks	X					
Automated air valve	X				X	
DAC 5					X	
Automated brake test		X				
Automated technical wagon inspection						X
Automated parking brake				X		
Tail light (control device)			X			

Table 9 – Link between DAC, additional components and functionalities for shunting activities and train preparation

Considering the table above and the technical packages presented in §0 above, the functionalities can be linked with the following technological packages:

- Tech package 1 is assessing functionalities 1 & 3

- Tech package 2 is assessing functionality 12
- Tech package 3 is assessing functionality 2
- Tech package 4 is assessing functionalities 11 and 13

The time benefits associated with each tech package are presented below:

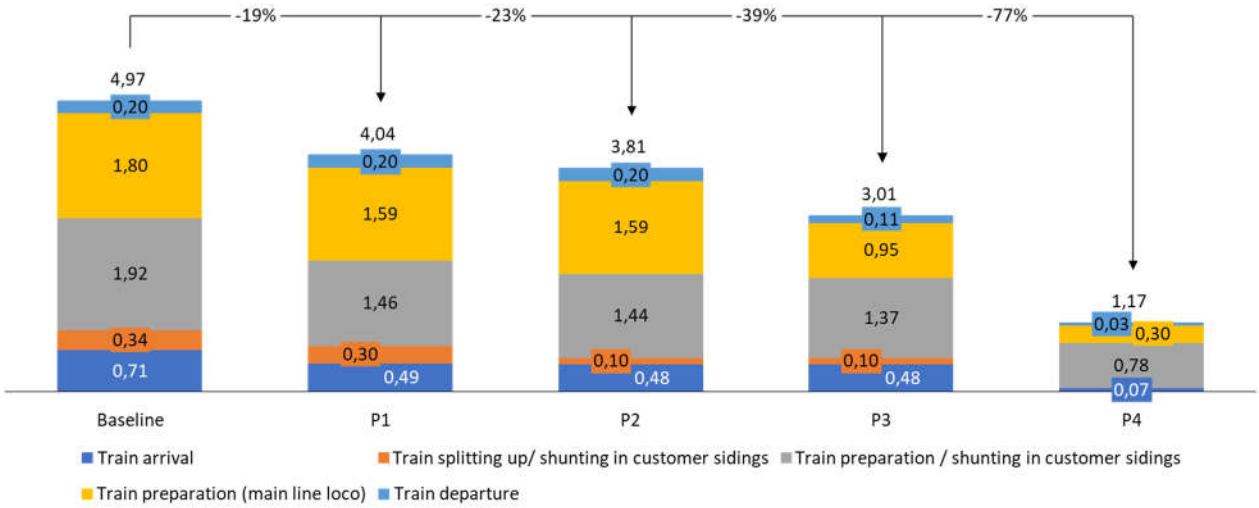


Figure 32 – Relative change in time operation compared with baseline for different tech packages (block trains)

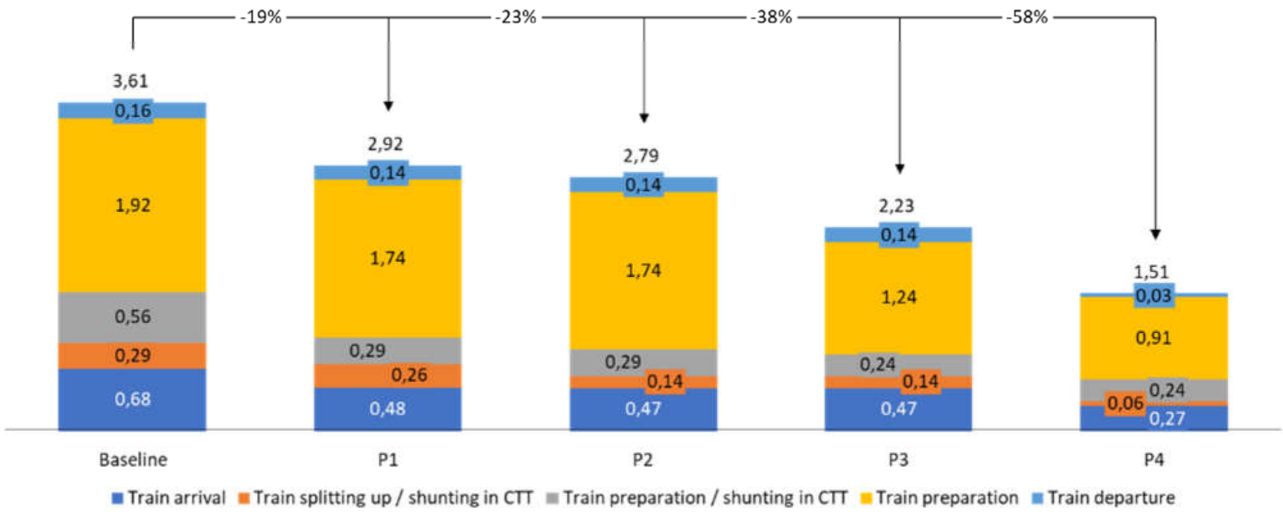


Figure 33 – Relative change in time operation compared with baseline for different tech packages (intermodal)

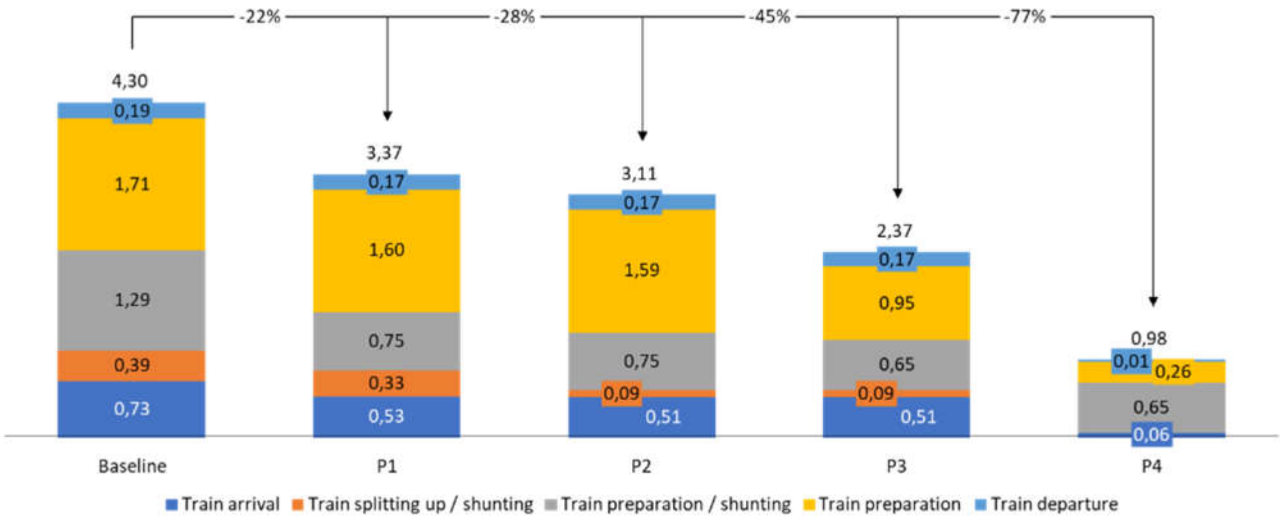


Figure 34 – Relative change in time operation compared with baseline for different tech packages (single wagon load)

Finally, these time benefits have been multiplied by the traffic for each production system, in order to assess a total time gain per year, per country and per production system.

8.1.4. MONETIZATION OF TIME BENEFITS

The next issue is to translate these time gains into €. Indeed, the fact that one hour is saved thanks to DAC does not mean that the operator of the site will be able for instance to save one shunting locomotive or one shunting staff. For instance, in a marshalling yard with 3 people per shift (8 hours) and one shunting locomotive, DAC will not enable any savings.

The increase on the number of trains thanks to DAC is facing a similar issue: gaining 1 or 2 hours in shunting and train preparation might not be sufficient to produce a new train systematically.

Nevertheless, considering that DAC will never allow an improvement in the use of the asset would neither be realistic. Therefore, some conversion factors have been introduced in order to translate the total time gain into monetized time gains.

The overall logic of translating time benefits into € is the following:

- Railway operations have been split in different categories of staffs and assets: operational staff, shunting locomotives, main line locomotives, main line drivers and wagons;
- For each category of staff / asset, a conversion factor has been introduced, in order to translate the total time saved into time saved leading to increased productivity of staff / asset;
- Then, this time has been multiplied by a cost / hour, in order to translate time savings into euros.

The detailed assumptions on conversion factors are summarized in the figure below:

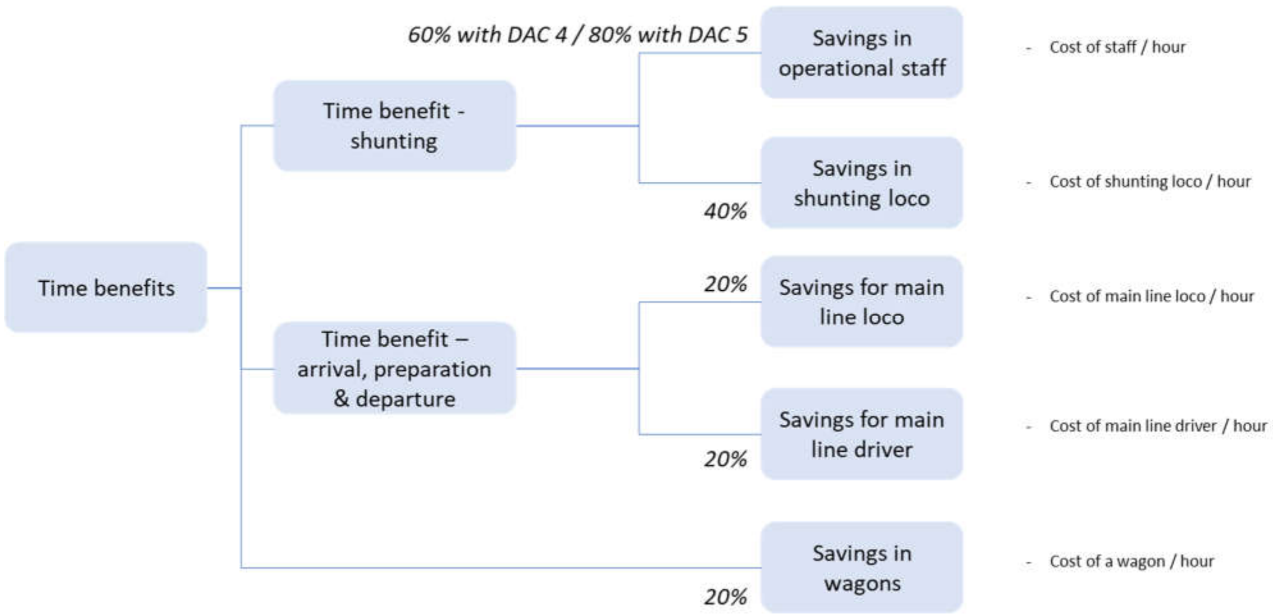


Figure 35 – Conversion factors for time benefits

The detailed assumptions used to calculate the costs / hour are summarized in the table below:

Cost parameter	Unit	Value
Cost per hour marshalling personnel	EUR/h	42
Shunting locomotives		
Cost of a locomotive for terminal and shunting services	EUR/day	1 000
Number of hours of use of a shunting loco	EUR/h	10
Hourly cost of a shunting locomotive	EUR/h	100
Long distance locomotive		
Cost for a long distance locomotive	EUR/day	2 000
Number of hours of use of a main line loco	EUR/h	10
Hourly cost of a main line locomotive	EUR/h	200
Train driver		

Cost parameter	Unit	Value
Train driver costs	EUR/day	300
Driving hours / day	EUR/h	4
Hourly cost of a main line driver	EUR/h	75
Wagon		
Wagon cost	EUR/day	35
Number of hours of use of a wagon	EUR/h	10
Hourly cost of a wagon	EUR/h	4
Composition of the trains		
Block - average number of wagons	Wagons	20
IT - average number of wagons	Wagons	20
SWL - average number of wagons	Wagons	18

Table 10 – Detailed assumptions on costs used to monetize time benefits

8.2. MAINTENANCE AND DESIGN OF WAGONS

The direct benefit on maintenance and design of wagons is induced by three DAC functionalities. Functionalities and their impacts were assessed individually, based on the interviews with stakeholders, and are as follows:

8.2.1. FUNCTIONALITY 5: INCREASED PAYLOAD

The potential benefit explored here was the opportunity to develop a different design thanks to DAC that could lead to a reduced wagon weight, which would allow an increased payload in the train. Unfortunately, based on the feedback received, the uncertainty is too high on this aspect, and some experts also see a risk of an increase of the gross weight of the wagon, which would lead to a decrease in the payload.

Considering the uncertainty associated with this functionality, it has not been quantified in the CBA.

8.2.2. FUNCTIONALITY 8: REDUCED WEAR ON WHEELSETS AND BRAKING SYSTEM – WITH EP BRAKE AS AN ADDITIONAL COMPONENT

EP brake is expected to reduce wear on wheelsets and brakes by providing synchronized release or engagement of brakes along the train (at almost no propagation period). However, the sample of surveyed stakeholders largely had no experience with EP brakes and therefore the effects cannot be estimated with any precision. One hot wheel case replacement was indicated at 5000 EUR, in which the effect can be measured (though the expected rate of savings of hot wheel cases with an EP brake is not specified in the responses). **Therefore, this potential benefit has not been quantified in the CBA.**

8.2.3. FUNCTIONALITY 9: WAGON CONDITION/PERFORMANCE INFO (INCL. DERAILMENT DETECTION) – WITH WAGON TELEMATICS AS AN ADDITIONAL COMPONENT

Sensors can be used to monitor wear / failure of components on the freight wagon and introduce condition-based maintenance. If DAC enables this functionality, cost reduction is expected through: less labour hours (on field and in the workshop), condition-based maintenance and lower risk of accidents which is viewed as an important benefit in the industry according to the survey. Nevertheless, condition-based maintenance is already being introduced by the industry, and the stakeholders were not able to provide an assessment of the potential extra benefit linked to DAC. **Therefore, this benefit has not been quantified in the CBA.**

8.3. TRAIN RUN

The direct benefit on train run is induced by seven DAC functionalities. Functionalities and the summary of the key findings of the analysis, coming from the interviews with stakeholders and discussions with WP5, are summarized below.

8.3.1. FUNCTIONALITY 4: LONGER AND HEAVIER TRAINS (WITHIN EXISTING INFRA LIMITATIONS)

The use of DAC provides an opportunity to increase the weight of the train thanks to stronger couplers, allowing a longitudinal force of 1000 kN instead of 850 kN with screw couplers. However, most of the stakeholders have quoted other limitations which would prevent rail transport to benefit from this increased capacity, such as infrastructure limitation, slope of the tracks, towing capacity of the locomotive, etc.

Nevertheless, this benefit has been included in the calculation either through national values (when it was provided[30]) or through a default assumption of 3%, which is based on a study commissioned by DB Cargo in January 2022[31]. This assumption has then been translated into a number of trips saved per production system:

[30] National specific values have been used for Austria, Switzerland, Czech Republic, Germany, France, Hungary, Italy, Poland, Portugal, Romania and Sweden. If no benefit is expected, then a value of 0% has been used

[31] 'Analysis of additional capacities in rail freight transport through the introduction of digital automatic couplers (DAC), SCI Verkehr', January 2022

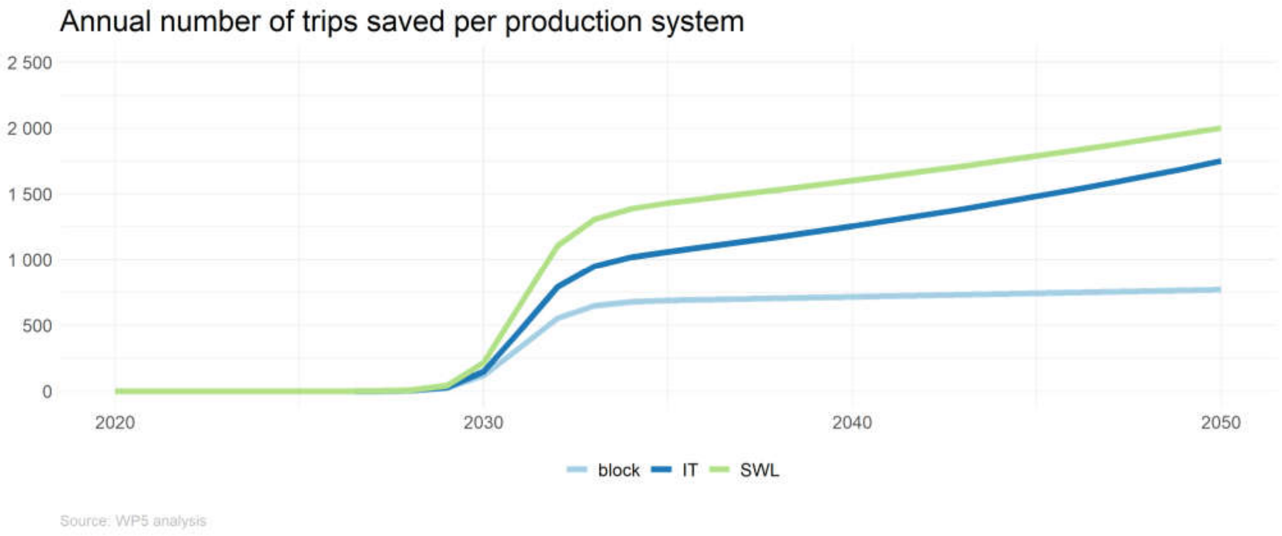


Figure 36 – Annual number of trips saved per production system

Finally, those trips saved are monetized using the following values per production system:

Cost parameter	Unit	Block	Intermodal transport	Single wagon load
Hourly cost of a main line locomotive	€ / h	200	200	200
Hourly cost of a main line driver	€ / h	75	75	75
Hourly cost of a wagon	€ / h	4	4	4
Block - average number of wagons	#	20	20	18
Block - average trip duration	h	15	12	16
Monetised benefit of a trip 'saved'	€ / trip	5 175	4 140	5 408

Table 11 – Detailed assumptions on costs used to monetize trips saved

8.3.2. FUNCTIONALITY 14: LONGER TRAINS – UP TO 1500M

Increasing the productivity through the use of longer trains (target length of 1,500 m on European transport corridors) would require additional automation components, infrastructural adaptations and EP-brake/distributed power. The effect of DAC alone on any significant increases in train length was largely contested by the stakeholders. The argument used consistently throughout almost all responses was the fact that the main limitation of train length today is infrastructure rather than the coupling technology (or any other low-cost/soft constraint). **Therefore, this benefit has not been considered in the CBA.**

8.3.3. FUNCTIONALITY 2: AUTOMATIC BRAKE TEST & CALCULATION OF BRAKING CAPACITY - AUTOMATIC BRAKE TEST DURING LOCOMOTIVE CHANGE

DAC could introduce large time savings related to the automatic brake test when changing the locomotive. The brake test was indicated by many stakeholders to be a lengthy process and thus a burden on the operational optimisation. If DAC eliminates the need for brake test entirely, a large benefit can be expected according to stakeholders. However, no data on the number of changes of locomotives / train is available. Moreover, as for time savings for shunting operations and train preparation, a conversion factor would have to be used on this benefit, as it is not because 1 hour is saved that the driver and the locomotive can be used for something else. Consequently, **this benefit has not been quantified in the CBA.**

8.3.4. FUNCTIONALITY 7: EASIER CROSS-BORDER OPERATION THROUGH ELIMINATION OF BRAKE LEVER ADJUSTMENT "G" – "P"

DAC would eliminate the need for changing brake lever at borders, thereby reducing operation time and increasing punctuality. Stakeholders have remained reserved in estimating any significant benefits from DAC on this domain. The main remark is that in a lot of corridors the brake lever adjustment is no longer required in cross-border operation. Though a few stakeholders which operate in areas where this is necessary, have indicated that this is a sizeable operational burden, overall, this benefit is expected to be marginal. **Therefore, this benefit has not been quantified in the CBA.**

8.3.5. FUNCTIONALITY 8: INCREASED SPEED VIA BETTER BRAKING PERFORMANCE (FROM 100 TO 120 KM/H, FOCUS ON THE INCREASED SPEED EFFECT)

The EP brake feature of DAC has brought interest from stakeholders. Benefits of EP brake include shorter stopping distance and reduction of compressional longitudinal forces. This would allow freight trains to run at a higher speed. However, the survey responses have shown that the quantification of the expected effects is difficult since there aren't many cases of EP brake being implemented on freight wagons around the EU (and hence there is no data to base the predictions on).

The estimations by stakeholders on the increase of speed due to improved braking power ranged from 5% to 15%. However, it was emphasized that increasing speed brings many other investments as a requirement, including the infrastructure, safety requirements, new wagons that can run at 120 km/h (currently only a certain share falls under this category). An interviewed wagon keeper has indicated that only 5% of its fleet can run at 120 km/h.

Thus, due to the limit on the fleet, the functionality is currently not feasible. However, over the coming years, a significant shift of rail freight traffic from block trains to intermodal traffic can be expected due to coal phase-out (large share of block traffic) and the emergence of large demand for container transport, as well as the increase in diversity of goods transported by rail, which (as per the traffic forecast by OECD[32]) which will largely be met by intermodal traffic growth. For this transition a faster renewal of wagons will be necessary, especially in the intermodal segment. This results in an early decommissioning of current wagons that are not able to achieve 120 km/h. The wagon readiness level is therefore a constraint that could be overcome at a relatively low cost (i.e. soft constraint), but over a relatively long period.

