ATM value-chain redesign

D3.1

COCTA

Grant:	699326
Call:	H2020-SESAR-2015-1
Topic:	SESAR-05-2015
Consortium coordinator:	Univerzitet u Beogradu – Saobracajni fakultet
Edition date:	17 August 2017
Edition:	01.00.00

Authoring & Approval

Authors of the document

Name/Beneficiary	Position/Title	Date
Frank Fichert/HW	Principal Researcher (Economics)	21/06/17
Radosav Jovanović/UB-FTTE	Principal Researcher (ATM)	21/06/17
Vojin Tošić/UB-FTTE	Senior Expert (ATM)	13/02/17
Nikola Ivanov/UB-FTTE	Researcher (ATM)	21/06/17
Arne Strauss/UW	Principal Researcher (OR)	21/06/17

Reviewers internal to the project

Name/Beneficiary	Position/Title	Date
Obrad Babić/UB-FTTE	Senior Expert (ATM)	22/06/17
Stefano Starita/UW	Post-doc Researcher (OR)	22/06/17

Approved for submission to the SJU By — Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date
Radosav Jovanovic/UB-FTTE	Principal Researcher (ATM)	22/06/17
Arne Strauss/UW	Principal Researcher (OR)	22/06/17
Frank Fichert/HW	Principal Researcher (Economics)	22/06/17

Rejected By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date

Document History

Edition	Date	Status	Author	Justification
00.00.01	23/01/17	Draft	Frank Fichert, Radosav Jovanović, Vojin Tošić, Nikola Ivanov, Arne Strauss	Initial draft
00.00.02	30/01/17	Mature draft	Frank Fichert, Radosav Jovanović, Vojin Tošić, Nikola Ivanov, Arne Strauss	Draft sent to the Advisory Board
00.00.03	10/02/17	Final Draft with Advisory Board comments addressed	Frank Fichert, Radosav Jovanović, Vojin Tošić, Nikola Ivanov, Arne Strauss	Advisory Board comments considered/ Ready for the Consortium board approval

00.01.00	14/02/17	Final	Frank Fichert, Radosav Jovanović, Vojin Tošić, Nikola Ivanov, Arne Strauss	Approved
00.01.01	11/06/17	Final Draft, following up on the SJU feedback	Frank Fichert	Final Draft sent to the COCTA research team
00.02.00	23/06/17	Final	Frank Fichert, Radosav Jovanović, Nikola Ivanov, Arne Strauss	Approved
01.00.00	17/08/17			Approved by the SJU.

COCTA

COORDINATED CAPACITY ORDERING AND TRAJECTORY PRICING FOR BETTER-PERFORMING ATM

This deliverable is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 699326 under European Union's Horizon 2020 research and innovation programme.

Abstract

In this deliverable (D3.1) we develop a conceptual framework for the COCTA mechanism, assign roles to the different stakeholders in the value chain, and draft the process of capacity planning as well as the use of incentive schemes. The suggested process is designed in order to minimize the overall costs of capacity provision as well as costs resulting from insufficient capacity supply, provide flexibility in case of changing traffic patterns, and introduce incentives within the charging scheme that contribute to an overall efficient outcome.

At the beginning of the COCTA process, the Network Manager, based on a traffic forecast, determines a preliminary capacity demand and asks the Air Navigation Service Providers (ANSPs) to submit binding offers for providing this capacity (defined in terms of sector hours) as well as for a higher or lower level of capacity. Based on these offers the Network Manager is able to determine the cost minimizing network structure and to order capacity from the ANSPs. Moreover, the Network Manager can calculate the necessary charges for cost recovery. The Network Manager offers a set of trajectories to the Aircraft Operators, enabling them to choose their preferred option within the given capacity supply ('purchased specific trajectory'). In general, charges are set on an airport pair level (avoiding detrimental incentives due to differing unit charges), but include incentives for an early booking of trajectories which improves the traffic predictability for the Network Manager. A differentiation of charges might also be added in cases of capacity bottlenecks. Moreover, the Network Manager might offer a discounted product, named 'flexibly assigned trajectory', allowing a short-term allocation of trajectories to those Aircraft Operators having purchased the flexible product. In case of significant deviations from the traffic forecast, the Network Manager might redesign the network structure, again based on the ANSPs' capacity offers. The process also includes an ex post assessment based on Key Performance Indicators, serving as a basis for incentive schemes for the Network Manager as well as for ANSPs.

In addition to the process outlined above, which is based on fixed maximum capacities, we also develop ideas for coordinating long-term investment decisions by the different ANSPs. Moreover, we describe several options for the institutional framework of the Network Manager.

Acknowledgment

We would like to thank to members of COCTA Advisory Board Marc Baumgartner and Gerard Boydell for their valuable feedback on a draft of this deliverable. We have incorporated many of the suggestions, whereas we intend to discuss some other issues in more detail during AB meetings and other opportunities. However, all opinions expressed in this document are exclusively those of the authors.

Table of Contents

1 Introduction

The COCTA concept to improve the performance of Air Traffic Management (ATM) in Europe consists of two major elements. The first key feature is to develop a new charging scheme which also provides incentives to Aircraft Operators (AOs) resulting in an earlier disclosure of their trajectory preferences. This will enable the Network Manager (NM) to have a better insight regarding airspace use in terms of time and location. Consequently, the Network Manager is in a better position to determine capacities needed in the network, based on more accurate information on future demand. This is complemented by a new product – named 'flexibly assigned trajectory' – which allows the Network Manager to allocate trajectories, within an agreed level of flexibility, to Aircraft Operators, later in the process.

The second key element is a better coordination of capacity which is ordered by the Network Manager and produced by independent Air Navigation Service Providers (ANSPs). This will lead to a higher degree of capacity utilization and therefore a better economic performance of the overall system. Both elements are interconnected, leading to positive reciprocal effects.

In previous steps of the COCTA research project we have analyzed the state of the art (see deliverable D2.1) which also serves as a background of further developing the concept in this deliverable. Moreover, in a simplified framework we have shown that a centralized decision on decentralized capacity provision is a suitable approach to improve the overall cost efficiency of ATM (see Strauss et al., 2016).

