Rabat (Morocco), 7 November 2017

COST BENEFIT ANALYSIS (CBA) FOR SBAS COVERAGE ACROSS GCC, YEMEN AND IRAQ

success²

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Contents

Background: why the CBA ?

- Conclusions of **ACAC/ICAO MID workshop** on GNSS on “Regional developments related to GNSS” (**Rabat-Morocco, 5 April 2016**)
- Official exchanges EC-ACAC (**Jan-Feb 2017**)

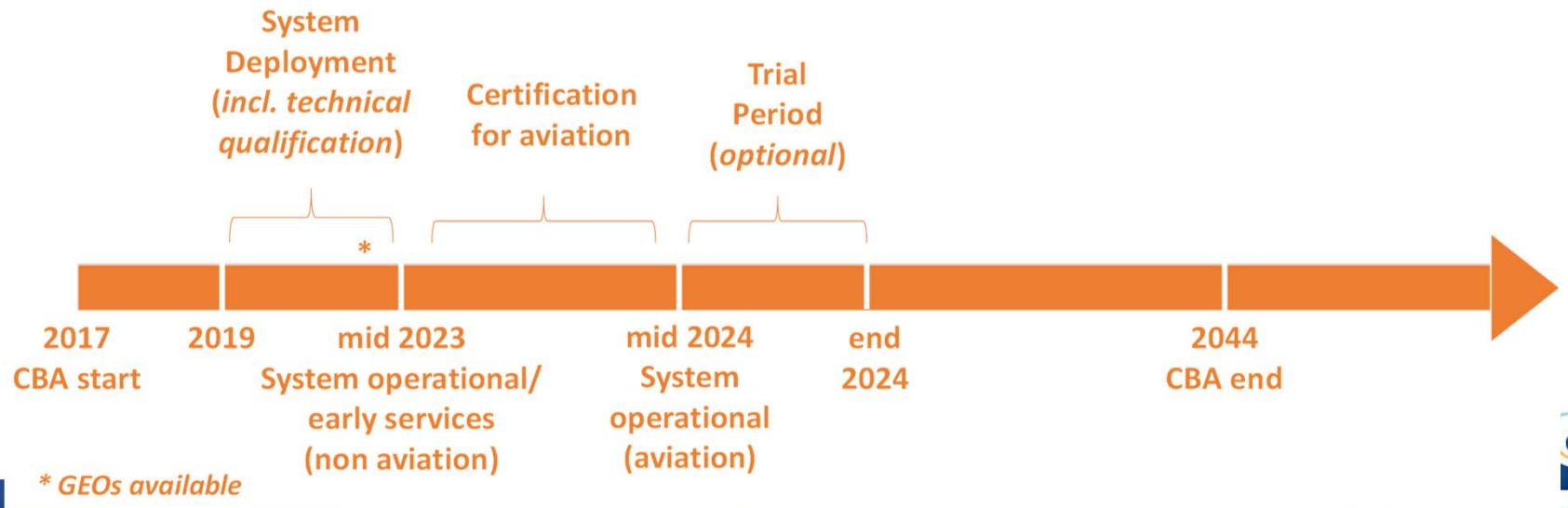
- Design of the **SBAS system, implemented through a European SBAS export** *:
  - Autonomous system, independent from the European one/EGNOS
  - SBAS coverage across GCC, Yemen and Iraq
  - With committed performances and a defined deployment plan

- Associated CBA as a tool to:
  - **Evaluate the initiative in monetary terms**
  - **Assess the economic feasibility**
  - **Help decisions on the investment**
  - **Identify impacting key factors**
  - **Guide actions/prioritisation**

** Thales Alenia Space*

CBA's vs system's timing

- **CBA's timeframe: 2017 - 2044**
  - SBAS system development: 2019 - mid 2023
  - SBAS system operational for other domains/early services: mid 2023
  - Certification for aviation: mid 2023 - mid 2024
  - SBAS system operational for aviation: mid 2024
  - Trial period before operational introduction for aviation: end 2024
  - 20 year services: beg. 2024 - end 2044
  - 2044 onwards: SBAS system operation



CBA's methodology

- Usage of **the SBAS APV-I certified service** in aviation [1]
- **LPV application**

- **From the perspective of a specific involved stakeholder**

- Identification/quantification of **costs and benefits**
- Computation of **Net Present Value** (NPV [2])
- Calculations based on **assumptions for key parameters**
- Realistic and conservative assumptions [3]
- **Sensitivity analysis** to take into account uncertainty of key parameters and effects of relevant changes on NPV

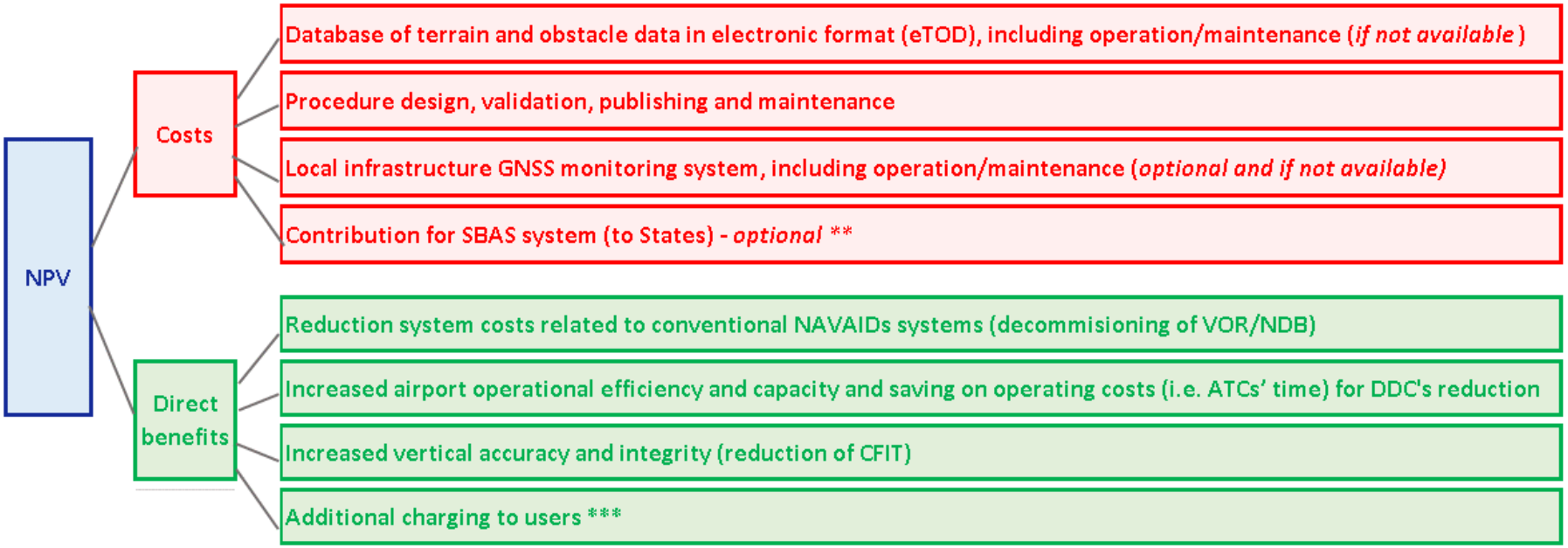
1 Certification required

2 Present value - discounted at the required rate of return - of an investment's cash inflows minus cash outflows or costs of investment

