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1. What is a Business Case, CBA, Economic Impact Analysis (EIA), and Cost Effectiveness Analysis (CEA) and how are they different?

1.1. All organizations are faced with decisions on how best to pursue their objectives. To guide investment decisions, organizations use evaluation techniques that focus on the options, and search for that which maximizes net benefits. There are several different types of evaluation techniques that organizations and States can use depending on what type of analysis they want to include. Section 2 highlights three of the more commonly used evaluation techniques – Business Case, Cost Benefit Analysis (CBA)/Benefit Cost Analysis (BCA), Economic Impact Assessment (EIA) – however; there are other evaluation techniques that could be used depending on the investment decision being made.

1.2. It is important to note that these evaluation techniques are all tools that support planning and decision-making. They should be used in conjunction with other information such as the broader strategic context for the investment, political and social environments and other possible relevant factors. A negative result from any of these evaluation techniques should not necessarily rule out making the investment.

What is a business case?

1.3. A business case describes the business rationale for undertaking a programme (or group of projects). Importantly, it also facilitates coordination with all parties involved in the investment decision and supports negotiations with financial institutions. A business case sets out the context, identifies the issue(s) to be addressed and provides a detailed description of the proposal selected as well as the rationale for its selection from among other options. The development of a business case is a complex process and includes a number of assumptions and assessments that go beyond the scope of the organisation's budget and business plan. Typical assessments in a business case are a financial analysis, strategic drivers, organisational performance factors, cost benefit analysis (covered in more detail below), a risk assessment and stakeholder impact.

1.4. Financial cost considerations are important and a business case would include information such as overall cost projections, cash flow statement, and capital and financing factors. The strategic drivers of the investment decision could include relevant information and analysis of the market, other products and services, and political and social environment factors that cannot be measured in financial terms.

1.5. Organisational performance and productivity factors and critical success factors should be identified and discussed as mainly non-financial benefits. These could be wide ranging depending on the nature of the investment decision – e.g. improvements in service, cost efficiency, reductions in delay, human workload and productivity, facilities and equipment use, technological productivity, contingency plans, safety and security improvement and compliance with standards and regulations. In labour intensive areas other human resources issues are important with regards to the demands of recruitment, redeployment, training and discharging.

1.6. Key risk factor identification together with the indicators which would alert of changes in the results is important in business cases. For each risk factor, mitigating measures should also be indicated.

1.7. Finally, a business case should identify and appraise the impacts on stakeholder groups and users of air navigations services. This is to identify, as early as possible, the divergence of interests between stakeholder groups and anticipate early mitigation measures, if possible. For example, investments in air navigation facilities and services could lead to increase airspace capacity and consequential improvements in quality of service (more direct flight routes and reduced traffic delays), which could be an incentive to increase user charges in order to recover the higher costs.

What is a CBA? (also known as Benefit Cost Analysis (BCA))

1.8. A CBA identifies the investment option that best conforms to the economic goal of maximizing net societal benefits. It exams all costs and benefits related to the production and consumption of an output, whether the costs and benefits are borne by the producer, the consumer or a third party. As the CBA takes into account both public and private benefits and costs of a project, it tends to be more appropriate in cases where projects are publicly funded.

1.9. In a CBA the ultimate objective is to compare the benefits and costs. Therefore, a CBA objectively identifies all costs and benefits, quantifies them and converts them into the same monetary unit of measurement. A CBA also takes full account of the times at which the costs are paid and benefits accrue. A CBA obviously goes well beyond a financial analysis that focuses on the financial accounts and cash flows.

1.10. CBA involves evaluating a project option(s) against a base case, which can be referred to as the "do nothing" or "counterfactual" option. Defining and clearly articulating the base case is a very important and often challenging aspect of CBA.

1.11. A CBA will help:

- Identify all costs and benefits
- Quantify these costs and benefits to calculate the economic value of the project
- Make a cash flow projects
- Select the best option
- Classify costs and benefits by order of importance; and
- Determine the critical factor(s) of success

What is an EIA?

1.12. An EIA attempts to identify the cumulative economic effect of a major investment project and is used mainly for publicly funded projects. An EIA is often performed to determine whether a project should be carried out with respect to national or regional economic development, even if it will not generate positive net benefits in any traditional sense.

1.13. The contribution of an infrastructure project to the economy can be assessed on the basis of the following five key indicators of direct, indirect and induced economic activity:

- employment
- personal incomes
- business revenues
- tax revenues
- capital investment

1.14. Beyond the direct and indirect economic impact of the infrastructure project, there is the induced impact on the economy created by the "multiplier effect"[1] of direct and indirect impacts or activities. An economic impact survey can reveal the benefits to the economy from tourism and various related activities.

What is CEA?

1.15. CEA is similar to CBA except that it does not attempt to place a value on the major benefits of a proposal. It is often not possible to assign monetary values to all costs and benefits and therefore alternative assessment techniques such as CEA can be useful.

1.16. CEA compares the costs of alternative ways of producing the same or similar outputs/benefits. It is often used to find the option that meets a predefined objective at a

[1] Normally expressed as a factor showing how much the direct economic impact of the airport is increased by the indirect and induced economic effects of airport activities. The value of the multiplier will differ between States.

minimum cost. Therefore CEA provides a measure of the relative effectiveness of alternative interventions in achieving a given objectives. CEA results are useful for projects whose benefits are very difficult, if not impossible, to evaluate, while costs can be predicted more confidently.

1.17. The use of CEA is limited as it is applicable when only a single dimension of an outcome matters.

What is the difference between a Business Case, CBA, CEA and EIA?

1.18. There are similarities between the different techniques – all are formal techniques for generating facts to help decision-makers make more informed decisions - but they are not the same and their use should be matched to the context that the decision is being made in.

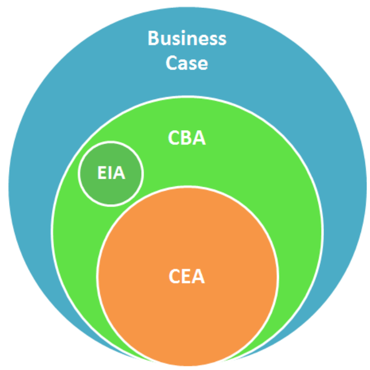


Figure 1 – Relationship between business case, CBA, CEA and EIA

1.19. A business case goes beyond financial analysis and includes a much broader range of factors. A business case will often include a CBA as an input alongside a wider set of qualitative and qualitative assessments that are fundamental to determining the value of the project, such as safety, security, the environment, human performance and strategic fit. It will assess potential impacts from a multi-criteria perspective including analysis of synergies and trade-offs. Assessments in a business case can range from qualitative expert judgements quantitative and monetary impacts, whereas a CBA requires that all costs and benefits be converted into monetary terms in order to compare.

1.20. A business case is also a collaborative process generally involving a multi-disciplinary team and it is targeted at ensuring ownership and buy-in for the investment decision. The main audiences involved in the business case are

- The business case practitioners.
- The project/programme team members.
- The validation experts (those in charge of assessing the various performance impacts).
- The impacted stakeholders.
- The decision makers.

1.21. A CBA should be a "neutral" and objective assessment. It develops key facts in monetary terms regarding the costs and benefits of a project and compares a few viable options to provide guidance on which is the most advantageous. A CBA is generally used in projects that are publicly funded as it identifies all costs and benefits associated with the project whether accrued by the producer, consumer or a third party.

1.22. A CEA can be used where it is not possible to quantify all the benefits of a project or it can also be used where the desire is to measure the relative effectiveness of alternative interventions in achieving a given objectives.

1.23. An EIA is a more specific type of CBA to look at cumulative impacts of major publicly funded infrastructure projects where there may be national or regional development factors. EIA is less relevant in the context of air navigation services (ANS) projects than airport projects because ANS projects tend to have limited effects on the national economy.

1.24. Finally, there are also differences between a financial evaluation and a CBA in the treatment of capital costs. While a financial evaluation normally restates the capital costs into annual depreciation and interest expenses, a CBA measures capital costs by the cash expenditures required in future years — not by depreciation and interest. The cash stream of expenditures is compared to the stream of benefits, and the annual net amounts are discounted to compute a net present value (NPV)[1] for the investment option.

1.25. To illustrate the difference in scope between a financial evaluation and a CBA, consider:

A. The extension of a passenger terminal at an airport. The financial evaluation would look at the financial cash flows and required user charges associated with this investment, while a CBA would consider the benefits and costs to all parties involved. These would include the air carriers' benefits from improved passenger processing and the passengers' benefits from time-savings. Additionally, if considering the wider social effects, the negative effects, such as increased traffic and noise experienced by individuals living or working in the vicinity of the airport, need to be taken into account.

B. The installation of radar in a previously non-radar airport location. The financial evaluation would look at the financial cash flows and required user charges associated with this investment, while a CBA would consider the benefits to and costs for all parties involved. These would include the benefits to aircraft operators from fuel savings and to passengers from time savings. Additionally, if considering the wider social effects, the negative effects like increased traffic and noise experienced by individuals living or working in the vicinity of the airport would need to be taken into account.

2. When should you conduct a Business Case and/or CBA?

2.1. Every major investment decision taken by a State, an airport or a provider of air navigation services should be supported by analyses to demonstrate to providers, users and, as appropriate, the wider community, the costs and benefits accruing from investment in infrastructure. CBAs and business cases should be tailored to be proportionate to the size of planned investment, an appropriate use of resource and should add value to the decision making process.

2.2. Consultation with users should assist States and providers with their major investment decisions. With regard to analyses undertaken, commonality in approach within a State or region is desirable and most States or regions will have agreed guidance or processes for undertaking such analyses.

2.3. The decision of when and to what extent CBAs and businesses cases should take into account the different key decision points in the life cycle of a particular investment programme, such as the aviation system block upgrade (ASBU) modules.