In this deliverable (D3.1) we will develop a conceptual framework for the COCTA mechanism, assign roles to the different stakeholders in the value chain, and draft the process of capacity planning as well as the use of incentive schemes. Within this conceptualization several elements will be described in a rather general way, leaving some specifications to our further research activities which are also expected to benefit from information received during stakeholder consultations. For example, in this deliverable we make a suggestion for the sequence of decisions which are taken within the COCTA environment. However, we are not able to determine the precise length of the different steps yet, since they depend, amongst other factors, on individual planning horizons of the respective ANSPs, operational requirements of Aircraft Operators, etc.

The remainder of this deliverable is organized as follows. In chapter 2 basic assumptions and definitions are presented with a specific focus on Air Traffic Control (ATC) cost functions and the decision making process of Aircraft Operators. In chapter 3, the different steps within the COCTA concept are described, providing a general overview as well as a detailed analysis of the key elements. Chapter 4 discusses a framework for the COCTA concept also with respect to long term investment decisions. Chapter 5 describes institutional options and the regulatory framework for the

Network Manager within the COCTA framework. In chapter 6 the next steps of the COCTA research project which will follow the submission of this deliverable are explained.

2 Basic assumptions and definitions

With respect to capacity provision we make the following assumptions:

- For each Area Control Centre (ACC) there is a maximum number of sectors which can be opened, e.g. during one hour, and ACCs declare the maximum capacity of each of these sectors (which is influenced by the traffic structure, e.g. vertical movements or crossing trajectories, and other factors). In a sense, for a given traffic pattern the maximum number of sectors open reflects an upper capacity limit[1] that could be provided by an ACC (within a given period of time). Additional restrictions, e.g. due to limited availability of staff, might reduce the maximum number of sector hours during longer periods (e.g. one week or one month) below the theoretical maximum, which is defined by the maximum number of sectors per hour multiplied by the number of hours in the respective period.
- We assume that an increase in the maximum capacity requires additional investment (e.g. purchase of new equipment, training of Air Traffic Controllers (ATCOs), and/or changes in airspace sectorization), and we consider these investments to be long(er) term decisions. Depending on the necessary changes to increase maximum capacity, the timeframe might vary between several months and several years. The concept developed in this deliverable only covers short term capacity variations within the boundaries set by the maximum capacities of each ANSP as described in the previous paragraph. We will provide some ideas on coordinated long term decisions in the discussions chapter at the end of this deliverable.
- Within the given maximum, an ANSP can change its capacity provision, especially by adapting the sector configuration (i.e. opening and collapsing sectors). These capacity variations influence the number of ATCO hours needed and therefore the cost of capacity provision.
- The cost function is determined, amongst others, by ATCOs' labour contracts and specific restrictions regarding staff planning. The precise cost function is known to the respective ANSP only, but not to the Network Manager or other entities.

However, the following features of such a cost function are realistic and in line with standard assumptions of cost and production theory as well as with the specifics of providing Air Traffic Control Services:

[1] For the sake of easier reading, herein after we will use the term *maximum capacity* to reflect general (and current) structural and operational limits for capacity provision by an ANSP.

- Capacity is usually increased incrementally, but this increase comes only in larger batches, i.e. by opening one or more extra sectors, each of which typically enables several dozens of additional aircraft entries per hour (up to the point where all the elementary sectors are open and no further capacity increase is possible). Therefore, within these batches the marginal costs of controlling one additional flight are very close to zero until the maximum throughput of a given sector configuration is reached (step-wise total cost function with respect to output).
- With respect to the distance between the different steps of the total cost function we expect an asymmetric structure. Adding capacity will lead to an increase in the average costs of capacity provision (e.g. due to premiums for working overtime (CANSO, 2015) and smaller capacity gains with each additional sector opened) whereas decreasing capacity leads to smaller cost reductions. This assumption does not contradict empirical studies which suggest increasing returns to scale in ATC provision (e.g. Helios Economics and Policy Services 2006: 28 et seq., Performance Review Unit 2011) since we refer to short term changes whereas the analysis of scale economies refers to a long term perspective.
- With a decreasing time span between decisions on capacity supply and the actual provision of the service, costs for increasing capacity will grow (e.g. because rosters have to be changed) whereas for decreasing capacity cost savings will be the smaller the later the decisions are made.

Regarding the demand side, we make the following assumptions:

- We assume that Aircraft Operators are profit maximizers. Since revenue will not be affected by the COCTA concept, we can assume that Aircraft Operators aim at minimizing the overall costs for a given flight. These costs are, amongst others, determined by the aircraft with which a particular flight is operated, the fuel price, air navigation services (ANS) charges, the actual number and structure of an airline's customers (e.g. number of passengers, type of passengers or cargo), and operational restrictions like airport operating hours and flight crew planning. Moreover, the costs of different flights might be interrelated within an airline's network, especially in the case of a hub and spoke business model. The exact costs for a given flight are known to the Aircraft Operators only, but not to the Network Manager or other entities.

However, the following aspects are undisputed with respect to Aircraft Operators' decision making:

- Airlines offering scheduled services are in a position to plan their flights rather early whereas in other (significantly smaller – see section 3.2) market segments demand arises at a rather short notice (esp. business aviation providing on-demand services).
- Once information on user charges as well as all other cost categories (especially fuel) is provided, airlines offering scheduled services can determine their trajectory preferences already when deciding on their schedules.

Concerning capacity related decisions of ATM providers (Network Manager and ANSPs) and trajectory related decisions of Aircraft Operators several trade-offs exist. From the ATM perspective, the sooner Aircraft Operators submit their trajectories (4D), the higher the predictability of the ATM system, in terms of spatio-temporal traffic distribution in the network. This facilitates capacity and ATCO roster planning and should lead to decreasing cost of capacity provision. On the other hand, the optimum trajectory, from an Aircraft Operator's standpoint, can only be determined days or even hours in advance, especially due to weather conditions and actual payload. Any trajectory submitted well in advance might be optimal for 'expected' or 'typical' conditions but may not be the most cost efficient option for that particular flight. Therefore, there is an obvious trade-off between lowering the cost of capacity provision (requiring an early decision of Aircraft Operators) and reducing the other costs of an actual flight (enabled by a late decision of Aircraft Operators). This trade-off will be further elaborated in the forthcoming deliverables (D4.1 and D5.1).

