06.08.01 Initial Safety and Performance Requirements (SPR) for Time Based Separation

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Abstract

This deliverable outlines the framework for conduct of safety assessment in P6.8.1 Phase 1 – Time Based Separation (TBS). Due to low maturity of critical inputs (AIM wake model & SPR template not compatible with SESAR Safety Reference Material), it can not provide the complete list of initial safety and performance requirements, but it does attempt to provide the main inputs required for their definition.

The initial work was structured along the following main themes: Establish accident incident models impacted, identify impacted services/barriers, derive safety acceptance criteria and identify success safety objectives.

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Executive summary

This deliverable outlines the framework for conduct of safety assessment in P6.8.1 Phase 1 – Time Based Separation (TBS). Due to low maturity of critical inputs (AIM wake model & SPR template not compatible with SESAR Safety Reference Material), it can not provide the complete list of initial safety and performance requirements, but it does attempt to provide the main inputs required for their definition.

The initial work was structured along the following main themes: Establish accident incident models impacted, identify impacted services/barriers, derive safety acceptance criteria and identify success safety objectives.

The project team will continue to work on TBS safety assessment in 2012 and if required, the final set of SPR can be produced based on the outcome of the full safety assessment.

1 Introduction

1.1 Purpose of the document

The Initial SPR for Time Based Separation (TBS) document specifies the safety and performance requirements for TBS services and functions as defined in the current version (v0.1) of Wake induced accident model developed by 16.6.1 [1]. This deliverable also outlines the next steps for the full safety assessment of TBS concept.

1.2 Scope

This document supports the validation of operational services and concept elements identified in the TBS Initial Operational Service and Environment Definition (OSED) [2]. These services are expected to be operational (IOC) in the 2014+ time frame.

It was intended that the performance requirements would be defined using the top-down principle, originating at B.04.01 level, cascaded down from strategic targets to Operational 06.02 federating project level and subsequently to primary projects. However the final B4.1 validation targets for Step 1, as well as some important elements of Step 1 DODs from 6.2 and 5.2 were not available at the time of elaborating this document. Therefore this Initial SPR seeks to define only baseline safety and performance requirements based on material currently available.

1.3 Intended audience

The document is to support the system project operational concept and operational services environment review activities with the corresponding system projects P10.4.4 and P12.2.2.

At a higher project level Ops 06.02, 05.02, WP16 and WPB are expected to use this document as an input into the consolidation activities.

1.4 Structure of the document

The structure of the document is as follows:

- §1 (this section) introduces the document.
- §2 provides the summary of the TBS operational concept (from OSED)
- §3 describes the initial safety and performance requirements
- §4 shows the traceability matrix
- §5 lists references and applicable documents
- Appendix A lists the CCDF curves as initial evidence for achieving the high-level safety acceptance criteria.

1.5 Background

The **Time Based Separation for Arrivals (TBS) concept** has been extensively evaluated refined and partially validated by EUROCONTROL and NATS since 2001:

- Model based assessments have been conducted in order to quantify the risk of a wake vortex encounter associated with the use of time based separations.
- Model based assessments have been conducted in order to quantify the costs and benefits and the return on investment of the time based separation concept.
- NATS has developed, evaluated and carried out initial validation of the ATC tools that can provide for spatial visualisation of the time based separation rules to the final approach controller and Tower runway controllers.
- Real time simulations were conducted in order to assess the usability of time based separations by the final approach controller (including recent real time simulation executed

both by EUROCONTROL for the TBS project, and by the Swedish ANSP, LFV for EC 6th FP RESET project).

- A detailed TBS concept of operation has been produced in cooperation with NATS.
- An IP1 implementation project is ongoing in cooperation with NATS to implement a reduction of the wake turbulence separations in strong head wind conditions.
- A dedicated wake vortex and wind LIDAR measurement campaign has been ongoing for more than 2 years at London Heathrow (since October 2008).
- TBS user group workshops have been held in NATS throughout 2010 and planned throughout 2011with Heathrow approach controllers and Tower runway controllers.
- A human-in-the-loop real time simulation validation with Heathrow approach controllers was conducted by NATS in October 2010.

The positive outcome of all of these activities has demonstrated the benefits and the operational feasibility of the concept (V2). So the TBS concept is considered to be at maturity level V3.