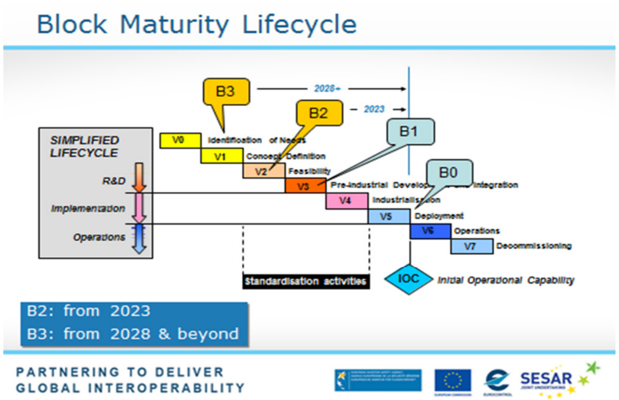
2.4. Different assessments are generally warranted at the different lifecycle stages due to the level of data which is available at that time and the amount of time that is proportionate to spend to prepare such an evaluation. Figure 1 below provides a simplified example of a maturity lifecycle model for the aviation system block upgrade (ASBU) programme and includes three main lifecycle stages - research and development (R&D) identification of needs and concept definition, R&D validation and feasibility, and implementation and deployment. Following the identification of needs and concept definition R&D phase, a State or organisation would be looking for a very high level assessment of whether there are potential benefits to be exploited in a particular area and might consider a high level strategic CBA a proportionate and acceptable technique at that point in time. Evaluation at this stage would look to help answer the question – *"Is it worth our investment to explore possible benefits in this area?"*

2.5. As further detail emerges and the project decision moves into the R&D validation and feasibility stage, a more detailed CBA assessment would be possible and warranted in order to be able comprehensively compare the known possible options that could be industrialized and deployed. Evaluation at this stage would look to help answer the question – *"Should we continue to invest in this area, and if so, which of the possible options should we commit to?"*

2.6. Finally, the investment programme moves into the most important milestone stage of deciding to invest in actual deployment and operations. At this stage a full business case would be required all factors relating to the financing of the investment, the impact on performance and operations, risks, safety and security and stakeholder impacts would need to be considered before deploying. It is useful to refer to the planning process described in the Global Air Navigation Plan[2], in particular to assess needs and the different available solutions that can best fulfill them. Evaluation at this stage would look to help answer the question – *"What are all the possible implications of proceeding to deployment with this investment, and given these should we proceed?"*

[2] http://www.icao.int/sustainability/pages/GANP.aspx

Figure 2 -SESAR



3. What should a Business Case or CBA include?

3.1. There are many ways to conduct a business case or CBA, but economic evaluations including CBAs and businesses cases include the following general stages:

- Define the objective and scope
- Specify assumptions
- Define the base case and identify alternatives
- Set the analysis period
- Identify the benefits and costs
- Compare the costs and benefits
- Conduct sensitivity analysis
- Consider distributional aspects
- Make Recommendations

3.2. Approaches to CBAs and business cases may differ from jurisdiction to jurisdiction and therefore these guidelines should not serve as a prescriptive list but rather as a reference tool for reviewing or undertaking CBAs and business cases. The following sections highlight the key factors to be considered for each of these stages and highlight some of the issues unique to aviation that may arise in evaluations of investments for ASBUs.

Define the Objective and Scope

3.3. A first step in any evaluation should be to define and describe the problem. The objectives for the CBA or business case for the investment project (or regulation) must then be clearly stated in terms of the desired outputs.

3.4. It is a common failing for evaluations to describe an action in terms of the inputs required to accomplish it rather than the desired outputs. For example, the objective of providing airspace surveillance should be stated in terms of the expected improvements in benefits – enhanced safety, increased system capacity, reduced costs, better weather detection, etc. – rather than as a need to procure a new radar system.

3.5. The scope of the CBA or business case should be clearly identified which will define the timescale, geographic area, relationship to other projects, developmental stage, and possibly indicative cost estimates. The scope should also state whether there are indirect cross border or network impact that need to be taken into account, or at least identified.

ATM Special Considerations – "Enablers"

An enabler is a technology that provides an improvement only in combination with another technology. Therefore neither technology by itself provides the improvement, but together a benefit is provided.

The scope of a CBA or business case should ideally include all enabling technologies required to deliver an operational improvement. Otherwise, the full extent of the costs will not be captured, and it would be difficult to calculate benefits attributable only to those aspects included in the scope.

For example, ADS-B Out in an enabler for ADS-B In. Operators that equip with ADS-B Out will have started implementing the initial technologies that will be required in the future to equip with ADS-B In. Therefore, if the CBA or business case scope included only ADS-B In then the investment already make on ADS-B Out technologies should be treated as a sunk cost and not included, and only the additional benefits of ADS-B In should be included (not the benefits already accrued from ADS-B Out). However, if the scope of the CBA or business case included both ADS-B Out and ADS-B In capabilities then the costs of all associated technologies should be included, along with the benefits.

3.6. In addition the scope needs to address which airspace users are affected. By their nature airspace users are mobile and can use the given geographic area only from time to time as well as operating in other areas. Identifying the airspace users will help to ensure there is no double counting or that benefits or costs are forgotten. Synchronisation between different geographic areas can also improve respective CBA or business cases.

3.7. Clarifying the objective and scope for the evaluation will provide the purpose and perspective from which the CBA or business case is being done, which will help identify the costs and benefits to include in the assessment. This stage may be time consuming but many project and evaluations fail because they have not got the scope and objectives clear from the start.

3.8. ANS changes impact many different stakeholders and it is essential to ensure that the objective and the scope of the CBA or business case recognises this and is clear about the impacts of this for different stakeholders. This is particularly important for business cases as the non-quantifiable and non-financial factors may differ greatly

ATM Special Considerations - Cross Country Impacts

International air transport is a service that connects at least two points in two different countries. This distinct characteristic will complicate defining the scope or objectives of a CBA or business case. Careful thought must be given to whether or not the scope includes benefits in all areas impacted by the operational change, or only the country or region undertaking the study. CBA and business cases should acknowledge any possible cross country impacts even if they are outside of the scope of that particular study.

The operational performance of the service is impacted by performance in the airspace of each of the countries flown. Improving performance in one country will, all else equal, improve the connection with benefits incurrent in both countries. It is also possible that benefits accrue in other countries indirectly impacted by the improvement.

For example, a round trip flight that connects Beijing and Warsaw that improves approach procedures at Warsaw airport (reducing fuel burn and flight time) will improve the service, generating benefits in Warsaw and Beijing. If the flight path is made more direct over Russian airspace these benefits will also accrue to the users of this service and more broadly. Pilots flying improved procedures in one country will be able to fly these improved procedures in other countries and if aircraft are equipped, the ANSPs will be incentivized to implement the new procedures. If a CBA or business case in this example included only the benefits accrued at Warsaw airport, it would underestimate overall benefits as the positive cross-country impact would not be captured.

However, if operational changes are made in only one country and not another country impacted by the operational change it is possible the benefits accrued in the first country could be negated when the aircraft reaches the border of the other country.

For example, one country relies on ADS-B Out for monitoring aircraft and is able to reduce aircraft separation in en route. If the adjacent country has not implemented ADS-B Out, aircraft separation would be increased once the aircraft reach the border of the adjacent country. If a CBA or business case in this example only included the first country in the scope then it would overestimate the benefits as the negating cross-country impact would not be captured.

Non-Aviation Examples - Cross Country Impacts

Cross country spillovers are well documented phenomena in terms of economic growth and financial system performance outside of aviation. They have also been documented in other infrastructure contexts and are sometimes referred to as "transit effects".

"For example, exporting firms rely not only on the quality of infrastructure provided by their home governments, but also on that of neighboring countries through which goods must transit. Because of this, the relationship between road quality and trade may not be entirely linear. Upgrades in important transit countries or resolution of regional bottlenecks could have impact well beyond the individual countries concerned." *(Journal of Economic Integration, December 2007)*

A recent impact assessment for the proposed carbon pollution guidelines for existing power plants and emission standards for modified and reconstructed power plans undertaken by US EPA incorporates the worldwide impacts of CO_2 emissions in order to reflect the global nature of the problem. The US government indicates that they expect that other governments will consider the global consequences of their greenhouse gas emissions when setting their domestic policies.
http://www2.epa.gov/sites/production/files/2014-06/documents/20140602ria-clean-power-plan.pdf

between different groups of stakeholders. Including stakeholders in the development of the object and the scope will allow for the potential different factors to be identified and addressed.

Specify Assumptions

3.9. Any evaluation will require assumptions to be made. This may be because of a lack of all data and information, or because the project will have an impact in future years and therefore involves a substantial amount of uncertainty. In aviation, investment and regulatory evaluations generally include assumptions on aircraft fleet characteristics, levels of aircraft activity, equipment life, number of passengers and or/shipment revenues, the cost of fatalities and injuries or the value of passenger time. Any assumptions made should be explicitly stated and their basis justified – judgment, econometric forecast.

3.10. The assumptions should also address the other planned changed to occur in the meantime which may affect the base case. A rigorous approach is needed at this stage to ensure that benefits are not double counted or overestimated at later stages.

3.11. It will not always be possible to identify all assumptions at the beginning of the project. The processes of identifying and updating the assumptions made in the evaluation should be iterative throughout the entire CBA or business case development as more information is obtained or information gaps appear that can only be filled by assumption.

Define the base case and identify alternatives

3.12. There are usually several different ways to achieve a desired objective. In evaluations it is important to identify all reasonable ways to achieve the desired objectives and to compare these alternatives against a base case scenario.

3.13. The base case provides the benchmark against which the proposed project, or investment, can be measure. It is the 'do nothing' or 'maintain status quo' option that describes what is likely to occur in the absence of the project being evaluated. It does not imply that the base case is a costless option. The base case should be considered as what needs to be done without the project to maintain the current or prescribed levels of service, rather than simply continuing in the existing state. Therefore it is not 'before' or 'after' that we are interested in, but rather the best 'with' and the best 'without' the project. A CBA cannot be conducted without a base case scenario.

3.14. If an option is viewed as providing an improvement to the status quo, it should be included as a project alternative. It is not necessary to include every possible alternative

ATM Special Consideration – Dependencies

Delivery of benefits from the introduction of certain technologies may be dependent on the existence of other investments being made. Therefore, the timing of when benefits are generated may not be related only to the deployment of the technology but rather the deployment of other technologies.

It may also be the case that as dependent technologies are deployed the scale of benefits changes, such as an investment in ground infrastructure by ANSPs and an investment in avionics by the operators.

Where possible these dependencies and assumptions should be acknowledged in a CBA or business case. It may also be appropriate to conduct sensitivity analysis or model different alternative scenarios on the impact of changes in dependencies.

For example, PBN procedures are dependent on:

- ANSP developing the procedures
- aircraft being equipped with RNP
- flight crew being certified to fly the procedure

Air traffic controllers may not issue those procedures until a substantial number of aircraft and flight crew are equipped and certified to fly those procedures. Therefore, ANSPs and operators may not accrue benefits until a substantial number of aircraft and flight crew are equipped and certified to fly those procedures.

Ground system architecture is also another key dependency for ATM improvements particularly if there are several independent developments and procurements in a given area.

A CBA for the feasibility study of the North East Functional Airspace Block (NEFAB) in Europe provides an example of how dependencies have been highlighted and incorporated into the CBA study.

http://ec.europa.eu/transport/modes/air/single_european_sky/doc/2011_08_26_nefab_anx8.pdf way of achieving the project objective in the evaluation. Many technically possible alternatives may be ruled out from the beginning as inferior to others which are being considered; however, care should be taken in decisions to remove alternatives from the evaluation. A decision to remove an alternative from the evaluation should be well founded and supportable, and should not be made based on past practice or external constraints. Successful identification of alternatives is often not confided to any singe area of expertise. Therefore, it is advisable to involve one or more technical experts at this stage of the evaluation.

3.15. It is also important that the alternatives included in the evaluation are defined in a consistent and fair way. In particular, comparisons between two alternatives cannot be made if they are at different scales, occur at different times, or involve different ownership.

3.16. Involving stakeholders at this stage is vital to ensure that the base cases identified is a true representation of current operations and that all possible feasible alternatives are identified.

Set the evaluation time horizon

3.17. The time horizon for the analysis is a critical decision as future streams of costs and benefits must be adjusted by a discount factor from the year in which they occur to a base year for the evaluation.