The COCTA concept aims at improving the economic performance of the European ATM system, which includes the cost of capacity provision as well as the costs resulting from insufficient capacity supply. Since fuel consumption is closely linked to trajectory choices, there might also be an influence in terms of environmental performance indicators. Safety, as the most important target of ATM, is not directly affected by the institutional changes suggested within the COCTA concept. Therefore, we assume that all safety regulations will remain in force and all projects aiming at an even further improvement of the safety levels will be continued. Consequently, since we can assume that COCTA has no direct impact on safety levels we will not analyse this Key Performance Area (KPA) in the remainder of this delivery.

3 Process of coordinated capacity ordering and trajectory pricing

3.1 Overview

Within the COCTA environment all entities need specific information in order to make their decisions. As mentioned above, Aircraft Operators need to know the level of trajectory charges in order to choose their preferred trajectories whereas fixing the trajectory charges requires information on the costs of capacity provision as well as the expected level of overall demand. The following concept of a suitable COCTA process takes these information requirements into account. To some degree it is based on current processes in the ATM environment and it includes the specific innovations suggested by the COCTA concept.[2]

In general, mandatory and formalized consultations between the different decision-making units are important supplements to the COCTA mechanism described below. We assume that they will be of particular relevance when deciding on timelines as well as on details of the process. Therefore, we do not make a suggestion on the specific design of the consultation process[3], but we assume that a suitable consultation process will be established.

The COCTA process consists of nine steps (with a possible inclusion of additional feedback loops, see step 7). This subchapter provides an overview of the entire process (see also figure 1). Key elements will be further explained in the following subchapters.

1. Based on past data, available information on airlines' schedules, and other relevant exogenous variables (e.g. GDP and oil price forecasts) the Network Manager prepares a forecast for future traffic within the European airspace (base case scenario - traffic). This starting point of the COCTA process is very similar to the current practice of ANS capacity planning.
2. Based on the traffic forecast (step 1), the Network Manager calculates the necessary capacity which would have to be provided by the different ANSPs (base case scenario - capacity). For this calculation the Network Manager generally assumes that Aircraft Operators prefer the

---

[2] The network capacity planning and Air Traffic Flow and Capacity Management processes are described in COCTA Deliverable 2.1; in Deliverable 3.1 we emphasise the most important differences and potential improvements to those processes.
[3] Note that there is already a well-established Collaborative Decision Making (CDM) process in place (EUROCONTROL NMOC 2016), which could serve as a basis for COCTA negotiation process.

shortest route, but already takes potential capacity bottlenecks (see chapter 2 of this deliverable: maximum capacities) into account.

3. The Network Manager asks all ANSPs to submit binding offers for the following scenarios:
    a. Costs of capacity provision for the base case scenario according to step 2, assuming capacity ordering within a given period after the offer has been made (e.g. a few weeks).
    b. Costs of a higher or lower provision of capacity than in the base case scenario (scenarios defined by the Network Manager), assuming capacity ordering within a given period after the offer has been made (e.g. a few weeks).
4. Based on its traffic forecast and the ANSPs' offers for different levels of capacity provision the Network Manager determines the cost minimizing network structure[4] (impacted by traffic distribution and airspace sectorization), taking into account the costs of capacity provision as well as the expected costs resulting from capacity insufficiencies. The Network Manager orders capacity based on the result of this optimization, and also calculates the necessary trajectory charges for cost recovery.

    The charges are based on the following principles:
    a. Charges are set for trajectories between airport pairs (origin and destination within Europe), combinations of airports and standard entry or exit points (for flights to/from airports outside Europe), and combinations of standard entry and exit points (for flights between two extra European airports).
    b. Aircraft Operators may buy trajectories based on a set of trajectories and associated charges offered by the Network Manager ('purchased specific trajectory' – PST). The offered set of trajectories is based, amongst others, on the Network Manager's historical analysis of flown trajectories for a given city pair and on a consultation process between the Network Manager and Aircraft Operators. If the capacity limit of a certain airspace volume is reached, the Network Manager does not offer trajectories anymore which require the use of this airspace volume. In cases of foreseeable capacity bottlenecks the Network Manager might also implement differentiated charges (as a deviation from the uniform charge for each airport pair).
    c. Aircraft Operators might receive an early booking advantage (discount) on trajectories. Together with the previous feature this serves as an incentive for early trajectory bookings.
    d. If an Aircraft Operator cancels a booking there will be a refund which is smaller than the purchasing price. If Aircraft Operators change a booking there will be an additional surcharge.

[4] The term 'network structure' is used in this deliverable to describe the number of sectors opened by the different ANSPs in the European airspace as well as the sector opening scheme at a given point in time.

e. The Network Manager might offer a 'flexible product' ('flexibly assigned trajectory' – FAT) at a reduced charge. If an Aircraft Operator has bought a FAT, the Network Manager will assign a specific trajectory (from a set of trajectories within the 'flexible product') to the Aircraft Operator only rather shortly before the flight.

5. The Network Manager publishes the charges for airspace use (en route). Aircraft Operators purchase trajectories.
6. The Network Manager uses the information that has been generated through the booking process according to step 5 as well as additional information that he has gathered in the meantime (e.g. shifts between tourist destinations due to external factors) for an updated determination of the optimum network structure. He asks the ANSPs to make binding offers for changes in the capacity provision according to his updated demand forecast, if necessary. Based on these capacity offerings the Network Manager recalculates the cost minimizing network structure.
7. The Network Manager might change its capacity orders based on the results of step 6. Afterwards, trajectory bookings will be possible based on the revised network structure, trajectory prices might be adapted to the changed costs of capacity provision.

   Note that steps 6 and 7 might be repeated once or even several times.
8. Exact trajectories are assigned by the Network Manager shortly before the day of operation to those airlines which purchased a FAT.
9. Regulators assess the network performance, which is the result of the decisions taken by the Network Manager, as well as the performance of the ANSPs and decide on bonus payments and penalties, respectively. Although COCTA project tackles the process of establishing demand-capacity balance at strategic and pre-tactical level, we include one more step which encloses tactical and post-ops phase. Since the scope of COCTA research includes high level policy considerations, we emphasise and elaborate in more detail performance monitoring and analysis.