1.6 Glossary of terms

Additional Spacing: The extra spacing above the required separation or spacing required for accommodate the distance spacing changes and the time spacing changes that will occur between both lead and follower aircraft establishing on the final approach localiser, until the lead aircraft crosses the runway landing threshold to touchdown.
Duty Runway-In-Use: The identifier of the runway designated for in-use.
Glideslope Wind Conditions: The wind conditions profile on the final approach glideslope
Ground Speed Profile: The evolution of the ground speed values over a defined path segment. In the context of TBS over a defined path segment on the final approach glideslope.
Final Approach: The approach path commencing at the interception of the localiser and ending at the runway landing threshold or a missed approach.
Final Approach Arrivals Sequence: The order intended for arrival aircraft on final approach.
Forecast Wind Conditions Aloft Profile: The wind conditions forecasted at a specified time in the future in the form of an evolution of the wind speed and the wind direction over a defined path segment aloft. In the context of TBS over a defined path segment on final approach.
Intermediate Approach: The downwind, base and intercept approach path segments for positioning and turning on to merge on to final approach ending at the interception of the final approach localiser and glideslope.
Landing Stabilisation Speed Profile: The evolution of the indicated airspeed on final approach path from the reference position from the runway landing threshold for commencing landing speed stabilisation and ending at the runway landing threshold.
Reference Airspeed Profile: A specified evolution of the indicated airspeed over a defined path segment used as a reference speed behaviour profile. In the context of TBS the reference evolution of the IAS over a defined path segment on the final approach glideslope.
Runway Contaminants: Substances on the runway surface that impact the operational performance of aircraft on the runway.
Runway Landing Threshold: The start of the touchdown zone on the runway.
Separation Constraint: The separation to keep aircraft operating safely on final approach. Examples

are minimum radar separation to keep risk of collision to an acceptable safe level and wake turbulence radar separation to keep the risk of an adverse wake turbulence encounter to an acceptable safe level.
Spacing Constraints: The spacing required to be set on final approach for runway operations in the prevailing meteorological conditions. Examples are VIS2 spacing, LVP spacing, runway surface inspection spacing and non-nominal runway occupancy spacing.
Spacing Minimum Pairs: Arrival pairs with no wake turbulence separation constraint which can be separated by the minimum separation or spacing constraint on final approach.
Spacing Practice: The practice of the final approach controller for managing the uncertainties in the changing distance spacing and time spacing between each arrival pair on the final approach glideslope such that the required Separation Constraints and Spacing Constraints are observed.
Standard Procedural Air Speed Profile: The reference airspeed profile resulting from standard practice application of the controller speed control instructions. In the context of TBS the standard practice application of the controller speed control instruction on intermediate approach and final approach up to the start of landing speed stabilisation.
TBS: The TBS is the distance separation equivalence of the TBS rules in the prevailing wind conditions on final approach for displaying to the final approach controller and the tower runway controller. The TBS rules are converted to the TBS by applying the reference airspeed profile used to derive the TBS rules to the runway landing threshold. The reference airspeed profile is to be applied in the context of the final approach wind conditions on the glideslope that the lead aircraft is forecast to experience over the distance separation to the runway landing threshold.
TBS Rules: The time based wake turbulence radar separation rules on final approach derived from the distance based wake turbulence separation rules. The TBS rules are based on a ground speed profile conversion from applying the DBS rules in low headwind conditions. The ground speed profile conversion is based on a reference airspeed profile over the distance based separation to the runway landing threshold that the ICAO DBS rules are applied. The reference airspeed profile is aligned to a 150kt IAS standard reference landing stabilisation speed profile to the runway landing threshold and is aligned to a 170kt IAS standard procedural airspeed profile to 6NM from the runway landing threshold prior to landing speed stabilisation.
Wind Conditions Profile: The evolution of the wind speed and wind direction over a defined path segment. In the context of TBS over defined path segments of the final approach glideslope.