Considering all those elements, **this benefit has not been quantified in the CBA.**

[32] OECD (2021) Freight transport: Bold action can decarbonise movement of goods [Available at: https://www.oecd-ilibrary.org/sites/0c13b23d-en/index.html?itemId=/content/component/0c13b23d-en#section-d1e22595]

8.3.6. FUNCTIONALITY 9: WAGON CONDITION/PERFORMANCE INFO (INCLUDING. DERAILMENT DETECTION)

DAC, including the power line it comes with, would secure the electrical power supply for the wagons. In addition, it could transmit safety-relevant information via the data bus to the locomotive driver. As a result, unscheduled wagon breakdowns could be reduced.

Most of the stakeholders agreed with the rationale proposed by this functionality. The number of wheel damages and braking system failures was reported to be high due to lack of feedback flows from the wagons. There seems to be a large potential for DAC to improve operation from this functionality. However, stakeholders claim that the wagon telematics could be enabled without DAC since new power configurations are lately becoming financially viable solutions (batteries, solar panels etc.).

As for wagon condition / performance information, it is not possible to assess the benefit brought by DAC compared to other solutions currently developed to allow similar functionalities. Therefore, **this benefit has not been quantified in the CBA.**

8.3.7. FUNCTIONALITY 10: TELEMATICS FOR CUSTOMERS

DAC would enable continuous power supply to the (rechargeable) batteries of the telematics devices to allow for uninterrupted power supply to single wagon loads. This permits a higher degree of utilisation for telematics applications. Most stakeholders have expressed a positive outlook of this functionality's impact on the attractiveness of rail freight service. The ongoing rapid decline of costs of solar panels and batteries is expressed as a convenient enabler for powering such features on single wagon loads. However, it is highlighted that the power source must be stable and reliable to allow for this functionality of DAC. Moreover, it is difficult to assess at this stage the new services which could be provided by wagon keepers, and the monetary value of these new services. Therefore, **this benefit has not been quantified in the CBA.**

8.4. TRACKSIDE TRAIN DETECTION SAVINGS

Under ETCS Level 3 (L3) the train separation function is performed based on train position and train integrity confirmation. For freight trains there is currently no reliable and operationally robust train integrity monitoring system. DAC would fulfil that role and, as such, allow for the removal of trackside train detection (TTD) equipment. For illustration, RINF currently contains information on about 80 000 sections of lines with loops, track circuits, and wheel detectors that are in operation.

Even without a full L3 implementation, but rather a hybrid L3[33], a significant reduction in trackside train detection equipment and maintenance is anticipated.

Acknowledging the limitations of several assumptions and their tentative nature, it was put forward that 80% of the TEN-T network will be fitted with at least Hybrid L3 by 2040. Within the network in scope, TTD equipment will be gradually reduced when at end of life and generally not replaced. TDD will be restricted to areas where points are located. This results in an approximated CAPEX reduction of 30 000 EUR per track kilometre. Maintenance costs are considered to be a yearly percentage of the investment and set at 5%.

Hence, DAC enables the hybrid L3 concept and decreases TTD and related costs.

[33] ERTMS Users Group (2022) https://ertms.be/sites/default/files/2022-02/16E0421E_HL3 %28clean%29.docx

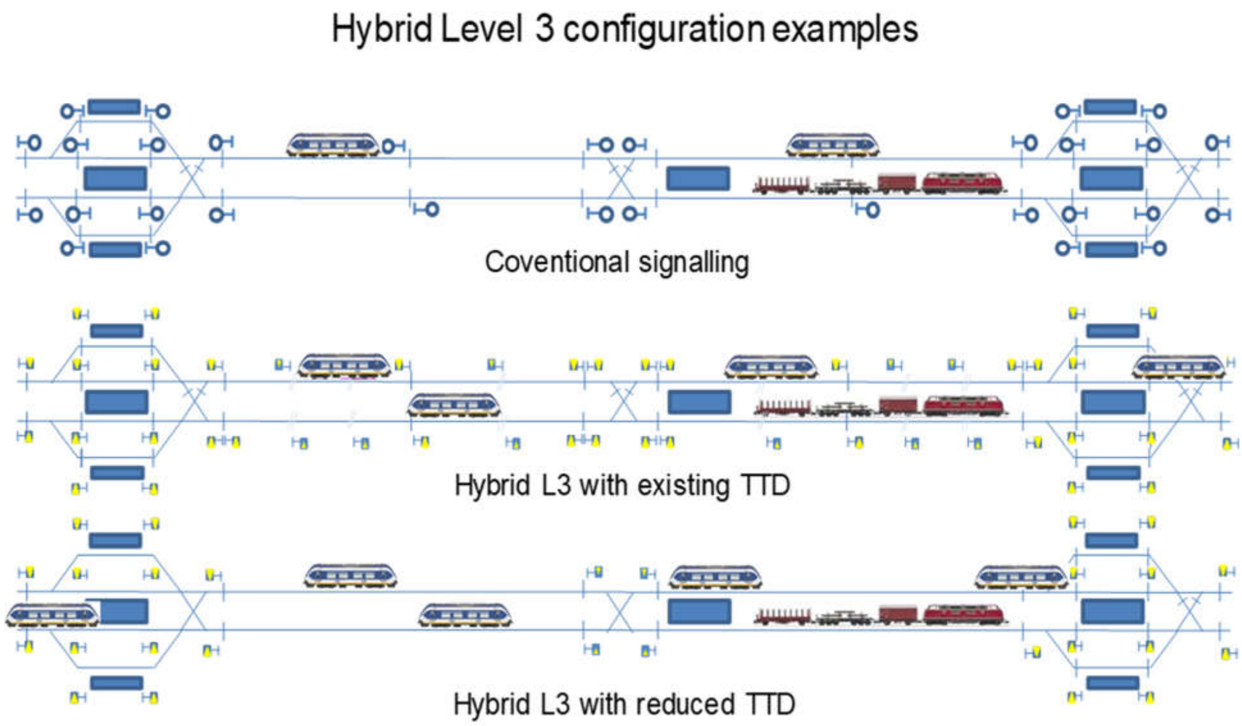


Figure 37 – Hybrid L3 concept explained (ERTMS Users Group 2022)

9. INDIRECT BENEFITS

Indirect benefits are the benefits which are linked with other direct effect from DAC, such as:

- Increased capacity in terminals and on the infrastructure (DAC associated with ETCS level 3)
- Modal shift due to the decrease of rail freight operating costs and to improved reliability of rail freight transport
- Decrease of external costs due to modal shift (coming from increased capacity or improved performance of rail freight)
- Improvement of safety for rail workers

These benefits, which are sometimes societal benefits, are more difficult to quantify. The assumptions used to monetize them have been developed by ERA and the consultant, with the support of WP5. They are based on a review of the academic literature, other studies and discussions with experts of the sector (through bilateral interviews or WP5 meetings).

9.1. PRELIMINARY CONSIDERATIONS ON PROFIT MARGINS PER PRODUCTION SYSTEM

Even without DAC, a significant growth of rail freight traffic is expected in the baseline scenario. One of the first question raised is: what will be the impact of this growth on the economic situation of rail freight operators?

In order to answer this question, an analysis of the current economic situation of rail freight has been carried out, followed by an analysis of its evolution in the baseline scenario.

9.1.1. CURRENT ECONOMIC SITUATION OF THE RAILWAY INDUSTRY

There is no public and aggregated figures of the financial results of rail freight companies in Europe. Moreover, the past months have been strongly disrupted, due to the COVID 19 crisis and the war in Ukraine[34]. Therefore, some assumptions on the revenues and profit margin per production system have been defined with the support of WP5 members, based on the following logic:

- Overall, and without considering the current crisis, the profit margin of rail freight would be close to 0
- The highest profit margin is done with block trains
- Intermodal transport is in strong competition with road; the profit margin is positive but limited
- Single wagon load transport is losing money, and cancelling the positive results of the other production systems

Based on this logic, the following assumptions have been used to assess the revenues and profit margins of the industry in the base year of the model (2020):

Cost parameter	Unit	Block	Intermodal transport	Single wagon load
Revenues	c€ / t x km	3,33	3,16	6
Profit margin	%	10%	5%	-15%

Table 12 – Assumptions on revenues and profit margin per production system

Of course, these values are raising concerns on the sustainability of the single wagon load market segment. As a reminder, in the economic theory, in a market with perfect competition, the market equilibrium is reached when marginal cost is equal to average cost:

[34] Especially the impact of the war in Ukraine on electricity prices, which are not expected to last in the long term

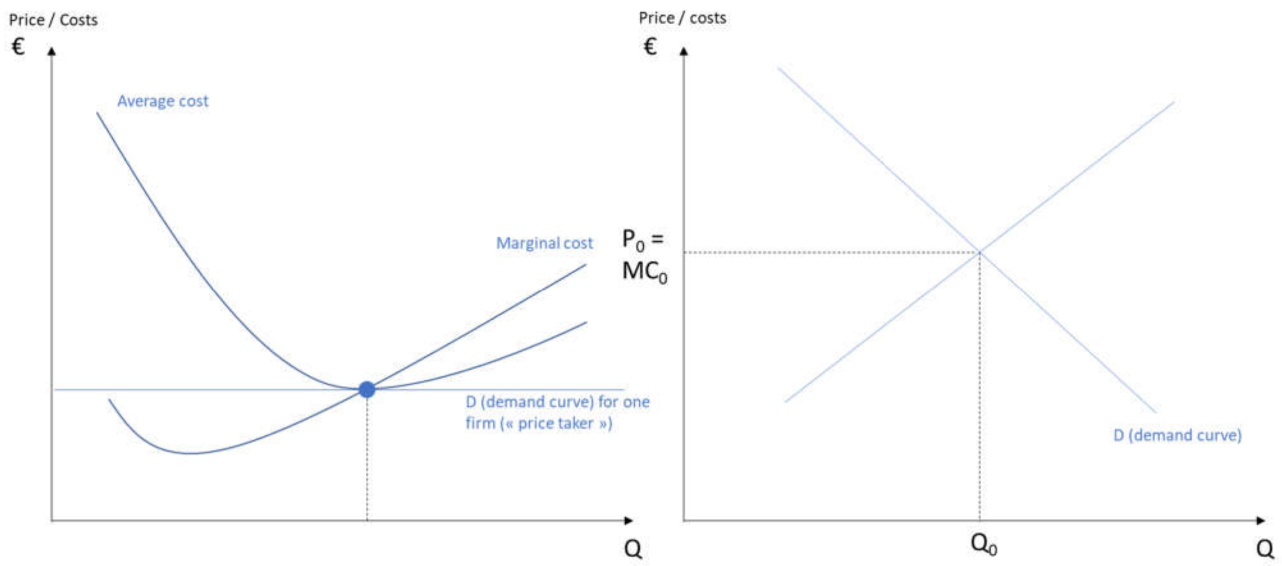


Figure 38 – Market equilibrium in perfect competition

The current situation for single wagon load can be described in the figure below:

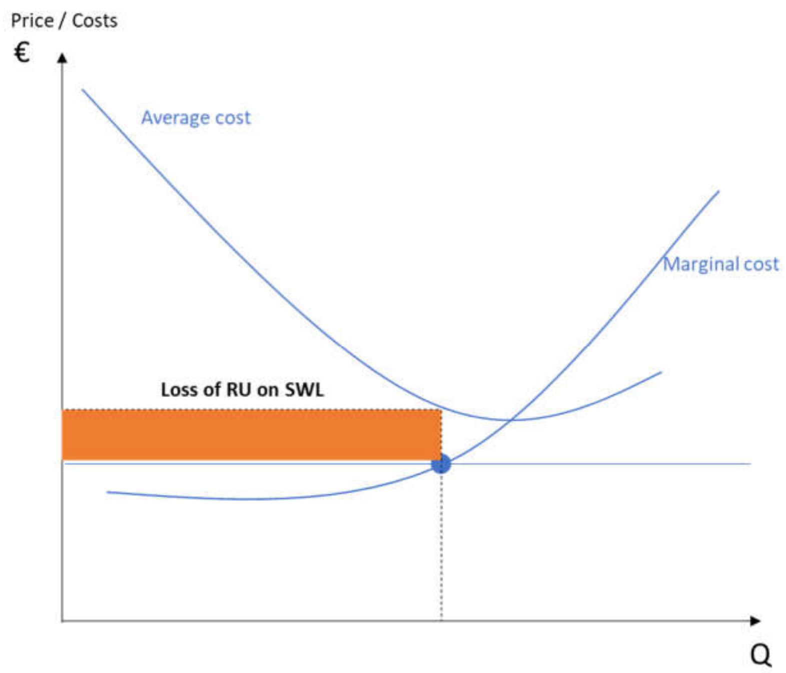


Figure 39 – Market situation of single wagon load

This situation is not sustainable over a period of 30 years; therefore this assumption has to be adapted in the baseline scenario.

9.1.2. ASSUMPTIONS USED IN THE BASELINE SCENARIO (WITHOUT DAC)

In the baseline scenario without DAC, rail freight traffic is expected to grow significantly, thanks to multiple policy measures taken at EU level and already quoted in §6.1.2.1. Target growth is reminded in the figure below:

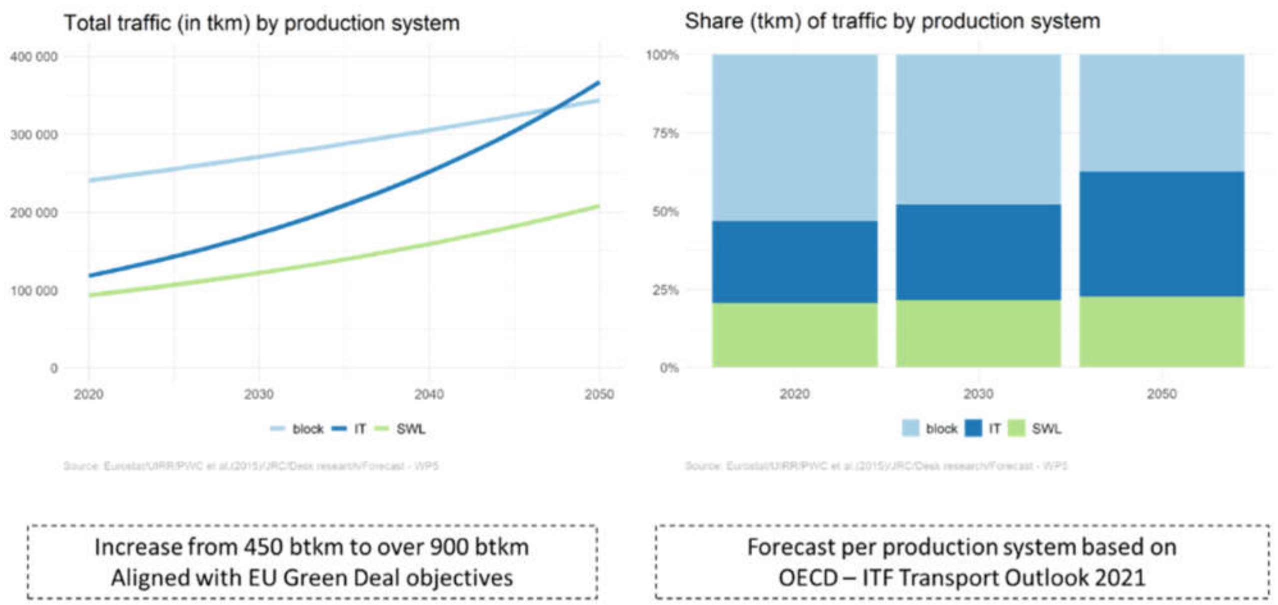


Figure 40 - Traffic forecast per production system

As the profit margin per production system is calculated as a % of revenues, and as the production with highest profit margin is the one with the lowest growth, the overall profit margin of rail freight operators would be stable overall, but with a huge dive of the results of single wagon load, where the lost would increase from approximately 850 M€ in 2020 to 1850 M€ in 2050. This assumption is clearly not realistic, and is not taking into account the impact of all the other policy measures taken to improve the economic position of rail freight.

Therefore, in the baseline scenario, it has been considered that rail freight operators would only accept new traffic at a reasonable price which would not damage their profit margin. Moreover, rail freight business is a business of fixed costs: the more you use your asset, the more competitive you are. Single wagon load has decreased significantly in Europe in the past year, and the use of assets in this market segment is far from being optimal today. Consequently, a growth of single wagon load traffic associated with a reasonable pricing should lead to scale effect which will improve the economic situation of this market segment.

These considerations, discussed with sector, have been translated into the following assumptions in the CBA modelling tool:

- The loss of the SWL production system is capped at 900 M€
- The scale effect is estimated at 20% in 2050, meaning that the loss will be capped at 720 M€ in 2050

These assumptions also mean that without further innovation and investments (such as DAC), SWL will remain a loss-making centre for rail freight operators.

9.2. CAPACITY

Two kinds of capacity benefits have been considered in the analysis:

- Quantitative benefits in combined transport terminals thanks to DAC
- Qualitative capacity benefits coming from ERTMS level 3 which can only be achieved with DAC

9.2.1. INCREASED CAPACITY IN COMBINED TRANSPORT TERMINALS

Thanks to shorter operation in terminals, DAC is expected to increase the capacity in congested yards and terminals. Based on discussion with the EDDP Work Package 5, this benefit is only relevant for Combined Transport Terminals, as there is no clear capacity issues yet in most of the marshalling yards in Europe.

The proposed methodology to assess the benefits for the assessment of increased capacity of combined transport terminals is presented below:

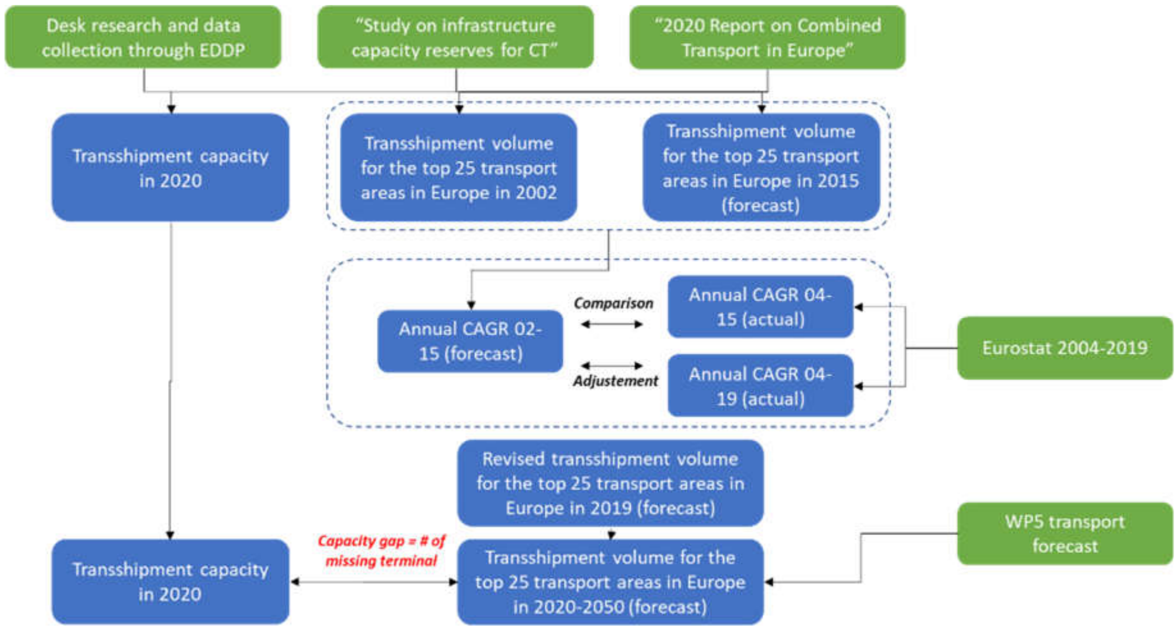


Figure 41 – Methodology to assess the benefits for the assessment of increased capacity of combined transport terminals

The only comprehensive study available on terminal capacity is the "Study on infrastructure capacity reserves for Combined Transport by 2015"[35]. This study provides baseline information on the traffic and the capacity of the biggest combined transport terminals in Europe, but unfortunately it dates back from 2004. Therefore, an important effort of data collection has been carried out in order to update the information included in this report and assess the traffic in 2019 (based on Eurostat) and beyond (based on the traffic forecast presented above).

The following key adjustments have been made on the capacity of terminals identified in the "Study on infrastructure capacity reserves for Combined Transport by 2015":

- When new capacity has been found or a new site has been identified, it has been used
- When capacity was not available but recent data on traffic were, capacity has been set at 120% of the traffic
- When no information was available, default increase of 50% of the capacity has been used

The list of terminals considered and their estimated capacity is presented in Annex 3.