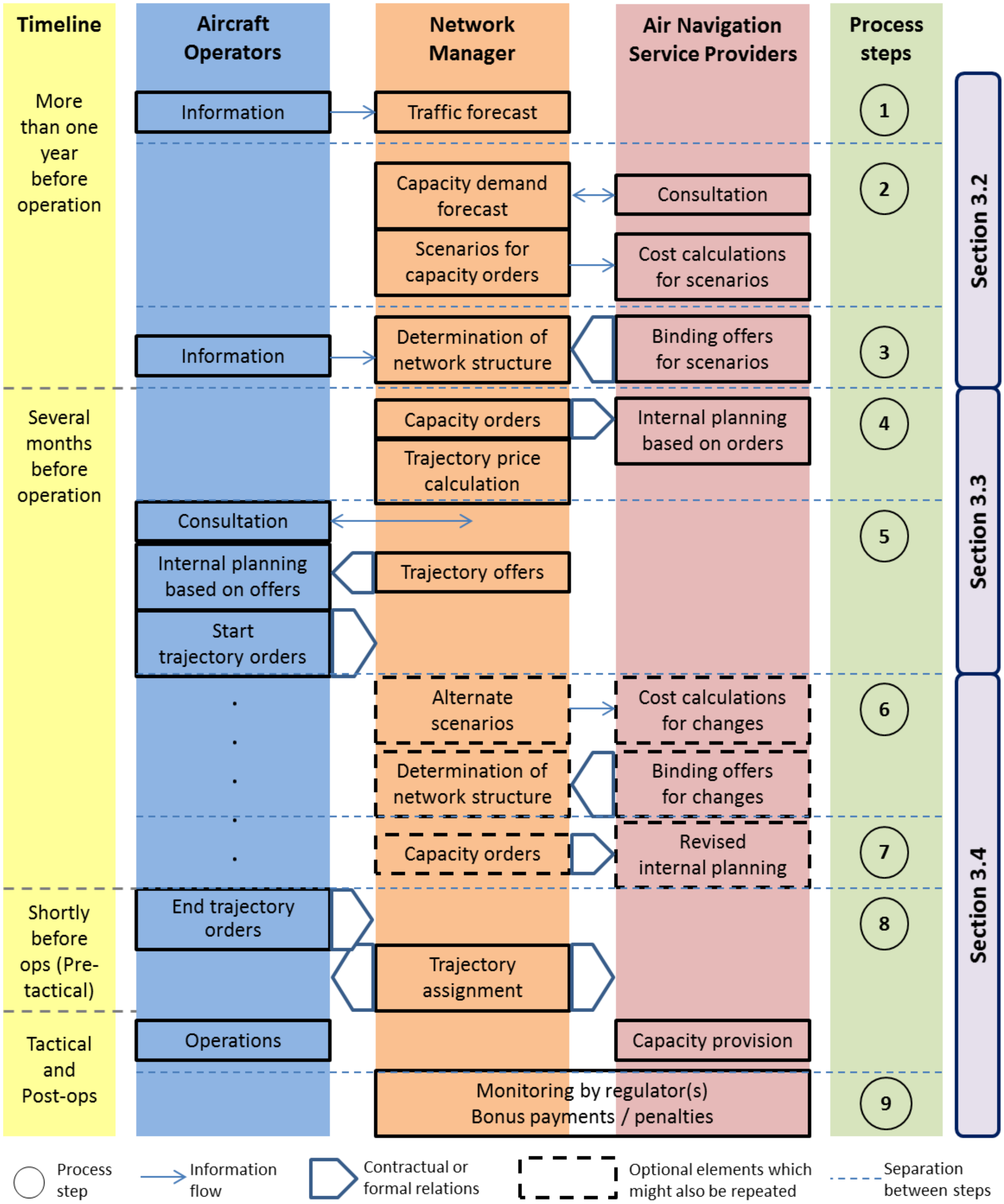

Figure 1. COCTA Process overview

3.2 Traffic forecast and capacity offers (Steps 1 – 3)

The largest share of air traffic within the European airspace is operated by airlines offering scheduled flights. Almost 83% of all IFR flights in Europe in 2016 were operated either by traditional or by Low-Cost Carriers (see figure 2). Compared to 2010 the share of all scheduled flights has been slightly increasing (2010: 79%), with a significant shift towards Low-Cost operations (Source: EUROCONTROL, 2016c, p. 4).

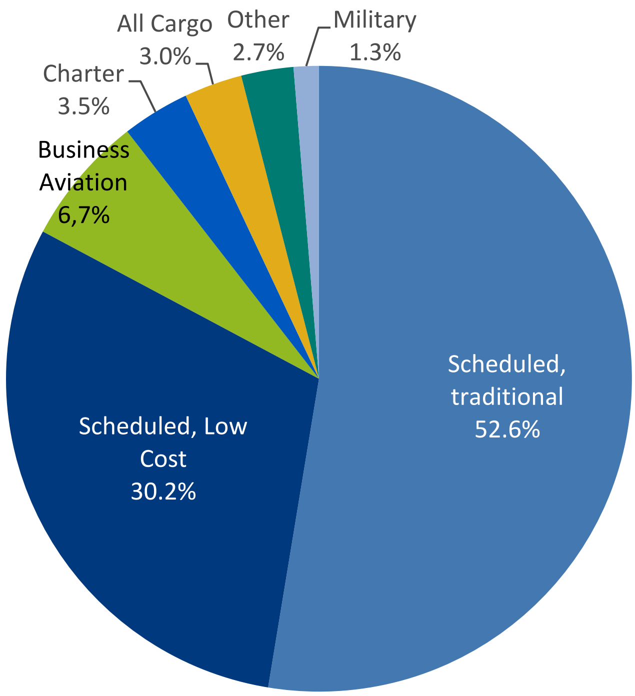

Figure 2. IFR flights in the European airspace (Jan-Nov 2016). Source: EUROCONTROL 2016a

The schedules of most airlines show a high degree of regularity (EUROCONTROL 2016c). Therefore, a forecast of daily traffic patterns which is based on past experience and updated according to overall developments (e.g. GDP growth and changes in the oil price) as well as available information on changing airline network structures (e.g. opening or discontinuation of airline services between two airports) is a suitable starting point for the process. Such forecasts are already prepared today by the Network Manager and individual ANSPs, respectively. In general, the later a forecast is prepared, the higher the expected accuracy. On the other hand, an early forecast facilitates an early planning of ATM capacity, which might lead to reduced costs. Also due to seasonal patterns of demand, we assume that forecasts for a specific day can be prepared already twelve months in advance. Such a forecast might be used as a starting point for the consultation process between the Network Manager and the ANSPs, however being subject to later adjustments.