3 Approach, assumptions, key parameters for sensitive analysis defined by/validated with ACAC

Main input data provided by ACAC /For missing data, EUROCONTROL sources validated by ACAC

CBA's from the perspective of ANSPs



- **Assumptions on costs and benefits allocation:**
  - No costs for SBAS system/services CAPEX and OPEX
  - SBAS system/services CAPEX and OPEX paid by States (i.e. governments' investment) *
  - Costs for the SBAS operations (LPV)
  - Costs for procedures beginning in 2022 (2 years before SBAS system operational for aviation)
  - ANSPs possibly contributing to States for SBAS system/services CAPEX and OPEX **
  - ANSPs possibly recovering incremental costs through additional users' charging ***

** As typically done in SBAS systems, and agreed by ACAC*

*** ACAC hypothesis to be considered*

**** Foreseen by ICAO ANSEP conclusions/recommendations*

ANSPs' costs - eTOD and GNSS monitoring

Today's situation for eTOD and GNSS monitoring

Country	eTOD	GNSS monitoring
Bahrain	Available	
Iraq	Under development	
KSA	Under development	Operational
Kuwait	Under development (ready by end 2017)	
Yemen		
OMAN	Under development (ready by end 2017)	
Qatar	Available	
UAE	Available	Planned to be developed at Dubai airport

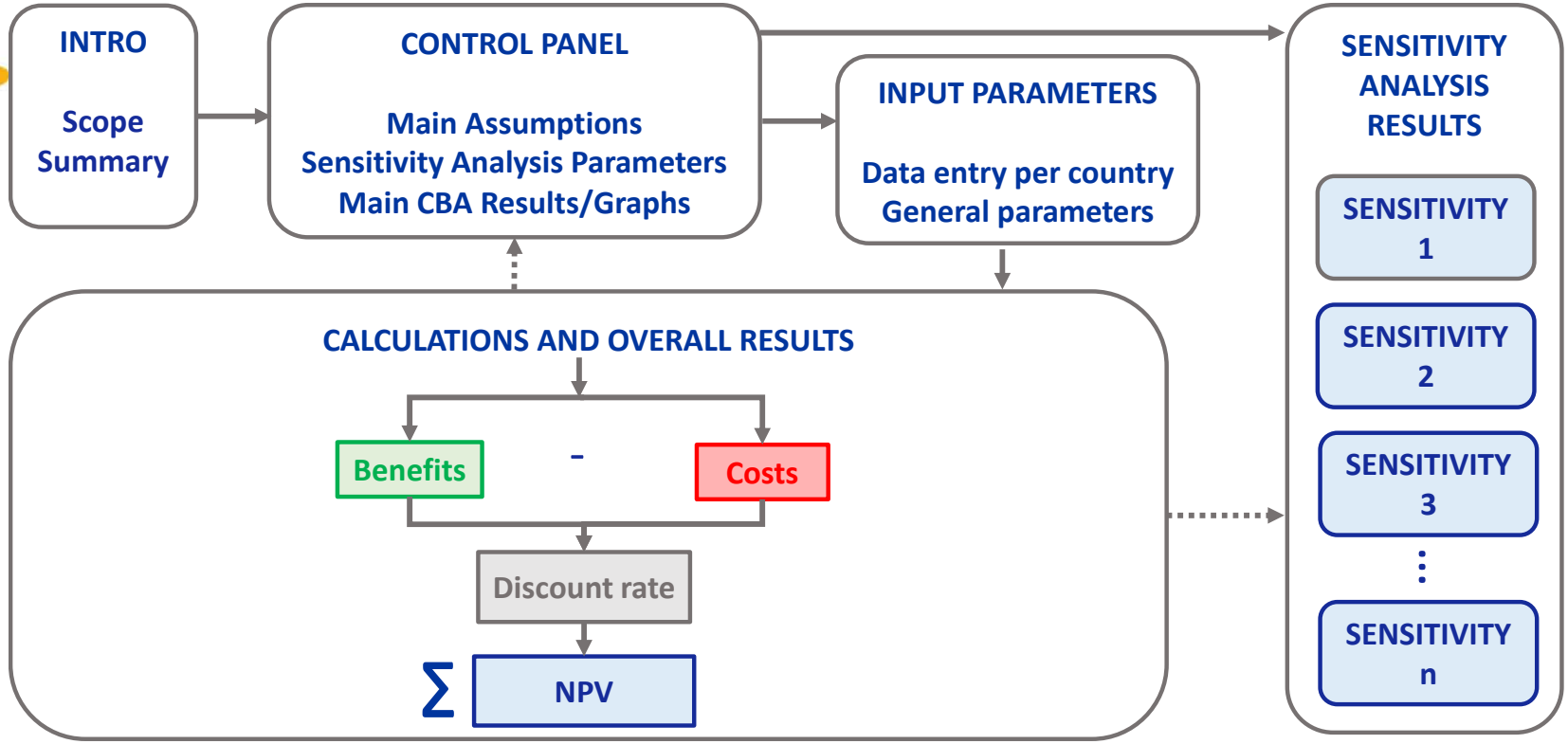
- **Costs for eTOD and GNSS monitoring not needed or negligible**

ANSPs' benefits quantification *

Parameter	Assumption		
Traffic growth	Constant growth based on today's growth rate	→	- Possible traffic increasing not considered - Additional traffic growth in non-ILS airports possibly generated by the introduction of SBAS operations not foreseen
Number of airports	Today's airports Countries' infrastructure evolution plan not considered	→	New possible additional airports not included
Number of users	Countries' defence fleets not included	→	-Further potential users not considered
Increased airport capacit	Flight routes optimisation thanks to ADS-B improvement not considered	→	Further benefits generated by possible consequent increased airport capacity not included

** Conservative assumptions*

CBA model and structure *



- Overall, as sum of countries' contributions
- NPV discounted @ 2017 + financial flows of costs (negative cash flows, i.e. investments) and benefits (positive cash flows, i.e. thanks to use of SBAS)
- Sensitivity analysis - NPV changes due to variations of key parameters (baseline/optimistic/pessimistic)