1.7 Acronyms and Terminology

Term	Definition
4DME	4NM from the runway landing threshold (The DME zero datum for final approach)
A-SMGCS	Advanced Surface Movement Guidance and Control System
aal	above aerodrome level
Ac	Aircraft

Term	Definition
ACC	Area Control Centre
ADS-B	Automatic Dependent Surveillance - Broadcast
AIM	Accident Incident Model
AIP	Aeronautical Information Publication
AMAN	Arrival Manager (System)
ANSP	Air Navigation Service Provider
AOC	Airline Operations Centre
ATC	Air Traffic Control
ATFCM	Air Traffic Flow and Capacity Management
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
BTV	Brake to Vacate
CAVOK	Ceiling and Visibility OK
CCDF	Complementary Cumulative Distribution Function
CDM	Collaborative Decision Making
CSPR	Closely Spaced Parallel Runways
D-ATIS	Digital service ATIS
DBS	Distance Based Separation
DMAN	Departure Manager (System)
DME	Distance Measurement Equipment
DOD	Detailed Operational Description
EA	Enterprise Architecture
EC 6^{th} FP	European Commission 6^{th} Framework Project
ECAC	European Civil Aviation Conference
ETA	Estimated Time of Arrival
FAF	Final Approach Fix
FAP	Final Approach Point
FIN	Final Approach Controller

Term	Definition
FMS	Flight Management System
GBAS	Ground Based Augmentation System
GS	Ground Speed
HF	Human Factors
HIL	Human-in-the-loop
HMI	Human Machine Interface
HWS	Headwind component Speed
IAF	Initial Approach Fix
IAS	Indicated Air Speed
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
INTEROP	Interoperability
IP1	Implementation Period 1
KPA	Key Performance Area
KPI	Key Performance Indicator
kt or kts	Knots (Nautical Miles per Hour)
LIDAR	Light Detecting and Ranging (system)
LFV	Swedish ANSP
LVC	Low Visibility Conditions
LVP	Low Visibility Procedures
MATS	Manual of Air Traffic Services
MLS	Microwave Landing System
MTOW	Maximum Take-Off Weight
NATS	UK ANSP
NM	Nautical Mile
NOP	Network Operations Plan
OCD	Operational Concept Description
OFA	Operational Focus Area

Term	Definition
OI	Operational Improvement
OM	Outer Marker
OS	Operational Scenario
OSED	Operational Service and Environment Definition
P&S	Processes & Services
PANS	Procedures for Air Navigation Services
PI	Performance Indicator
R/T/RT	Radio Telephony/Radio Telephone
RESET	EC 6^{th} FP Reduced Separation Minimum project
REQ	Requirement
RTS	Real-Time Simulation
RVR	Runway Visual Range
SAC	Safety Acceptance Criteria
SARPS	Standards and Recommended Practices
SEMP	System Engineering Management Plan
SESAR	Single European Sky ATM Research
SL2	Service Level 2
SJU	SESAR Joint Undertaking
SM	Spacing Minimum
SPR	Safety and Performance Requirements
SUP	Supervisor
T	Tonnes (1,000kg)
TAS	True Air Speed
TBS	Time Based Separation (for Arrivals)
TMA	Terminal Manoeuvring Area/Terminal Movement Area
TTA	Target Time of Arrival
TTOT	Target Take-Off Time
TWR	Tower

Term	Definition
UK	United Kingdom
VIS2	Visibility Conditions 2 Procedures
WTE/WVE	Wake Turbulence Encounter/Wake Vortex Encounter
WT	Wake Turbulence
WV	Wake Vortex

2 Summary of Time Based Separation Concept (from OSED)

2.1 Description of the Concept Element

This section provides a brief description of the TBS concept including how the TBS operational concept is proposed to be integrated with all of the other separation and spacing constraints of final approach operations. For more details, the current version of TBS OSED (v0.6) describes the concept in section 2.

2.1.1 Objective

The objective of the TBS for arrivals concept is to develop a solution to permanently provide arrival capacity resilience to headwind conditions on final approach. With today's DBS operations the achieved arrival capacity is impacted as headwind conditions on final approach increases the time to fly the distance based separation.

2.1.2 Time Based Separation Concept Proposal

The TBS operational concept applies on final approach, from when both the lead and follower aircraft establish on the final approach localiser, until the lead aircraft crosses the runway landing threshold to touchdown.