As will be discussed later in more detail (see section 3.2, second paragraph), current traffic patterns are also influenced by different unit rates charged by neighbouring ANSPs (see also Delgado 2015). The starting point of the traffic forecast/distribution across the network in the COCTA approach is based on the shortest distance of each flight as long as this would be feasible within the maximum capacity of each ANSP. Technically this could be calculated by assuming either no ATC charge or a uniform charge which is only based on distance flown and MTOW. The result is a network structure (traffic distribution over the network) which minimizes airline's operating costs (except for ANS charges) and also avoids unnecessary fuel consumption and thereby CO_2 emissions, assuming no-wind condition. This network structure can also serve as a base case for assessing the network structure generated through the COCTA process.

Tools, e.g. EUROCONTROL NEST (Network Strategic Tool), are available to determine the ATC capacity load (defined by sector configurations and sector hours) which results from a given traffic pattern. Therefore, assuming that the same tools are used, the determination of the ATC capacity load could be done either by the Network Manager or by the ANSPs based on the Network Manager's traffic forecast. For two reasons we suggest that the Network Manager calculates the necessary sector configurations and sector hours. First, only the Network Manager can already determine a capacity provision which optimizes the entire airspace network rather than separate parts of the network. Second, the Network Manager shall be subject to an incentive scheme based on network performance. Therefore, it is crucial that decisions which potentially influence the network performance, e.g. the provision of capacity in the different parts of the network, are actually taken by the Network Manager, in contrast to the current process. However, we suggest a comprehensive consultation process between the Network Manager and the ANSPs on the assumptions used for determining network structures.

Unlike the demand for sector hours, the costs for providing a predefined level of capacity are only known to the ANSPs. Therefore, ANSPs have to make binding offers to the Network Manager for capacity provision. Moreover, in order to be able to determine the efficient structure of the overall network, the Network Manager needs to know the additional costs of increasing capacity in different airspace volumes as well as the potential cost reductions in case of a reduced level of capacity provision. This is of particular relevance if the overall number of flights and/or their structure (in time or space) changes significantly after the initial capacity ordering. If the Network Manager would not be able to change his offers, overcapacities (with avoidable costs of providing unused capacity) and/or capacity shortages might result. However, the later capacity provision would have to be changed, the higher the costs of additional capacity and the lower cost savings due to capacity reductions will be (see above, section 2).

Within the COCTA environment ANSPs are still subject to an economic regulation which incentivizes a cost efficient provision of services. Similar to the regulation scheme currently applied (European Commission, 2013), bonus payments or penalties would be based on changes in the average costs of service provision, generating an incentive for ANSPs to also make their alternative capacity offers based on realistic cost calculations. Moreover, as the Network Manager takes into account the different costs of capacity provision when deciding on the optimum network structure, there is also a 'competitive' incentive for efficient capacity provision and offers according to the costs of an efficient capacity provision. Once the Network Manager has placed his orders, ANSPs are generally obliged to provide the capacity according to these orders. If ANSPs fail to deliver the capacity which has been ordered, payments from the Network Manager will be reduced accordingly, unless the capacity reduction is due to external reasons, out of ANSP's influence. Consequently, in the COCTA environment ANSPs face the risk of unforeseen cost increases as well as the risk of not being able to provide the capacity which has been ordered. On the other hand, there is no more revenue risk for the ANSPs as long as they provide the services which have been ordered (since their revenue is determined by the capacity orders from the Network Manager).

3.3 Network design and trajectory pricing (Steps 4 – 5)

Based on the capacity offers received from the different ANSPs, the Network Manager is able to determine the cost minimizing network structure. Deviations from the network design calculated in step 2 might occur due to two different reasons. First, traffic demand in one airspace volume might be slightly above the threshold which requires the opening of another sector whereas the neighbouring ANSP still has ample capacity. In this case, shifting a small number of flights, by means of economic demand management measures (incentives), would reduce the overall cost of capacity provision. Second, if the costs per sector hour significantly differ between neighbouring ANSPs, it might be efficient to schedule more traffic via the segments with lower average costs. This also increases competition between neighbouring ANSPs and provides additional incentives for improving cost efficiency.

Once the Network Manager has ordered capacity from the ANSPs the total costs of providing ATC services are known and the cost recovering charges can be calculated. Many options for allocating the overall costs of capacity provision to the different users exist. Based on the framework set by ICAO, the charge should be based on distance flown and on the MTOW of the aircraft. Currently, the unit rate is set by each ANSP separately. One major drawback of the current system might be an incentive to fly longer routes if this reduces the distance flown over the territory of ANSPs with a relatively high unit rate or even avoids using services provided by these ANSPs. Examples for this kind of behaviour include flights which can choose between the Italian and the Croatian airspace (Performance Review Body 2013:21) as well as the avoidance of the German airspace after a significant increase in the German unit rate in 2015 (EUROCONTROL 2016b). Moreover, since charges are based on the trajectories filed in the flight plan and not on the actual trajectories, there might also be an incentive to file a flight plan which avoids 'expensive' ANSPs but to ask ATC for the permission to take the direct way when actually performing the flight (Bucuroiu, 2016).

One of the potential charging schemes within the COCTA framework, comprising the lowest level of complexity could be a uniform unit rate for the entire European airspace. However, compared to the current situation this would imply that flying in areas where the costs of providing ATC services are high would be cheaper than today (e.g. Western Europe), whereas using the airspace in regions with currently relatively low unit rates, e.g. due to relatively low ATCO wages (e.g. Eastern Europe), would be more expensive. This would also lead to a 'cross-subsidization' between ASNPs since the Network Manager would receive revenues which exceed the costs of service provision in regions with low average costs and would make a deficit in regions with relatively high average costs. Therefore, equity considerations suggest differentiated unit rates which reflect the diverging costs of providing ATC services in different parts of Europe.