3.18. The evaluation time horizon should cover the entire time period over which the project's costs and benefits occur. The determination of an appropriate time horizon will be specific to each evaluation but factors such as the lifespan of capital investments, the period over which a policy is likely to apply, and other demographic, economic or social factors that may impact on the suitability of the project's objectives. In general, physical capital investments such as airport runways or terminals will have a longer time horizon for evaluation compared to air navigation technology developments or other government policies or regulations.

3.19. A CBA or business case can be improved if costs can be spread across time, and therefore longer time periods will generally result in more positive results; however, the time horizon set must reflect be realistic and reflect the lifecycle of the operational improvement and technologies or capabilities employed.

Identify the Benefits and Costs

3.20. All costs and benefits must be identified for the base case and for each of the alternatives under consideration in a CBA or business case. Once identified, costs and benefits should be quantified in monetary value were possible. Intangible benefits or costs – those which cannot be evaluated in monetary terms – should be listed and described for the decision maker. If possible, a range in which a monetary value could be reasonable expected to fall should be reported. Intangibles should not be neglected as they are often extremely important to the overall decision making process.

3.21. There are several factors that need to be considered when identifying the costs and benefits for a CBA or business case. Only incremental benefits and costs caused by the project should be compared, not those are merely associated with the project in some way. The analysis must avoid double counting and therefore must maintain a consistent point of view throughout. In a CBA we count resources that are created or used up and therefore resources that are simply transferred from one place to another are not counted as costs or benefits. The opportunity cost is the true value of any resource foregone and must be included even if explicit cash transactions are not involved. A sunk cost, a cost that is irretrievably made or committed, should not to be counted in a prospective CBA because it cannot be affected by the decision in question.

3.22. Each individual evaluation will identify its own set of relevant costs and benefits and this will vary significantly between different types of project objectives. Typical cost categories could include capital infrastructure, fleet, IT equipment and software, staff costs, maintenance and repairs, and social cost of externalities such as noise or CO_2. Typically benefits will fall into the ICAO key performance areas (KPAs) of access and equity, capacity, cost effectiveness, efficiency, environment, flexibility, global interoperability, participation by the ATM community, predictability, safety and security. Ideally any relevant indirect or societal costs and benefits should be included; however, in many cases this may not be proportionate to the overall assessment and a judgments needs to be made, and explained, as part of each assessment. Annex 1 of this guidance highlights the expected benefit and cost categories for the Block 0 aviation system block upgrades (ASBUs).

3.23. ICAO's Committee on Aviation Environmental Protection (CAEP) undertook work to fully scope the requirements of assessing the environmental benefits from ASBU Block 0. CAEP's steering group published fuel savings benefits possible from planned and full global ASBU Block 0 implementation between 2013 and 2018 in November 2013. The methodology developed to support this analysis was included.

3.24. The measurement of safety benefits requires an analysis of the safety risks, which are a composite measure of the probability and the severity of an adverse occurrence. A CBA takes the consequences determined by a risk analysis and attributes a specific monetary value to them. Where accident losses involve tangible goods such as property, accident risks can be valued on the basis of replacement or repair costs. Where losses have intangible consequences such as personal injury or loss of life, the proper valuation of accident risk becomes more uncertain and judgmental and should be approached with care. Given the difficulties involved with measuring safety benefits, they are often not quantified in these analyses unless the safety benefits would differ among the options considered or prove decisive in establishing a positive net benefit for a single infrastructure investment. Where a project cannot be justified by consideration of the non-safety benefits, it may be necessary to consider whether the project will lead to an improvement in the level of safety. In other situations, safety benefits will be the primary purpose of a project and the change should be pursued even if the CBA is not positive.

ATM Special Consideration – Propagation of Delay

A reduction of delays around one airport can reduce delays at other airports through a reduction in propagated delay. A propagated delay is always linked to an upstream original delay.

Delay propagation is a network phenomenon and is influenced by a wide variety of factors across the network. It is a benefit and should be included in a cost-benefit analysis where applicable and possible. To avoid double counting benefits, not all delay propagation ought to be included in every CBA or business case.

For example, if an aircraft begins its operational day with a 45-minute late departure, that delay is classified as an original delay.

- If the aircraft arrives at its next stop 45 or fewer minutes late, those minutes are classified as propagated delay from the original late departure.
- If the aircraft arrives more than 45 minutes late, then 45 minutes are classified as propagated and the balance of the delay (e.g., 10 minutes of a 55-minute arrival delay) is classified as original delay from the inbound segment.
- If the aircraft has an on-time arrival or departure later in the day, then none of the morning delay can propagate further into the rest of the aircraft's operational day.

Delay propagation can be estimated using techniques such as multipliers, which capture the total reduction in delay across the network given an estimated reduction in original delay at an airport.

For example, the FAA has calculated delay propagation multipliers based on the US network for use in cost benefit analysis. http://ipv6.faa.gov/regulations_policies/policy_guidance/benefit_cost/media/faabca.pdf

3.25. The impact on the environment is an important factor in many large transportation projects. Whether considered as a cost or as a negative benefit (environmental effects are often unintended and typically negative), these effects are difficult to measure in a precise way. Nevertheless, it is important that they be identified and carefully evaluated. Extensive research has been carried out in the quantification of environmental effects. Projects may have negative or positive effects that are experienced by third parties (for example, environmental impacts). The identification and measurement of these effects are less readily identifiable and may have no obvious market value. It is nevertheless useful to list these and quantify them using analytical techniques, if at all possible.

3.26. In terms of potential productivity gains, airport and ANSP projects may have different considerations that need to be taken into account. At an airport for example, an investment in an enhanced baggage handling system may reduce the number of agents required in the future thereby reducing future operating costs. Transportation efficiency benefits may also accrue to the air carriers and would include savings arising from the quicker turnaround of aircraft, and possibly greater service reliability and predictability. For an ANSP, for example, an investment in modern ATS technology may reduce the number of air traffic controllers required in the future thereby reducing future operating costs. Transportation efficiency benefits may also accrue to the aircraft operators and would include savings arising from the more efficient operation of aircraft and greater service reliability and predictability.

ATM Special Consideration – Network Reliability

Airport network reliability can have broader impacts.[1] There are several quantification methods of assessing value of travel/transport time variability. Several studies using empirical evidence and theoretic frameworks have assessed the value of reliability and developed approaches on how to incorporate considerations of network reliability when undertaking CBAs .[2]

There are three important aspects to consider for reliability:

- Measurement (collecting data related to travel time reliability such as traffic speeds from the link or network of interest);
- Modeling (methodology for simulating scenarios for assessing reliability changes); and
- Valuation (monetary equivalents to reliability changes; covered in detail in the main article).

For example, airlines operate a network of flights and they value network integrity and predictability. Their ability to fly their flights and deliver passengers to their destinations depends on the reliability of the system. If they cannot plan their flights and connections, they cannot deliver a reliable product.

1 - http://www.internationaltransportforum.org/Proceedings/reliability/index.html
2 - http://bca.transportationeconomics.org/benefits/travel-time-reliability

3.27. For more information on the more technical aspects of undertaking CBAs or business cases, there are many guidance documents on conducting CBAs or business cases available. Some of the material more relevant for aviation or transport studies has been highlighted in Annex 2 for reference. This is not an exhaustive list and there may be other reference materials relevant to your particular State or region that could also be used.

3.28. The realization of benefits and the incurrence of costs are likely to vary greatly between the different stakeholders affected by the change being proposed. The different types of expected costs and benefits from the major ANS improvements set out in ICAO's GANP are explore in more detail in Annex 1. It is important to recognise the distribution of costs and benefits across different stakeholder groups as well as identifying to overall values. In some cases for some operational improvements, the party who has made the investment will receive very few or none of the benefits. The extent of this will depend on the nature of the operational improvement and the strength of competition in the area of the ATM value chain where the benefits are created.

Compare Costs and Benefits

3.29. Once all costs and benefits have been identified and forecast, they then need to be converted into a comparable format in order to determine if a project is cost-beneficial or to assess which option yields the greatest net benefits. In order to convert the stream of benefits and costs into a comparable format, they need to be discounted to "today's value" or the value in the base year for the project. As mentioned above, the need for discounting stems from the fact that the value placed on costs and benefits depends on when they occur. One unit of currency spent or accrued in the future is worth less than the value of one unit of currency today because of inflation and the time preference for money, because of the opportunities foregone during the year. Two approaches to discounting can be used:

- Approach 1: Put all costs and benefits in real (inflation adjusted) terms. Then use a real interest rate to discount
- Approach 2: Leave all costs and benefits in nominal (not inflation adjusted) terms. Then use a nominal interest rate to discount for inflation and the real value of money simultaneously.

3.30. It is very important to follow only one of the approaches above, and do not mix and match approaches across the different types of costs and benefits. The choice of the right discount rate is also a very important decision for the evaluation. If you are doing a CBA or business case from a private sector entity perspective a common approach is to use the interest rate on a financial asset with similar risk properties as the as the project being considered. Although, this choice must be made carefully as in some cases this can product misleading results. If you are doing a CBA or business case from a public sector perspective, in the context of social cost-benefits analysis, you should convert all costs and benefits into their certainty equivalents and then use a risk free discount rate. If public financing is used you may also need to make other adjustment. In summary, in making choices about discount rates it is important to make sure that issues such as uncertainty, crowding-out of private investment by debt financed projects and deadweight loss in tax financed projects are accounted for.

3.31. It is important to remember that benefits and costs will not necessarily follow the same distribution of cash flows arising from a financial evaluation. In addition, benefits accruing to aviation users may be insufficient to cover the total cost of the project.

3.32. Once costs and benefits have been discounted and are in a comparable format, then different criteria are available to establish whether or not the benefits exceed the costs for any or all of the alternatives. These include net present value (NPV), benefit to cost ratio (BCR), internal rate of return (IRR) and the payback period.

Net Present Value (NPV)

3.33. NPV is generally the preferred method for the evaluation of projects in a CBA or business case. NPV is the sum of the discounted project benefits less discounted project costs. Using NPV as a decision rule, a project is potentially worthwhile (or viable) if the NPV is greater than zero - that is the total discounted value of benefits is greater than the total discounted costs.

3.34. The advantage of NPV is that when considering a single project it is easy to determine whether to go ahead with the project, which is when the NPV is positive. When considering multiple, mutually exclusive projects, choosing the one with the highest benefit, i.e. NPV, is a clear approach to selection. The disadvantage of NPV is that it may make it difficult to account for distributive impacts.

Benefit to Cost Ratio (BCR)

3.35. The BCR is the ratio of the present value of benefits to the present value of costs, and can be expressed as:

$$BCR = \frac{PV_{Benefits}}{PV_{Costs}}$$

3.36. A project is potentially worthwhile if the BCR is greater than 1. This means that the present value of benefits exceeds the present value of costs. Using this decision rule the alternative with the highest BCR would be most favourable.

3.37. The advantage of BCR is that it can help order projects in situations where you are choosing among projects with scarce resources. The disadvantage of BCR is that projects of different sizes are not comparable. It can also be manipulated by shifting cost as negative benefits and vice versa leading to distortion in results when comparing across options.