** Delivered to ACAC with instructions on how to use it*

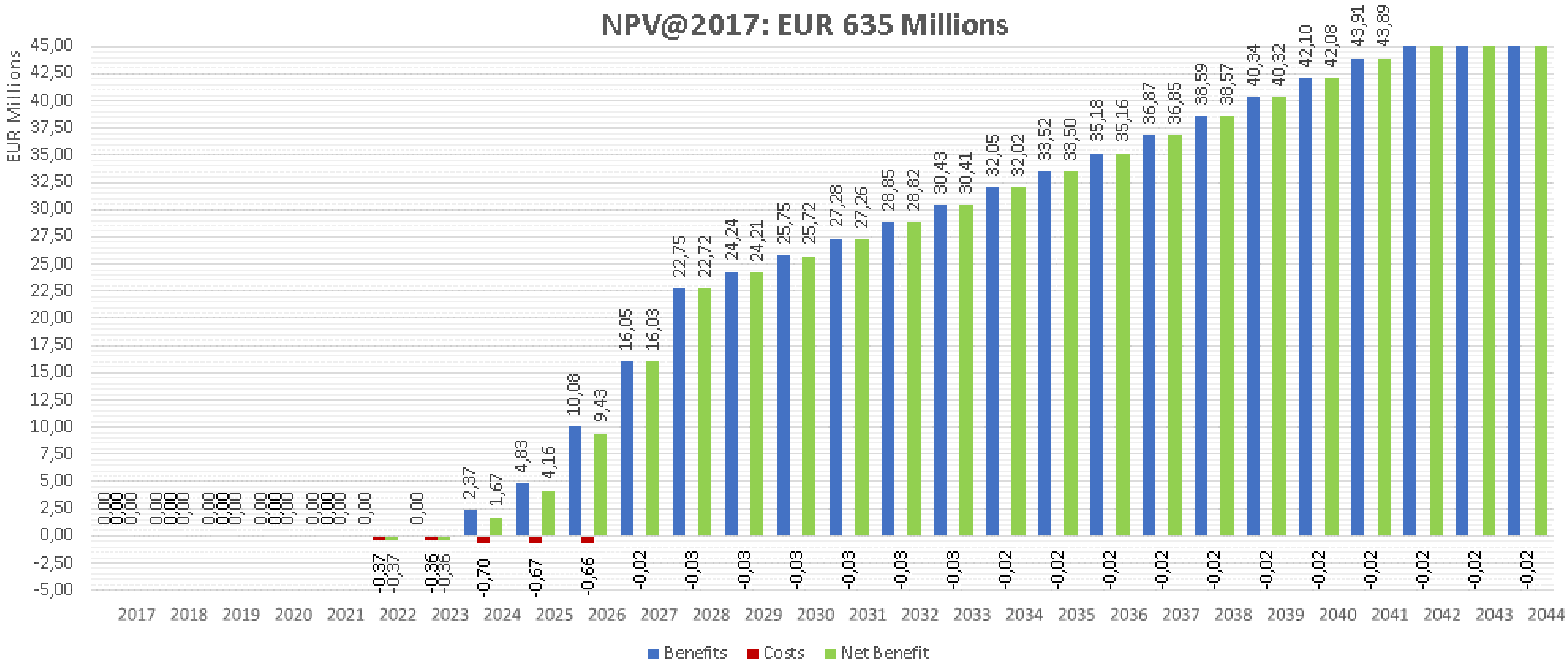
CBA baseline and sensitivity analysis

		Sensitivity analysis	
	Baseline	Optimistic	Pessimistic
Year of system operational for aviation	end 2024	end 2023 * (- 1 year)	end 2025 (+ 1 year)
Year of 100% service adoption penetration	end 2028	end 2026 (- 2 years)	end 2030 (+ 2 years)
SBAS avionics penetration growth rate (aircrafts equipped)	+ 1 % starting from 7% in 2017 (EUROCONTROL today's penetration 7% with growing rate of 1 %/year)	+ 2% **	+ 1%
Estimation of benefits linked to impact of SBAS on DDC reduction (variations wrt EUROCONTROL)	based on EUROCONTROL	+ 10%	- 10%
Estimation of benefits linked to NAVAIDs (variations due to NAVAIDs costs uncertainty)	desk researches	+ 10%	- 10%
Estimation of costs related to procedures (variations of costs)	based on commercial values in Europe	- 10%	+ 10%
Types of airports considered	all airports (international and domestic)	all airports (international and domestic)	international airports only (no domestic)
Discount rate	4% (typical value for initiatives in the region)	4%	6%

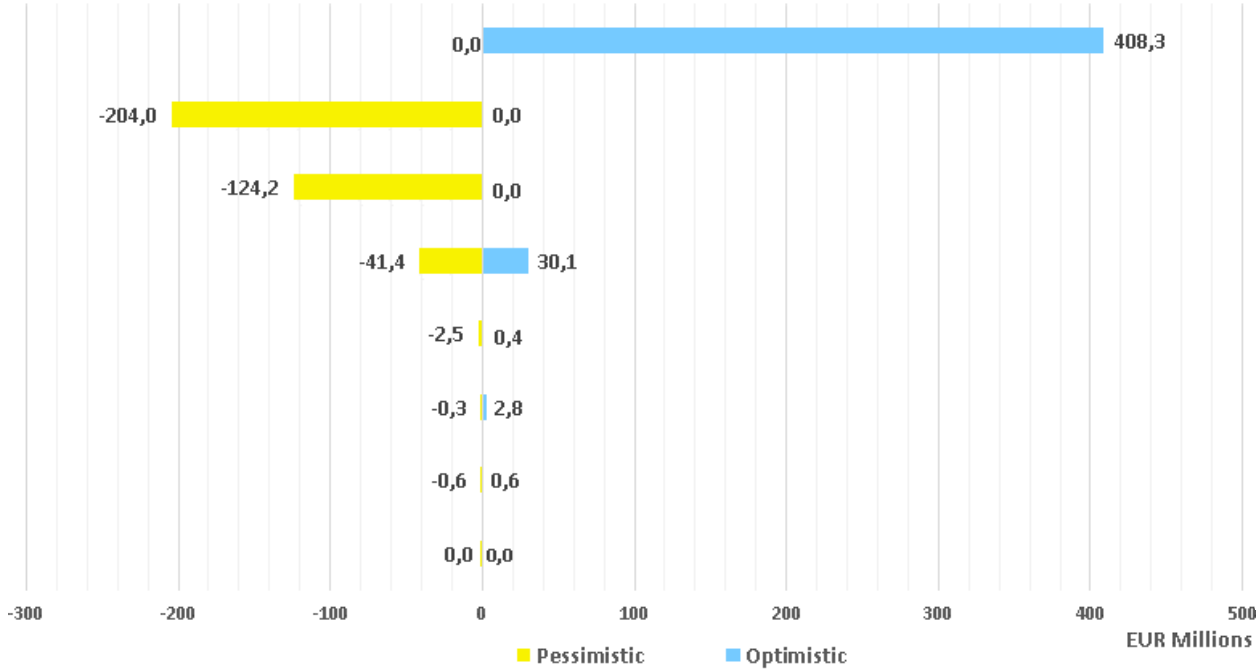
** Thanks to optimisations (e.g. certification start date, SBAS system development schedule)*