[35] https://uic.org/IMG/pdf/2015_combinedtransport_study_capacity_report.pdf

The other key assumptions which have been used are detailed in the table below:

Parameters	Key assumption
Capacity in 2030	- Equal to capacity in 2019
Traffic growth / terminal	- Homogeneous distribution in traffic growth / country for 2019-2030 and therefore per terminal
Possibility to shift traffic to another terminal?	- Not considered
Actual need of a new terminal	- Threshold when you need a new combined transport terminal = 100% of capacity
Capacity increase of combined transport terminals thanks to DAC	- 30%
Cost of a new terminal	- 150 M€

Figure 42 – Assumptions for the assessment of capacity increase of combined transport terminals

Then, the following logic has been applied, both for baseline scenario and project scenario

- Theoretical traffic for each terminal is calculated for 2020-2050
- This theoretical traffic is compared to actual capacity of the terminal (for the project scenario, this capacity is increased thanks to DAC)
- If the traffic is higher than capacity, the construction of a new terminal is required

In the "project scenario", thanks to DAC, the construction of a new terminal is delayed. As costs and benefits are discounted in the CBA, the later an investment happens, the lower its cost. Therefore, delaying the construction of new terminals leads to a benefit in the CBA, as total discounted costs in the project scenario is lower than in the baseline scenario. In the end, this assessment has been translated into a unique value / year equal to 50 M€ / year.

9.2.2. INCREASED CAPACITY ON THE RAILWAY INFRASTRUCTURE (FUNCTIONALITY 6)

Thanks to DAC, it is possible to check all the time if the train has not lost a wagon. This functionality is called train integrity. Train integrity is required to deploy ERTMS level 3, which is using the logic of moving blocks. The difference between fixed blocks and moving blocks is shown in the figure below[36]:

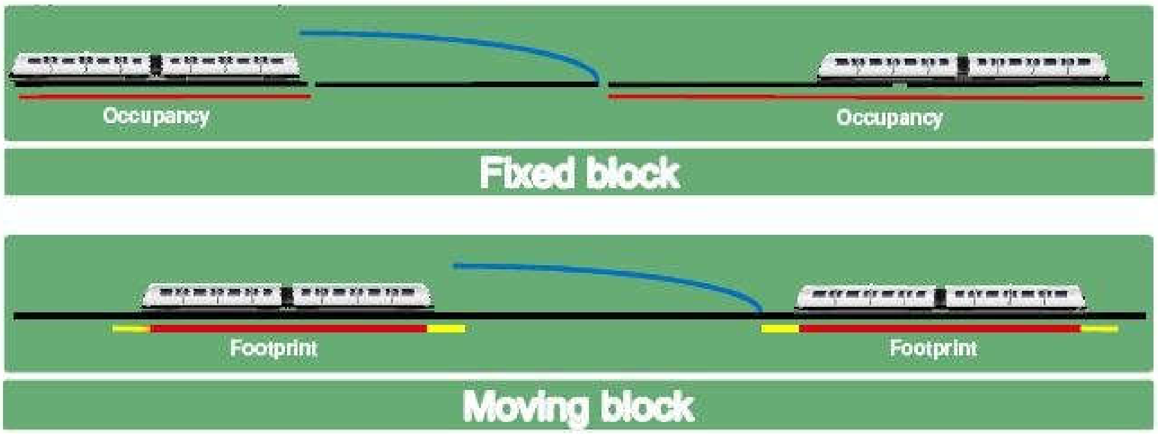


Figure 43 – Fixed blocks versus moving blocks

The deployment of ERTMS level 3 will lead to multiple benefits:

- Savings on infrastructure cost and maintenance, as axle counters will not be required anymore to check train integrity
- Increased capacity thanks to moving blocks

As explained in §6.1.2.1, an extra growth of 5% has been considered in 2050 thanks to DAC, as reminded in the figure below:

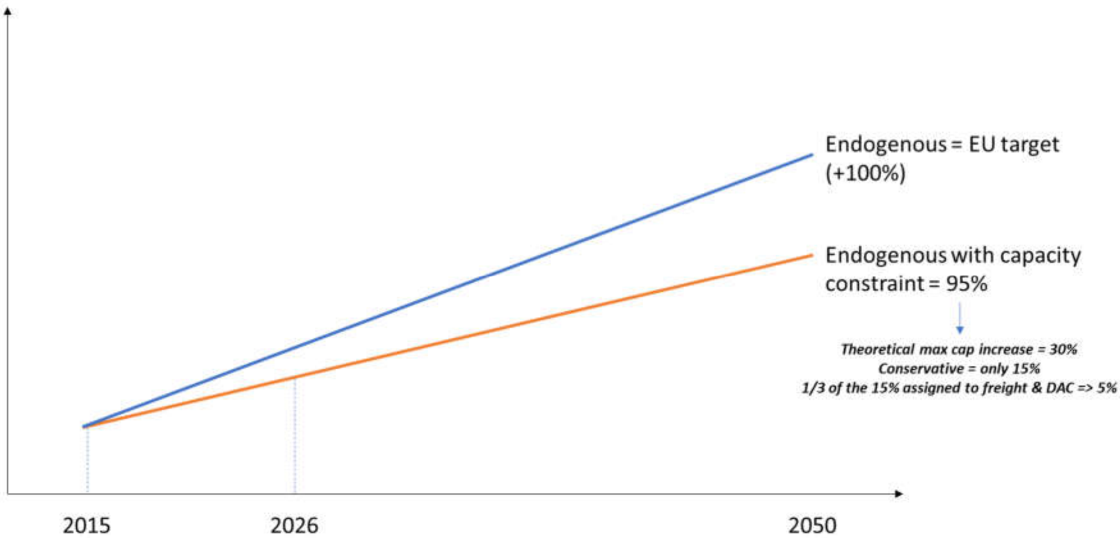


Figure 44 – rail freight traffic growth with and without capacity constraint

36 https://www.researchgate.net/figure/Fixed-block-vs-moving-block_fig1_327551416

The economic surplus linked with this new traffic has then been monetized based on the profit margin per market segment, which has been adjusted for single wagonload:

Cost parameter	Unit	Block	Intermodal transport	Single wagon load
Profit margin	%	10%	5%	**10%**

Table 13 – Assumptions on revenues and profit margin per production system

The profit margin for the new traffic of single wagon load is set at 10%. This aligned with the profit margin in the block train market segment, and is also aligned on some economic considerations: in the economic theory, the marginal costs is also supposed to include a reasonable benefit for the service provider. This profit can for instance be the weighted average cost of capital (WACC).

9.3. MODAL SHIFT

DAC is expected to lead to a decrease in operating costs, in relation with the time benefits presented in §8.1. But the key question is: will this time benefit lead to a decrease in transportation price, which could lead to an increase in the market share of rail freight? The answer to this question is difficult, and will depend on the production system considered, which are not in the same competitive environment.

The logic adopted to assess modal shift is the following:

- First of all, an analysis of the competitive environment of rail freight for each production system has been carried out, using the 5 forces of Porter
- The conclusion of this analysis has been translated into an evolution of the price per market segment in a second step
- In the third step, a modal shift effect has been calculated, using price elasticity from academic literature applied to the evolution of price
- Finally, an additional modal shift effect linked with the improvement of the performance of rail freight has been estimated (access to new market segment)

9.3.1. ANALYSE OF THE 5 FORCES OF PORTER

In order to better appreciate the potential transfer of cost decrease to the final client (the shippers), an analysis of the 5 forces of Porter has been carried out. The 5 forces considered are:

- **The competition in the industry**, which represents the competitiveness within rail freight business
- **The potential of new entrants**, which represents the capacity for new companies to enter the market
- **The power of suppliers**, which is linked with the number of suppliers for rail freight operators
- **The power of customers**, which depends on the number of costumers per company
- **The threat of substitutes**, which represents the capacity for the shippers to find alternative solutions to rail

The results of this analysis is presented in the table below:

Market segment	Competition in the industry	Potential of new entrants	Power of suppliers	Power of customers	Threat of substitutes
Block trains	◕	◔	◕	◑	◑
Intermodal trains	◕	◔	◕	◑	●
SWL	○	◔	◕	◑	●

Table 14 – Analysis of competition in rail freight – 5 forces of Porter

The **competition in the industry** is considered to be high for block trains and intermodal trains, as there are multiple service providers in Europe. For single wagon load, which is a loss making market segment, only incumbent companies are active, therefore the competition within the industry is neglectable.

The **potential of new entrants** is considered low for all production systems: indeed, there is a high initial cost (for the rolling stock), and a lack of paths on the infrastructure.

The **power of suppliers** is considered to be high, as there is a limited number of suppliers for rail freight operators in Europe, especially for freight locomotives.

The **power of customers** can vary strongly from one company to another, as some companies have a large number of customers, whereas other ones will only depend on a few of them.

Finally, the **threat of substitute** is considered very high for intermodal trains and single wagon load, as shippers can easily switch from rail to road. Competition is lower for block trains, as rail can offer very competitive price in this market segment.

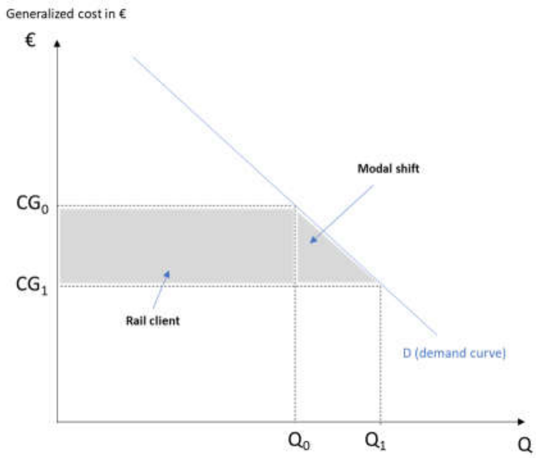
Considering the current competitive position of rail for the different market segment, and the starting point described in §9.1.1, the assumptions used for each market segment are described in the paragraphs below.

9.3.2. PRICE EVOLUTION PER MARKET SEGMENT

9.3.2.1. Price evolution for block trains

For block trains, market is considered in perfect competition. The margin, at 10%, is close to the WACC. Therefore, in the long term, it has been considered that all the economic surplus will be passed to the client.

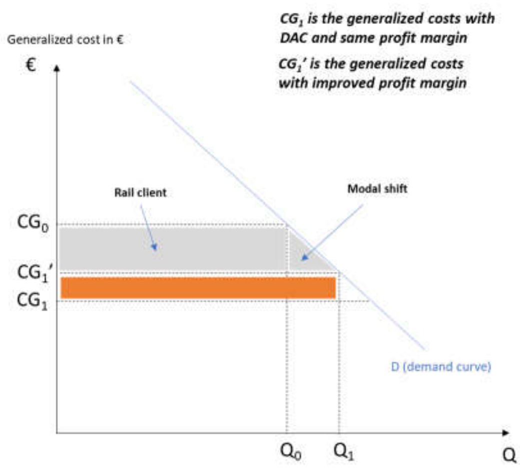
Rail industry will nevertheless benefit from increased revenues due to modal shift.



9.3.2.2. Price evolution for intermodal trains

For intermodal trains, the market is also considered in perfect competition. However, the margins (5%) are lower, below the WACC. Therefore, in the long term, a portion of the economic surplus is expected to be used to restore profit margins, the rest will be passed to the shippers. The portion kept by the railway industry is estimated at 10%.

Rail industry will also benefit from increased revenues due to modal shift.



9.3.2.3. Price evolution for single wagon load

As a starting point, margins are negative for railway undertakings operating in SWL. It means that average costs are higher than marginal costs.

The market is not a perfect competition, but railway undertakings are still considered as “price takers” due to road competition. In the long term, a portion of the economic surplus will be used to restore profit margins, if something is left the rest will be passed to the shippers.

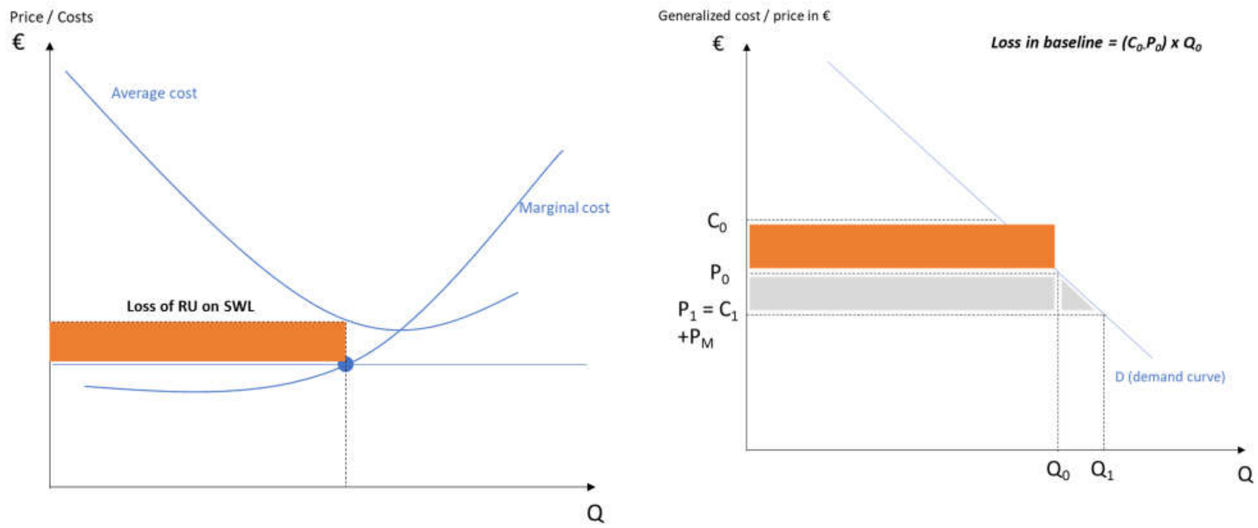


Figure 45 – competitive position of single wagon load

9.3.2.4. *Ramp up curve*

As explained above, for block trains and intermodal trains, it is expected that all or a large share of the economic surplus will be passed progressively to the final customers (the shippers). But the pace of this transfer still has to be specified. Indeed, in the economy, a pricing drop is never following immediately the cost decrease. An adaptation period is necessary, where the railway undertakings actually get the majority of the economic benefit of the cost decrease. At a micro level, the cost decrease is firstly enacted by the most dynamic players on the market. These dynamic players will then try to increase even more their benefits by slightly decreasing their pricing, coupling their profitability increase with a market share increase. Soon enough, both cost decrease (generated by the innovation) and the subsequent pricing decrease will “diffuse” in all the market. The pricing will drive down until it reaches the new economic equilibrium. In this transition period, the overall railway system will get a part of the net cost decrease, and individual railway undertakings will also get a higher market share.

This delay in the price decrease has been translated in the CBA by a transition period, which occurs after the first year of system benefits (2028 in the conservative scenario). In this transition period, the benefits are slowly transferred from the railway system to shippers. The assumption used for the duration of this transition period is 7 years in the CBA. This value is based on real life experiences[37] (mostly the American rail freight liberalisation in the 1990s[38]).

[37] This period has been extended to 7 years instead of 5 as could be observed in past experience, as benefits from DAC are expected to be close to zero in 2028 and 2029

[38] *Productivity of the U.S. Freight Rail Industry: a Review of the Past and Prospects for the Future,* Youssef Kriem, MIT (2011)

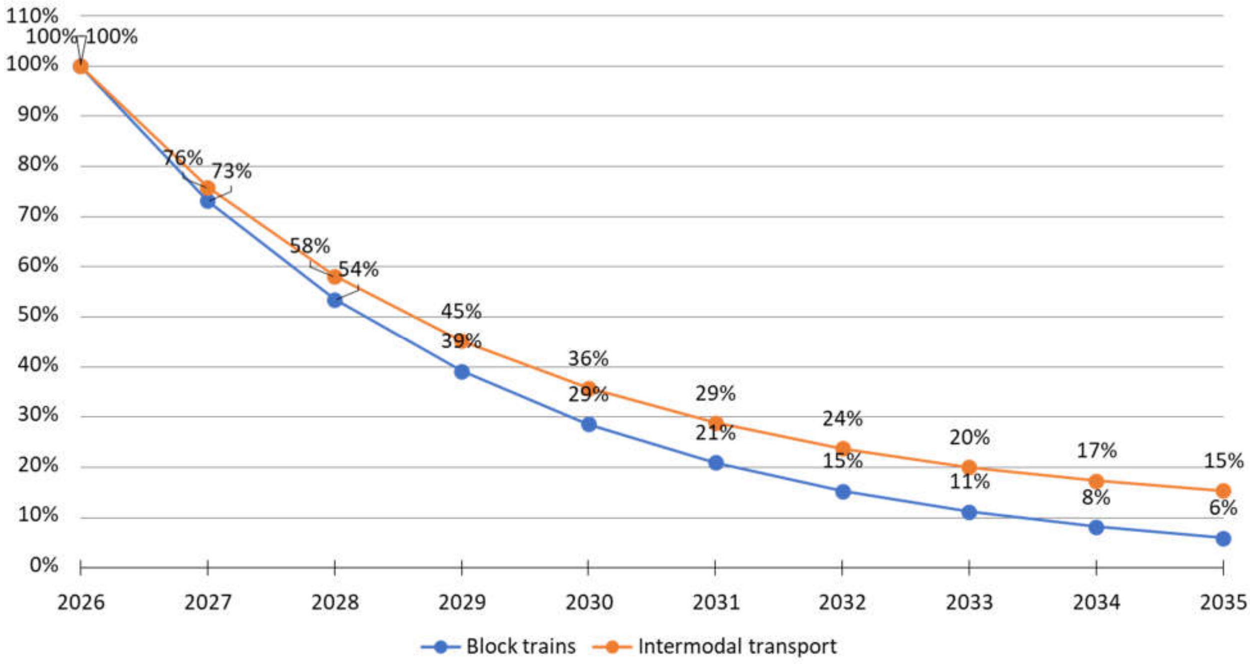


Figure 46 – Share of the economic surplus allocated to the railway system

Therefore, considering the figure above, in the first years after DAC deployment starts, most of the economic surplus will be kept by the railway system, price will not decrease. Then, progressively, the economic surplus is passed to the shippers: prices are decreasing, but the market share of rail is also increasing.

Single wagon load is not represented in the figure above, as the economic surplus is kept by the railway system as long as single wagon load is losing money. According to the CBA, single wagon load will not become beneficiary thanks to DAC only: price on this market segment will not decrease.

9.3.3. ASSESSEMENT OF MODAL SHIFT USING PRICE ELASTICITY

Unfortunately, there was no traffic modelling tool available to assess in a detailed manner the potential impact of DAC on the modal share of rail freight. Therefore, it was decided to use cross mode price elasticities coming from various sources and studies[39]. Of course, this approach is simplified, as it is not taking into account the relative evolution of competitiveness of rail versus road. Indeed, there are many factors which are expected to impact the competitiveness of those 2 modes in the long term, in different directions:

- Low emissions zones, carbon pricing, the new rules set in Directive (EU) 2020/1057 and the shortage of truck drivers in Europe today will improve the competitiveness of rail against road;
- On the other hand, the cost of energy for rail transport, and the technical innovations in road transport (which are deployed at a faster pace due to the size of the market and the life duration of a truck) will improve the competitiveness of road against rail;
- Other factors, such as the price of crude oil and the exchange rate €/$ also have an impact on the relative competitiveness of road and rail, and are very difficult to predict.

In the end, price elasticities were the only option available; they give a useful indication of the potential impact of DAC on rail freight market share, but should be considered taking into account the limitations mentioned above.

The price elasticities used per production system are shown in the table below:

	Unit	Block	Intermodal transport	Single wagon load
Price elasticities	%	-1.0	-1.5	-1.2

Table 15 – Assumptions on revenues and profit margin per production system

These values show a strong sensitivity of rail freight transport to transportation price. For instance, in intermodal transport, an increase of rail prices by 1% (with constant road prices) would lead to a decrease of intermodal transport by 1.5%.

9.3.4. ADDITIONAL MODAL SHIFT DUE TO HIGHER PERFORMANCE OF RAIL FREIGHT

The elasticities described above are only dealing with the impact of a price decrease on the modal share of rail freight. But DAC is also expected to improve dramatically the competitiveness of rail freight, and especially single wagon load, against road. This improved competitiveness is due to:

- **A higher reliability of rail freight transport:** the decrease in the coupling / uncoupling time will give more margins to railway undertakings to manage incidents and be on time for their path on the

[39] Gerard de Jong (2018) Determining price elasticities of rail transport demand for market-can-bear tests [Available at: https://significance.nl/wp-content/uploads/2019/04/2018-GDJ-Determining-price-elasticities-of-rail-demand-for-market-can-bear-tests.pdf]
Jourquin & Beuthe (2019) Cost, transit time and speed elasticity calculations for the European continental freight transport, Transport Policy 83, pp 1-12
BITRE Australia (2022) Transport Elasticities Database [Available at: https://www.bitre.gov.au/databases/tedb]

infrastructure. For instance, if a train is ready, but a damage is detected on a wagon during train inspection, then it will be easier to remove this wagon from the train and get the train ready for departure again;

- **A lower transit time:** for some categories of goods, transit time is very important (for instance: electronic products). And today, single wagon load is not able to propose a competitive transit time for shippers, due to the time spent in marshalling yards (some stakeholders quoted transit time of 60 hours for a wagon, as it has to go through multiple yards, and sometime spend 24 hours in a yard waiting for the train). DAC will be a game changer, as it will enable huge gain in the time spent in marshalling yards, leading to a shorter transit time for the goods;
- Finally, DAC will also be an enabler for **additional digital and telematic services**, which will enable the shippers to know where there goods are, and for railway undertakings to have quicker reactions when an incident occur on one of their train.