Internal Rate of Return (IRR)

3.38. The IRR is the discount rate at which the NPV of a project is equal to zero, i.e., discounted benefits equal discounted costs. A project is potentially worthwhile if the IRR is greater than the discount rate applied in the evaluation. If projects are mutually exclusive, this rule suggests that the project with the highest IRR would be most favourable.

3.39. The advantage of IRR is similar to that of BCR in that with scarce funds you can choose projects in the order from the highest IRR, and it can be useful for projects for which it is very difficult to determine a suitable discount rate; however, IRR does not adjust for projects size and can give the wrong answer if costs come after benefits and can also give multiple answers making it difficult to know which one to use.

Payback period

3.40. The project's payback period is determined by counting the number of years it takes before cumulative forecast cash flows equal the initial investment. Many organisations will have an agreed 'rule' for a cut-off date for payback in order to assess whether or not to do the project or not. The disadvantages of the payback period is that is does not discount cash flows, it does not take account of cash flows beyond the payback period, and it a measure of time and not value. The advantage of the payback period is that it is a simple measure and in some cases some stakeholders are more interested in shorter term returns rather than longer term societal benefits.

Conduct sensitivity analysis

3.41. In a CBA the outcome is typically influenced by several uncertain factors. A complete picture of the situation is best presented if this uncertainty is

ATM Special Consideration – Congested vs. uncongested airport/airspace conditions

An ANSP may decide to make an investment in a specific technology and deploy it throughout the country. That technology may provide a benefit to a congested airport/airspace during peak traffic demand but provide no benefit to that airport/airspace during uncongested conditions or provide no benefit to an uncongested airport/airspace in that country.

The costs of that investment throughout the country will be taken into account but there will be different benefits that accrue during congested vs. uncongested conditions. Sensitivity analysis should be done to identify any differences due to the impacts of congestions.

For example, a study by Helios at Heathrow and Gatwick airports found that at Heathrow (which operates very near to capacity) ATFM, airborne and ground holding delays can be very sensitive to the addition of even a single flight at a congested time and can increase very significantly. This highlights understanding the impact of changes made in congested vs. uncongested conditions and it could significantly impact on the benefits or costs of a change.
https://www.caa.co.uk/docs/589/ICF_runway_resilience_final_report_16Feb09.pdf

explicitly considered and decision makers know how 'sensitive' the outcome is to change in uncertain factors. This analysis also helps to communicate the extent of the uncertainty and risk in the project to decision makers. In helping to deal with uncertainty, this type of analysis also provides feedback on the economic analysis process used in the evaluation. Key assumptions can be updated, additional alternatives can be identified or the methodology can be revised, making the economic analysis process iterative and ultimately improving the quality of the analysis.

3.42. Techniques for understanding the impact of uncertainty include sensitivity analysis, Monte Carlo simulation and decision analysis. By using these methodologies it is possible to examine how the outcomes of the different alternatives holds up to changes in assumptions and, given uncertainty, how likely it is that the project is or is not worth doing.

3.43. Robust research and development (R&D) and validation are also instruments to assess the likely impact and reduce uncertainties.

Sensitivity analysis

3.44. Sensitivity analysis examines how NPVs, total cost or other outcomes vary as individual assumptions or variables are changed. It can be used to test the robustness of the analysis as well. In cases where the impact is insignificant or at least has no affect on the sign of the NPV, one might conclude that the project is insensitive to a particular value. However, in cases where a small change in an assumption has dramatic affects on the NPV or outcome then the project would be considered to be sensitive to this variable and caution applied by decision makers.

Monte Carlo simulation

3.45. Monte Carlo simulation is a tool for considering many more possible combinations of changes compared to basic sensitivity analysis. It uses simulation techniques to calculate the entire range of all possible outcomes of the project and the likelihood of each actually occurring.

Distributional Aspects

3.46. For many Governmental investments and regulations, the recipients of the benefits are not those who bear the costs. From an overall perspective, society's welfare is improved as long as all accepted projects and regulations have benefits in excess of costs. This is true because those who benefit could fully compensate those who bear the costs and still be better off. However, while the potential for compensation may exist, it may not occur, or it may require further initiatives to implement. If costs are imposed on parties who neither benefit nor are compensated, the impact will be inequitable.

3.47. Benefit-cost analysis should identify gainers and losers of Governmental investments and regulations and whether gainers actually compensate losers. When benefits and costs have significant distributional effects, these should be analyzed and discussed.

Make Recommendations

3.48. The final outcome of the economic analysis process is a recommendation concerning the proposed objective. The presentation of the conclusions and recommendations of the CBA is as important as the underlying analysis. It is important that the relevant points are highlighted in a clear and concise manner that meets the information needs of decision makers and provides objective guidance. There are main two parts to a recommendation – should the activity be undertaken, and if so, which alternative should be selected to achieve it.

4. Discussion of benefits and costs associated with ASBU Block 0 modules

4.1. The Global Air Navigation Plan (GANP) describes the planning process regarding the selection of solutions to be implemented to satisfy performance needs of the international aviation community. The solution set includes the Aviation System Block Upgrades (ASBUs), as well as the continuing recourse to traditional techniques (e.g. sector splitting). As suggested by the GANP there is not a one-size-fit all approach to solving the needs of the international aviation community. In fact, even the process of identifying prospective solutions is not necessarily linear. Frequently, it may be necessary to iterate toward a solution, refining the scope, benefits, and costs of a project, until a business case can be established reflected the fully scope of the impacts. Such refinements may also include the use of operational and financial incentives.

4.2. It is widely understood that local factors – traffic volume, airspace complexity, and user composition are just a few of the many variables that can strongly influence the benefits and costs of a proposed solution. As a result, this guidance material is limited to generally accepted "economic principles" for project evaluation without being prescriptive as to which module a State or organisation should implement, or the extent to which it should be implemented.

4.3. The ASBU modules are designed to allow all member States to advance their Air Navigation capacities based on their specific operational requirements. To this end, ICAO has identified eleven Key Performance Areas (KPAs) for the purpose of assessing performance of each module; however, not all of the KPAs lend themselves to empirical quantification. Those KPAs which can be closely tied to specific quantifiable benefit drivers have been identified and are listed in the tables in Annex 1 as:

- Access and Equity
- Capacity
- Efficiency
- Environment
- Safety
- Cost Effectiveness

4.4. A complete reference to all eleven ICAO KPA can be found in ICAO Doc 9883. While it is somewhat arbitrary which KPA bucket a particular benefit driver resides, the important aspect is that we quantify each benefit driver as fully as possible regardless of which particular KPA bucket it may ultimately reside.

4.5. The way a module is deployed can impact the benefits categorized under the module's KPAs. For instance, the same module deployed by two different States, can produce very different benefits and costs. The characteristics of the operating environment of a particular State or region (e.g. air traffic density) can dictate the benefits that might be accrued from a particular module. Even in similar operating environments the scope to which a State choose to deploy a module (e.g. at one airport versus state-wide) can create a wide range of costs and benefits. Consequently, the benefits measured under KPAs associated with a particular module will vary according to the extent they are deployed and where.

4.6. Given that lack of a one-to-one relationship between a module and the benefits categorized under each KPA, no attempt is made to explicitly estimate the economic benefit and costs associated with each model. Annex 1 is intended to serve as a starting point for an economic analysis. It serves to highlight those potential benefits and costs that may exist under each relevant KPA by module. During an initial evaluation process, Annex 1 provides each State or organisation a roadmap from which it can identify potential benefits according to key performance areas. Being able to identify benefit categories early on in the evaluation process can allow States or organisations to work with its stakeholders to develop positive business causes which will further encourage adoption of the technologies necessary to support module implementation. The analysis is performed initially for all Block 0 modules; at a later stage, the other Blocks will also need to be considered, relying on the experience derived from identifying the benefits and costs associated with Block 0.

Benefits

4.7. A plain text description of the drivers of the effects of the module, in relation to performance areas has been included in the tables in Annex 1. Influence Diagrams could be developed for each module to illustrate the cause-effect relationships, prevent double counting, and also help to determine the impact to specific stakeholder categories.

Costs

4.8. The tables in Annex 1 also include a plain text description of the drivers of the effects of the module on systems (air and ground) and human resources (incl. training) and other "soft" actions (design of procedures, etc.). Costs will also be associated to specific stakeholder categories.

4.9. It should be noted that because the physical units (quantification of benefit) as well as their associated monetary values are likely to vary by State, region, and the fact that there is no one-to-one relationship between a modules and the KPAs (benefit drivers), it is best left to the individual States to conduct their own economic analysis and aggregation of benefits across KPAs and modules. An illustrative example for SBAS implementation has been included in this guidance to show how this economic analysis and aggregation of benefits could be conducted.

General approach to translating operational improvements to economic benefits

4.10. Implementation of ASBU modules can generate operational improvements through implementing projects and undertaking investment on the ground, tower, approach or en route. As stated above, ICAO has identified eleven KPAs for the purpose of assessing performance of each module. However, the working group has focused on six KPAs (i. access and equity ii. Capacity iii. Efficiency iv. Environment v. safety vi. Cost effectiveness) that lend themselves best to empirical quantification. The operational benefits generated translate to four broad categories of economic benefits:

1. Time savings, created by reducing the time it takes to transport a person or freight from one point to another
2. Efficiency improvement and cost reduction, achieved by reducing the cost of moving a person or freight from one point to another
3. Wide economic benefits, these benefits are reflected by spillovers to non-users
4. Safety improvement, improved safety

Approach and attribution of benefits

4.11. A first step in identifying the scale of operational improvements is to undertake a scenario analysis whereby the appraiser identifies:

- A scenario that explains what happens from the implementation of the program
- A counterfactual scenario that explain what would happen if the program was not implemented

4.12. Comparing the two scenarios will enable to the identification of the operational benefits associated with the implementation of the project. Translating the operational improvements to economic benefits will also require consideration of the specific circumstances of each scenario. The translation of the operational impacts to economic values is an essential step to be able to undertake economic analysis. Following the identification of the operational improvement the evaluator can subsequently assess how each of the four broad benefit categories will be impacted from the operational improvement.

4.13. It is critical to keep in mind that the entity generating the economic benefits will not necessarily be the entity to which the benefits accrue. The main factors that will determine to whom the generated benefits accrue will depend on the level of competitive forces in the air transport value chain. Where the generated benefits accrue will depend on the level of bargaining power of buyers, channels and customers as well as the extent to which there is a threat of new entrants or substitutability of products.

Types of benefits

4.14. **Time savings** – travel time savings often are the most important source of benefits generated when capacity improvements or flight efficiencies enhancements are realized. Time savings generated for producers in the value chain (for example airlines) are captured under the cost reduction section. Benefits to travelers and shippers can be broken down in the following categories:

- Door to door travel time – which is the directly visible component, where flight efficiency improvements most clearly have an influence. However, capacity improvements can also have an impact.
- Schedule delay, which is linked to capacity improvements and is comprised of:
  - Travel delay is the delay is the difference between the scheduled travel time and the actual travel time
  - Frequency delay is the difference between passenger's preferred departure time and actual time when flight is available.
  - Overcapacity delay is when a passenger is unable to take a desired flight because it is full.