The time based separation concept proposal is to apply time based wake turbulence radar separation rules on final approach, so as to aid towards stabilising the overall time spacing between arrival aircraft across the headwind conditions experienced on final approach. This will partially recover the reduction in achieved arrival capacity currently experienced when applying distance based wake turbulence radar separation rules in the headwind conditions experienced on final approach. The amount of recovery is dependent on the other surveillance and runway operations separation and spacing constraints.

The final approach controller and the tower runway controller are to be provided with the necessary TBS tool support to enable consistent and accurate delivery and monitoring to time based wake turbulence radar separation rules on final approach. An indicator is to be displayed on the extended runway centre-line of final approach of the separation or spacing required behind the lead aircraft of each arrival pair as a separation or spacing reference for the follower aircraft.

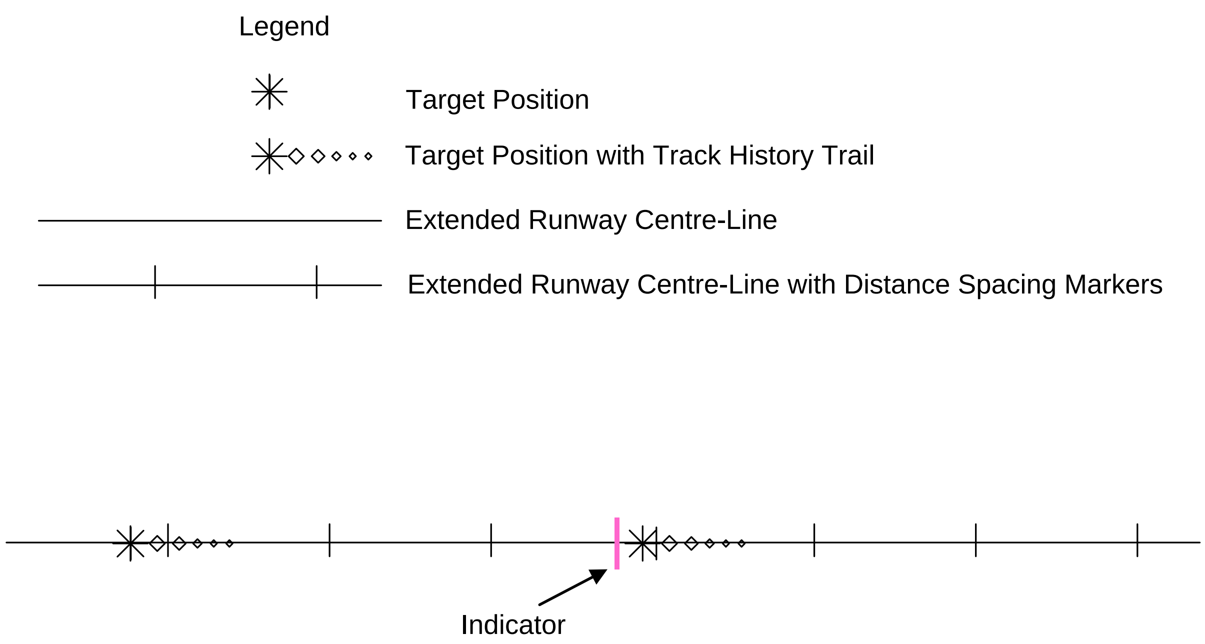


Figure 1: Indicator of the Separation or Spacing required behind the Lead Aircraft

The final approach controller and the tower runway controller remain responsible for monitoring for separation infringement and for timely intervention action. There is a significant potential for separation infringement scenarios on final approach because of the diversity of approach speed profiles being employed and the resulting uncertainties about the amount of distance spacing change and time spacing change that will be experienced between each arrival pair on final approach.

The final approach controller and the flight deck will be required to adopt procedures and practices to ensure that the variations in the distance spacing changes and time spacing changes on final approach are consistently managed.

2.1.3 Time Based Wake Turbulence Radar Separation Rules

The time based wake turbulence radar separation rules (TBS rules) are derived from the distance based wake turbulence separation rules (DBS rules) in wind conditions when the achieved arrival capacity with the DBS rules are currently acceptable to busy capacity constrained aerodrome operations. From operational experience this is in low headwind conditions.

The TBS rules are to be based on a ground speed profile conversion from applying the DBS rules in low headwind conditions. The ground speed profile conversion will be based on a reference airspeed profile over the distance based separation to the runway landing threshold that the DBS rules are applied.