These qualitative improvements are expected to give access to new markets for single wagon load (or rather to allow them to be competitive again on markets they had to abandon for multiple decades): the demand for rail freight is expected to increase, as shown in the figure below:

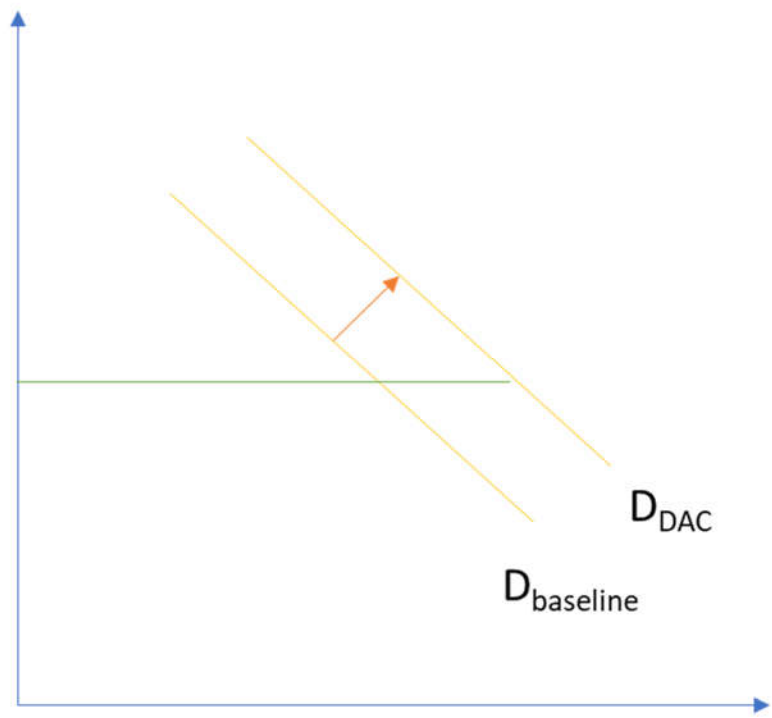


Figure 47 – Shift in the demand curve for single wagon load thanks to DAC

The impact of this shift in the demand curve is very difficult to assess. After discussions with WP5, it was decided to use a conservative value of 0.5% increase of single wagon load traffic in the CBA.

9.4. EXTERNALITIES AND SAFETY

9.4.1. EXTERNALITIES

The calculation of externalities is based on the "Handbook on the external costs of transport" from 2019. This handbook provides external costs per t-km for road and rail. The values used in the CBA are directly extracted from this report:

	Unit	Value 2020
Road externality costs	€ / M t-km	42 000
Rail externality costs	€ / M t-km	13 000
Delta road - rail	€ / M t-km	29 000

Table 16 – External costs or road and rail

Moreover, a decrease of road external costs of 0.5% / year and of rail external costs of 0.25% / year have been used in the CBA, in order to take into account the expected technological improvements of these two modes of transport.

These values are then multiplied by the new rail freight traffic, which is coming from:

- Modal shift calculated on price elasticities
- Modal shift due to higher performance of single wagon load
- Extra traffic coming from additional capacity on the network[40]

9.4.2. SAFETY

DAC is expected to dramatically improve the work conditions of shunting staff, and also have a positive impact on the overall safety of the railway system.

Acknowledging that no complete perspective on the safety impacts is available, the following assumptions have been used:

- During migration, the risks are expected to increase, unless some mitigation measures are put in place. Therefore, a cost for these mitigation measures has been considered in the CBA, equal to 75 M€ / year over the period 2028-2031.
- After implementation, railway operations become substantially safer, as fewer manual operations needs to be performed. The number of serious injuries for staff is expected to decrease significantly. Equally, the increased coupler strength is also contributing to fewer derailments, even if no derailment detection function is activated on the DAC. The relative reduction in fatalities, serious injuries and derailments as shown in the figure below:

[40] The underlying assumption is that this additional traffic was done by road transport before

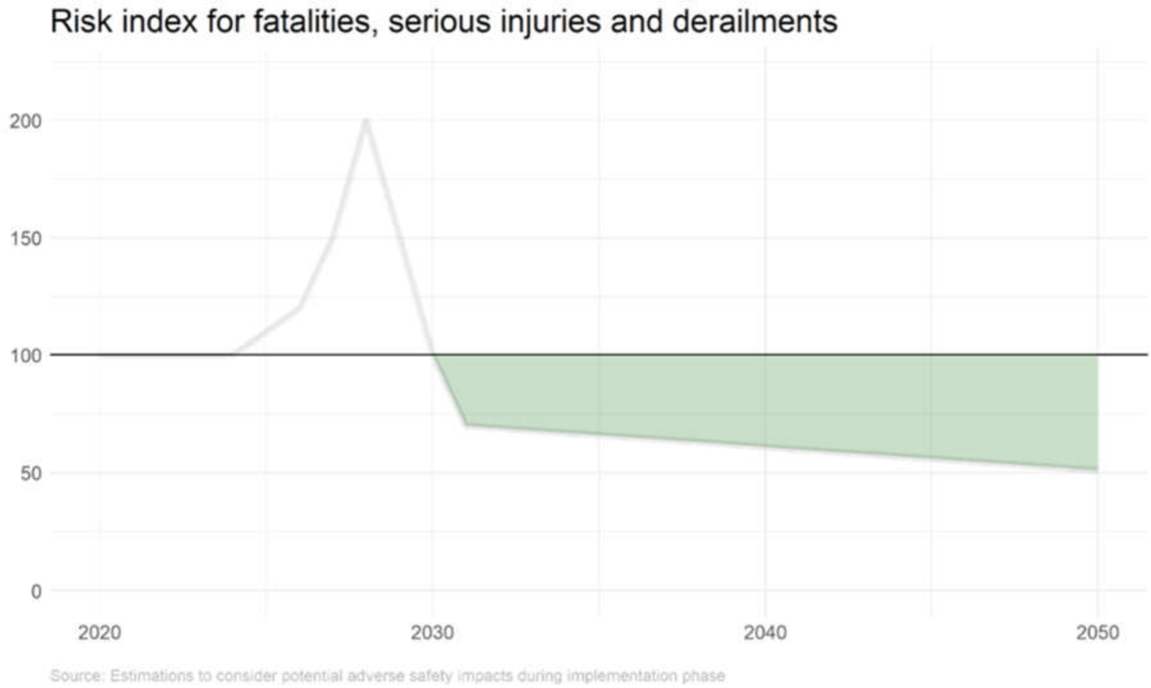


Figure 48 – Risk index for fatalities, serious injuries and derailments

A difficulty in assessing the total number of accidents at sites is that the Common Safety Indicators (CSI) , being the key source for safety related data, do not necessarily include accidents at terminals and sidings. The CSI guidelines excludes accidents at those locations from being reported. Problematically, some parts of the network may be totally excluded from the scope of a reporting obligation, as Member States do not apply the Safety Directive to parts of the network based on (EU) 2016/798 Art 3.

As such, the number of accidents on sites related to shunting, coupling and (un)loading is likely to be strongly underestimated. In absence of better numbers, the current statistics and projection are applied to calculate the DAC induced evolution of safety, as shown in the figure below.

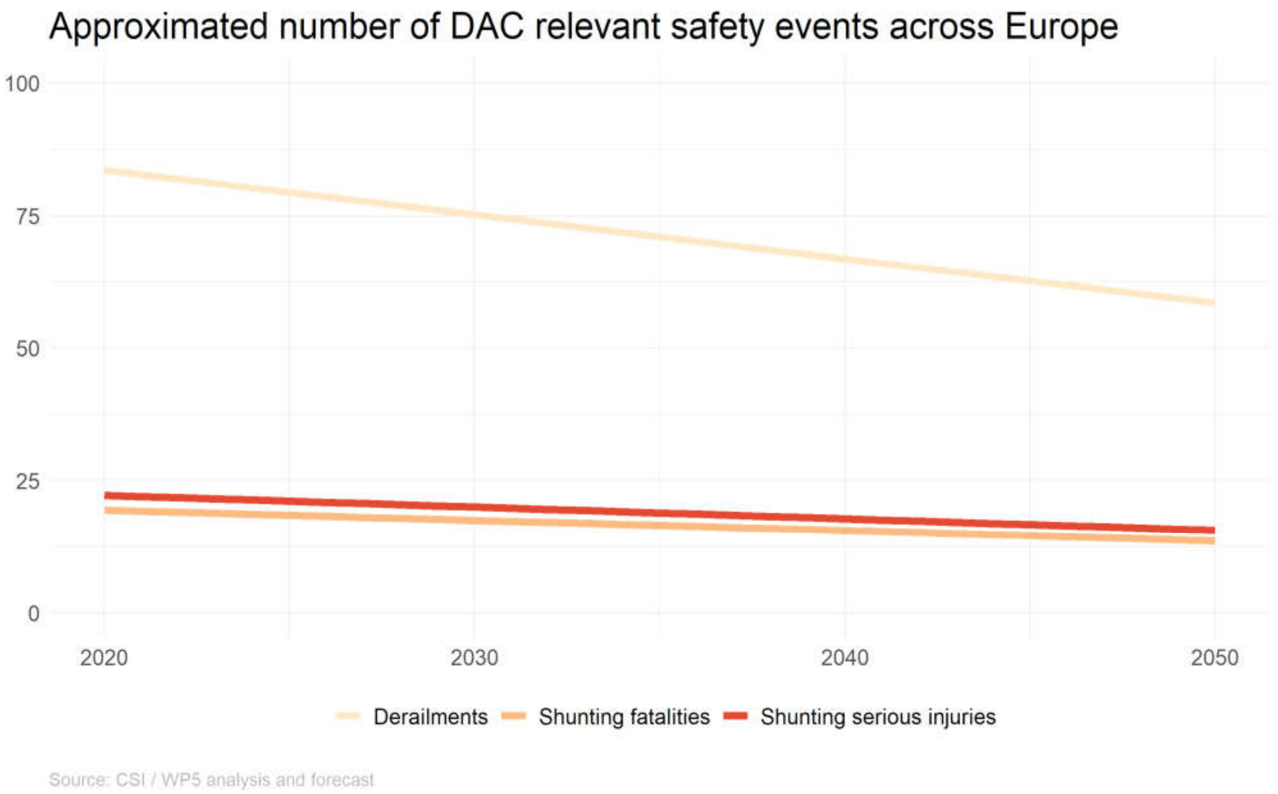


Figure 49 – Safety forecast considering impact of DAC

The safety benefits have been monetised using the average European values for preventable fatalities, serious injuries, and derailments. As shown in the table below.

	Value
Value of preventable fatalities	3 192 919 €
Value of preventable serious injury	486 161 €
Value of preventable derailment	1 123 036 €

Table 17 – Value of preventable fatalities, serious injuries and derailments

10. MAIN RESULTS

This section presents the main results of the DAC CBA. Firstly, the main results are presented for the four technological packages listed in section 0. Then, the distribution of the costs and benefits are presented for each technological package. As a reminder, the main logic of the technological packages is described below:

- The **first "tech package"** only considers DAC 4 and the associated communication system.
- The **second "tech package"** corresponds to DAC 5.
- The **third "tech package"** considers an automated brake test device on top of tech package 2.
- And finally, the **fourth "tech package"** considers all the components from tech package 3 plus equipment required for automated wagon inspection on the wagon and for automated parking brake. It can be seen as **the upper bond of the potential effect of DAC with the functionalities identified and quantified today**.

It should also be noted that a high level of uncertainty is still associated with tech package 4 both on costs (which additional components required?) and benefits (how much time could be saved on wagon inspection?). **Therefore, the most robust upper bound of the current CBA is the tech package 3.**

10.1. OVERALL RESULTS

As explained in the presentation of the methodology in §5.1, the CBA is considering a long term timeline of 30 years, starting at the first year of deployment (2028-2057). Unfortunately, this timeline is not aligned with the return of investment expected by the sector, which is not going beyond 10 years after initial investment. Therefore, in this sub-chapter, the results are presented with the two timelines, and an overall conclusion is drawn from these results.

10.1.1. ON THE LONG TERM, DAC IS A VERY POSITIVE PROJECT FROM AN EU PERSPECTIVE

The main results of the CBA over 2028-2057 are presented in the table below:

Tech package	Start	Duration	Big bang	Variable	Results 2028-2057 *(mEUR)*
1	2028	6	2031	Total benefits (not discounted)	55,604
				Total costs (not discounted)	21,357
				Total benefits (discounted)	29,373
				Total costs (discounted)	14,307
				BC-ratio (discounted)	2.1
				IRR	11%
2	2028	6	2031	Total benefits (not discounted)	64,027
				Total costs (not discounted)	26,590
				Total benefits (discounted)	33,967
				Total costs (discounted)	17,433
				BC-ratio (discounted)	1.9
				IRR	11%
3	2028	6	2031	Total benefits (not discounted)	87,970
				Total costs (not discounted)	30,043
				Total benefits (discounted)	47,012
				Total costs (discounted)	19,428
				BC-ratio (discounted)	2.4
				IRR	15%
4	2028	6	2031	Total benefits (not discounted)	124,066
				Total costs (not discounted)	37,770
				Total benefits (discounted)	66,704
				Total costs (discounted)	23,895
				BC-ratio (discounted)	2.8
				IRR	19%

Table 18 – Main results of the CBA (2028-2057)

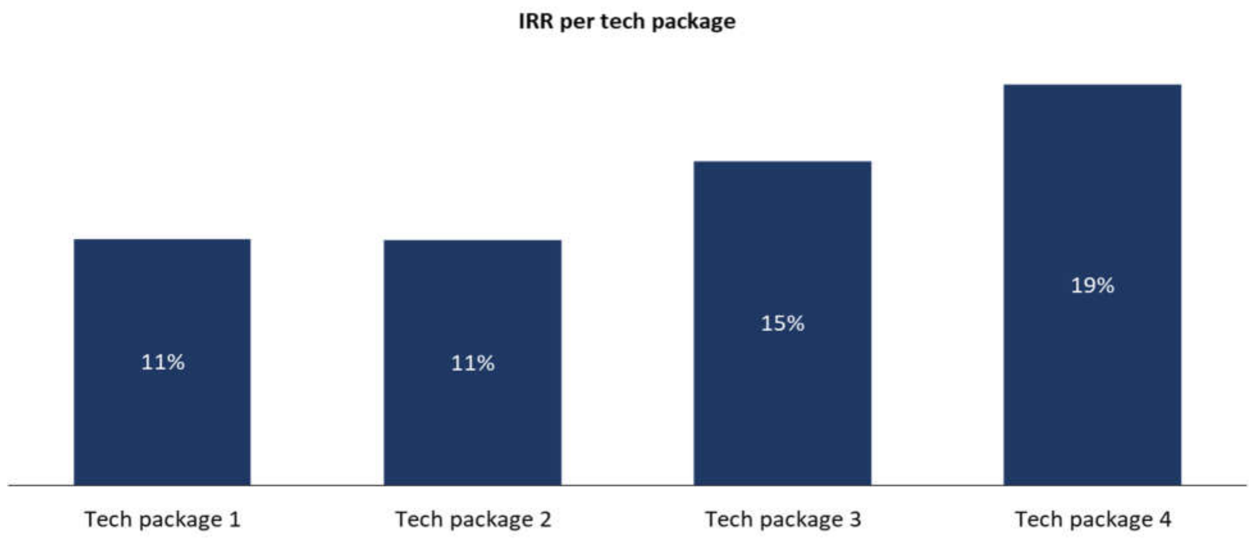


Figure 50 –IRR per technological package (2028-2057)

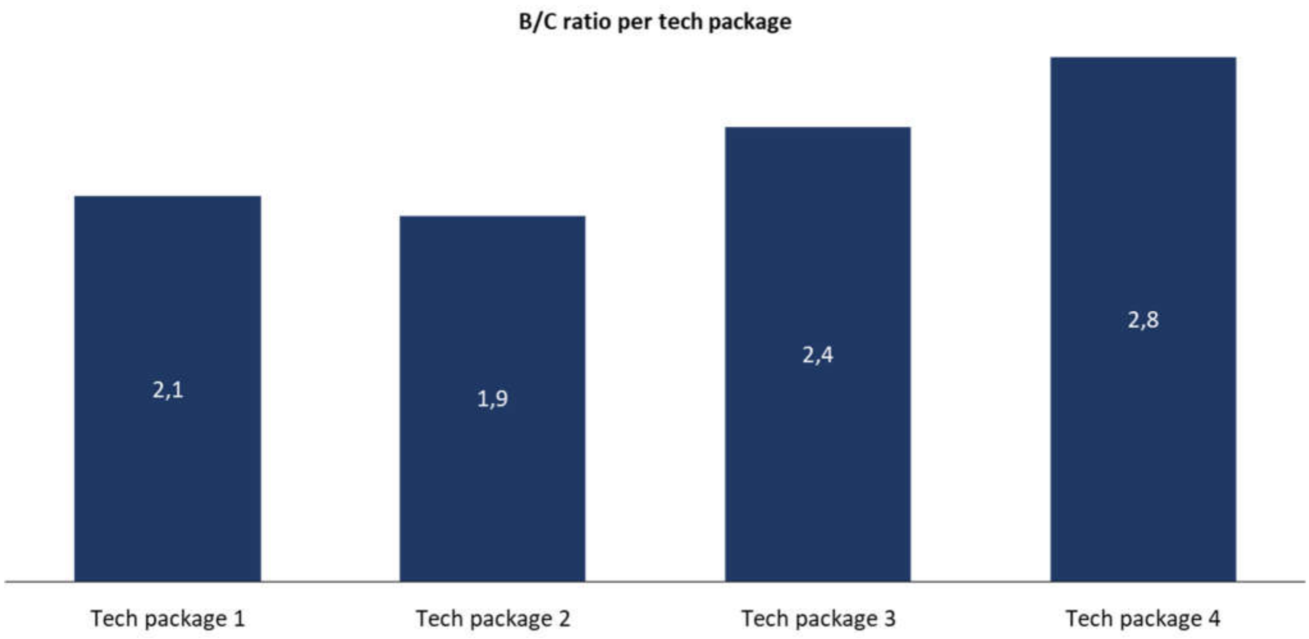


Figure 51 –B/C-ratio per technological package (2028-2057)

Overall, all scenarios have a strong result from a societal perspective, with IRR and B/C ratios ranging from 11% to 19% and from 1.9 to 2.8 respectively.

The best technological package is the fourth one, but there is a high level of uncertainty on the capacity to reduce the time for train inspection as much as proposed in the current CBA (time for train inspection is divide by 2). Moreover, for a strong decrease in train inspection, additional investments might be required (like for instance video gates), which are not yet considered in the current version of the CBA.

Therefore, the most realistic upper bound to be considered is the technological package 3, with automated brake test, which would lead to an IRR of 15% and a B/C ratio of 2.4.

Finally, tech packages 1 & 2 have very close results, as the extra costs to go from DAC 4 to DAC 5 are approximately equal to the extra benefits brought by DAC 5.

10.1.2. BUT ON THE SHORT TERM, COSTS OF DAC DEPLOYMENT ARE HIGHER THAN THE BENEFITS

The main results of the CBA over 2028-2037 are presented in the table below:

Tech package	Start	Duration	Big bang	Variable	Results 2028-2037 *(mEUR)*
1	2028	6	2031	Total benefits (not discounted)	6,491
				Total costs (not discounted)	10,621
				Total benefits (discounted)	4,815
				Total costs (discounted)	8,908
				BC-ratio (discounted)	0.5
				IRR	\
2	2028	6	2031	Total benefits (not discounted)	7,769
				Total costs (not discounted)	12,180
				Total benefits (discounted)	5,765
				Total costs (discounted)	10,209
				BC-ratio (discounted)	0.6
				IRR	\
3	2028	6	2031	Total benefits (not discounted)	11,365
				Total costs (not discounted)	13,061
				Total benefits (discounted)	8,439
				Total costs (discounted)	10,928
				BC-ratio (discounted)	0.8
				IRR	\
4	2028	6	2031	Total benefits (not discounted)	16,837
				Total costs (not discounted)	15,032
				Total benefits (discounted)	12,508
				Total costs (discounted)	12,537
				BC-ratio (discounted)	1.0
				IRR	\

Table 19 – Main results of the CBA (2028-2037)

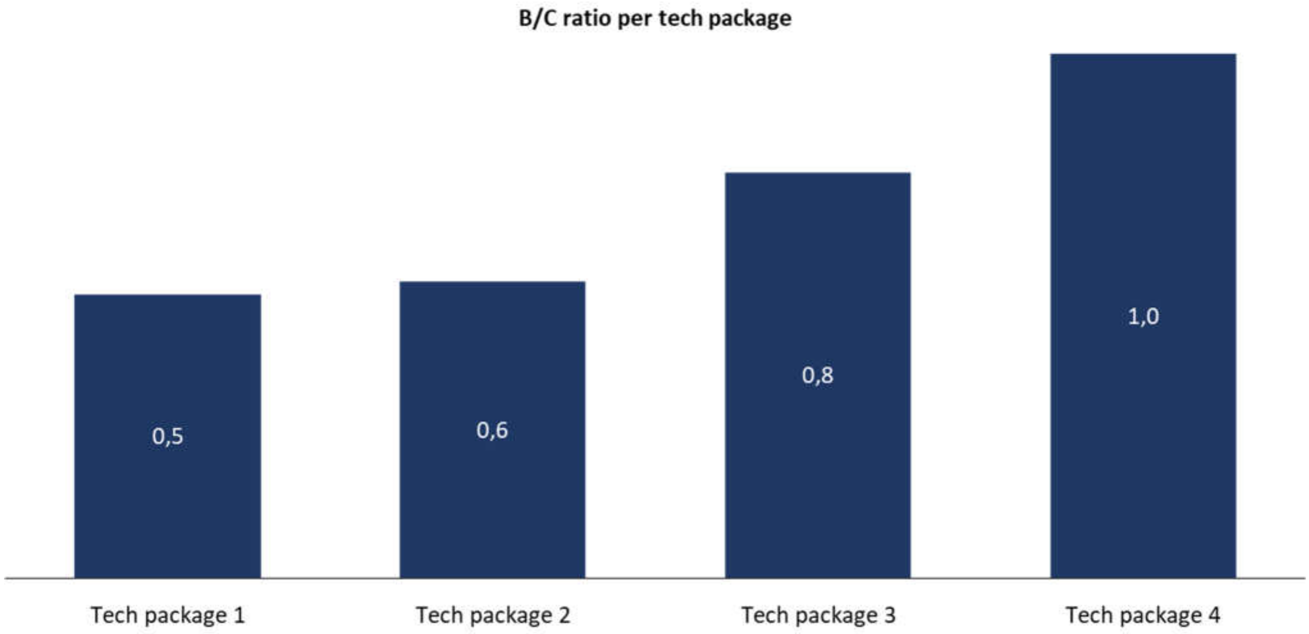


Figure 52 – Benefits / costs ratio (discounted) per technological package (2028-2037)

The figure shows that the benefits / costs ratio does not exceed 1. Moreover, the benefits considered include societal benefits, which will not directly generate additional revenues for the railway system. Therefore, DAC might prove very difficult to finance solely by the railway sector.