In order to avoid the inefficiencies described above, a uniform base charge might be set for each airport-pair within the European airspace, based on the average costs of ATC provision for such flights assuming the shortest distance between those two airports.[5] Similarly, base charges would be defined for flights between European airports and points of entry or exit (for flights between European and Non European airports) and for points of entry and exit for overflights. This base charge (before applying incentives described below) for a flight between, for example, FRA (Frankfurt) and LHR (London) would only depend on the MTOW of an aircraft but not on the chosen trajectory between them. Therefore, there would be no longer a rationale for 'strategic' flight plans which are already filed with the intention of actually trying to use another route. Moreover, Aircraft Operators would generally have an incentive to choose the shortest route unless other determinants, like weather conditions, suggest some other decision. Note that a more detailed elaboration of pricing mechanism design is foreseen in the next deliverable (D4.1), but for the sake of describing the basic ATM-value chain redesign principles, we choose an airport-pair charging option.

In general, the Network Manager could offer Aircraft Operators a set of several trajectories between two European airports (or an airport and a point of exit or entry in case of flights to/from airports outside Europe, or a point of entry and a point of exit to the European airspace in the case of overflights).[6] Once an Aircraft Operator purchases a specific trajectory (PST), the corresponding 'portion' of capacity will be reserved for this user. Once the capacity limit in a certain volume of the airspace is reached, routes which cross this volume of the airspace would not be offered anymore by the Network Manager. Therefore, a first-ordered, first-assigned principle would be applied in principle.

We define a 'purchased specific trajectory' (PST) as the subject of a contract between an Aircraft Operator and the Network Manager, with mutually agreed level of flexibility inbuilt in the PST. This means that a PST incorporates certain acceptable ranges for its key elements, such as departure time, cruise flight level, arrival time, etc. Given the planning horizon involved (strategic and pre-tactical), it would not be realistic to guarantee the delivery of an exact 4D trajectory. However, the magnitude of *uncertainty* ranges (margins) incorporated in the PST is such that it has a practically negligible effect on Aircraft Operators' costs, whereas the impact of those margins concerning demand/capacity management is tangible.

In addition, several incentives might be implemented within the COCTA model and will be described in more detail below. However, these differentiated charges might be only necessary in regions where capacity bottlenecks can be expected or where a potential to increase efficiency by shifting traffic between neighbouring ANSPs exists. In regions with an overall low volume of traffic or during periods of low traffic where the minimum capacity is sufficient, differentiated charges will not lead to cost savings or other efficiency improvements. Therefore, the following options are of particular

[5] Verbeek/Visser (2016) suggest a route charge which is calculated for an airport pair (origin and destination airport) based on the great circle distance. This concept is similar to the basic approach within COCTA, however COCTA adds several elements of differentiated charges.

[6] In the case of low traffic volumes or very short flights, only one option for a reasonable route might exist.

relevance to those parts of the network which are characterized by high traffic volumes and neighbouring ANSPs with different average costs and/or different degrees of capacity utilization.

- The sooner the Network Manager is informed about the actual demand on airspace use the better he can adapt supply to demand and the lower will be the costs of overall capacity provision. Therefore, additional incentives for early trajectory purchasing decisions are an important element of the COCTA concept. Such charging schemes could either be based on time only (e.g. with a lower charge if the trajectory is purchased at least x months in advance) or it might also take into account the number of trajectory purchases which have already been made (see e.g. Jovanovic et al., 2015).
- If an Aircraft Operator changes his plans, adjustments to the trajectory booking should be possible. Otherwise there will be 'no shows' i.e. Aircraft Operators which have purchased a trajectory but are not operating the flight, resulting in excess capacity. However, in case of cancellations the refund should always be significantly less than 100% and should be decreasing with time (otherwise Aircraft Operators have an incentive to 'store' trajectories and return them rather late). Likewise, changing a trajectory purchase should always be more expensive than buying the particular trajectory for the first time. One option for implementing such an element into the charging scheme would be a surcharge for changed bookings which is also implemented by airlines when offering partially flexible booking classes.

  Likewise to the general trade-off between predictability and flexibility discussed above (see section 2), there are pros and cons of allowing Aircraft Operators to change their trajectory purchases. Too much flexibility for trajectory modification decreases the level of predictability and reduces potential capacity cost savings, but also potentially decrease flights' costs. The financial incentives described above are intended to serve as a barrier against too many changes of initial capacity purchases.
- The Network Manager might implement differentiated charges in some parts of the network, providing Aircraft Operator with an incentive to choose other trajectories. In contrast to the current charging scheme, different charges would not reflect the different average costs of ANSPs but capacity bottlenecks in the ATC network.
- As already introduced in COCTA D2.1, in contrast to the purchased specific trajectory (PST) we envisage a 'flexible product', the so-called 'flexibly assigned trajectory' (FAT). A flexible product is, in general, a set of alternative specific products. A customer who buys a flexible product will know only at a later stage which alternative has been eventually assigned to him. FATs thus leave a rather high degree of flexibility with the Network Manager, allowing it to allocate a specific trajectory to Aircraft Operator shortly before the day of operation.
- The charge for the flexibly assigned trajectory has to be lower than the regular charge. It can be assumed that this product will be purchased by Aircraft Operators with a high degree of flexibility in time or in space (because they *ex ante* accept possible displacements made by the Network Manager). Moreover, Aircraft Operators might expect trajectories which are longer than the shortest distance between two airports if the Network Manager can reduce the overall cost of capacity provision by making use of its extended flexibility to assign trajectories.

3.4 Potential network redesign (Steps 6 – 7)

The capacity orders of the Network Manager are based on a traffic forecast and on the assumption that Aircraft Operators always choose the trajectory with the lowest total costs. However, the Network Manager is not fully informed about the costs of individual Aircraft Operators. For example, airlines' fuel costs might be different due to hedging strategies and actual demand data (passengers and cargo) is not available to the Network Manager. Moreover, traffic patterns are likely to change over time, e.g. due to overall (economic) developments. Such changes would also influence the trajectory bookings, providing the Network Manager with more accurate information. Therefore, capacity demand might be above or below the level which has been ordered by the Network Manager.