*** Higher penetration possibly stimulated by countries' new fleets/aircrafts, upsides derived from presently on-going actions/initiatives in EU/US/India, ADS-B deployment requiring SBAS (depending of the ANSP)*

NPV and financial flow - baseline



Sensitivity analysis - variations wrt NPV baseline



SBAS avionics penetration growth rate
(baseline/pessimistic 1%, optimistic 2%)

Discount rate
(baseline/optimistic 4%, pessimistic 6%)

Types of airports considered
(baseline/optmistic all airports, pessimistic international/no domestic)

Year of 100% service adoption penetration
(baseline end 2028, ± 2 years)

Year of system operational for aviation
(baseline end 2024, ± 1 year)

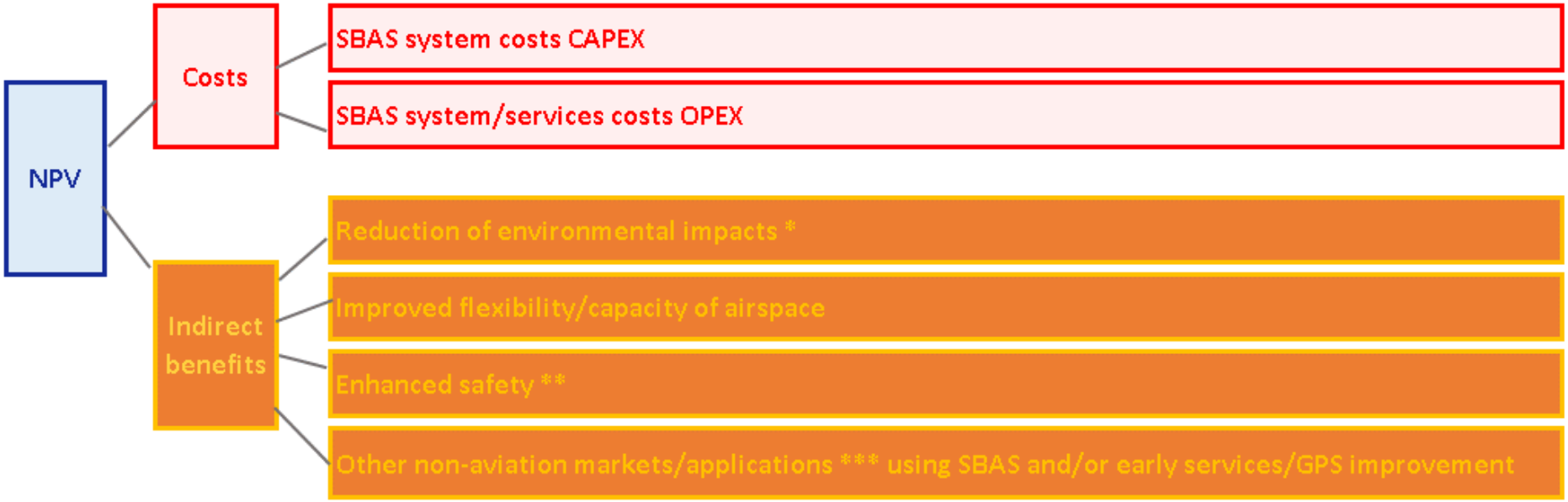
Estimation of costs related to procedures
(variation of ± 10%)

Estimation of benefits linked to NAVAIDs
(variation of ± 10%)

Estimation of benefits linked to impact of SBAS on DDC reduction
(variation of ± 10%)

- SBAS avionics penetration growth rate strongly impacting (+ 64% variation on NPV due to + 1 % increase of growth rate)
- Introduction of SBAS operations also in domestic airports in addition to international increasing NPV (thanks to increase of safety)
- Service adoption penetration influencing NPV
- Negligible impacts due to uncertainties on 1 year variation of system operational for aviation, and due to costs/benefits calculation

CBA's from the perspective of States



CAPEX - initial investments

OPEX - costs per year

Two GEO payloads cases:

- **2 hosted payloads on GEO Sat(s) - costs among system CAPEX**
- **GEO leased services (x 2) - costs among system OPEX**

Three scenarios for OPEX:

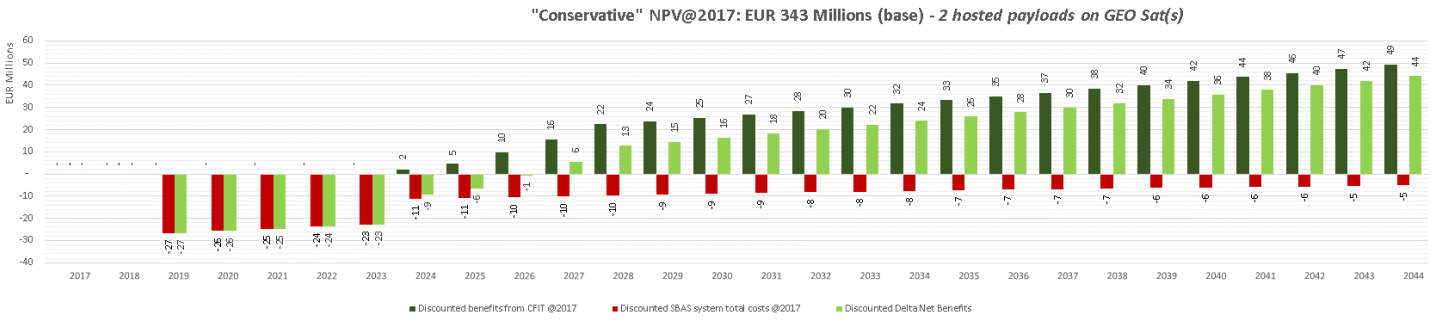
- **Base**
- **Best**
- **Worst**

** Thanks to more precise and shorter approaches e.g. CO2 emissions, noise pollution*

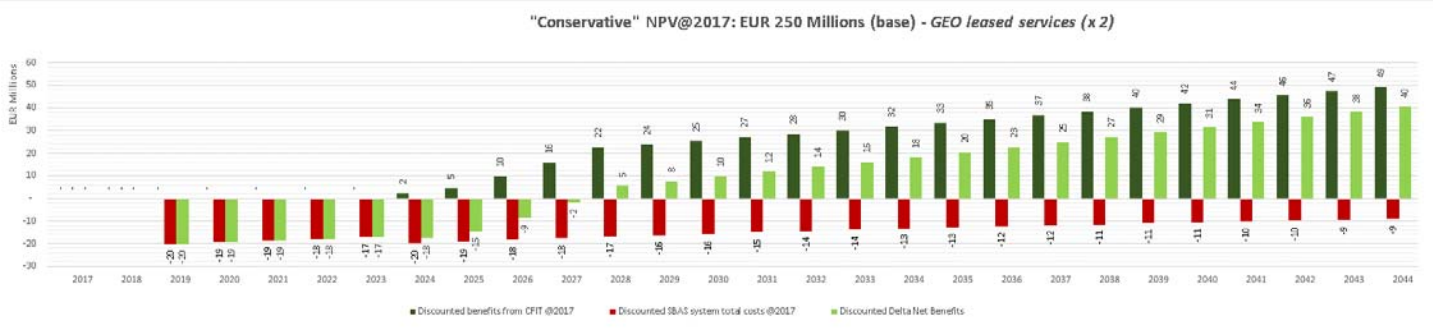
*** Thanks to improved safety levels, reduction of CFIT, etc.*