10.2. OVERVIEW OF COSTS AND BENEFITS

10.2.1. OVERVIEW OF COSTS AND BENEFITS FOR TECH PACKAGE 1

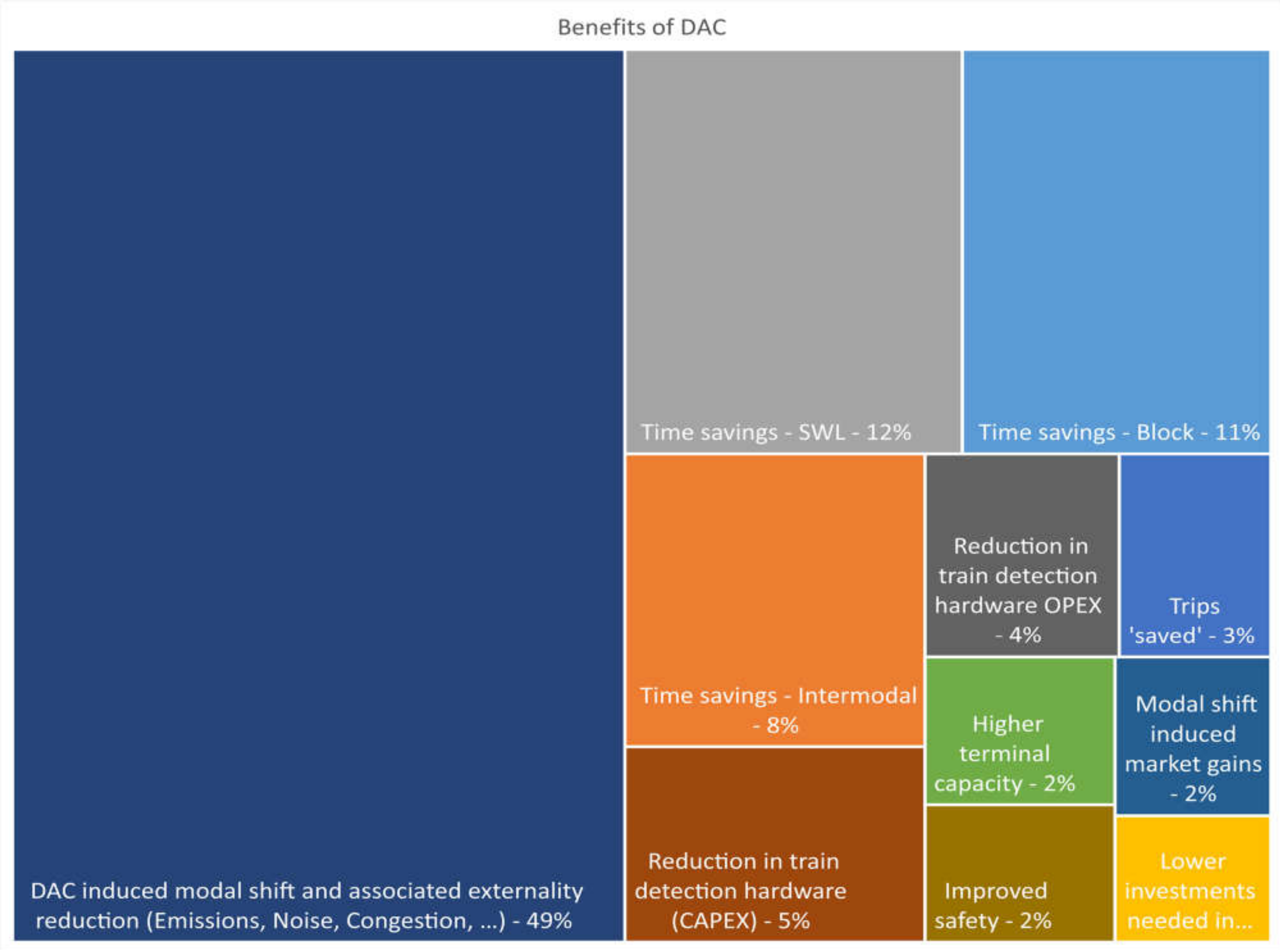


Figure 53 – Overview of the benefits for technological package 1

For this first technological package, **the main benefit of DAC is the decrease of transport externalities**, which are coming from the modal shift enabled by DAC (mainly coming from capacity increase). This benefit represents **49%** of the overall benefits. The other benefits are coming from **time savings** (approx. **31%** of total benefits).

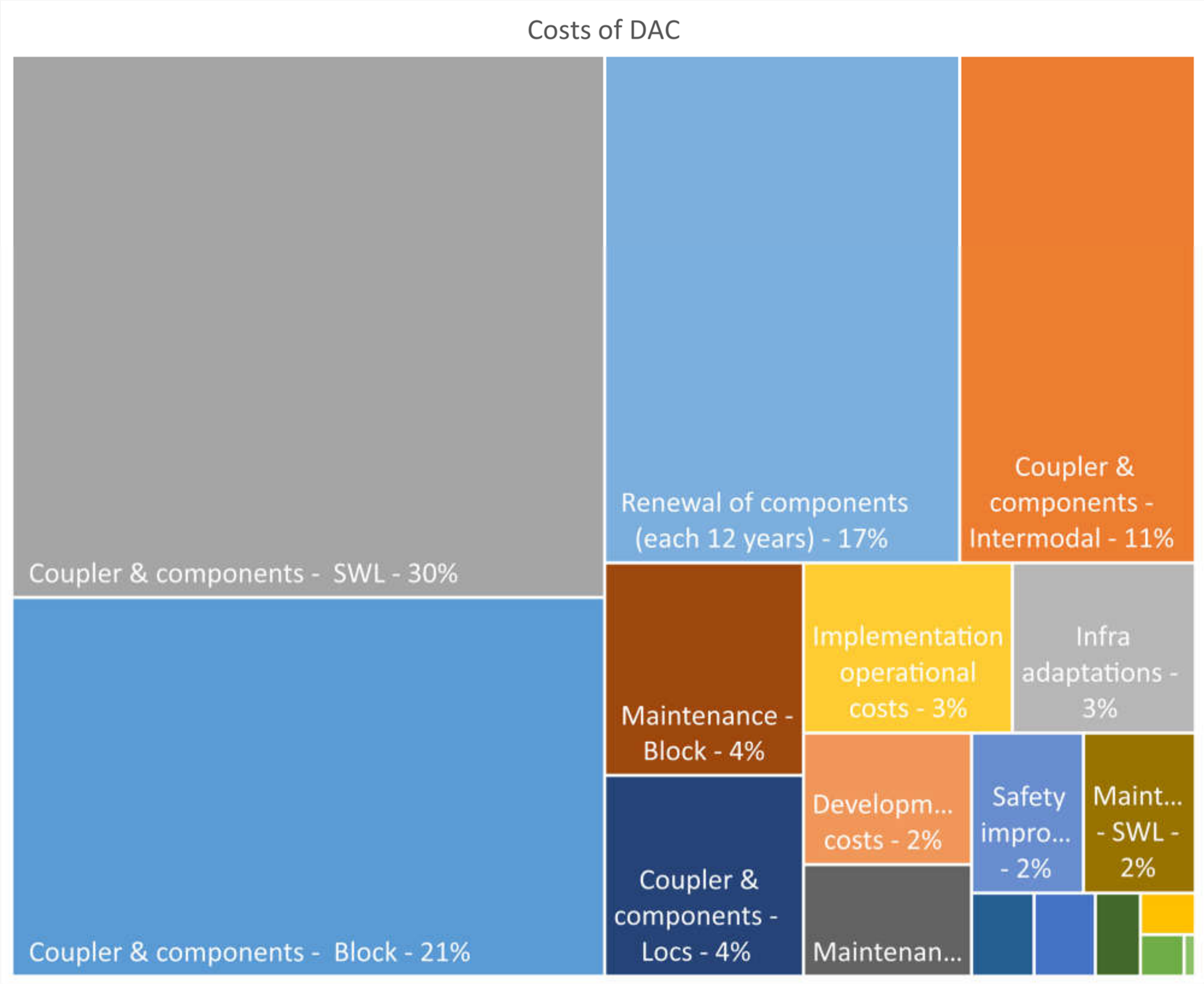


Figure 54 – Overview of the costs for technological package 1

On the costs side, the deployment of the couplers and additional components represent approx. 66% of the total costs. Extra maintenance and the renewal of additional components is not negligeable, as it represents approx. 25% of total costs.

10.2.2. OVERVIEW OF COSTS AND BENEFITS FOR TECH PACKAGE 2

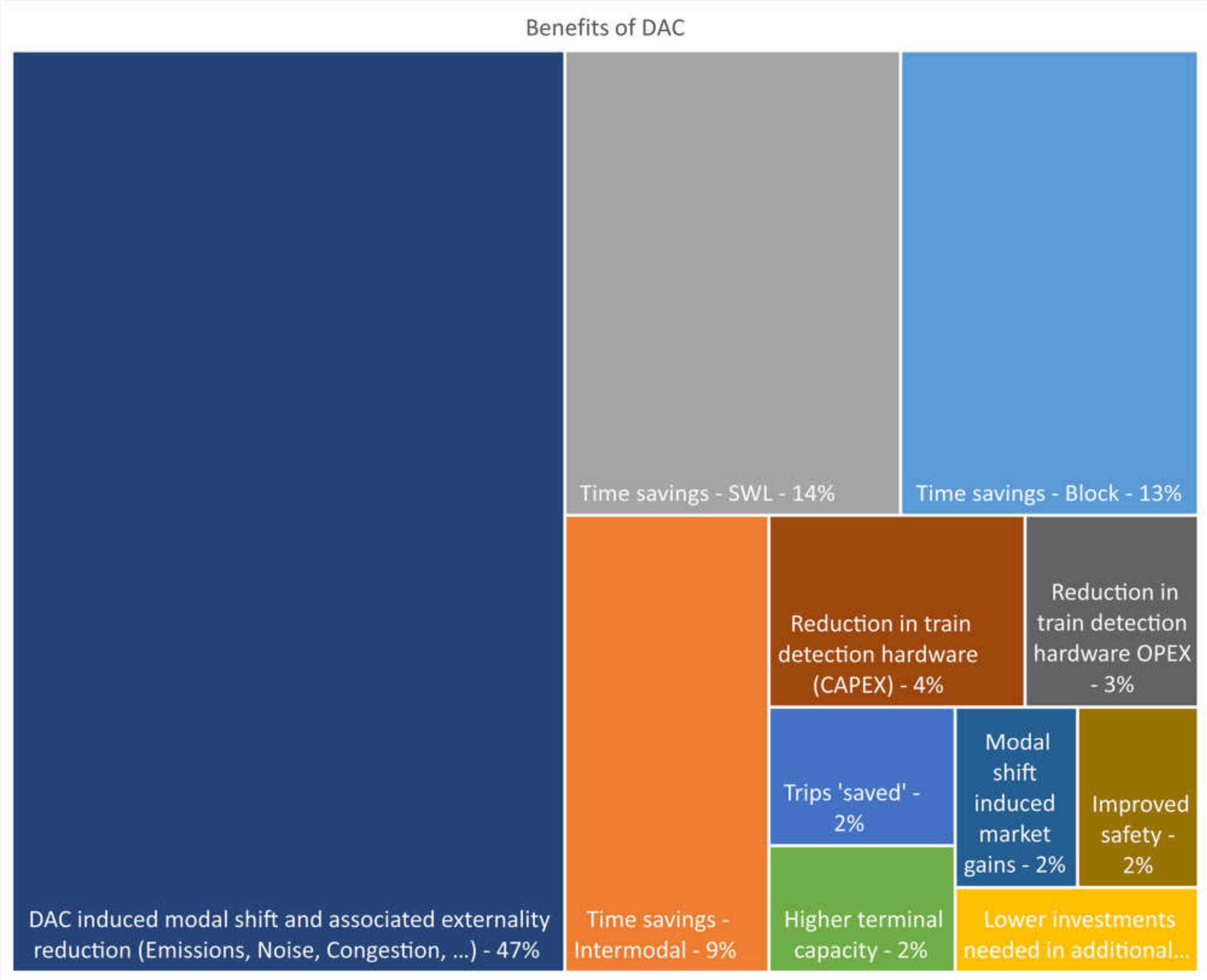


Figure 55 – Overview of the benefits for technological package 2

The overall distribution of the benefits does not change significantly for tech package 2, with a small shift from external costs reduction (47%) to time savings (36%).

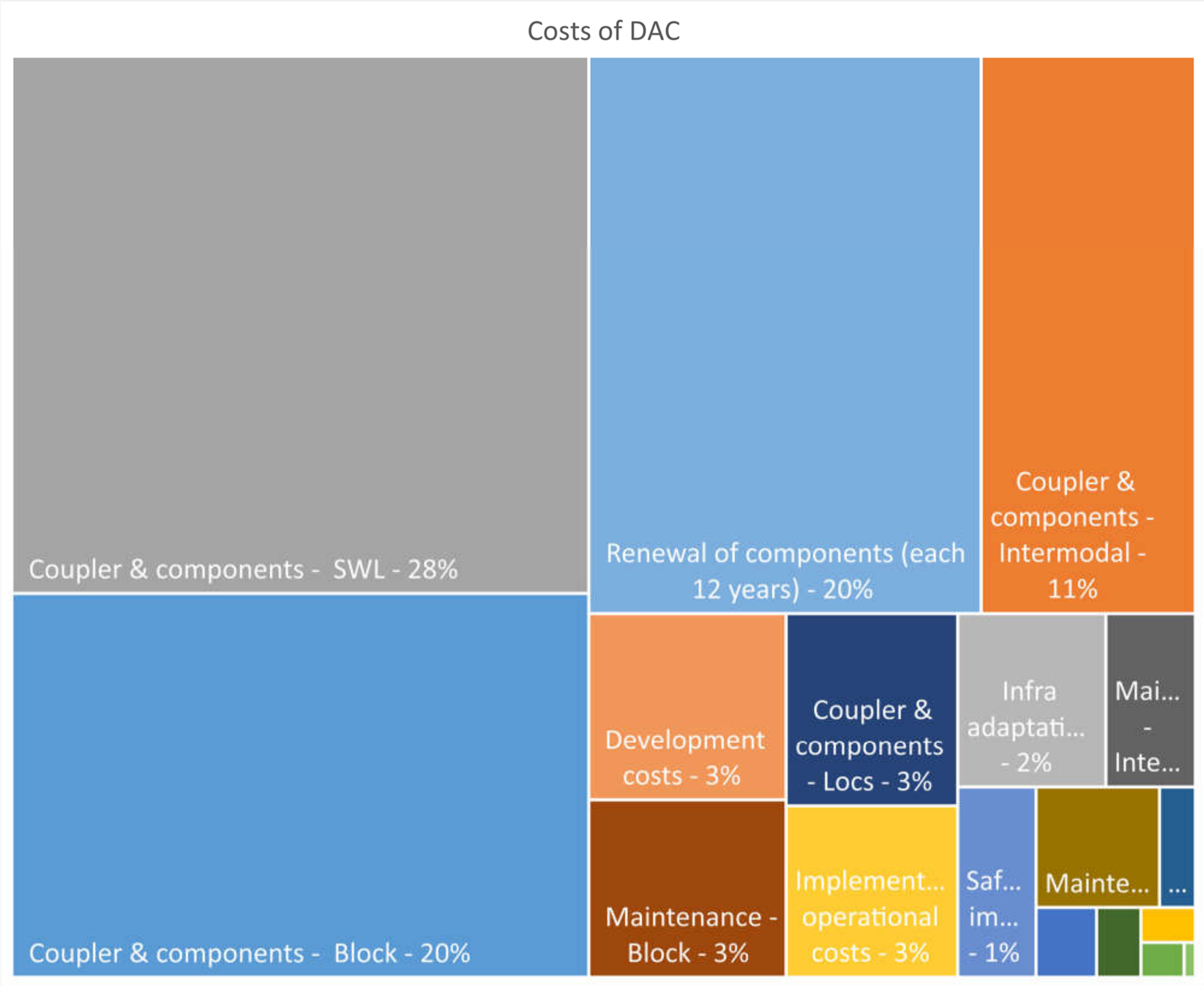


Figure 56 – Overview of the costs for technological package 2

The distribution of costs is similar to the one for tech package 1, with an increase of the cost of renewal of the components (but same total for renewal + maintenance).

10.2.3. OVERVIEW OF COSTS AND BENEFITS FOR TECH PACKAGE 3

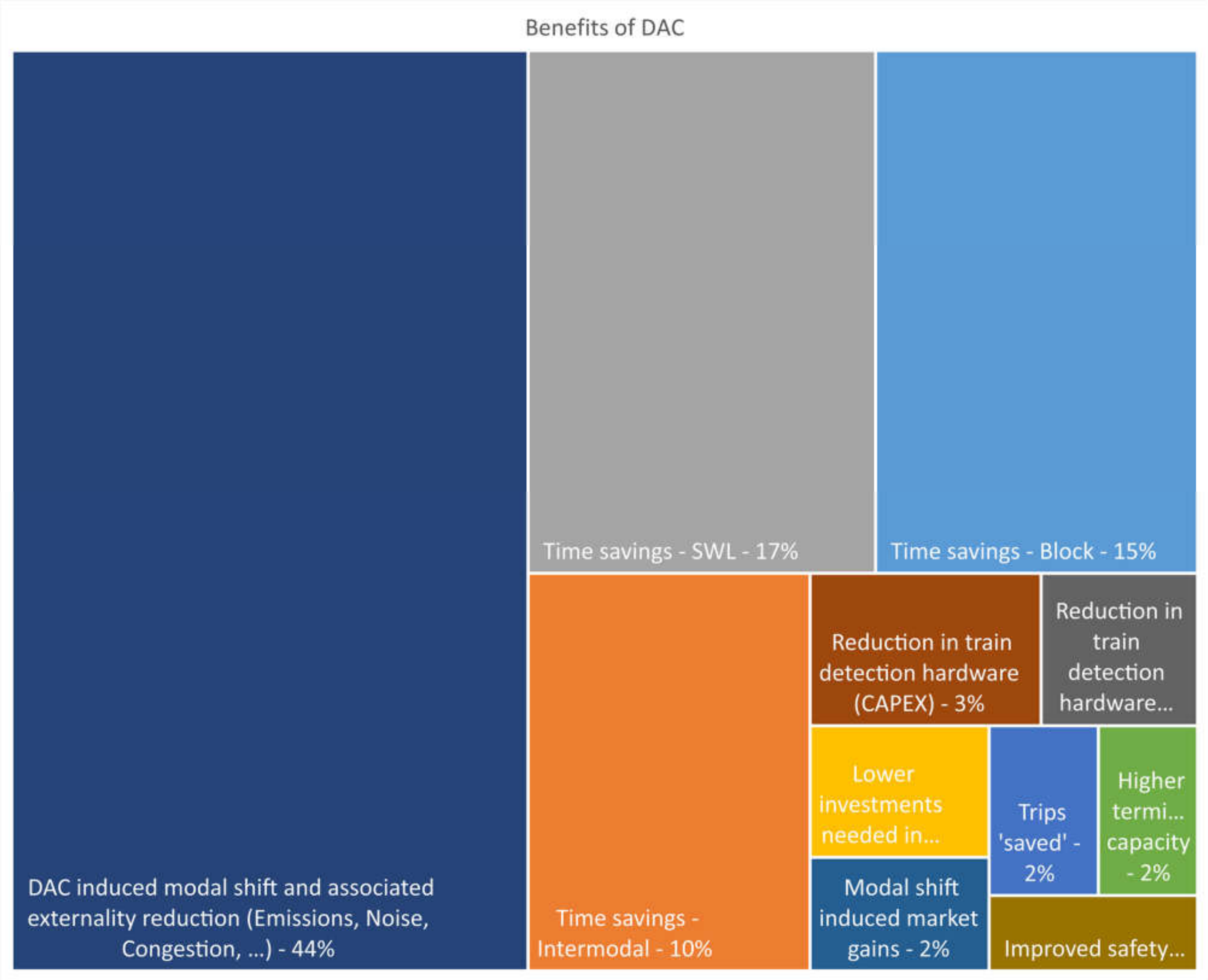


Figure 57 – Overview of the benefits for technological package 3

For tech package 3, thanks to automated brake test, benefits are more balanced between **external cost reduction (44%) and time savings (42%)**.