4.15. Approaches to time saving monetization: It is generally accepted that working time, leisure time and community time have different values, with evidence pointing to a higher willingness to pay for working travel time. Many studies have tried to quantify the value of air travel time for business and leisure travelers. The latest US DoT guidance recommends USD 57.2 per hour for business travel and USD 31.9 for personal trips. Other estimates exist in other regions.[3]

4.16. **Efficiency improvement and cost reduction**– Efficiency improvement that can reduce the cost of providing a service will create benefits for consumers and/or producers. The 'out of pocket' costs to the consumers can influences the decision on whether/where to travel and the overall value of the benefit they are able to retain. Cost reduction can also help producers improve their performance.

- Consumers: Together with the time spent on the journey, the 'out of pocket' cost to the traveler constitutes the key factors that influence the decision of the traveler on what trip to take and whether the trip is made at all. Any reduction in costs that results in

[3] Example translating time savings to econ values: http://www.iata.org/whatwedo/Documents/economics/EU_Airspace_Efficiency_Final.pdf

lower out of pocket costs compared to what they otherwise would have been will create benefits for travelers and shippers.

- Less flight time, shorter flight distance and reduced delay:
    - Airline[4] more efficient flight trajectories can reduce input costs (fuel burn, staff time, and maintenance) and increase scope for aircraft utilization (thereby reducing aircraft ownership cost per flight). An example of how to undertake such an assessment is provided in the footnote below with each of the following components assessed separately:
        - Fuel cost savings per flight
        - Reduced maintenance costs per flight
        - Reduced crew costs per flight
        - Reduced aircraft ownership costs per flight
    - ANSP more efficient flight trajectories can improve the performance of the ANSP and in congested airspace can create additional capacity. These impacts can be quantified by assessing:
        - Improved workload unit performance -in congested airspace the benefits from greater airspace utilization may also need to be considered in assessing workload unit performance
    - Airport can stand to improve performance from such improvements as improved flight trajectories and reduced delays can improve airport resilience and in congested airport create additional capacity.

4.17. **Wide economic benefits** – Assessing wider economic benefits is critical for identifying the full scale of potential benefits of implemented measures.

- Long run economy wide productivity - Air connectivity plays a critical role in cost-effectively bringing inputs needed for production and taking high-value outputs to other markets, thereby contributing to trade competitiveness and productivity. Several studies have shown that increased air connectivity will raise the level of long-run productivity in the economy - a 10% increase in connectivity (relative to GDP) will raise the level of long-run productivity in the economy by 0.07-0.5%.[5]
- Network reliability: Airport network realizably can have broader impacts.[6] There are several quantification methods of assessing value of travel/transport time variability. Several studies using empirical evidence and theoretic frameworks have assessed the value of reliability and developed approaches on how to incorporate considerations of network reliability when undertaking CBAs .[7]

4.18. **Safety improvements**: implementation of ASBUs can generate important benefits but the working group has decided not to attempt to translate operational safety improvements to economic values.

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[4] Example translating identified airline cost reductions to economic values:http://www.iata.org/whatwedo/Documents/economics/PRD-airspace-apr14.pdf

[5] Oxford Economic on behalf of EUROCONTROL 2005, Oxford Economics 2006, InterVISTAS Consulting Inc. 2006.
[6] http://www.internationaltransportforum.org/Proceedings/reliability/index.html
[7] http://bca.transportationeconomics.org/benefits/travel-time-reliability

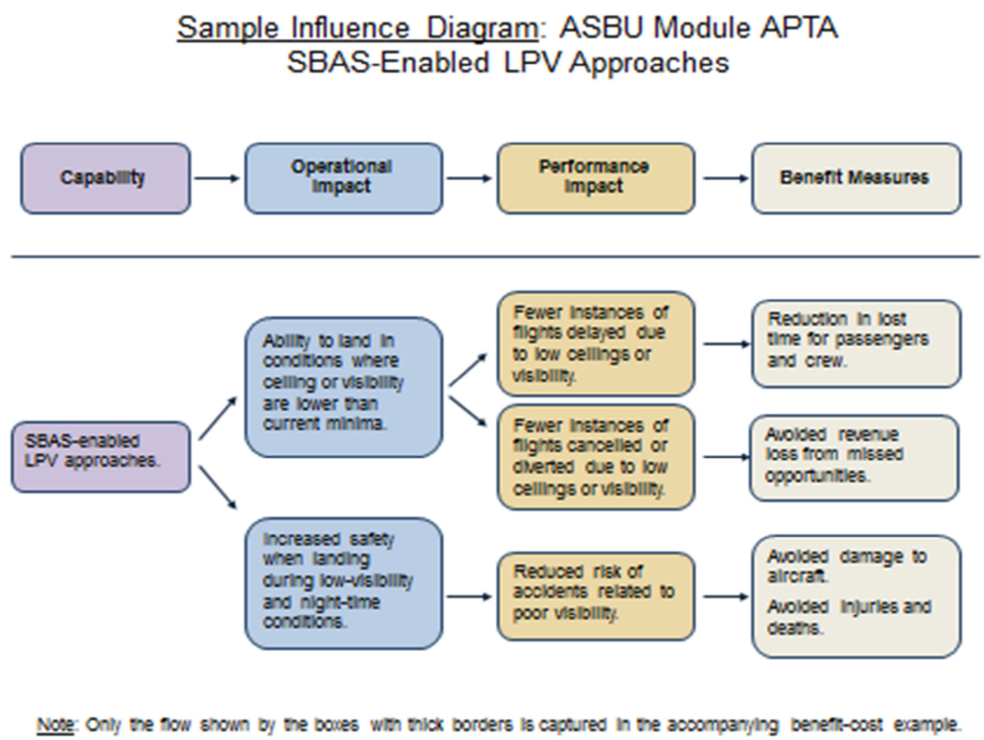
Illustrative Example - SBAS

4.19. The following is an illustrative example of how to model and then quantify some of the benefits associated with the implementation of block 0 module (APTA), in particular, SBAS-Enable LPV Approaches. A simple influence diagram is presented with the steps necessary to begin the quantification process. Following that discussion, a representative economic analysis of the benefits and costs associated with SBAS is also presented, but no attempt is made to quantify the safety benefits associated with this example.

4.20. SBAS-Enabled LPV Approaches provide aircraft operators the ability to land in weather conditions where the ceiling or visibility are lower than the current minima without additional ground infrastructure. Specifically, SBAS-enabled LPV approaches provide the capability to land in weather minima that are similar to Category I ILS minima.

Influence Diagram

4.21. The following influence diagram illustrates how the capabilities associated with SBAS are translated into operational and performance impacts, and then into economic benefits.



Quantification Process

4.22. The following example illustrates a very simple scenario in which a member state is evaluating the case for publishing a pair of SBAS LPV approach procedures. These would serve each end of a runway at a single-runway airport which currently does not have an instrument landing system (ILS). In this example, we assume that SBAS services are available already, and that cost to the ANSP is the publication and maintenance of the LPV procedures.

4.23. For the airport of interest, the following steps would be followed:

1. Collect data on aircraft operations at the airport.
   a) Assemble a table with the percentage of each aircraft type.
   b) Estimate the percent of aircraft that are equipped to fly LPV approaches.

2. Compute the average cost per hour of delay (assuming that any delay due to low ceilings or visibility would be taken on the ground at the origin airport).
   a) For each aircraft type, obtain the average number of passengers per flight.
   b) Compute a weighted average cost of passenger delay for the airport by multiplying the percentage of each aircraft type by its average number of passengers and the estimated cost per passenger for each hour of delay.
3. Collect the number of hours that the local weather conditions are below the minima for landing, given current procedures available at the airport.
4. Estimate the current delay impact of these local weather conditions.
   a) By time of day, estimate how many flights are delayed during incidents of low ceilings and visibility.
   b) Then, using only the percentage of flights that are equipped, estimate how much less delay would take place if LPV procedures allowed for lower decision altitudes or visibility. Non-equipped flights would be assumed to have the same delay as above.
   c) The difference between these two values is the anticipated delay savings due to the LPV procedures.
5. Compute the annual dollar value of delay savings.
   a) For the first year of expected LPV implementation, multiply the amount of estimated delay savings per year by the average cost of delay. This represents the total annual savings by implementing SBAS-enabled LPV approaches.
   b) Repeat this for the number of future years that you expect the procedures to be in effect. (A typical value would be in the range of 10 to 20 years.)
6. For each of these years, estimate the cost to publish and maintain the LPV procedures.
7. Perform economic analysis of the investment
   a) Using standard economic analysis techniques, discount the costs and benefits back to a Present Value (PV). A typical discount rate is 7%, but can vary by local conditions.
   b) Subtract the PV costs from the PV benefits to yield a Net Present Value (NPV).
   c) If the NPV is greater than $0, then discounted benefits exceed discounted costs, and the investment may be considered worthwhile.
   d) If the NPV is less than $0, then discounted costs exceed discounted benefits, and the investment is not justified by delay benefits alone.
8. Nevertheless, safety considerations could also be included, which may cause policy-makers to deem a project to be worthwhile in spite of insufficient cost savings.

4.24. The spreadsheet in figure 3 serves as a representative example of what such an analysis might look like.

Case Study – B0 – CCO Continuous Climb Operations

To help quantify the benefits that the UK's Future Airspace Strategy (FAS) can deliver, and the costs of implementing these, the UK CAA undertook a study of the benefits that FAS could deliver by implementing ASBU module B0-CCO – systemised continuous climb operations (CCOs).

You can read more about how the study was conducted, including its scope, assumptions made, the quantification of benefits and costs, sensitivity analysis, and the impact distribution across stakeholders here: https://www.caa.co.uk/docs/33/CAP%201062%20FAS%20UK%20CCO%20CBA.pdf

Figure 3 – SBAS illustrative example

Representative Economic Analysis of SBAS Approach Procedures with Vertical Guidance (LPV)

Assumptions

- This an overly simplified cost-benefit analysis provided for illustrative purposes only. Values used are meant to be realistic, but are not based on actual data.
- GNSS Augmentation satellite service is assumed to be already available, and is therefore treated as a sunk cost and not considered in this analysis.[1]
- Only benefits for currently equipped aircraft are considered. Therefore, user equipage costs are not included in this analysis.
- Assume 2 LPV procedures (one for each runway end) at a small, single runway airport with no ILS.
- Monetary values expressed in constant dollars (adjusted for inflation).