**** Road, maritime, freight transport and logistics, high precise positioning applications (e.g. surveying, mapping, mining) agriculture*

“Conservative” NPV for States *



2 hosted payloads on GEO	
Scenario (OPEX)	NPV@2017 (EUR Millions)
Base	343
Best	430
Worst	255



GEO leased services (x 2)	
Scenario (OPEX)	NPV@2017 (EUR Millions)
Base	250
Best	397
Worst	114

** Calculated considering only benefits linked to enhanced safety generated by reduction of CFIT System CAPEX and OPEX commercial in confidence information*

CBA's outcomes for ANSP

- **Profitability for ANSPs of GCC, Yemen and Iraq generated by using SBAS, also under conservative and pessimistic assumptions:**
  - NPV@2017* for over EUR 600 Millions
  - Net Benefit end 2024 (mid 2024 SBAS system operational for aviation)
  - Additional users' charging to recover incremental costs
- **SBAS avionics penetration growth rate strongly impacting:**
  - Higher growth rate creating additional benefits
  - SBAS avionics fleet saturation (100% penetration) in 2042 in case of 4% penetration growth rate

**NPV: financial indicator representing the present value of a stream of expected financial flows, discounted to reflect the time value of money and the investment risk. It is a measurement of the profitability of the initiative*

CBA's outcomes for States

- **Net benefits for States investing in SBAS system/services CAPEX and OPEX**
- **Potentials in other non-aviation markets/applications *** using SBAS and/or early services/GPS improvement to be explored
- **2 hosted payloads on Geostationary Sat(s) more profitable wrt GEO leased services (x 2)**
- **Contribution from ANSPs to States for SBAS system/services CAPEX and OPEX not needed**

** Road, maritime, freight transport and logistics, high precise positioning applications (e.g. surveying, mapping, mining), agriculture, training & research*

Recommendations from CBAs

- **ANSP** to:
  - Liaise with States/evaluate the initiative
  - Start preparatory activities (e.g. procedures, training)
  - Liaise with States/identify policies to facilitate SBAS penetration

- **States** to:
  - Evaluate the initiative and launch the activities - including the definition of a mission for hosted payloads on Geostationary Sat(s)
  - Liaise with ANSPs/identify policies to facilitate SBAS penetration
  - Consider possible use of SBAS in markets/applications other than aviation and stimulate introduction/adoption

Thank you for your attention

For questions:
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ICAO ANSEP

Conclusions of the study on Global Navigation Satellite System (GNSS) cost allocation performed by the ICAO ANSEP (Air Navigation Services Economical Panel) (2011): “The incremental costs for more advanced GNSS services should be allocated amongst all the users who can actually derive benefits from them. Such cost allocation should take place at the regional level and take into account the requirements of different user categories, where the service level can be adjusted to satisfy different requirements”.

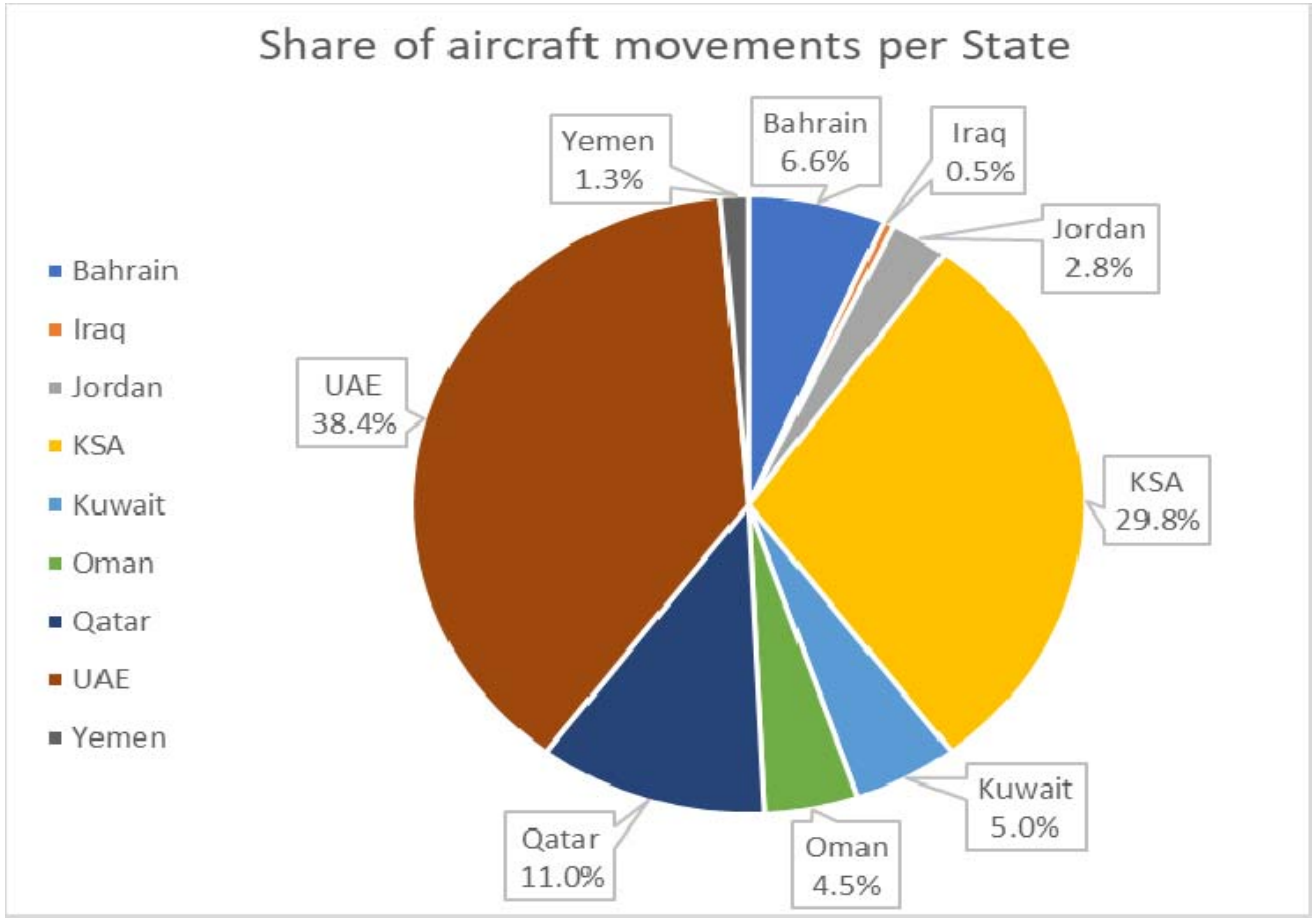
ANSEP also recommends the use of current mechanisms designed to recover ANS costs.