A variety of local procedural airspeed profiles are employed on final approach. These are typically between 220kt and 160kt on joining the final approach localiser, reducing to between 180kt and 160kt to the start of landing speed stabilisation, with landing speed stabilisation starting from between 6NM and 4NM from the runway landing threshold.

The landing stabilisation speed profiles, starting from around 6NM to 4NM from the runway landing threshold until touchdown, vary considerably depending on aircraft type, landing weight, stabilisation altitude, stabilisation mode, and the associated airline operator cockpit procedures. The range of stabilisation airspeeds varies from under 100kt for some Light aircraft types to over 160kt for some Heavy aircraft types.

In low headwind conditions the time to fly the distance based separation of the DBS rules is dependent on which portion of final approach the DBS rules are being applied, on what procedural airspeed profile is being employed, and on what landing stabilisation speed profile is being employed.

The ground speed profile conversion will be based on a reference airspeed profile over the distance based separation to the runway landing threshold that the DBS rules are applied.

The reference airspeed profile is to be aligned to a standard reference landing stabilisation speed profile to the runway landing threshold.

2.1.4 Calculating the TBS

The TBS is the distance separation equivalence of the TBS rules in the prevailing wind conditions on final approach for displaying to the final approach controller and the tower runway controller. The TBS is to be applied in same way as the DBS is applied on final approach as a stable distance separation equivalence of the TBS rules independent of the actual airspeed and ground speed profiles of the lead aircraft or follower aircraft on final approach.

The TBS rules are converted to the TBS by applying the reference airspeed profile to the runway landing threshold. The reference airspeed profile is to be applied in the context of the final approach wind conditions on the glideslope that the lead aircraft is forecast to experience over the distance separation to the runway landing threshold.

This will result in the distance separation of the TBS changing as the final approach wind conditions on the glideslope change over the distance separation to the runway landing threshold. The TBS compared with DBS, will reduce in increasing headwind conditions over the TBS to the runway landing threshold, and will increase in calm wind conditions and in tailwind conditions over the TBS to the runway landing threshold.

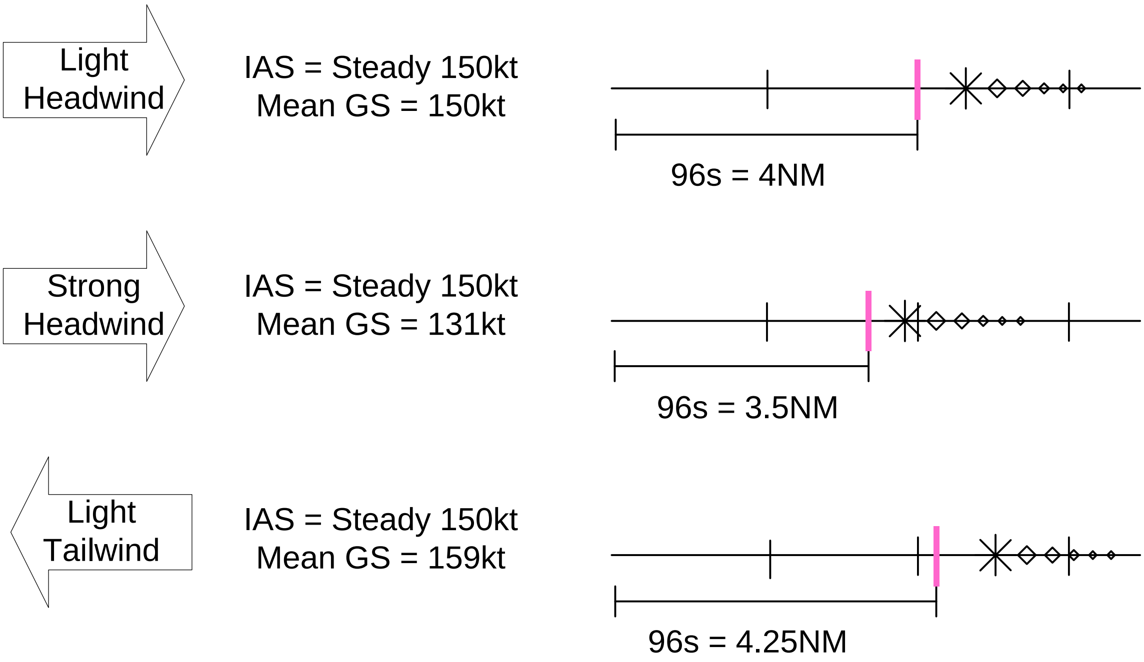


Figure 2: Variation of the Distance Separation of the TBS with Headwind Conditions