	Parameters	Value	* Values provided below are notional. In actual usage, they would be based on local conditions.
A.	Average cost per hour of delay, based on to local fleet	$500	
B.	Percent of flights impacted by weather conditions below current minima [2]	15%	<-- applies to all users in the absence of an LPV approach, and non-equipped users in all cases
C.	Percent of flights impacted by weather conditions below LPV minima [3]	10%	<-- applies to SBAS equipped users if an LPV approach is available
D.	Average hours duration of low visibility	1.5	
E.	Percent of arriving aircraft equipped with SBAS	25%	
F.	Discount rate for economic analysis	7%	

		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
	Costs											
	- Procedure development (both runway ends)	$250,000										
	- Procedure maintenance		$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000
	TOTAL COST	**$250,000**	**$20,000**	**$20,000**	**$20,000**	**$20,000**	**$20,000**	**$20,000**	**$20,000**	**$20,000**	**$20,000**	**$20,000**
	DISCOUNTED COST (PV)	**$364,927**										
	Benefits											
G.	Annual arrivals (derived from data and forecast)	7,200	7,225	7,250	7,275	7,300	7,325	7,350	7,375	7,400	7,425	7,450
H.	Equipped (= row G. x row E.)	1,800	1,806	1,813	1,819	1,825	1,831	1,838	1,844	1,850	1,856	1,863
I.	Non-equipped (= row G. - row H.)	5,400	5,419	5,438	5,456	5,475	5,494	5,513	5,531	5,550	5,569	5,588
J.	Current annual hours of flight delay due to low ceilings	1,620	1,626	1,631	1,637	1,643	1,648	1,654	1,659	1,665	1,671	1,676
K.	Equipped (= row H x row B x row D)	405.00	406	408	409	411	412	413	415	416	418	419
L.	Non-equipped (= row I x row B x row D)	1,215.00	1,219	1,223	1,228	1,232	1,236	1,240	1,245	1,249	1,253	1,257
M.	Estimated hours of flight delay per year with LPV	1,485	1,490	1,495	1,500	1,506	1,511	1,516	1,521	1,526	1,531	1,537
N.	Equipped (= row H x row C x row D)	270	271	272	273	274	275	276	277	278	278	279
O.	Non-equipped (= row I x row B x row D)	1,215	1,219	1,223	1,228	1,232	1,236	1,240	1,245	1,249	1,253	1,257
P.	Estimated hours of delay saved (= row J - row M)	135	135	136	136	137	137	138	138	139	139	140
Q.	Value of delay savings (= row P x row A)	$67,500	$67,734	$67,969	$68,203	$68,438	$68,672	$68,906	$69,141	$69,375	$69,609	$69,844
	TOTAL BENEFIT	**$67,500**	**$67,734**	**$67,969**	**$68,203**	**$68,438**	**$68,672**	**$68,906**	**$69,141**	**$69,375**	**$69,609**	**$69,844**
	DISCOUNTED BENEFIT (PV)	**$513,770**										
	Net Present Value =	**$148,843**										

Notes

1. If service from a GNSS augmentation satellite is not available, then a fixed cost for subscription to this service would need to be considered.
   This would not be difficult to do, but it would require a more comprehensive analysis, covering all planned or potential LPV approaches, since no single approach would likely break even.
2. This information is ideally archived in historical records of local meteorological conditions.
3. One of the benefits of an LPV approach is that it typically allows for a lower minimum ceiling.

Annex 1 – Benefits and Costs associated with ASBU Block 0 modules

Table 1: Airport Operations

AIRPORT OPERATIONS	Benefit Discussion	Cost Discussion

B0-APTA
Optimization of Approach Procedures including Vertical Guidance
 	
KPAs and Related Module Benefits
 	
1. Access and Equity
• Additional potential movements may be enabled during poor weather to runways without an ILS. May be captured as a consumer surplus calculation if the flight would not have taken place otherwise. If the flight would have taken place but been delayed, use the value of passenger time.
2. Efficiency
• Some flights would still take place, but may need to fly a longer trajectory to a runway end with an ILS. If GNSS approaches save flight time, then this can be valued using
  • Reduced Aircraft Operating Costs
  • Passenger Time Savings
3. Environment
• Reductions in GHG (Reduced fuel burn)
4. Safety
• # injuries avoided
• # of lives saved
• Avoided hull loss
• Avoided accident investigation costs
5. Cost Effectiveness
• If one GBAS can avoid installing several ILS, the avoided cost is a benefit
	Increased access at those airports where an ILS may not be feasible. Benefit depends on how often flights to an airport are delayed or diverted due to instrument meteorological conditions.
	
	May be cost savings in cases where one GBAS system can cover several runway ends.
	
	SBAS offers similar benefits, and is particularly useful in cases where there are many small airports which individually would not justify ground-based augmentation.
	
	There is also a safety benefit associated with this module from the ability to execute instrument approaches where none may have been possible.
	
	These benefits are greatest where no other precision approach is available.
		Ground infrastructure costs for GBAS compare favourably with ILS.
		
		SBAS, on the other hand, has higher up-front costs, as it includes purchase or lease of at least one satellite. Once this investment has been made, however, it is very cost effective on a per unit basis.
		
		For both GBAS and SBAS, there is also a cost associated with the development and publication of appropriate procedures.
		
		For both GBAS and SBAS, aircraft must be equipped with the proper avionics.

AIRPORT OPERATIONS	Benefit Discussion	Cost Discussion

B0-WAKE
Increased Runway Throughput through Optimized Wake Turbulence Separation
 	
KPAs and Related Module Benefits
 	
1. Capacity
• The principle benefit of reduced wake separation is increase throughput. This can be valued using
  • Reduced Aircraft Operating Costs
  • Passenger Time Savings
2. Environment
• Reductions in GHG (Reduced fuel burn)
	Reduced inter-arrival spacing can lead to increased throughput during busy periods. This reduces delays and saves fuel.
	
	These benefits occur when traffic demand is sufficiently high. The greater the pressure on the runway, the higher the benefit. Conversely, if there is no pressure on the runway (for example, if there is seldom a departure or arrival queue) then there is little benefit.
		Development costs may be relatively small, but there is a substantial training component.
		
		No specialized aircraft or ground equipage is required.

AIRPORT OPERATIONS	Benefit Discussion	Cost Discussion

B0-RSEQ
Improved Traffic Flow through Sequencing (AMAN / DMAN)
 	
KPAs and Related Module Benefits
 	
1. Capacity
• Runway sequencing can make better use of existing capacity by spacing arrivals and departures. This can be valued using
  • Reduced Aircraft Operating Costs
  • Passenger Time Savings
 	
2. Efficiency
• The principal benefit is efficiency. Sequencing and spacing pushes traffic management initiatives to a higher altitude, and farther from the runway, which reduces the cost of excessive low-altitude manoeuvring. The time saved can be valued using
  • Reduced Aircraft Operating Costs
  • Passenger Time Savings
3. Environment
• Reductions in GHG (Reduced fuel burn)
	A steady stream of arrivals leads to less wasted airport capacity and less holding and vectoring of aircraft. This can lead to increased throughput at busy airports. This benefit occurs when traffic demand is sufficiently high. The greater the arrival demand, the higher the benefit.	Complex time-based metering will likely involve the deployment of custom decision-support tools to assist traffic flow managers in merging and sequencing aircraft. This may be costly.
		
		No specialized aircraft equipage is required.

AIRPORT OPERATIONS	Benefit Discussion	Cost Discussion
B0-SURF **Safety and Efficiency of Surface Operations (A-SMGCS Level 1-2)** **KPAs and Related Module Benefits** **1. Efficiency** • Reduction in operating costs (fuel) through reduced taxi times. **2. Safety** • # injuries avoided • # of lives saved • Avoided hull loss • Avoided accident investigation costs	The most easily identifiable benefit for surface surveillance systems is improved situational awareness. This may lead to a reduced risk of accidents, in particular due to runway incursions. The addition of advanced-surface movement guidance and control systems (A-SMGCS) automation will also allow controllers to use the surveillance data to better separate traffic, especially during low visibility. More complex and busier airports will have greater benefit than airports with simple layouts or relatively limited traffic.	As multilateration and ADS-B surface surveillance become more commonplace, they may be considered off-the-shelf purchases. The addition of A-SMGCS automation will increase costs above the basic surveillance infrastructure. For improved situational awareness there are two possible approaches: 1. ADS-B based systems would require ADS-B Out equipage on board all aircraft. 2. Multilateration, although presumably more expensive in terms of ground infrastructure, would not require any additional avionics.

B0-ACDM
Improved Airport Operations through Airport-CDM
 	
KPAs and Related Module Benefits
 	
1. Capacity
• By utilizing surface CDM, departure queues on the taxiway can be reduced, resulting in increased departure and arrival throughput. This can be valued through
  • Reductions in Operating Costs (fuel)
  • Passenger Travel Time Savings
2. Environment
• Reduced GHG emissions from reduced fuel burn and lower engine run time.
	Surface CDM can have an impact at busy airports where surface congestion is a problem or scarce resources need to be used efficiently (e.g. de-icing facilities).
	
	CDM mechanisms can have an impact by eliminating gridlock caused by such things as flights trying to enter a departure queue without having an open departure route available.
	
	CDM improves the information flow among the different actors at an airport and allow them to optimise their processes and resource deployment.
		Simple schemes may be implemented with relatively little additional technology. However, surface surveillance systems and decision support tools can help.
		
		Additional aircraft avionics are not required for basic CDM mechanisms.

Table 2: Globally Interoperable Systems and Data

INTEROPERABLE SYSTEMS	Benefit Discussion	Cost Discussion
B0-FICE **Increased Interoperability, Efficiency and Capacity through G/G Integration** **KPAs and Related Module Benefits** **1. Cost Effectiveness** • Reduced ATC operating cost due to reduced controller workloads **2. Capacity** • Reduced controller workload can lead to increased capacity, which can be valued using ADOC and PVT • However, it may be difficult to quantify how much capacity increase could result from increased controller efficiency	Cost savings for the ANSP because the IT and communications infrastructure is more flexible and easier to upgrade and maintain.	May involve a significant investment in communications infrastructure. This could be undertaken as part of a planned tech refresh to reduce costs. No special aircraft avionics should be required.
B0-DATM **Service Improvement through Digital Aeronautical Information Management** **KPAs and Related Module Benefits** **1. Cost Effectiveness** • Reduced ATC operating cost due to reduced controller workloads and more efficient, digital processes **2. Capacity** • Reduced controller workload can lead to increased capacity, which can be valued using ADOC and PVT • However, it may be difficult to quantify how much capacity increase could result from increased controller efficiency	The Aeronautical Information Exchange Model (AIXM) is a global standard for achieving interoperable exchange of aeronautical information. The usage of standard mediates interaction between systems, agencies, countries. It enables common situational awareness and incident management. It also simplifies global data exchange. As a result, greater flexibility and cost savings for the ANSP and better service for airspace users could be achieved.	This module assumes that the physical communications infrastructure is compatible with AIXM. (See B0-FICE). No special aircraft avionics should be required.

INTEROPERABLE SYSTEMS	Benefit Discussion	Cost Discussion

B0-AMET
Meteorological Information Supporting Enhanced Operational Efficiency and Safety
 	
KPAs and Related Module Benefits
 	
1. Access and Equity
• Additional potential movements may be enabled by better weather information. May be captured as a consumer surplus calculation if the flight would not have taken place otherwise. If the flight would have taken place but been delayed, use the value of passenger time.
2. Efficiency
• Shorter reroutes around weather can be valued using
  • Reduced Aircraft Operating Costs
  • Passenger Time Savings
3. Environment
• Reductions in GHG (Reduced fuel burn)
4. Safety
• # injuries avoided
• # of lives saved
• Avoided hull loss
• Avoided accident investigation costs
	Information sharing improves situational awareness. Results should be visible in terms of reduced reroutes or shorter hold times on the ground.	Infrastructure investment in automation tools may be significant.
		
		No special aircraft avionics should be required.