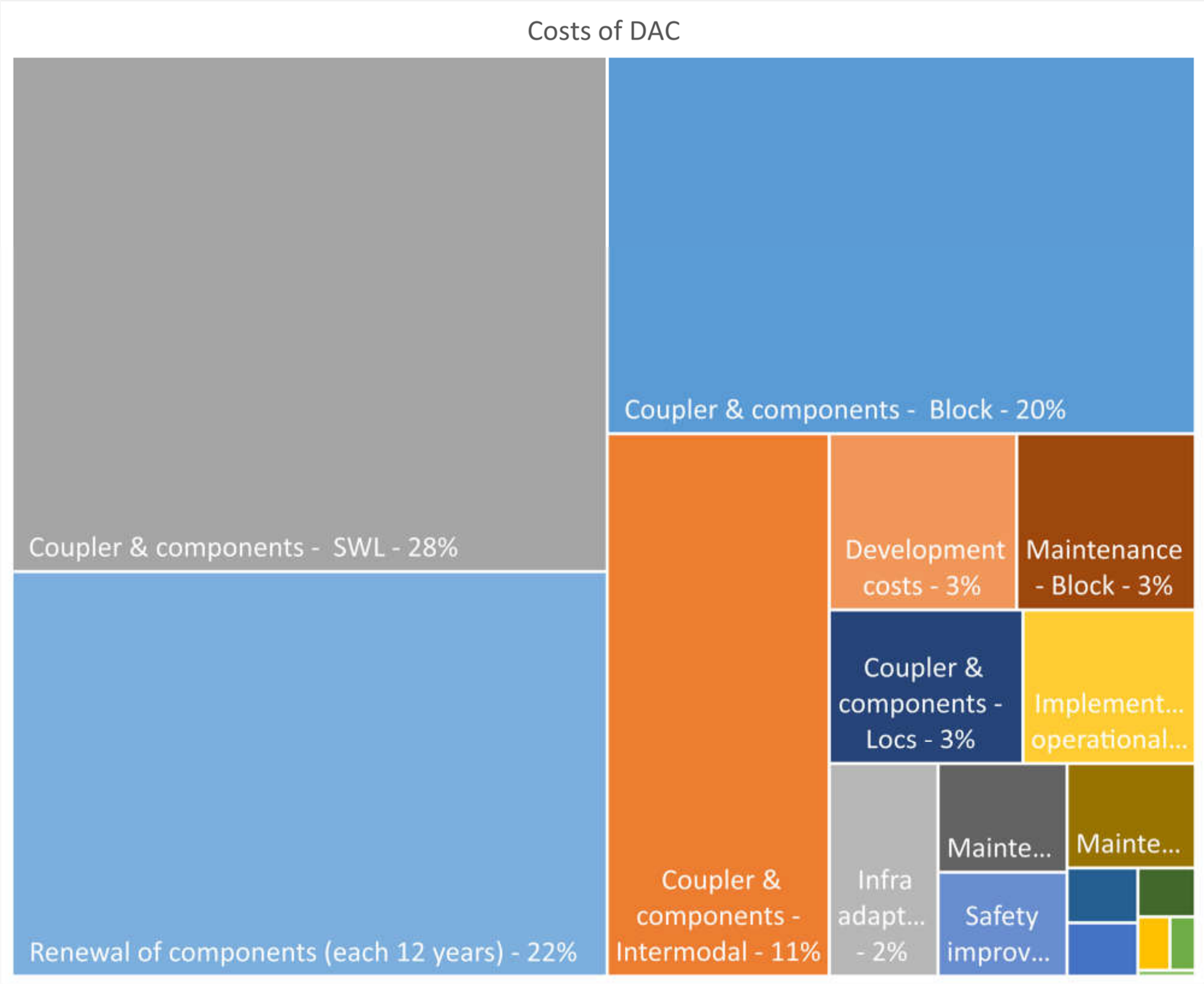


Figure 58 – Overview of the costs for technological package 3

The distribution of costs is similar to the one for tech package 1 & 2, with an increase of the cost of renewal of the components (but same total for renewal + maintenance).

10.2.4. OVERVIEW OF COSTS AND BENEFITS FOR TECH PACKAGE 4

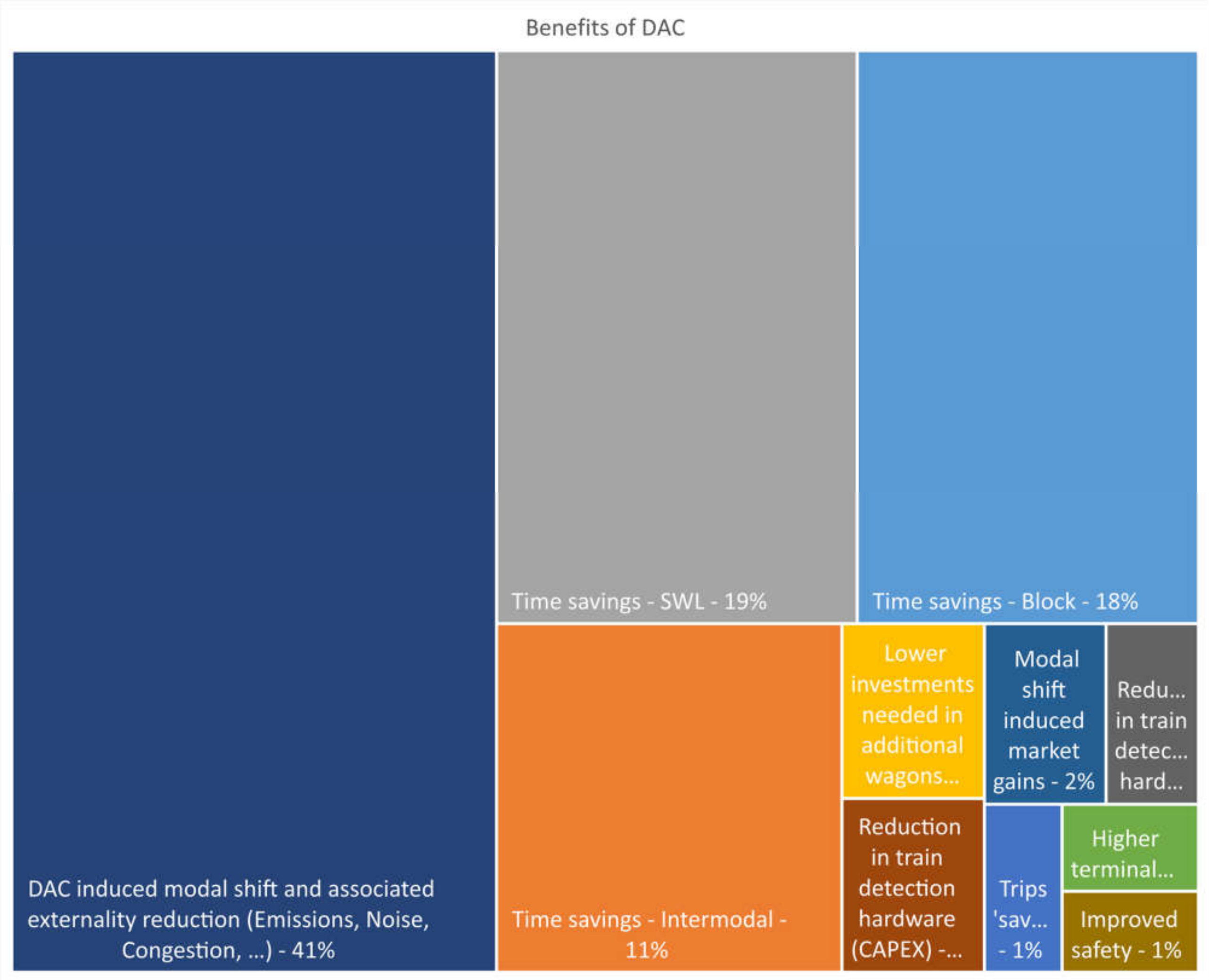


Figure 59 – Overview of the benefits for technological package 4

For tech package 4, and with all the limits listed in the introduction of this chapter, the main benefit is coming from time savings (48%), followed by external costs reduction (41%).

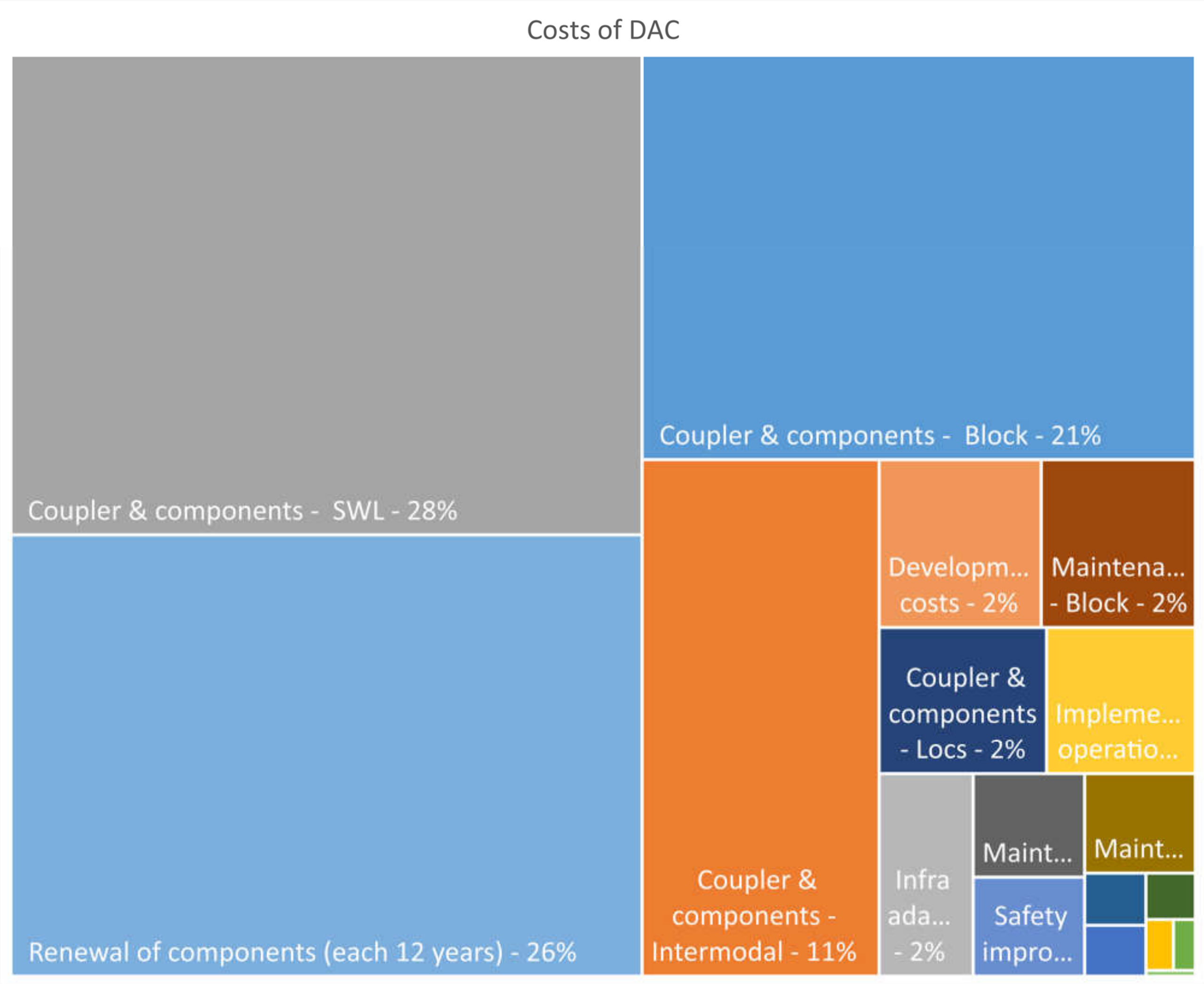


Figure 60 – Overview of the costs for technological package 4

The distribution of costs is similar to the one for tech package 1, 2 and 3, with an increase of the cost of renewal of the components (but same total for renewal + maintenance).

10.3. MAIN FINDINGS

DAC is a very good project from a socio-economic perspective. The CBA also shows that the most interesting option is the tech package 3, bundling DAC5 with automated brake test. Indeed, this option is based on robust assumptions, and leads to a benefits / costs ratio of 2.4 and an IRR of 15%. But there are many more functionalities that DAC might enable and which have not been explored yet: therefore, the result of this tech package can be seen as a low bound of what could be achieved with DAC.

The costs of deploying DAC represent 60% of the total costs (11 to 15 bn€ not discounted according to the tech package considered), whatever the scenario, while the costs of maintaining / renewing the new system represent 30% of the total cost. Rest of the costs are linked to one-off costs during migration (like for instance training of staff during migration to keep the same level of safety, cost of adapting the IT system, etc.).

For 3 out of the 4 tech packages, the main benefit is the decrease of external costs (41 to 49% of total benefits), which is a socio-economic benefit for the society. It is followed by the time benefit, which represents 31 to 48% of total benefits. Other benefits also include savings for infrastructure managers on train detection systems (thanks to train integrity), improved safety, etc.

11. SENSITIVITY ANALYSIS

The feedback received during the consultation of November 2022 pointed at some assumptions with high level of uncertainty, namely:

- The traffic forecast from the baseline scenario
- The coupler cost
- The locomotive coupler installation cost
- The maintenance costs of DAC
- The conversion factors used to monetize time savings

In order to test the robustness of the CBA against these assumptions, some sensitivity tests have been developed with the modelling tool, as described below**. All the sensitivity analysis have been done using tech package 3 as the baseline scenario.**

11.1. SENSITIVITY TESTS - RATIONALE

The DAC CBA study has been done in a period with a high level of uncertainty due to:

- The aftermath of the COVID 19 crisis, and the uncertainty on the time for the economy to recover from this global crisis;
- The war in Ukraine, and its impact on inflation (and on the economic growth).

Moreover, DAC is at an early development stage, and there is still a high level of uncertainty on several parameters. Therefore, **sensitivity analysis have been carried out in order to test the robustness of the CBA against a change in one of the key parameter of the calculation**.

The sensitivity tests carried out and their rationale are explained in the table below:

Parameter	Proposed value	Rationale
Traffic forecast	1) Eurostat trend 2012-2019 (+22% in 2050) 2) Intermediate scenario (+50% in 2050)	As a reminder, the traffic growth used in the baseline scenario is +100% in 2050, aligned with EU policy objectives (and accompanying measures). As several stakeholders were questioning this assumption, two sensitivities have been developed. The first one is based on the trend observed between 2012 and 2019 for railway traffic in Europe (+0,67% / year). But this might mean that rail market share will continue to decrease, as road transport increased by 1.1% / year over the same period. As this assumption is not aligned with the EU objectives on climate change but also raises some questions on the capacity of the road network to absorb this extra traffic, an alternative sensitivity analysis has been developed, based on a rail traffic growth of +50% by 2050.

Parameter	Proposed value	Rationale
Coupler cost	1) +50% 2) +100%	The cost of a coupler has not been revised recently, and some analysis are still on-going to review it. As the current crisis in Europe is having a strong impact on production and energy costs, an increase of the coupler cost of +50% and +100% has been tested.
Locomotive installation cost	+100 %	The installation cost of a coupler on locomotives has already been revised in the baseline scenario (from 5,300 € for a basic retrofit to 20,000 €, and from 10,000 € for a complex retrofit to 40,000 €). But as there is still a strong uncertainty on this parameter, a sensitivity analysis with a cost increase of +100% has also been tested.
Maintenance cost	1) -50% 2) +100%	Today, there is a lack of information on the future cost of maintenance of a DAC. A default value of 300 € / wagon (or 150 € / coupler) has been used so far, representing 3% of the cost of a coupler. Considering the high level of uncertainty on this parameter, a wide range of -50% / +100% has been tested for the maintenance cost of a DAC.
Conversion factor	3) 75% for BT 4) 50% for IT 5) 100% for SWL	One of the critical question on the impact of DAC is how much of the time saved in operation can actually be used to optimize the use of the workforce and of the assets. Only qualitative feedback has been received so far, and no alternative values to the ones used in the CBA has been provided by the sector. Nevertheless, a sensitivity analysis has been developed to check the robustness of the assumptions used: 1) For block trains, the case studies carried out are suggesting that we might actually underestimate the potential benefits of DAC, as we do not take into account all use cases. Nevertheless, the conversion factors on time saved thanks to DAC (80% for operational staff, 40% for shunting locomotives, 20% for main line locomotive, 20% for main line driver, 20% for wagon utilization) has been multiplied by 75%. 2) For intermodal transport, the same conversion factors have been multiplied by 50% (meaning for instance that only 10% of the time saved on main line locomotives can actually be re-used) 3) For single wagon load, the initial conversion factors have been kept, as the effect of DAC are less challenged on this market segment

Table 20 – Sensitivity analysis carried out

11.2. SENSITIVITY TESTS - RESULTS

These alternative assumptions have been tested on the technological package 3; results can be found in the figures below:

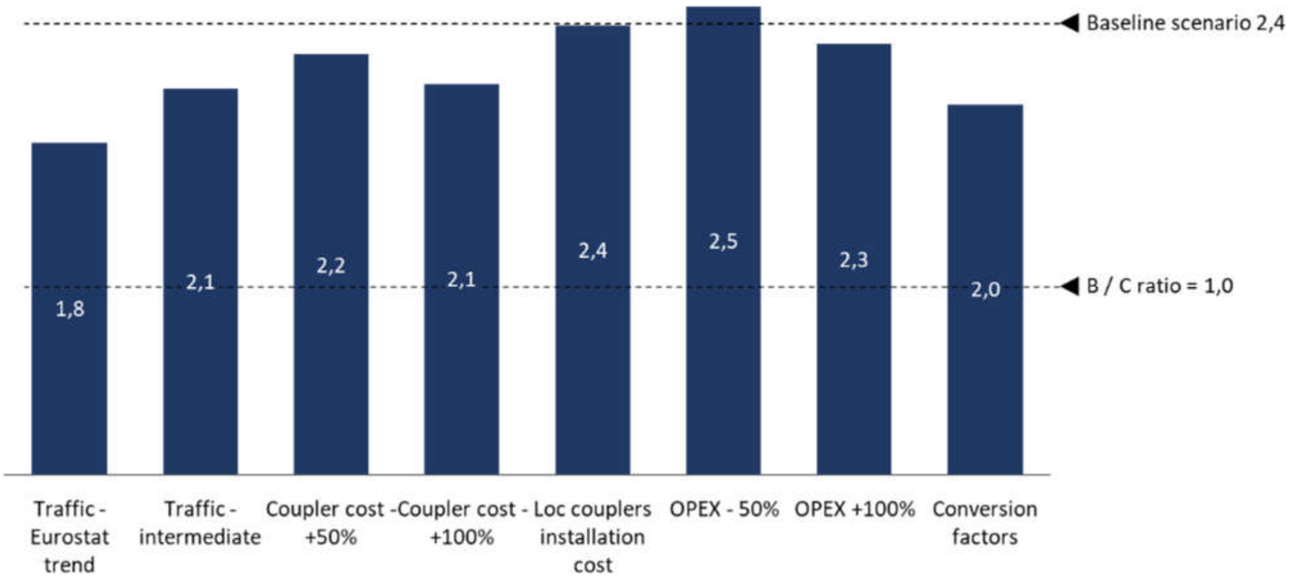


Figure 61 – Sensitivity analysis – impact on the BC ratio

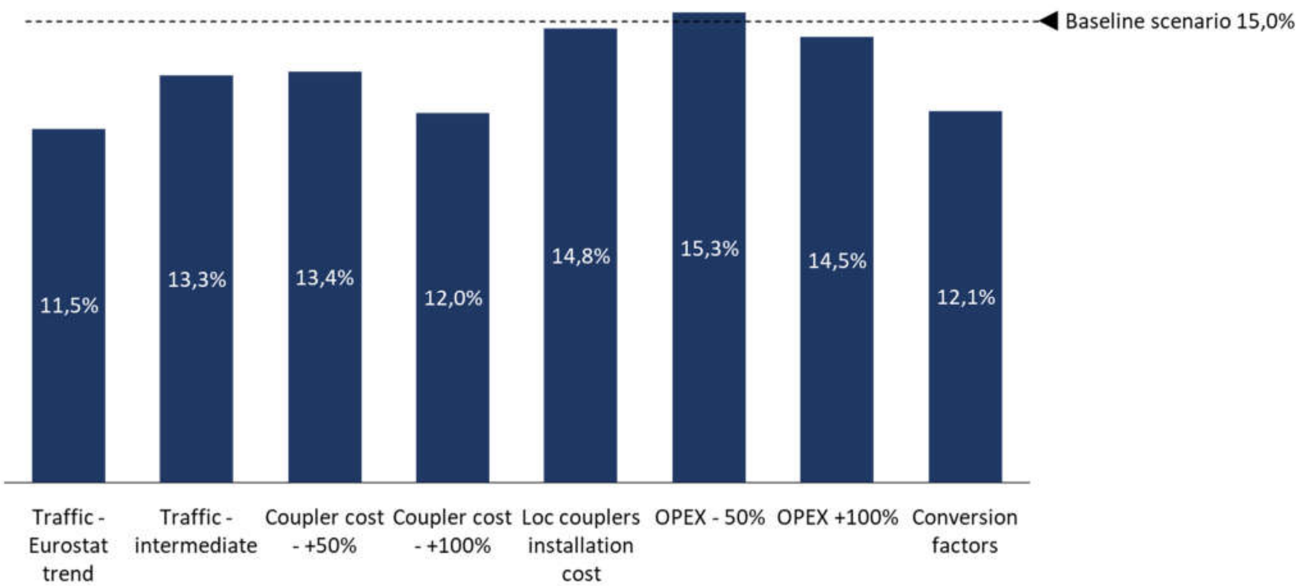


Figure 62 – Sensitivity analysis – impact on the IRR

Overall, the sensitivity analysis have a limited impact on the benefits / costs ratio and on the IRR of the CBA, with a low bound around 1.8 and 11.5% respectively, which are still very good results. **This demonstrates the robustness of the results of the CBA**. The parameters with the higher impacts are:

- the conversion factors, as time savings represent a significant share of the benefits (approximately 40% for tech package 3). But even with a sharp decrease of conversion factors for block trains and intermodal transport, the benefits / costs ratio and the IRR remain high at 2.0 and 12.1% respectively.
- the traffic forecast, especially the Eurostat trend scenario – which is a very pessimistic scenario and not consistent with other EU objectives to cut GHG emissions by 2050. Even with this assumption, the benefits / costs ratio and the IRR remain high at 1.8 and 11.5% respectively.
- the doubling of coupler costs; but even with such an increase, results of the CBA are still positive with a benefits / costs ratio of 2.1 and an IRR of 12.0%.