The TBS is required to be displayed to the final approach controller from when the follower aircraft is on intermediate approach, before the turn on decisions that sets up the initial distance spacing on merging on to final approach. This may be over 20NM to 25NM flying distance to the runway landing threshold or over 7 to 10 minutes flying time to the runway landing threshold.

The final approach glideslope wind conditions that the lead aircraft is forecast to experience are the wind conditions at the time the lead aircraft predicted to fly the separation to the runway landing threshold.

The latest measured average wind conditions on the glideslope over the distance separation to the runway landing threshold from a wind profiler or the previous aircraft to fly final approach to the runway threshold in pressured traffic may sufficiently represent the wind conditions in stable wind conditions.

In changing wind conditions, either some contingency provision for the changing wind conditions, or forecast wind conditions, may be required, dependent on the potential impact on the wake turbulence encounter risk.

2.1.5 Harmonisation with Other Separation and Spacing Constraints on Final Approach

The TBS rules and the TBS are required to be applied in the context of all of the other separation and spacing constraints on final approach. The other surveillance and runway operations separation and spacing constraints need to be taken into account alongside the dynamically calculated TBS.

The other surveillance and runway operations separation and spacing constraints that are to be applied at any time are determined by the Tower ATC Supervisor in coordination with the Approach ATC Supervisor.

The minimum separation or spacing to be set up on final approach is required to be at least that of the maximum separation or spacing constraint that is required to be applied.

The indicator position is required to reflect the maximum separation or spacing constraint to be applied between the arrival pair.

2.1.6 Management of the Other Separation and Spacing Constraints on Final Approach

In order to be able to calculate the minimum separation or spacing that needs to be set up between each arrival aircraft on final approach there is a need for the other surveillance and runway operations separation and spacing constraints to be specified and maintained through, for example, a separation/spacing mode tool.

The Tower ATC Supervisor in coordination with the Approach ATC Supervisor is required to specify and maintain the other separation and spacing constraints.

2.1.7 Establishing the Required Separation or Spacing between each Arrival Pair

All of the final approach separation and spacing constraints need to be taken into account when establishing the minimum required separation or spacing between each arrival pair. The other surveillance and runway operations separation and spacing constraints need to be taken into account alongside the dynamically calculated TBS.

There is a need for the provision of a reliable final approach arrival sequence order. Additionally for the multiple runway operational layouts of closely spaced and dependent parallel runway operations there is a need for the provision of reliable landing runway intent for each arrival aircraft. This is so as to be able to establish the minimum required separation for both in-trail arrival pairs established on the same final approach localiser and not-in-trail arrival pairs established on separate parallel localisers. This should be the AMAN sequence order with landing runway intent with the incorporation of late sequence order and landing runway intent changes.

For mixed mode interlaced operations, there is also a need for the provision of reliable interlaced sequence information of where the departures are to be interlaced into the arrival sequence order. This should be the combined AMAN and DMAN sequence order with the incorporation of late changes of arrival sequence order or interlaced departure intent.

2.1.8 TBS Tools Support for Visualisation of the Required Separation or Spacing

To provide for the consistent and accurate delivery and monitoring to time based wake turbulence separation rules the final approach controller and tower runway controller require visualisation of the TBS distance separation of the TBS rules. This is to at least a distance separation step resolution of 0.1NM.

Current workstation facilities support consistent and accurate spacing delivery to the DBS rules which are defined to a step resolution of 1.0NM for wake turbulence radar separation and 0.5NM for the minimum radar separation. Extended runway centre-line distance markings are provided on the surveillance display of the approach controllers and the air traffic monitor display of the tower runway controller of the distance to the runway landing threshold in 2NM and sometimes 1NM steps as illustrated in figure 4.