Ideas on contribution from ANSPs to States for SBAS system/services CAPEX and OPEX

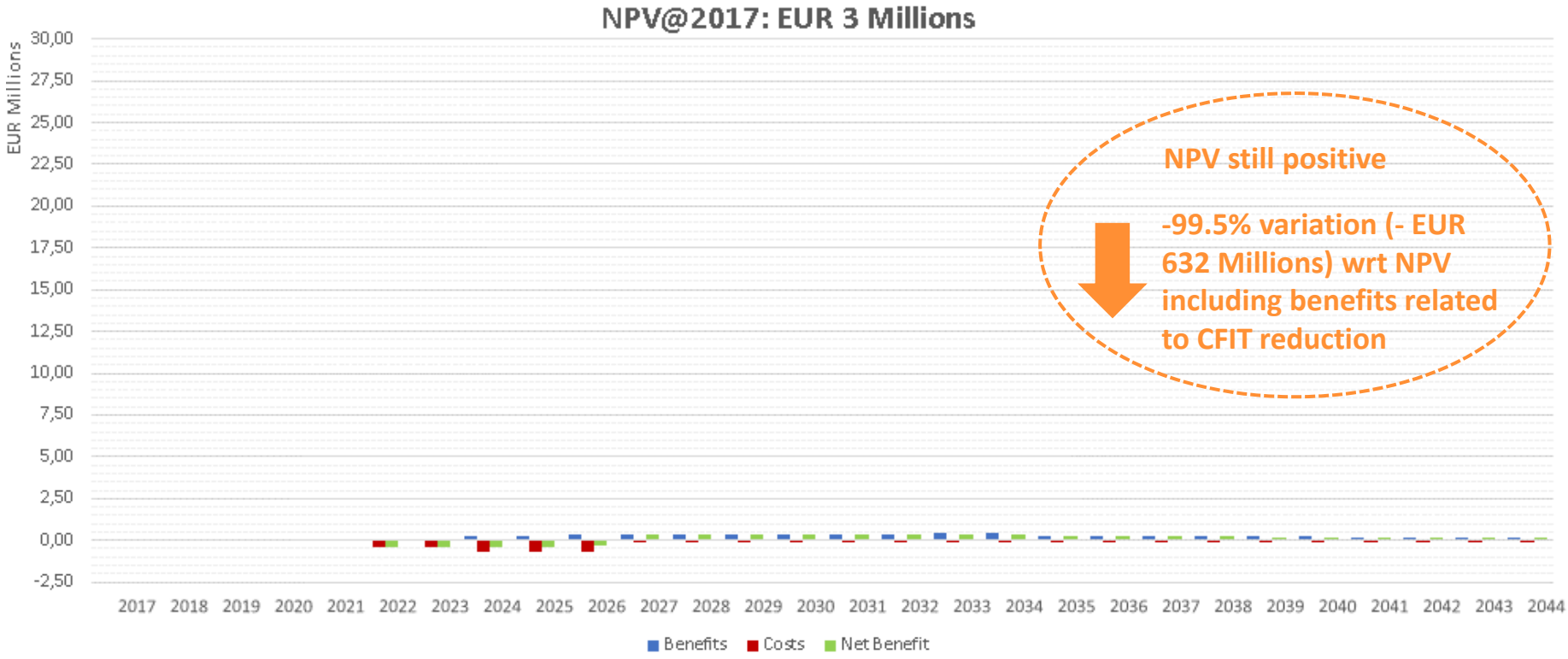
- **Upon request of ACAC**
- **Not applied for other SBAS in the word**
- Assumption - **part of the Net Benefit as ANSPs contribution to States for SBAS, starting from 2025**
- **Repartition among ANSPs could be based on number of landings (SoL usage)**

ANSP's yearly contribution from 2025	EUR 5 Millions
Total ANSPs contribution to States till 2044 (20 years) - not discounted	EUR 100 Millions
DTotal ANSPs contribution to States till 2044 (20 years) - NPV discounted @2017	EUR 50 Millions
Delta Net Benefit for ANSPs	EUR 504 Millions

ANSPs contribution to States for SBAS costs – proposal for repartition based on number of landings (i.e. SBAS SoL use)



NPV and financial flow (baseline) - benefits related to reduction of CFIT not included to ANSP *