Doubling the installation costs for locomotives does not have a huge impact on the CBA, as the total cost linked to locomotives is less important than the one for wagons.

Another sensitivity analysis, combining a change in several parameters, has also been carried out. This extra test is considering:

- The intermediate sensitivity for traffic growth (+50% by 2050), as the Eurostat trend does not seem sustainable from a climate and also from a congestion perspective.
- An increase of coupler costs of +100% and an increase of the cost of mounting the coupler on a locomotive by +100%.
- The reduction of the conversion factors proposed above.
- OPEX have not been changed, it is not known yet whether maintenance costs will be higher or lower than 300 €/ wagon / year.

The results of this additional test are presented in the figures below:

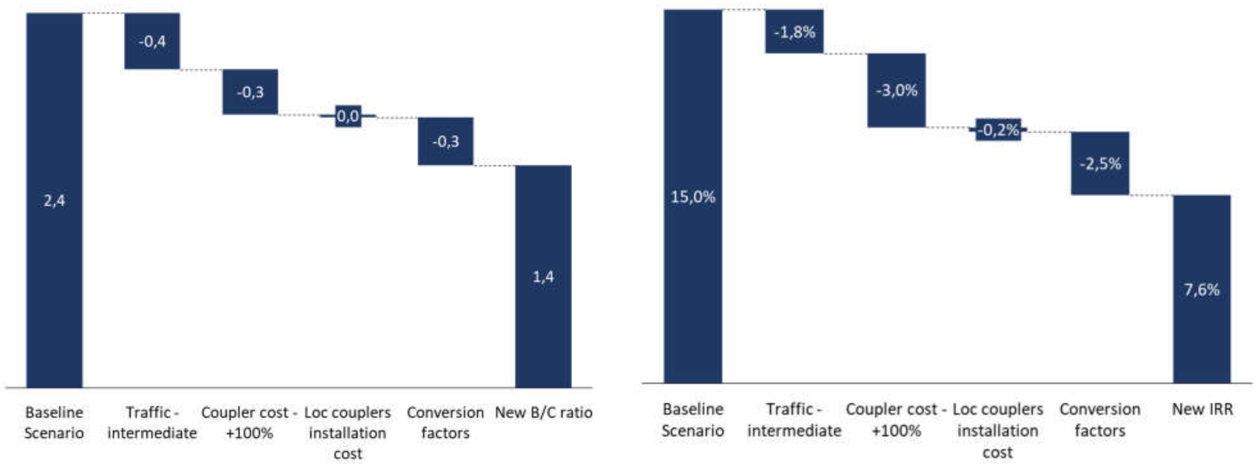


Figure 63 – Sensitivity analysis – worst case variant

Even with this "worst case variant", the results of the CBA are still positive, with a B/C ratio of 1.4 and an IRR of 7.6%.

12. ALLOCATION OF THE COSTS & BENEFITS

In order to better understand the potential impact of DAC on the railway system, an allocation of costs and benefits has been carried out.

This allocation is based on some generic economic rules, but the results might depend on the market power between the different stakeholders in the value chain. Therefore, it is just giving a preliminary indication of who will bear the costs and who might reap the benefits of DAC, and should be handled carefully.

12.1. METHODOLOGY FOR ALLOCATION

Two parameters have to be considered here:

- First of all, the list of stakeholders considered in the analysis
- Secondly, the allocation used for each cost and benefits

12.1.1. LIST OF STAKEHOLDERS CONSIDERED

The following stakeholders have been considered in the analysis:

- Railway undertakings; who are operating trains but who can own rolling stock (locomotives and wagons);
- Wagon leasing companies, who own and maintain wagons;
- Rolling stock companies (ROSCO), who own and maintain locomotives
- Shippers (the customer), who are buying railway services, but who can also partially own their fleet of wagons
- Infrastructure managers. It has to be noted that in some countries, infrastructure managers are also operating some marshalling yards; but as a simplification, this possibility has not been considered in the analysis
- The society (government), who will benefit from the reduction of external costs and an increased safety

12.1.2. ALLOCATION OF COSTS

12.1.2.1. Allocation of CAPEX

The CAPEX have been allocated in the following way:

Type of investment	RUs	Wagon leasing companies	ROSCOs	Shippers	IMs	Government
Wagons	X	X		X		
Locomotives	X		X			
Infrastructure					X	
Development costs	X					
Component replacement	X	X		X		

Table 21 – Allocation of CAPEX

For costs which are split among multiple stakeholders, the following rules have been used:

- For wagons, the costs are split according to the distribution of the wagon fleet among shippers, wagon leasing companies and shippers. This split has been assessed based on data from UIP, interviews and the BMVI study. One of the main issue is that most of the time, wagon leasing companies and shippers are mixed within the same category (wagon keepers). But based on the data collected through interviews, the number of wagons owned by shippers is not negligeable. As it was not possible to calculate an accurate value, the assumptions in the opposite figures have been used in the CBA.

Figure 64 – Distribution of the wagon fleet among stakeholders

- For locomotives, the costs are also split according to the distribution of the fleet among stakeholders. Calculation have been based on interviews and on the database of the consultant[41]. One of the main issues is that the market share of ROSCOs is increasing: their market share on the total fleet is around

[41] Blue Arches database on the fleet of locomotives in Europe

13% today, but their market share on new locomotives bought recently is much higher (around 40%). Therefore, in the CBA, the total number of market share of ROSCOs is expected to grow progressively from 13% today to 40% in 2050.

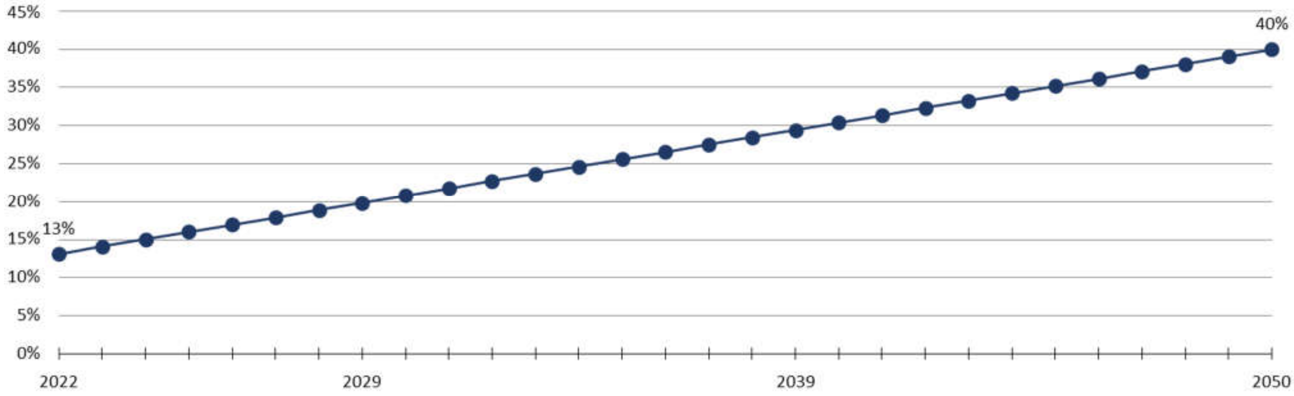


Figure 65 – Evolution of the market share of ROSCOs

12.1.2.2. Allocation of OPEX and one-off costs

Redirected costs, write off costs and OPEX are allocated using the same rule as the one applied for the allocation of CAPEX.

12.1.3. ALLOCATION OF BENEFITS

Some of the benefits could be allocated directly to one stakeholder, like for instance:

- The increase of capacity in terminals (allocated to infrastructure managers)
- The savings on investment costs on track equipment (allocated to infrastructure managers)
- The savings on maintenance costs of track equipment (allocated to infrastructure managers)
- Decrease in external costs of transport (allocated to the "government")
- Improvement of safety (allocated to the "government")
- Increase of revenues coming from modal shift (allocated to railway undertakings)

For the other benefits, the following rules have been used:

- For the allocation of the economic surplus allocated to the railway system, a 2 steps approached has been used:
  - First of all, the economic surplus has been split between shippers and the railway system, based on the principles described in §9.3.2
  - Then, the economic surplus allocated to the railway system has been split using the following rules:
    - For block trains and intermodal transport, the economic surplus is allocated based on the costs bore by each stakeholder. The underlying idea is that if wagon leasing companies and ROSCOs invest in DAC, they will be willing to increase their price to recover their investment.

- For single wagon load, the economic surplus is allocated to railway undertakings as long as this market segment is not profitable[42]. As this market segment never becomes profitable only thanks to DAC, this rule is used for 2028-2057.
- These assumptions also lead to a transfer between stakeholders, as the economic surplus captured by wagon leasing companies is coming from the increase of the price of the rolling stock for railway undertakings but also for shippers[43].

- The benefit coming from a lower investment in wagons thanks to higher utilization rate has been distributed based on the split of wagons per category of stakeholder.

12.1.4. CBA PER STAKEHOLDER

The results of the allocation exercise for technical package 3 is presented in the table below:

M€, 2028-2057, discounted	RUs	Wagon leasing companies	ROSCOs	Shippers	IMs (rail)	Gvt	TOTAL
Economic surplus				11,889			11,889
Capacity in terminals					703		703
Safety						437	437
Externalities						20,987	20,987
Rolling stock leasing	-260	387	9	-135			0
Increased profit margin on existing traffic	8,486						8,486
Increased margin from modal sh	907						
Track access charges							0
CAPEX	-5,377	-3,993	-109	-998	998	0	-9,480
CAPEX - Wagons	*-5,485*	*-4,388*		*-1,097*			*-10,970*
CAPEX - Loco	*-386*		*-109*				*-495*
CAPEX - Infra					*998*		*998*
Lower investments needed in additional wagons thanks to higher utilisation rates	*493*	*395*		*99*			*987*
Redirected costs	-17	-14	0	-3			-34
Write off costs	-75	-60	0	-15			-150
Development cost	-549						-549
OPEX	-986	-411	-15	-103	1,013		-502
Component replacement	-2,555	-2,044		-511			-5,110
TOTAL	-426	-6,135	-116	10,123	2,714	21,424	27,584

Table 22 – Allocation matrix

[42] This rule is only applied to time benefits, for the economic surplus linked with longer and heavier trains, the economic surplus is split according to the costs bore by each stakeholder – but this is marginal for single wagon load

[43] It is considered that 35% of the wagon fleet belonging to wagon keepers is rented to shippers (*source: wagon keeper*)

The same allocation matrix has also been developed over the period 2028-2037:

M€, 2028-2037	RUs	Wagon leasing companies	ROSCOs	Shippers	IMs (rail)	Gvt	TOTAL
Economic surplus				3,215			3,215
Capacity in terminals					248		248
Safety						-82	-82
Externalities						3,504	3,504
Rolling stock leasing	-164	244	6	-85			0
Increased profit margin on existing traffic	2,713						2,713
Increased margin from modal sh	118						118
Track access charges							0
CAPEX	-5,299	-3,887	-122	-972	577	0	-9,703
CAPEX - Wagons	*-5,006*	*-4,005*		*-1,001*			*-10,012*
CAPEX - Loco	*-441*		*-122*				*-563*
CAPEX - Infra					*577*		*577*
Lower investments needed in additional wagons thanks to higher utilisation rates	*148*	*118*		*30*			*295*
Redirected costs	-21	-17	0	-4			-43
Write off costs	-88	-70	0	-18			-175
Development cost	-600						-600
OPEX	-741	-195	-6	-49	100		-891
Component replacement	0	0		0			0
TOTAL	-4,083	-3,925	-122	2,087	924	3,422	-1,695

The following conclusions can be drawn from these results:

- DAC is an excellent project at EU level: it generates strong modal shift from road to rail, and therefore will lead to a strong decrease in air pollution and GHG emissions. It will also improve the safety of the railway system;
- It improves the transportation system at European level, and therefore improves the competitiveness of European industry;
- Nevertheless, the project is very expensive (12+ bn€ discounted) and the rail stakeholders will not be in the position to sustain it in a period of 10 years. Within this timeframe, this gap between project investment and return on investment will require considering adequate combination of funding and financing in order to make it realizable.

13. CONCLUSIONS

In December 2019, the European Commission presented the European Green Deal, a roadmap for making the EU's economy sustainable[44]. **One of the main objective of the EU Green Deal is to make Europe the first climate-neutral continent by 2050.** An intermediate milestone of at least -55% greenhouse gas reduction target by 2030 has also been set. These ambitious goals will only be achieved with a deep transformation of the EU transportation system, as outlined in the "Sustainable and Smart Mobility Strategy"[45]. This document is also proposing several measures and intermediate milestones to support the transition toward carbon neutral transport, including an increase of +50% of rail freight in 2030 and the doubling of rail freight by 2050. The European Rail Freight CEOs from the Community of European Railway and Infrastructure Companies (CER) and the International Union of Railways (UIC), are even going further, with "30 by 2030" commitment (a rail modal share of 30% by 2030), which is considered today as "an absolute and necessary minimum"[46].

As demonstrated in this report, **DAC technology is one of the key elements for rail freight to cope with the growth and to deliver on expectations**: it will **improve the competitiveness** of rail freight on all market segments, in particular on single wagon load which is on the verge of disappearing today due to financial difficulties; it will **improve the quality of work and the safety** of operations for the staff; moreover, it will have a **positive impact on capacity** in terminals and on the network (in association with ETCS level 3).

In order to better understand the potential impact of DAC (as DAC is an enabler to multiple new functionalities in rail freight), four 'tech package' scenarios were reviewed:

- The **first "tech package"** only considers DAC 4 and the associated communication system.
- The **second "tech package"** corresponds to DAC 5.
- The **third "tech package"** considers an automated brake test device on top of tech package 2. Due to the higher level of uncertainty linked with the fourth tech package, **the third tech package should be considered as the most robust upper bound of the current CBA.**
- And finally, the **fourth "tech package"** considers all the components from tech package 3 plus equipment required for automated wagon inspection on the wagon and for automated brake test. It can be seen as **the upper bond of the potential effect of DAC with the functionalities identified and quantified today**. It should also be noted that a high level of uncertainty is still associated with tech package 4 both on costs (which additional components required?) and benefits (how much time could be saved on wagon inspection?).

On the cost side, DAC will require an initial investment of €11 bn to €15 bn (not discounted) depending on the technological package considered for equipping around 410.000 freight wagons and 17.000 locos in Europe. Most of these costs will have to be borne by railway undertakings and wagon leasing companies.

On the benefits side, DAC is expected to contribute significantly to the increase of rail freight traffic. 5% are coming from the impact of DAC on capacity on the network, and 2 to 7.5% on the improved performance of

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[44] COM (2019) 640 final, "The European Green Deal"

[45] COM(2020) 789 final, "Sustainable and Smart Mobility Strategy – putting European transport on track for the Future"

[46] https://www.cer.be/media/press-releases/european-rail-freight-ceos-reaffirm-ambition-30-percent-modal-share-by-2030

rail freight (depending on the tech package considered**). Overall, rail freight traffic is expected to increase by 7 to 12.5% in 2050 compared to the baseline without DAC**. This will also lead to a strong decrease in the external costs of transport, **representing €19 bn to €53 bn (not discounted) between 2028 and 2057 of benefits on air pollution, congestion and greenhouse gases emissions**. Moreover, the overall energy consumption of the transport system is expected to decrease, as rail freight can carry more goods for the same quantity of energy. **DAC will also support the development of a more competitive European industry**, with a more reliable, faster and cheaper transportation system. Shippers are expected to get a net benefit of €11.1 bn to €30.5 bn (not discounted) according to the tech package considered.

In all cases, the **benefit cost ratio** of the CBA is higher than one with **1.9 to 2.8 over 30 years** but **only 0.5 to 1.0 over 10 years**. From a socio-economic perspective, the fourth tech package (DAC5 with automated brake test, sensors for automated wagon inspection) scores highest but **the more robust scenario (i.e. in terms of assumptions tested and modelling) is the third tech package** which includes DAC 5 with automated brake test. As a result, the **DAC project shows strong benefits from a societal perspective (30 years)**.

But this time horizon is not consistent with the one from railway industry, which is looking at a maximum of 10 years for investing. Moreover, up to half of the benefits are socio-economic benefits: they will not generate direct benefits for railway undertakings, wagon leasing companies and ROSCOs. **Considering the large societal benefits, there is a sound rationale for public support for DAC.**

In light of considerable ongoing research and testing activities, **these CBA results are preliminary and shall be adjusted based on updated insights**. Particularly, these first findings should be fine-tuned in the future to take into account:

- More accurate insights into the life cycle and retrofitting costs of DAC;
- the updated migration plan;
- operational analyses, including on the number of (non-centrally registered) trips;
- use cases not considered yet today (at least 14 of them have been identified);
- final assessment of administrative and possible authorisation costs;
- the applicability of use cases for specific business segments, such as combined transport.

Notwithstanding these limitations, the performed sensitivity analyses and expert feedback highlight that these first CBA results provide a robust indication of the possible economic value of deploying DAC in Europe.