Table 3: Optimum Capacity and Flexible Flights

FLEXIBLE FLIGHTS	Benefit Discussion	Cost Discussion

B0-FRTO
Improved Operations through Enhanced En-Route Trajectories
 	
KPAs and Related Module Benefits
 	
1. Access and Equity
• May prove difficult to assess/calculate.
2. Efficiency
• Improved flight trajectories due to increased flexibility and more direct routings. This can be valued using
  • Reduced Aircraft Operating Costs
  • Passenger Time Savings
3. Environment
• Reductions in GHGs due to more flexible/direct routings.
	Flexible routing should result in the granting of more direct routes, reducing miles flown. This can come from improved management of special use airspace or from allowing customized routing in cases where there is an obstruction, such as an active Special Used Airspace (SUA) or severe weather enroute.	Most costs involve automation to better identify alternative routes, and the development of ANSP operating procedures to grant these routes.
		
		No special avionics are required.

FLEXIBLE FLIGHTS	Benefit Discussion	Cost Discussion

B0-NOPS
Improved Flow Performance through Planning based on a Network-Wide view
 	
KPAs and Related Module Benefits
 	
1. Access and Equity
• Improved planning can lead to a more user-preferred allocation of scarce resources (e.g. departure slots.) However, this may prove difficult to assess/calculate
2. Efficiency
• Better flow management should lead to less airborne holding and vectoring. This can be valued using
  • Reduced Aircraft Operating Costs
  • Passenger Time Savings
3. Environment
  • Reductions in GHGs
	Improved decision support tools for central flow management should result in reduced delays, particularly those taken on the ground. While ground delays are preferable to airborne holding, their costs can still be significant.	The principal cost driver would be improved decision support tools, which could be deployed at one or two central locations. However, this presumes that data on flight plans and active flight trajectories is available.
		
		If these data are not available, then investment in systems to capture and process these data could be significant.
		
		No special avionics are required.

B0-ASUR **Initial Capability for Ground Surveillance** **KPAs and Related Module Benefits** **1. Safety** • # injuries avoided • # of lives saved • Avoided hull loss • Avoided accident investigation costs	The most easily identifiable benefit for surface surveillance systems is improved situational awareness. This may lead to a reduced risk of accidents. This can be valued using standard measures of value of life. More complex and busier airports will have greater benefit than airports with simple layouts or relatively limited traffic.	As multilateration and ADS-B surface surveillance become more commonplace, they may be considered off-the-shelf purchases. ADS-B based systems would require ADS-B Out equipage on board all aircraft. Multilateration, although presumably more expensive in terms of ground infrastructure, would not require any additional avionics.

FLEXIBLE FLIGHTS	Benefit Discussion	Cost Discussion

B0-ASEP
Air Traffic Situational Awareness (ATSA)
 	
KPAs and Related Module Benefits
 	
1. Safety
• # injuries avoided
• # of lives saved
• Avoided hull loss
• Avoided accident investigation costs
 	
2. Capacity / Efficiency
• Improved situational awareness in marginal meteorological conditions will allow for reduced delays and shorter flight times in terminal airspace. This can be valued using
  • Reduced Aircraft Operating Costs
  • Passenger Time Savings
	A primary benefit of both AIRB and VSA is safety.
	
	In addition, Enhanced Visual Separation on Approach (VSA) has the benefit of increasing arrival capacity during marginal meteorological conditions (MMC). Increased capacity translates into reduced airborne delay on arrival.
		If ADS-B and ADS-R ground infrastructure is already in place, then this benefit accrues solely based on an equipage.
		
		Both ADS-B Out and ADS-B In avionics would be required. However, ADS-B In would take the form of basic Cockpit Display of Traffic Information (CDTI).

B0-OPFL **Improved Access to Optimum Flight Levels through Climb/Decent Procedures using ADS-B** **KPAs and Related Module Benefits** **1. Efficiency** • The impact on flight efficiency can be estimated by comparing the fuel burn (based on flight level) with and without module improvements. **2. Environment** • Reductions in GHGs from reduced due to reduced fuel burn	The benefit of this module is in fuel savings and (possibly) the ability of operators to plan for larger cargo payloads. The principal domain of this module is oceanic or other non-surveillance airspace. It should have little benefit in positively controlled airspace.	This procedure does not require automation, although automation can help to facilitate. There are resources involved in procedure development and training, however. ADS-B Out avionics are required for the cruising aircraft, while the climbing aircraft must have basic ADS-B In.

FLEXIBLE FLIGHTS	Benefit Discussion	Cost Discussion
B0-ACAS **ACAS Improvements** **KPAs and Related Module Benefits** **1. Safety** • # injuries avoided • # of lives saved • Avoided hull loss • Avoided accident investigation costs **2. Capacity** • Although improved ACAS is expected to support reduced separation standards, it is not the principal driver.	The principal benefit of advanced ACAS is improved safety. However, it may also help to facilitate (but not solely support) reduced separation standards in cases where reduced separation might otherwise trigger a collision alert.	Aircraft would have to be equipped with advanced ACAS. This is the main cost involved.
B0-SNET **Increased Effectiveness of Ground-based Safety Nets** **KPAs and Related Module Benefits** **1. Safety** • # injuries avoided • # of lives saved • Avoided hull loss • Avoided accident investigation costs	The principal benefit for this module is safety. Reduced risk of accidents can be valued using standard measures of value of life.	There are up-front costs to develop and deploy the necessary improvements to ATC automation systems. The cost to do this will vary depending on the system currently in use.

Table 4: Efficient Flight Paths

EFFICIENT FLIGHT PATHS	Benefit Discussion	Cost Discussion
B0-CDO **Improved Flexibility and Efficiency in Decent Profiles (CDO)** **KPAs and Related Module Benefits** **1. Efficiency** • Reduction in aircraft operating costs (primarily fuel savings) **2. Environment** • Reduction in GHG due to reduced fuel burn	The main benefit mechanism for this module will be fuel savings during arrival. In the case of this module, the benefits will increase as traffic increases, up to a point. After that, benefits may actually decrease as it becomes more difficult to fly CDOs due to the possible interference among flights/flows.	ANSP costs mainly come from procedure development and testing. CDOs are typically incorporated in RNAV procedures, in which case RNAV capable avionics must be on board the aircraft. RNAV equipage is fairly common, however.

EFFICIENT FLIGHT PATHS	Benefit Discussion	Cost Discussion
B0-TBO **Improved Safety and Efficiency through the initial application of Data Link En-Route** **KPAs and Related Module Benefits** **1. Cost Effectiveness** • Reduced ATC operating cost due to reduced controller workloads and more efficient, digital processes **2. Capacity** • Reduced controller workload can lead to increased capacity, which can be valued using ADOC and PVT • However, it may be difficult to quantify how much capacity increase could result from increased controller efficiency **3. Safety** • A safety case can be based on the reduction of communications errors from voice transmissions. Safety can be valued using: • # injuries avoided • # of lives saved • Avoided hull loss • Avoided accident investigation costs	Enroute data link has two benefit mechanisms: it can reduce controller workload, allowing for increased enroute capacity, and it can be used to more efficiently re-route aircraft by up-linking specific trajectories to the aircraft. Both mechanisms should reduce delays enroute.	There are some significant investment costs for both the ANSP and the users. The ANSP must install the data communications equipment, as well as integrate it with their enroute ATC automation. Aircraft operators must equip with compatible data link avionics.

EFFICIENT FLIGHT PATHS	Benefit Discussion	Cost Discussion
B0-CCO **Improved Flexibility and Efficiency in Departure Profiles Continuous Climb Operations (CCO)** **KPAs and Related Module Benefits** **1. Efficiency** • Reduction in aircraft operating costs (primarily fuel savings) **2. Environment** • Reduction in GHG due to reduced fuel burn	The main benefit mechanism for this module will be fuel savings during departure. In the case of this module, the benefits will increase as traffic increases, up to a point. After that, benefits may actually decrease as it becomes more difficult to fly CCOs due to the possible interference among flights/flows.	ANSP costs mainly come from procedure development and testing. CCOs are typically incorporated in RNAV procedures, in which case RNAV capable avionics must be on board the aircraft. RNAV equipage is fairly common, however.

Annex 2: Guidance is available on how to do Business Cases and CBAs

Many different guides to doing CBA in the aviation industry or general public sector investments are available and several links have been provided below alongside links to guides with standard values to be used in the assessments.

Aviation Specific

- Australian Government Civil Aviation Safety Authority CBA Procedures Manual (2010) http://www.casa.gov.au/wcmswr/_assets/main/manuals/regulate/acm/257rfull.pdf
- FAA Airport Benefit-Cost Analysis Guidance (1999) – link to be provided
- FAA Economic Analysis of Investment and Regulatory Decisions Revised Guide (1998) – link to be provided
- Transport Canada Guide to Benefit-Cost Analysis (1994) – link to be provided
- Aviation Investment: Economic Appraisal for Airports, Air Traffic Management, Airlines and Aeronautics, Doramas Jorge-Calderon, 2014
- Eurocontrol – general documents (links to be provided)
  - ATM Cost Benefit Analyses for Beginners (2010)
  - ATM CBA Quality checklist
- Eurocontrol – EMOSIA (links to be provided)

  EMOSIA is the common approach for cost-benefit analyses of European ATM projects. The objective of EMOSIA is to facilitate decision-making by understanding the global impact on ATM performance of any proposed change, thus reducing investment risk. It is a platform for making informed decisions on ATM/CNS investments and ensures that all parties involved speak the same language when deciding. EMOSIA is the first cost-benefit analysis tool developed by the European ATM/CNS community for the European ATM/CNS community. With EMOSIA, informed decisions can be made on ATM/CNS (air traffic management/communication, navigation and surveillance) investments that are traceable, consistent and transparent. EMOSIA users are able to compare different projects in ATM, different stakeholder options and the results obtained at different stages of a project.