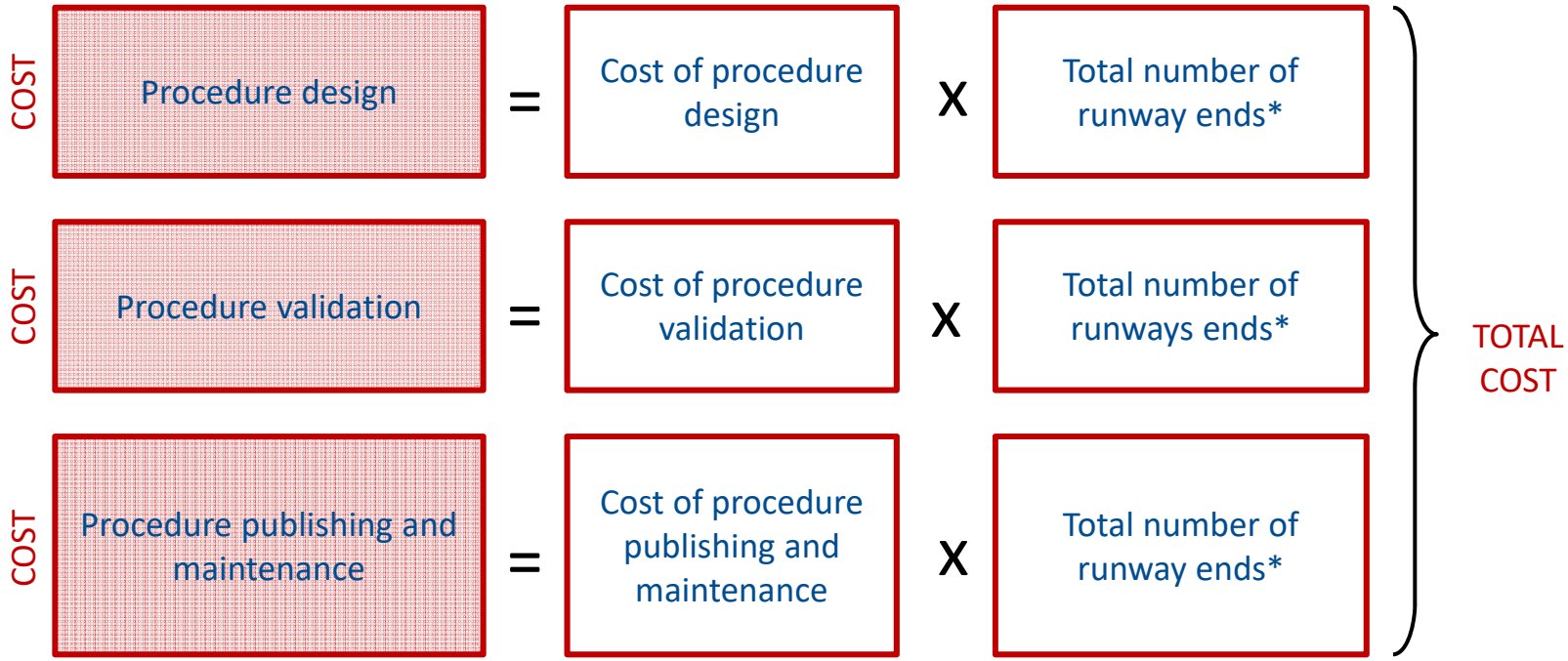
** considered to aircraft operators*

Calculation of benefits *

- **Reduction system costs related to conventional NAVAIDs systems**
  - Decommissioning of VOR/NDB after 15 years
  - Increased operational capacity i.e. full LPV operation during maintenance of ILS equipment
- **Increased airport operational efficiency and capacity and saving on operating costs (i.e. ATCs' time) (thanks to reduction of DDC)** on airports not equipped with ILS
- **Additional charging based on number of landings** - airlines to pay additional airport charges for SBAS capability of the airport/LPV approaches

** Defined/validated by ACAC*

Calculation of costs - procedure design, validation, publishing and maintenance



**Total number of runways per country*

Calculation of benefits - CBA parameters - NAVAIDS *

NAVAIDS

Parameter	Sub-Parameter	Value	Unit	Source
VOR	Lifetime (yrs)	**15**	Years	KSA
VOR	Underperforming ([%])	**100**	%	KSA
NDB	Lifetime (yrs)	**15**	Years	KSA
NDB	Underperforming ([%])	**100**	%	KSA
CAPEX VOR per unit		50	$ [000]	
OPEX VOR per unit		5	$ [000]	
CAPEX NDB per unit		15	$ [000]	
OPEX NDB per unit		5	$ [000]	

** Validated by ACAC*

Calculation of benefits - reduction system costs related to conventional NAVAIDs systems - VOR

BENEFITS

Reduction of system costs related to the decommissioning of conventional NAVAID systems - OPEX VOR -

=

Total VOR units per year*

x

OPEX (VOR)

**VOR will be decommissioned at the end of the lifetime of the equipment i.e. 15 years after deployment*

BENEFITS

Reduction of system costs related to the decommissioning of conventional NAVAID systems - CAPEX VOR -

=

Total VOR units per year**

x

CAPEX (VOR)

***New VOR units that would need to deployed to replace equipment reaching the end of their lifetime i.e. 15 years after deployment*

TOTAL BENEFITS

Calculation of benefits - reduction system costs related to conventional NAVAIDs systems - NDB

BENEFITS | Reduction of system costs related to the decommissioning of conventional NAVAID systems - OPEX NDB - | = | Total VOR units per year* | x | OPEX (NDB)

**NDB will be decommissioned at the end of the lifetime of the equipment i.e. 15 years after deployment*

BENEFITS | Reduction of system costs related to the decommissioning of conventional NAVAID systems - CAPEX NDB - | = | Total VOR units per year** | x | CAPEX (NDB)

***New NDB units that would need to deployed to replace equipment reaching the end of their lifetime i.e. 15 years after deployment*

TOTAL BENEFITS

Calculation of benefits - Aircraft equipment

Parameter	Calculated on	Source	Compatibility assessment
Aircraft fleet composition with IFR (SBAS compatible)	ECAC Member States	Eurocontrol (2015)	Considered compatible due to the cross-borders nature of international fleets, as well as current trends in aircrafts' standard equipment dotation. **= 9% of aircrafts SBAS compatible in 2019 (growth rate of 1% per year)**

Calculation of benefits - CBA parameters - DDC - Delays, Diversions and Cancellations *

DDCs

Parameter	Sub-Parameter	Value	Unit	Source
Total DDCs probability		0.19	%	EUROCONTROL
Weight of DDC category	Delay	75	%	EUROCONTROL
Weight of DDC category	Diversion	20	%	EUROCONTROL
Weight of DDC category	Cancellation	5	%	EUROCONTROL
Value of air traffic controllers time	Average air traffic controllers' wage	139,000	€ per year	EUROCONTROL
Value of air traffic controllers time	Working day per year	227	Days	Doing Business 2017
Value of air traffic controllers time	Working hour per day	8	Hours	Doing Business 2017

** Validated by ACAC*

Calculation of benefits - CBA parameters - Air Traffic *

Data for 2015

Type of Airport	Number of Movements	Percentage out of total
International	518,652	80%
Domestic	128,041	20%
Total	646,693	100%

Source: GACA Statistical Yearbook, 2015

Data for 2014

Type of Airport	Number of Movements	Percentage out of total
International	475,973	81%
Domestic	113,243	19%
Total	589,216	100%

Source: GACA Statistical Yearbook, 2015

ASSUMPTION FOR STATES NOT PROVIDING DOMESTIC MOVEMENTS DATA

Total = Domestic + International

Domestic Movements = 25% x International Movements

Data for International Airports - discrepancies between GACA and ICAO data

Source	Number of Movements – International Airports	Difference in Percentage
ICAO	356,988	+31%
GACA	518,652	
Difference	+161,664	

Source: GACA Statistical Yearbook, 2015, ICAO, 2017

ASSUMPTION FOR STATES NOT PROVIDING INTERNATIONAL MOVEMENTS DATA

International Movements = (1 + 30%) x ICAO data

** Validated by ACAC*

Calculation of benefits - CBA parameters - CFIT, ATCO, Training, Environment *

CFIT

Parameter	Sub-Parameter	Value	Unit	Source
Estimated cost of CFIT occurrence	cost of partial hull loss	**4,600,000**	$	EUROCONTROL
Estimated cost of CFIT occurrence	cost of full hull loss	**16,900,000**	$	EUROCONTROL