ANNEX 1. SURVEY TEMPLATES FOR REQUIRED PROCESS TIMES

Process	Sub-process	time total [min]	unit (per train/ wagon,…)	time walking [min] (already included in time total)	unit (per train/ wagon,…)
general assumptions	walking to and from the train	10	--	10	--
train arrival	train de-initialisation	0	--	0	--
	arrival notice	2.5	per train	--	--
	Handover of shipping documents	--	--	--	--
	putting safety stop (wagon)	0,5 (parking brake) 0,1 (putting safety stop)	per train	0.25	per wagon
	Uncoupling Loco	0.75	per loco	--	--
	train inspection at train arrival	1	per wagon	0.25	per wagon
	optional: check/recording train composition	0.5	per wagon	--	--
	Couple Shunting Loco	0.75	per loco	--	--
	Remove rear train end signal	0.1	per train	--	--
	removal of safety stop (wagon)	0.1	per train	remove and take away	--
train splitting up/ shunting in customer sidings	putting safety stop (wagon)	0,5 (parking brake) 0,1 (putting safety stop)	per train	0.25	per wagon
	Uncoupling Shunting Loco	0.75	per loco	--	--
	Venting	0.3	per wagon	0.25	per wagon
	Uncoupling	1	per wagon	0.25	per wagon
train preparation	check/recording of wagon list	0.5	per wagon	--	--
	train inspection before coupling	1	per wagon	0.25	per wagon
	Couple Shunting Loco	0.75	per loco	--	--
	Backing mov. of wagons (by shunting loco)	5	flat-rate	--	--
	Coupling	1	per wagon (coupling event)	0.25	per wagon
	Change brake (P/G) (long loco)	--	--	--	--
	simplified brake test within shunting operations - each time you couple a wagon - check if brakes are released	0,3 * train + 0,6 * wagon	per train + per wagon	0,5 min	per wagon
	Uncouple Shunting Loco - shunting mode ends	0.75	per loco	--	--

Figure 66 - Survey template for process times required in costumer sidings

Process	Sub-process	time total [min]	unit (per train/ wagon,...)	time walking [min] (already included in time total)	unit (per train/ wagon,...)
general assumptions	walking to and from the train	10	--	10	--
train preparation	check/recording of wagon list	0.5	per wagon	--	--
	Couple Main Line Loco	0.75	per loco	--	--
	full brake test	4 *train + 0,3*axle	per train +per axle	0.25	per wagon
	train inspection full after coupling + special inspection	12 * train +0,7 * axle	per train + per axle	0.25	per wagon
train departure	Putting train rear end signal	0.1	per train	--	--
	Handover of shipping documents	--	--	--	--
	train initialisation	0	per train	0	per train
	removal of safety stop (wagon)	0.1	per train	remove and take away	--
	departure notice in IT system	2	per train	--	--

Figure 67 - Survey template for process times required in departure sidings

Process	Sub-process	time total [min]	unit (per train/ wagon,...)	time walking [min] (already included in time total)	unit (per train/ wagon,...)
general assumptions	walking to and from the train	10	--	10	--
train arrival	train de-initialisation	0	--	0	--
	arrival notice	2.5	per train	--	--
	Handover of shipping documents	--	--	--	--
	putting safety stop (wagon)	0,5 (parking brake) 0,1 (putting safety stop)	per train	0.25	per wagon
	Uncoupling Loco	0.75	per loco	--	--
	train inspection at train arrival	1	per wagon	0.25	per wagon
	optional: check/recording train composition	0.5	per wagon	--	--
	Couple Shunting Loco	0.75	per loco	--	--
	Remove rear train end signal	0.1	per train	--	--
	removal of safety stop (wagon)	0.1	per train	remove and take away	--
train splitting up/ shunting in customer sidings	putting safety stop (wagon)	0,5 (parking brake) 0,1 (putting safety stop)	per train	0.25	per wagon
	Uncoupling Shunting Loco	0.75	per loco	--	--
	Uncoupling	1	per wagon	0.25	per wagon
train preparation	check/recording of wagon list	0.5	per wagon	--	--
	Couple Shunting Loco	0.75	per loco	--	--
	Backing mov. of wagons (by shunting loco)	5	flat-rate	--	--
	Coupling	1	per wagon (coupling event)	0.25	per wagon
	Couple Shunting Loco	0.75	per loco	--	--
	simplified brake test within shunting operations - each time you couple a wagon - check if brakes are released	0,3 * train + 0,6 * wagon	per train + per wagon	0,5 min	per wagon
	Uncouple Shunting Loco - shunting mode ends	0.75	per loco	--	--
	Couple Main Line Loco	0.75	per loco	--	--
	full brake test	4 *train + 0,3*axle	per train +per axle	0.25	per wagon
	train inspection full after coupling	4* train + 0,4*axle	per train + per axle	0.25	per wagon
train departure	Putting train rear end signal	0.1	per train	--	--
	Handover of shipping documents	--	--	--	--
	train initialisation	0	per train	0	per train
	removal of safety stop (wagon)	0.1	per train	remove and take away	--
	departure notice in IT system	2	per train	--	--

Figure 68 - Survey template for process times required in small marshalling yards

Process	Sub-process	time total [min]	unit (per train/ wagon,...)	time walking [min] (already included in time total)	unit (per train/ wagon,...)
general assumptions	walking to and from the train	10	--	10	--
train arrival	train de-initialisation	0	--	0	--
	arrival notice	2.5	per train	--	--
	Handover of shipping documents	--	--	--	--
	putting safety stop (wagon)	0,5 (parking brake) 0,1 (putting safety stop)	per train	0.25	per wagon
	Uncoupling Loco	0.75	per loco	--	--
	train inspection at train arrival	1	per wagon	0.25	per wagon
	optional: check/recording train composition	0.5	per wagon	--	--
	Couple Shunting Loco	0.75	per loco	--	--
	Remove rear train end signal	0.1	per train	--	--
	removal of safety stop (wagon)	0.1	per train	remove and take away	--
train splitting up	putting safety stop (wagon)	0,5 (parking brake) 0,1 (putting safety stop)	per train	0.25	per wagon
	Loosening of couplings	0.4	per wagon	0.25	per wagon
	Venting	0.3	per wagon	0.25	per wagon
	removal of safety stop (wagon)	0.1	per train	remove and take away	--
	Uncoupling	1	per wagon	0.25	per wagon
train preparation	Couple Shunting Loco	0.75	per loco	--	--
	Backing mov. of wagons (by shunting loco)	5	flat-rate	--	--
	Coupling	1	per wagon (coupling event)	0.25	per wagon
	Change brake (P/G) (long loco)	--	--	--	--
	simplified brake test within shunting operations - each time you couple a wagon - check if brakes are released	0,3 * train + 0,6 * wagon	per train + per wagon	0,5 min	per wagon
	full brake test	4 *train + 0,3*axle	per train +per axle	0.25	per wagon
	train inspection full after coupling	4* train + 0,4*axle	per train + per axle	0.25	per wagon
	Uncouple Shunting Loco - shunting mode ends at BMY	1	per wagon	0.25	per wagon
	check/recording train composition	0.5	per wagon	--	--
	Couple Main Line Loco	0.75	per loco	--	--
	simplified brake test with the main loco	0,3 * train + 0,6 * wagon	per train + per wagon	0.5	per wagon
train departure	Putting train rear end signal	0.1	per train	--	--
	Handover of shipping documents	--	--	--	--
	train initialisation	0	per train	0	per train
	removal of safety stop (wagon)	0.1	per train	remove and take away	--
	departure notice in IT system	2	per train	--	--

Figure 69 - Survey template for process times required in big marshalling yards

Process	Sub-process	time total [min]	unit (per train/ wagon,...)	time walking [min] (already included in time total)	unit (per train/ wagon,...)
general assumptions	walking to and from the train	10	--	10	--
train arrival	train de-initialisation	0	--	0	--
	arrival notice	2.5	per train	--	--
	Handover of shipping documents	--	--	--	--
	putting safety stop (wagon)	0,5 (parking brake) 0,1 (putting safety stop)	per train	0.25	per wagon
	Uncoupling Loco	0.75	per loco	--	--
	train inspection at train arrival	1	per wagon	0.25	per wagon
	optional: check/recording train composition	0.5	per wagon	--	--
	Couple Shunting Loco	0.75	per loco	--	--
	Remove rear train end signal	0.1	per train	--	--
	removal of safety stop (wagon)	0.1	per train	remove and take away	--
train splitting up/ shunting in customer sidings	putting safety stop (wagon)	0,5 (parking brake) 0,1 (putting safety stop)	per train	0.25	per wagon
	Uncoupling Shunting Loco	0.75	per loco	--	--
	Loosening of couplings	0.4	per wagon	0.25	per wagon
	Venting	0.3	per wagon	0.25	per wagon
	Uncoupling	1	per wagon	0.25	per wagon
train preparation	check/recording of wagon list	0.5	per wagon	--	--
	train inspection before coupling	1	per wagon	0.25	per wagon
	Couple Shunting Loco	0.75	per loco	--	--
	Backing mov. of wagons (by shunting loco)	5	flat-rate	--	--
	Coupling	1	per wagon (coupling event)	0.25	per wagon
	Change brake (P/G) (long loco)	--	--	--	--
	simplified brake test within shunting operations - each time you couple a wagon - check if brakes are released	0,3 * train + 0,6 * wagon	per train + per wagon	0,5 min	per wagon
	full brake test	4 *train + 0,3*axle	per train +per axle	0.25	per wagon
	train inspection full after coupling	4* train + 0,4*axle	per train + per axle	0.25	per wagon
	train inspection full after coupling + special inspection	12 * train +0,7 * axle	per train + per axle	0.25	per wagon
	check/recording train composition	0.5	per wagon	--	--
	Couple Main Line Loco	0.75	per loco	--	--
	simplified brake test with the main loco	0,3 * train + 0,6 * wagon	per train + per wagon	0.5	per wagon
train departure	Putting train rear end signal	0.1	per train	--	--
	Handover of shipping documents	--	--	--	--
	train initialisation	0	per train	0	per train
	removal of safety stop (wagon)	0.1	per train	remove and take away	--
	departure notice in IT system	2	per train	--	--

Figure 70 - Survey template for process times required in combined transport terminal

ANNEX 2. DETAILED ASSUMPTIONS ON TIME GAINS IN SHUNTING ACTIVITIES AND TRAIN PREPARATION

Small Marshalling Yards		DAC 4	DAC 5 actuator	communication system	automated venting device	automated park brake system	automatic brake test device	train integrity / eot system	automated wagon inspection
	train de-initialisation	-	-	0,2	-	-	-	-	-
	arrival notice	-	-	-100%	-	-	-	-	-
	Handover of shipping documents	-	-	-	-	-	-	-	-
	putting safety stop (wagon)	-	-	-	-	-100%	-	-	-
	Uncoupling Loco	-20%	-80%	-	-	-	-	-	-
	train inspection at train arrival	-	-	-	-	-	-	-	-50%
	optional: check/recording train composition	-	-	-100%	-	-	-	-	-
	Couple Shunting Loco	-100%	-	-	-	-	-	-	-
	Remove rear train end signal	-	-	-	-	-	-	-100%	-
	removal of safety stop (wagon)	-	-	-	-	-100%	-	-	-
Train arrival		-	-	-	-	-	-	-	-
	putting safety stop (wagon)	-	-	-	-	-100%	-	-	-
	Uncoupling Shunting Loco	-20%	-80%	-	-	-	-	-	-
	Uncoupling	-20%	-80%	-	-	-	-	-	-
Train splitting up/ shunting in SMY		-	-	-	-	-	-	-	-
	check/recording of wagon list	-	-	-100%	-	-	-	-	-
	Couple Shunting Loco	-100%	-	-	-	-	-	-	-
	Backing mov. of wagons (by shunting loco)	-	-	-	-	-	-	-	-
	Coupling	-100%	-	-	-	-	-	-	-
	Couple Shunting Loco	-100%	-	-	-	-	-	-	-
	simplified brake test within shunting operations - each time you couple a wagon - check if brakes are released	-	-	-	-	-	6,0	-	-
	Uncouple Shunting Loco - shunting mode ends	(0,2)	(0,8)	-	-	-	-	-	-
Train preparation / shunting in SMY		-	-	-	-	-	-	-	-
	Couple Main Line Loco	-100%	-	-	-	-	-	-	-
	full brake test	-	-	-	-	-	8,0	-	-
	train inspection full after coupling	-	-	-	-	-	-	-	-50%
Train preparation		-	-	-	-	-	-	-	-
	Putting train rear end signal	-	-	-	-	-	-	-100%	-
	Handover of shipping documents	-	-	-	-	-	-	-	-
	train initialisation	-	-	0,2	-	-	-	-	-
	removal of safety stop (wagon)	-	-	-	-	-100%	-	-	-
	departure notice in IT system	-	-	-100%	-	-	-	-	-
Train departure									

Big Marshalling Yards		DAC 4	DAC 5 actuator	communication system	automated venting device	automated park brake system	automatic brake test device	train integrity / eot system	automated wagon inspection
	train de-initialisation	-	-	0,2	-	-	-	-	-
	arrival notice	-	-	-100%	-	-	-	-	-
	Handover of shipping documents	-	-	-	-	-	-	-	-
	putting safety stop (wagon)	-	-	-	-	-100%	-	-	-
	Uncoupling Loco	-20%	-80%	-	-	-	-	-	-
	train inspection at train arrival	-	-	-	-	-	-	-	-50%
	optional: check/recording train composition	-	-	-100%	-	-	-	-	-
	Couple Shunting Loco	-100%	-	-	-	-	-	-	-
	Remove rear train end signal	-	-	-	-	-	-	-100%	-
	removal of safety stop (wagon)	-	-	-	-	-100%	-	-	-
Train arrival		-	-	-	-	-	-	-	-
	putting safety stop (wagon)	-	-	-	-	-100%	-	-	-
	Loosening of couplings	-	-	-	-	-	-	-	-
	Venting	-	-	-	-100%	-	-	-	-
	removal of safety stop (wagon)	-	-	-	-	-100%	-	-	-
	Uncoupling	-20%	-80%	-	-	-	-	-	-
	Uncouple Shunting Loco - shunting mode ends at BMY	-20%	-80%	-	-	-	-	-	-
Train splitting up/ shunting in BMY		-	-	-	-	-	-	-	-
	Couple Shunting Loco	-100%	0%	-	-	-	-	-	-
	Backing mov. of wagons (by shunting loco)	-	-	-	-	-	-	-	-
	Coupling	-100%	0%	-	-	-	-	-	-
	Change brake (P/G) (long loco)	-	-	-	-	-	-	-	-
	simplified brake test within shunting operations *- each time you couple a wagon* *- check if brakes are released*	-	-	-	-	-	6,0	-	-
Train preparation / shunting in BMY		-	-	-	-	-	-	-	-
	full brake test	-	-	-	-	-	8,0	-	-
	train inspection full after coupling	-	-	-	-	-	-	-	-50%
	Uncouple Shunting Loco - shunting mode ends at BMY	-20%	-80%	-	-	-	-	-	-
	check/recording train composition	-	-	-100%	-	-	-	-	-
	Couple Main Line Loco	-100%	0%	-	-	-	-	-	-
	simplified brake test with the main loco	-	-	-	-	-	6,0	-	-
Train preparation		-	-	-	-	-	-	-	-
	Putting train rear end signal	-	-	-	-	-	-	-100%	-
	Handover of shipping documents	-	-	-	-	-	-	-	-
	train initialisation	-	-	0,2	-	-	-	-	-
	removal of safety stop (wagon)	-	-	-	-	-100%	-	-	-
	departure notice in IT system	-	-	-100%	-	-	-	-	-
Train departure		-	-	-	-	-	-	-	-

Customer sidings		DAC 4	DAC 5 actuator	communication system	automated venting device	automated park brake system	automatic brake test device	train integrity / eot system	automated wagon inspection
	train de-initialisation	-	-	0,2	-	-	-	-	-
	arrival notice	-	-	-100%	-	-	-	-	-
	Handover of shipping documents	-	-	-	-	-	-	-	-
	putting safety stop (wagon) --> parking brake	-	-	-	-	-100%	-	-	-
	putting safety stop (wagon) --> putting safety stop	-	-	-	-	-100%	-	-	-
	Uncoupling Loco	-20%	-80%	-	-	-	-	-	-
	train inspection at train arrival	-	-	-	-	-	-	-	-50%
	optional: check/recording train composition	-	-	-100%	-	-	-	-	-
	Couple Shunting Loco	-100%	-	-	-	-	-	-	-
	Remove rear train end signal	-	-	-	-	-	-	-100%	-
	removal of safety stop (wagon)	-	-	-	-	-100%	-	-	-
Train arrival									
	putting safety stop (wagon) --> parking brake	-	-	-	-	-100%	-	-	-
	putting safety stop (wagon) --> putting safety stop	-	-	-	-	-100%	-	-	-
	Uncoupling Shunting Loco	-20%	-80%	-	-	-	-	-	-
	Venting	-	-	-	-100%	-	-	-	-
	Uncoupling	-20%	-80%	-	-	-	-	-	-
Train splitting up/ shunting in customer sidings									
	check/recording of wagon list	-	-	-100%	-	-	-	-	-
	train inspection before coupling	-	-	-	-	-	-	-	-50%
	train inspection before coupling	-	-	-	-	-	-	-	-50%
	Couple Shunting Loco	-100%	-	-	-	-	-	-	-
	Backing mov. of wagons (by shunting loco)	-	-	-	-	-	-	-	-
	Coupling	-100%	-	-	-	-	-	-	-
	Change brake (P/G) (long loco)	-	-	-	-	-	-	-	-
	simplified brake test within shunting operations - each time you couple a wagon - check if brakes are released	-	-	-	-	-	6,0	-	-
	simplified brake test within shunting operations - each time you couple a wagon - check if brakes are released	-	-	-	-	-	-	-	-
	Uncouple Shunting Loco - shunting mode ends	-20%	-80%	-	-	-	-	-	-
Train preparation / shunting in customer sidings									

Departure sidings		DAC 4	DAC 5 actuator	communication system	automated venting device	automated park brake system	automatic brake test device	train integrity / eot system	automated wagon inspection
	check/recording of wagon list	-	-	-100%	-	-	-	-	-
	Couple Main Line Loco	-100%	-	-	-	-	-	-	-
	full brake test	-	-	-	-	-	8,0	-	-
	train inspection full after coupling + special inspection	-	-	-	-	-	-	-	-50%
Train preparation (main line loco)									
	Putting train rear end signal	-	-	-	-	-	-	-100%	-
	Handover of shipping documents	-	-	-	-	-	-	-	-
	train initialisation	-	-	0,2	-	-	-	-	-
	removal of safety stop (wagon)	-	-	-	-	-100%	-	-	-
	departure notice in IT system	-	-	-100%	-	-	-	-	-
Train departure									

Combined transport terminals	DAC 4	DAC 5 actuator	communication system	automated venting device	automated park brake system	automatic brake test device	train integrity / eot system	automated wagon inspection
train de-initialisation	-	-	0,2	-	-	-	-	-
arrival notice	-	-	-100%	-	-	-	-	-
Handover of shipping documents	-	-	-	-	-	-	-	-
putting safety stop (parking brake)	-	-	-	-	-100%	-	-	-
putting safety stop (safety stop)	-	-	-	-	-100%	-	-	-
Uncoupling Loco	-20%	-80%	-	-	-	-	-	-
train inspection at train arrival	-	-	-	-	-	-	-	-50%
optional: check/recording train composition	-	-	-100%	-	-	-	-	-
Couple Shunting Loco	-100%	-	-	-	-	-	-	-
Remove rear train end signal	-	-	-	-	-	-	-100%	-
removal of safety stop (wagon)	-	-	-	-	-100%	-	-	-
Train arrival								
putting safety stop (wagon)	-	-	-	-	-100%	-	-	-
Uncoupling Shunting Loco	-20%	-80%	-	-	-	-	-	-
Loosening of couplings	-20%	-80%	-	-	-	-	-	-
Venting	-	-	-	-100%	-	-	-	-
Uncoupling	-20%	-80%	-	-	-	-	-	-
Train splitting up / shunting in CTT								
check/recording of wagon list	-	-	-100%	-	-	-	-	-
train inspection before coupling	-	-	-	-	-	-	-	-50%
Couple Shunting Loco	-100%	-	-	-	-	-	-	-
Backing mov. of wagons (by shunting loco)	-	-	-	-	-	-	-	-
Coupling	-100%	-	-	-	-	-	-	-
Change brake (P/G) (long loco)	-	-	-	-	-	-	-	-
simplified brake test within shunting operations - each time you couple a wagon - check if brakes are released	-	-	-	-	-	6,0	-	-
Train preparation / shunting in CTT								
full brake test	-	-	-	-	-	8,0	-	-
train inspection full after coupling	-	-	-	-	-	-	-	-50%
check/recording train composition	-	-	-100%	-	-	-	-	-
Couple Main Line Loco	-100%	-	-	-	-	-	-	-
simplified brake test with the main loco	-	-	-	-	-	6,0	-	-
Train preparation								
Putting train rear end signal	-	-	-	-	-	-	-100%	-
Handover of shipping documents	-	-	-	-	-	-	-	-
train initialisation	-	-	0,2	-	-	-	-	-
removal of safety stop (wagon)	-	-	-	-	-100%	-	-	-
departure notice in IT system	-	-	-100%	-	-	-	-	-
Train departure								

ANNEX 3. CAPACITY AND TRANSSHIPMENT IN COMBINED TRANSPORT TERMINALS IN 2019

		Capacity corrected 2019	Transshipment 2019
AT	Graz	195 000	91 978
AT	Saint Michael	40 000	15 000
AT	Villach	60 000	38 000
AT	Wels	210 000	138 000
AT	Wien	310 000	200 000
AT	Wolfurt	190 000	143 000
BE	Antwerpen	1 410 000	715 972
BE	Genk	183 000	116 101
BE	Zeebrugge	547 500	240 865
CH	Basel	585 000	252 352
CZ	Praha	600 000	552 971
DE	Bremen/Bremerhaven	1 435 200	1 088 677
DE	Duisburg	477 000	215 928
DE	Hamburg	3 240 000	1 713 825
DE	Koeln	450 000	533 783
DE	Luebeck	210 000	85 367
DE	Muenchen	480 000	401 726
DE	Neuss	210 000	150 832
DE	Nürnberg	480 000	238 625
DE	Mannheim/Ludwigshafen	519 000	523 754
DK	Taulov	180 000	91 919
ES	Barcelona	522 000	293 978
ES	Madrid	288 000	180 355
ES	Valencia	354 000	243 479
FR	Le Havre	250 000	118 425
FR	Paris	987 000	191 620
HU	Budapest	450 000	347 725
IT	Bologna	352 500	139 720
IT	Milano	1 586 888	728 458
IT	Novara	1 207 500	272 611
IT	Verona	1 170 000	334 068
NL	Rotterdam	2 100 000	1 410 216
PL	Gdansk	3 320 000	698 458
PL	Gdynia	1 836 000	184 860
PL	Szczecin & Świnoujście	220 000	0
PL	Gliwice / Katowice	846 410	360 582
PL	Kutno	250 000	106 503
PL	Lodz	184 000	78 387
PL	Poznan	660 400	281 340
PL	Warszawa	296 000	126 100
PL	Wroclaw	433 000	184 464
SI	Ljubljana	225 000	219 876