Based on an updated capacity demand forecast, which might be executed six months after the initial forecast which is six months before the day of operation, the Network Manager might ask ANSPs to make binding offers for capacity increases or reductions. Given this information the Network Manager can reconfigure the cost minimizing network structure and change his capacity orders. The Network Manager will only increase the initial capacity order, if this leads to a decrease in total costs for Aircraft Operators, i.e., if the costs for providing additional capacity are below the displacement costs which can be avoided due to the use of the additional capacity. Similarly, a reduction of capacity orders will reduce the costs of capacity provision but might cause increasing displacement costs. Consequently, an adapted capacity order will only be enacted if total costs are decreasing.

However, there is a trade-off between the frequency of network redesigns and administrative costs. Moreover, the shorter the time span between a requested change in capacity provision and the actual day of operations, the smaller are cost decreases for capacity reductions and the bigger are cost increases for additional capacity. Therefore, a redesign of the network might be conducted on a regular basis only once and additionally only if there are larger changes in demand pattern. Moreover, network redesigns do not always have to cover the entire network but might be limited to regions which are affected by larger differences between traffic forecasts and actual trajectory bookings.

If the Network Manager orders additional capacity, the average costs per capacity unit will increase (see section 2). Therefore also the charges for using the respective parts of the airspace will have to be adapted. This is in line with the overall COCTA concept of rewarding early bookings. In case of a reduction of the capacity order, total costs for capacity provision will decrease. However, since such a reduction of capacity provision will only be applied if the actual trajectory purchases are below the initial forecast, average costs per aircraft operation might even increase. Moreover, in order not to cause disadvantages for early bookings, charges will not be reduced in this case.

3.5 Operations and assessment (Steps 8 - 9)

Shortly before the day of operations the Network Manager will assign trajectories to Aircraft Operators. This assignment basically refers to the flexible product (FAT). Moreover, as explained in section 3.3, also the PST contains a small, mutually agreed level of flexibility.

Capacity provision (and therefore also capacity costs) cannot be changed at this point in time anymore. Therefore, when assigning those trajectories, the Network Manager will minimize fuel consumption (and thereby CO_2 emissions) given the remaining capacity in different segments of the airspace network.

Finally, the results of the capacity planning and allocation process will be assessed by independent regulators. Within the COCTA scheme, the Network Manager is responsible for the overall cost efficiency of the network as well as for environmental performance, and other Key Performance Indicators, as set by the regulator. Therefore, similar to the current regulatory framework for ANSPs, bonus payments and penalties for the Network Manager would be based on suitable indicators for these KPAs.

For ANSPs, two different types of incentives would be in place. First, their revenue will depend on actual capacity provision based on the contract with the Network Manager, providing an incentive for reliable capacity provision in line with the overall network optimization. Second, regulators will decide on bonus payments and penalties for ANSPs based on cost efficiency indicators. Unlike the current regulatory scheme, cost efficiency would not be assessed on the basis of average costs per traffic unit (since the Network Manager has a strong influence on traffic allocation), but on the basis of average costs per capacity unit (i.e. sector hours). This regulation provides an incentive for ANSPs to offer capacity to the Network Manager at prices which reflect the costs of an efficient service provision. However, it should be noted that, likewise to any other service contract, the capacity provider will not be punished if he cannot deliver his services due to an external event, e.g. extreme weather conditions.

4 Discussion: Framework agreements and investment decisions

Traffic patterns within the European airspace show inherent variability on a daily, weekly, monthly, and seasonal level. The COCTA process described above basically refers to daily and even hourly capacity provision. However, the flexibility of capacity provision is limited. Safety regulations, labour laws, union agreements, and individual labour contracts limit the maximum number of ATCO working hours for a given period (Hoefel, 2013), and also the level of short-term changes within this framework. Therefore, the COCTA process described above might be fenced by framework agreements between the Network Manager and the individual ANSPs, which govern the minimum and maximum purchase of sector hours within a longer period (e.g. one year) as well as possible variations within this period (e.g. minimum and maximum provision of sector hours within a month, a week, or a day). Such framework agreements also provide a certain degree of financial and operational reliability to the Network Manager as well as to the ANSPs.

Framework agreements can also be used to coordinate decisions on capacity expansion or other performance improvements. The Network Manager knows the bottlenecks within the entire European ANS system. Therefore, he might ask ANSPs under which conditions (especially costs) capacity expansions might be possible. In addition, ANSPs might propose investment projects which lead to better performance, e.g. also with respect to reliability of capacity provision. Knowing the different investment options, the Network Manager can determine the combination as well as the timing of investment projects which lead to the highest cost efficiency of the entire network. In order to provide incentives to the ANSPs for developing and implementing suitable investment projects, the Network Manager might adapt the framework agreements. If, for example, an ANSP invests in capacity expansion which has been approved by the Network Manager, the framework agreement might guarantee a higher minimum purchase of capacity as long as the price of capacity does not exceed a certain limit. Consequently, the ANSP could expect that the additional capacity will actually be used and will also lead to additional revenue which is needed to cover the additional costs of the investment.

5 The role of the Network Manager and institutional options

Although a Network Manager has already been designated within the European Air Traffic Management environment, its competencies will be expanded significantly within the COCTA concept. Therefore, also a new institutional framework has to be developed, which includes a different type of regulation. The key task of the Network Manager within COCTA is to enable a high degree of economic efficiency and to limit detrimental effects on the environmental by purchasing capacities from ANSPs and selling trajectories to Aircraft Operators. Therefore, the Network Manager serves as a connecting element, linking the decisions taken by ANSPs and Aircraft Operators, respectively.

Three principal options for the institutional layout can be distinguished.

- Option 1: Capacity provider(s) (ANSP(s))

  The position of the Network Manager might be assigned to an ANSP, or a cooperation consisting of some or even all European ANSPs. Whereas a comprehensive insight into the production side of ANS services might be expected within this framework, the lacking neutrality of the Network Manager appears to be a major shortcoming if this role is assigned to one or few ANSPs. Since the Network Manager is expected to increase the overall efficiency of European ATM, in this specific framework it may have to take measures which are against the interests of individual ANSPs. Depending also on the design of the decision process within the cooperative of capacity providers (e.g. majority decisions – with potentially different weights of the votes – vs. unanimous decision making), such decisions might be highly controversial.