  - User guide: a step-by-step guide of EMOSIA
  - Overall model: document describing the overall model
  - Military model: document describing the military model
  - Airport model: document describing the airport model
  - General aviation model: document describing the general aviation model
  - Airlines model: document describing the airline model
  - Brochure: an introduction to EMOSIA
  - Architecture: document describing the architecture of the EMOSIA models
  - Approach to assess the benefits and costs of ATM investments

General Government / Transport

- European Commission Guide to CBA of investment projects (2008) http://ec.europa.eu/regional_policy/sources/docgener/guides/cost/guide2008_en.pdf
- New Zealand Treasury Cost Benefit Analysis Primer (2005) http://www.treasury.govt.nz/publications/guidance/planning/costbenefitanalysis/primer
- Treasury Board of Canada Benefit-Cost Analysis Guide (2007) – http://www.tbs-sct.gc.ca/rtrap-parfa/analys/analys-eng.pdf
- UK Green Book: Appraisal and Evaluation in Central Government https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf

- UK Public Sector Business Cases https://w (HM Treasury, 2003)ww.gov.uk/government/uploads/system/uploads/attachment_data/file/277345/green_book_guidance_on_public_sector_business_cases_using_the_five_case_model_2013_update.pdf
- UK WebTAG

Annex 3: Examples of Aviation CBA studies

General (links to be provided)

EUROCONTROL

- **Automated Data Measurement System**: Set of input and output files of the initial evaluation of the costs and benefits of an application to automate data collection at airports
- **Controller Pilot Data Link supported by ATN in Europe**: Link 2000+ Cost Benefit Analysis Review: This document contains the latest review of the Cost Benefit Analysis carried out for the LINK2000+ Programme aiming at implementing CPDLC services in the core area of the ECAC region
- **European Model For Strategic ATM Investment Analysis (EMOSIA)** – A Practical Example
- **A report of the dry run of EMOSIA in 2003**. It contains an overview of the EMOSIA approach and its application to an example looking at investment in sector productivity tools

EXAMPLES OF CBA ASSESSMENTS:

- **Value of an average passenger flight in the EU-27:** http://www.iata.org/whatwedo/Documents/economics/Value_of_avg_flight_EU_FINAL.pdf
- **Benefits to Hong Kong from increasing airspace efficiency** http://www.iata.org/whatwedo/Documents/economics/PRD-airspace-apr14.pdf
- **Inefficiency in European Airspace** http://www.iata.org/whatwedo/Documents/economics/EU_Airspace_Efficiency_Final.pdf
- **Trade facilitation impact on trade cost and air freight** http://www.iata.org/whatwedo/Documents/economics/bali-impact-march14.pdf

ATM (links to be provided)

EUROCONTROL

- **Scoping Study - EATCHIP Overall Cost-Benefit Scoping Study**: An overall view of the economic feasibility of the EATCHIP Programme
- **CHAIN CBA**: A study of the Controlled and Harmonised Aeronautical Information Network (CHAIN) programme, including a software support tool known as the European Data Integrity Tool (E-DIT)
- **DMEAN Scoping CBA**: An initial assessment of the Dynamic Management of the European Airspace Network (DMEAN) Programme, prepared in order to seek approval for the Programme from EUROCONTROL Member States
- **DMEAN Full CBA**: A full cost benefit analysis undertaken to investigate the economic case for implementing the programme

United Kingdom

- **UK CAA Continuous Climb Operations (CCOs) CBA** – a strategic level CBA for implementing fully systemised CCOs in the UK; http://www.caa.co.uk/docs/33/CAP%201062%20FAS%20UK%20CCO%20CBA.pdf
- **UK CAA CCO CBA Summary** - https://www.caa.co.uk/docs/33/CAP%201075%20-%20FAS%20CBO%20factsheet.pdf

Airspace and Navigation (links to be provided)

EUROCONTROL

- **RVSM - Re-Validation of Cost-Benefit Assessment of Reduced Vertical Separation Minima**: A re-assessment of the business case for Reduced Vertical Separation Minima, updating a 1997 study
- **EGNOS - Multi-Modal Costs and Benefits - A study of the aviation case in ECAC**: This report presents the results of a study to assess the value to the aviation community of the introduction into service of the European Geostationary Navigation Overlay Service (EGNOS) in the thirty-eight States of the ECAC
- **Free Route Airspace**: Results of a Cost-Benefit Analysis (CBA) of Free Route Airspace (FRA) in Europe
- **Landing Systems Business Case**: A business case to define the optimum solution for the transition to the future landing system(s) in the ECAC area. Compares the relative financial merits of ILS, MLS and GLS
- **RNAV CBA**: In progress

Communication (links to be provided)

EUROCONTROL

- **Controller Pilot Data Link supported by ATN in Europe**: Link 2000+ Cost Benefit Analysis Review: the latest review of the Cost Benefit Analysis carried out for the LINK2000+ Programme aiming at implementing CPDLC services in the core area of the ECAC region

- **LINK 2000+ CBA Review**: A review and update of the previous cost benefit analyses carried out for the LINK2000+ Programme, which aims to implement datalink services in the core area of Europe

Surveillance (links to be provided)

EUROCONTROL

- **Mode S - Phase 1 of a Mode S Cost Benefit Analysis Project**: A preliminary study to collect and collate all Mode S/datalink studies, undertaken or foreseen in Europe, in the US or in Asia
- **Mode S - Phase 2 of a Mode S Enhanced Surveillance Cost Benefit Analysis**: An assessment of the costs and benefits generated by the operational use of Mode S in the High Density Area of Europe over the period 1998-2015
- **ATC Radar Tracker and Server (ARTAS) CBA**: A cost benefit analysis assessing the implementation of ARTAS in the ECAC area, taking into account of potential Mode S and ADS implementation
- **ADS - High Level CBA**: An initial analysis of the implementation of ADS in ECAC with the objective of making a first estimate of all cost items and identifying the potential benefits provided or enabled
- **The Case for Enhanced Surveillance**: A study to assess the value of Enhanced Surveillance in the Core Area of Europe, based on the use of eight downlinked aircraft parameters
- **The Case for Enhanced Surveillance – Revised CBA**: A revision and update of the CBA prepared as part of the earlier study of Enhanced Surveillance

Airports (links to be provided)

EUROCONTROL

- **Airports Initial Business Case Assessment**: A framework for assessing the costs and benefits of implementing one or more elements of the Airport Operations Programme and an initial high level assessment of potential benefits
- **Study of Airports CDM Level 1 Applications**: An initial cost benefit analysis for Airport CDM derived from EUROCONTROL airport trials at several major European airports, concentrating mainly on Brussels Airport
- **Study of Airports CDM Level 2 & 3 Applications**: In progress
- **A-SMGCS Generic CBA**: An analysis of the anticipated benefits and costs of implementing A-SMGCS Levels I & II, using the results of simulations and operational trials

Annex 4: Aviation information and data sources to support Business Cases or CBA

Data inputs and templates for Cost Benefit Analysis

- Eurocontrol (Eurocontrol, 2014)
  - **Standard Values for Eurocontrol Cost Benefit Analyses** http://www.eurocontrol.int/sites/default/files/publication/files/standard-input-for-eurocontrol-cost-benefit-analyses.pdf
  - **Overall model data input table**: excel spreadsheet to gather input data for the overall model
  - **Military data input table**: excel spreadsheet to gather input data for the military model
  - **General aviation data input table**: excel spreadsheet to gather input data for the general aviation model
  - **Airport data input table**: excel spreadsheet to gather input data for the airport model
  - **Airline data input table**: excel spreadsheet to gather input data for the airline model
  - **ANSP data input table**: excel spreadsheet to gather input data for the ANSP model
  - **Baseline ANSP 2010**: excel spreadsheet containing assumptions about the baseline for the ANSP. It includes assumptions about traffic growth and ANSP costs in 2010
  - **Baseline - ATM improvements by 2010**: excel spreadsheet containing assumptions about the ATM improvements that will have been implemented by 2010
  - **Baseline airlines 2010**: excel spreadsheet containing assumptions about the baseline for airlines. It includes assumptions about traffic growth, delay, flight inefficiency, route charges and other airline costs in 2010
  - **Baseline general aviation 2010**: excel spreadsheet containing assumptions about the baseline for general aviation. It includes assumptions about traffic growth, delay, flight inefficiency, route charges and other General Aviation cost in 2010
  - **Airline spreadsheet generated by EMOSIA**: spreadsheet generated in step 2 of EMOSIA containing inputs for the airline model, and outputs such as the cash-flows and the net present value. It can be re-used for other projects by entering different inputs directly in the spreadsheet
  - **ANSP spreadsheet generated by EMOSIA**: spreadsheet generated in step 2 of EMOSIA containing inputs for the ANSP model, and outputs such as the cash-flows and the net present value. It can be re-used for other projects by entering different inputs directly in the spreadsheet
  - **Air Transport Infrastructure Costs** – A briefing on air transport infrastructure costs http://www.iata.org/whatwedo/Documents/economics/Infrastructure-Cost-March-2013.pdf
  - **The potential for cost-effective CO2 abatement in commercial aviation** (presentation) http://www.iata.org/whatwedo/Documents/economics/IATA-CO2-abatement-modelling-report-July-2013.pdf

Data inputs on economic benefits in air transport for Cost Benefit Analysis

  - **Economic values on aviation contribution to global economy**: Analysis on the contribution of aviation to the economic impact: http://aviationbenefits.org/media/26786/ATAG__AviationBenefits2014_FULL_LowRes.pdf
  - **Economic value on aviation contribution to national economies**: Analysis on the contribution of air transport to the national economies. A detailed country level assessment for about 60 countries: www.benefitsofaviation.aero
  - **Aviation Economic Benefits**: Measuring the economic rate of return on investment in the aviation industry http://www.iata.org/whatwedo/Documents/economics/aviation_economic_benefits.pdf
  - **Airline Network Benefits**: Measuring the additional benefits generated by airline networks for economic development http://www.iata.org/whatwedo/Documents/economics/airline_network_benefits.pdf
  - **Profitability and the air transport value chain**: An analysis of the air transport value chains, including information on cost of capital and competitive forces in the industry. http://www.iata.org/whatwedo/Documents/economics/profitability-and-the-air-transport-value%20chain.pdf

Cost of Delay

- Eurocontrol
    - **Cost of Delay - Evaluating the true cost to airlines of one minute of airborne or ground delay**: The results of a study by the University of Westminster to evaluate the cost of delay to airlines
    - **Cost of Delay - Model based on the University of Westminster Report**: The model enables the tables within the Report to be reproduced but also allows users to change the input data to produce their own updated values. Note that the model is not protected so that the user is also able to change the logic within the model
    - **Cost of Delay – Notes**: Notes on estimating the cost of delay, using the University of Westminster Report and using the cost of delay model
- Examples of CBA assessments on cost of delay:
    - **Inefficiency in European Airspace**
      http://www.iata.org/whatwedo/Documents/economics/EU_Airspace_Efficiency_Final.pdf
    - **Benefits to Hong Kong from increasing airspace efficiency**
      http://www.iata.org/whatwedo/Documents/economics/PRD-airspace-apr14.pdf

Emissions

- **ICAO Engine Exhaust Emissions Data Bank (Doc 9646)**
    - Doc 9646 was published in 1995 and contains information available as of October 1993. The Data bank has since been further developed in electronic form and is accessible from this **link**
- **ICAO CAEP Steering Group Report, 3 to 7 November 2013**

  Adobe Acrobat Document

Noise

- **ICAO Noise Data Bank (NoiseDB)** – developed in electronic form and accessible from this link
- **www.aircraftnoisemodel.org**
- **www.boeing.com/commercial/noise/**

Traffic Forecasts and tools to assess demand

- **Air Travel Demand –** The impact of every air transport policy decision is an essential consideration. Without it, uncertainty over demand leads to ineffective or counter-productive decisions. This report describes how to assess the impact of policy changes on air transport demand.
  http://www.iata.org/whatwedo/Documents/economics/air_travel_demand.pdf
- **Estimating Air Travel Demand Elasticities –** This report by Intervistas consulting provides robust elasticity estimates.
  http://www.iata.org/whatwedo/Documents/economics/Intervistas_Elasticity_Study_2007.pdf

Equipment Databases

To be added

Fuel Consumption

- **Jet Fuel Price Monitor**: Jet fuel price index provides the latest price data from the leding energy information provider Platts. The index and price data shows the global average price paid at the refinery for aviation jet fuel at the reported date.
  http://www.iata.org/publications/economics/fuel-monitor/Pages/index.aspx

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