Air Traffic Controllers time saving

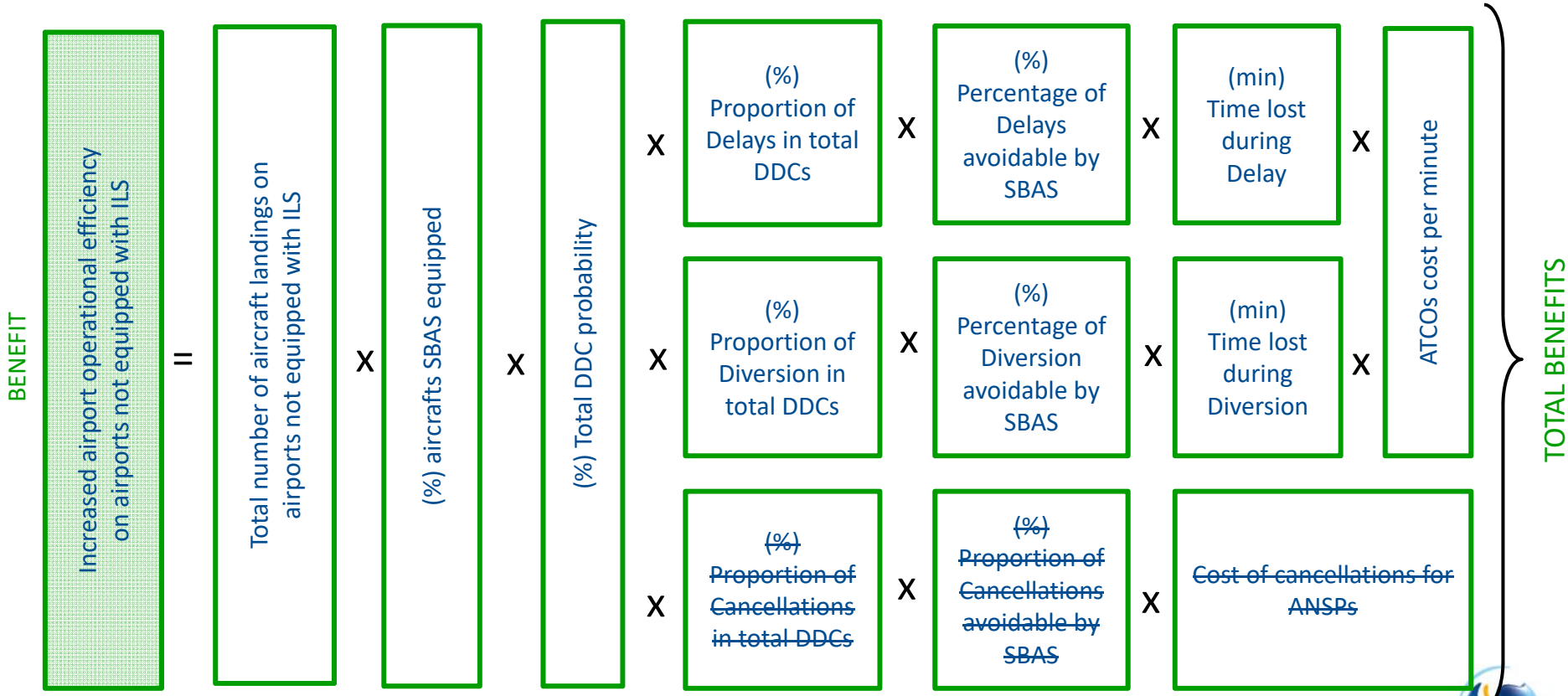
Parameter	Value	Unit	Source
Air traffic controller time savings per approach due to improved flexibility	**20%**	%	Conservative considerations on previous studies

Environment

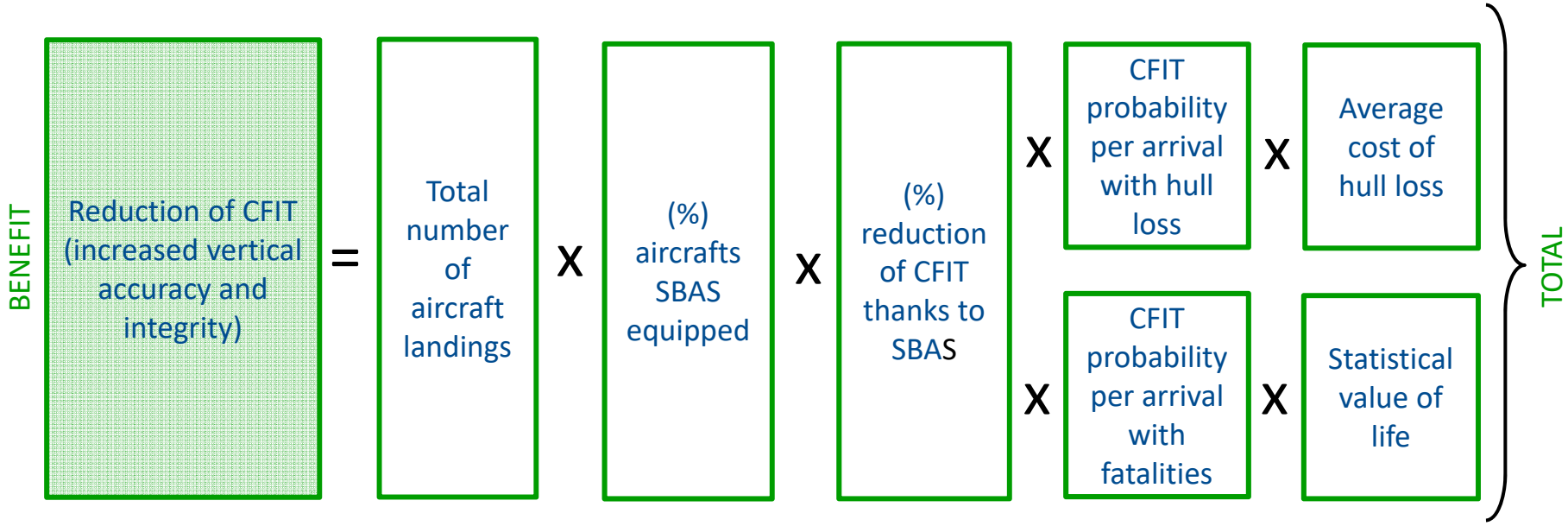
Parameter	Value	Unit	Source
Reduction CO2 emissions due to the use of SBAS	**10**	%	Stanford University, 2014

** Validated by ACAC*

Calculation of benefits - increased airport operational efficiency and capacity and saving on operating costs (thanks to reduction of DDC)



Calculation of benefits - increased vertical accuracy and integrity (reduction of CFIT)



Discount rate - Estimation for GCC, Yemen and Iraq

Discount rate has been developed following a well-established economic practice that links the discount rate to the borrowing costs of US denominated capital on the international financial market, primary source of funding for infrastructure projects financed by governments.

Recent US $ sovereign debt long-term-maturity issuance by GCC, Iraq and Yemen, corrected for US inflation *

Country	Maturity date	Term-to-maturity	Yield-to-maturity - annual	Yield-to-maturity - corrected by US inflation **
Bahrain	20/09/2047	20	7,50%	5,392%
Iraq	15/01/2028	10	5,80%	3,725%
Jordan	10/10/2047	20	7,38%	5,270%
Kuwait	20/03/2027	10	3,50%	1,471%
Oman	08/03/2047	20	8,50%	6,373%
Qatar	02/06/2046	20	4,63%	2,574%
Saudi Arabia	26/10/2046	20	4,50%	2,451%
United Arab Emirates	11/10/2047	20	4,13%	2,083%
Yemen	-	-	-	-
Average			5,74%	3,67%

** Source: Bloomberg, 2017*

** * US inflation has been considered equal to the long term equilibrium FED target value of 2%*

Yield-to-maturity = Discount Rate = 4% (baseline)

Discount Rate = 6% (pessimistic)