- Option 2: Capacity user(s) (Aircraft Operator(s))

  Similar to some ANSPs (see Deliverable 2.1) the shares of the Network Manager might be held by Aircraft Operators, especially airlines. It can be assumed that the Network Manager will have a strong incentive to increase overall efficiency. However, it might put less emphasis on environmental target in case of a trade-off with economic aspects. Moreover, in case of diverging interests within the group of Aircraft Operators, e.g. due to different business models or different regional traffic patterns, conflicts of interest might arise, making institutional arrangements for decision making particular important.

- Option 3: Independent Network Manager

  For an independent Network Manager, meaning that he is neither connected to the ANSPs nor to the Aircraft Operators, two basic options can be distinguished further. A Network Manager owned by private shareholders would have a strong incentive to increase efficiency if its profits depend on achieving specific performance targets. If the Network Manager is organized as a not-for-profit organization, incentives might be weaker, but on the other hand there may also be fewer incentives to abuse the strong position of the Network Manager for profit maximization.

Based on the three 'pure' institutional designs sketched above, different combinations between two or even all three groups are possible. Each option, as well as all potential types of mixed ownership between the groups, has specific advantages and disadvantages, some of them mentioned above. Moreover, political as well as legal criteria might be relevant which cannot be addressed within this research project. However, as long as key performance indicators in the fields of costs of service provision, displacements cost (delays), and environmental effects are clearly defined, monitored, and serve as a basis for an effective incentive scheme, the actual institutional layout of the Network Manager in the COCTA environment is of lesser importance. It determines the specific design of the regulatory framework rather than the overall outcome of the COCTA model. Consequently, the preceding considerations are based on the assumption that the Network Manager will make its decisions in order to maximize a weighted set of performance indicators defined by the political decision makers.

6 Next steps

After the submission of the first version of this deliverable, the concept has been discussed with the members of the COCTA Advisory Board as well as with others stakeholders. Moreover, an updated version of this deliverable will also be presented at the 21st World Conference of the Air Transport Research Society (ATRS) in July 2017. Furthermore, we developed a specific mechanism and a formal mathematical model in order to specify the process and calculate potential improvements of cost efficiency within the COCTA framework. This has been described in deliverables subsequent to D3.1.

7 References

[1] Bucuroiu, R., 2016. *Shorter routes possible with better flight planning*. EUROCONTROL Skyway magazine, Autumn-Winter 2016, pp. 31-33.

[2] CANSO, 2015. *CANSO ATCO Remuneration and HR Metrics Report 2015 (De-identified)*.

[3] COCTA Consortium, 2016. *State of the art report*. Project Deliverable 2.1.

[4] Delgado, L., 2015. European route choice determinants. Examining fuel and route charge trade-offs. *11th US-Europe ATM Research and Development Seminar*. Lisbon, Portugal. June 2015. http://www.atmseminar.org/seminarContent/seminar11/papers/487_Delgado_0126150532-Final-Paper-4-30-15.pdf

[5] EUROCONTROL, 2016a. Industry Monitor, No 189, 19. December.

[6] EUROCONTROL, 2016b. *Why variations in navigation charges can influence traffic patterns*. https://www.eurocontrol.int/sites/default/files/content/documents/official-documents/skyway/articles/2016-winter-skyway-variations-in-navigation-charges.pdf

[7] EUROCONTROL, 2016c. Market Segments in European Air Traffic 2015

[8] European Commission, 2013. Commission Implementing Regulation (EU) No 390/2013 of 3 May 2013 laying down a performance scheme for air navigation services and network functions.

[9] Helios Economics and Policy Services, 2006. *The impact of fragmentation in European ATM/CNS*. Report commissioned by the Performance Review Commission.

[10] Hoefel, N., 2013. *Air Traffic Controller Staffing at DFS*. Paper prepared for the Committee for a Study of FAA, Air Traffic Controller Staffing. Transportation Research Board, National Academies of Science, USA. Available on request from the Public Access Records Office of the National Academies, e-mail paro@nas.edu.

[11] Jovanovic, R., Babic, O. and Tosic, V., 2015. Pricing to reconcile predictability, efficiency and equity in ATM. *11th US-Europe ATM Research and Development Seminar*. Lisbon, Portugal. June 2015. http://www.atmseminarus.org/seminarContent/seminar11/papers/536_Jovanovic_0127150551-Final-Paper-5-6-15.pdf

[12] Performance Review Body, 2013. PRB Annual monitoring Report 2012. Volume 1. European overview and PRB recommendations, Brussels.

[13] Performance Review Unit, 2011. *Econometric Cost Efficiency Benchmarking of Air Navigation Service Providers*, Brussels.

[14] Strauss, A. et al., 2016. Maximizing ATM Cost-efficiency by Flexible Provision of Airspace Capacity, Paper presented at the *6th SESAR Innovation Days*. Delft, the Netherlands. http://sesarinnovationdays.eu/files/2016/Papers/SIDs_2016_paper_51.pdf

[15] Verbeek, R., Visser, H. 2016. Why aircraft fly more fuel-efficient on Friday?, 7th International Conference on Research in Air Transportation – ICRAT 2016, Philadelphia, USA, June 20-24, 2016. http://icrat.org/icrat/seminarContent/2016/papers/55/ICRAT_2016_paper_55.pdf

[16] Brevik, K., 2017. Predictability and Moving to 4D Trajectories, The Network Manager User Forum 2017, EUROCONTROL, Brussels. http://www.eurocontrol.int/sites/default/files/events/presentation/breivik-2601-1130-nm-user-forum-2017.pdf

Appendix A List of acronyms

ACC	Area Control Centre
ANS	Air Navigation Services
ANSP	Air Navigation Service Provider
AO	Aircraft Operator
ATC	Air Traffic Control
ATCO	Air Traffic Controllers
ATM	Air Traffic Management
COCTA	Coordinated capacity ordering and trajectory pricing for better-performing ATM
FAT	Flexibly assigned trajectory
GDP	Gross Domestic Product
IFR	Instrument Flight Rules
KPA	Key Performance Area
MTOW	Maximum Take-off Weight
NEST	Network strategic tool
NM	Network Manager
PST	Purchased specific trajectory

University of Belgrade
FACULTY OF TRANSPORT AND TRAFFIC ENGINEERING

WARWICK
THE UNIVERSITY OF WARWICK

Hochschule
Worms
University of Applied Sciences