Figure 3: Illustration of Displayed Extended Runway Centre-Line Distance Markings

To facilitate the visualisation of the TBS, to the required resolution of the converted TBS rules, an indicator is to be displayed on the final approach centre-line, behind the lead aircraft target position on the radar display as a visual separation reference to the follower aircraft. This is illustrated for in-trail follower aircraft in figure 5.

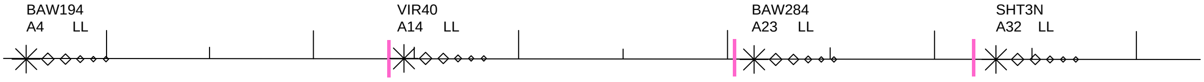


Figure 4: Illustration of Indicator Visualisation of the TBS behind each Lead Aircraft

For not-in-trail follower aircraft establishing on a different runway localiser the indicator is to be displayed on the extended runway centre-line of the landing runway of the follower aircraft. This is illustrated for parallel runway operations in the figure 6.

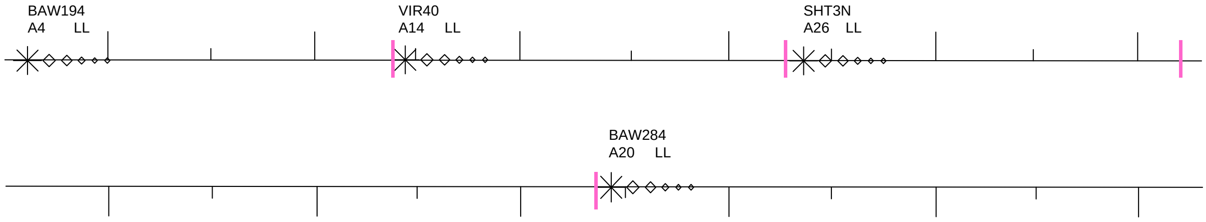


Figure 5: Indicator Visualisation for Not-In-Trail Aircraft in Parallel Runway Operations

The indicator position is required to reflect the maximum separation or spacing constraint that is required to be applied between the arrival pair.

The indicator position is to be updated in synchronisation with the track position updates of the lead and follower aircraft in order to provide for a stable visual reference of the applicable separation or spacing constraint.

The final approach controller requires a visual reference of the required separation or spacing constraint when setting up and refining the spacing when turning aircraft on from intermediate approach and establishing on the final approach localiser.

The final approach controller and the tower runway controller require a visual reference of the required separation or spacing constraint when monitoring for separation infringement as the arrivals descend on the final approach glideslope to the runway landing threshold.

The indicator is to be removed when the lead aircraft crosses the runway landing threshold to touchdown or the lead aircraft target position is removed from the radar display, or the lead aircraft executes a missed approach.

2.1.9 Final Approach Spacing Practice

The final approach controller is required to set up and refine the distance spacing on establishing on the localiser such that the required separation or spacing constraints are observed on final approach to the runway landing threshold.

The indicator is required to display a stable distance separation of the separation or spacing constraint that is required to be observed by the follower aircraft. The final approach controller is required to set up distance spacing with the additional spacing required to the accommodate distance spacing changes and time spacing changes that will occur between both lead and follower aircraft establishing on the final approach localiser, until the lead aircraft crosses the runway landing threshold to touchdown.

There is a need to ensure the efficiency of the final approach spacing practice with respect to the additional spacing applied with TBS. This efficiency is impacted by the amount of uncertainty about the intended landing stabilisation speed profiles of the respective lead and follower aircraft.

It is proposed that the flight deck inform Approach ATC or their intended landing stabilisation speed on first call to Approach ATC so as to enable the application of more consistent and efficient final approach spacing practice by the final approach controller.

The final approach controller and the tower runway controller remain responsible for monitoring for separation infringement and for timely intervention action.

There is a significant potential for separation infringement scenarios on final approach because of the diversity of approach speed profiles being employed and the resulting uncertainties about the amount of distance spacing change and time spacing change that will be experienced between each arrival pair on final approach.

2.1.10 Preliminary Safety Mitigation Elements for the TBS Concept

A preliminary safety assessment[1] has identified a number of safety mitigation elements for the TBS concept:

- Automatic monitoring and alerting of non-conformant final approach airspeed behaviour that significantly increases the risk of separation infringement.
- Automatic monitoring and alerting of separation infringement.
- Automatic monitoring and alerting for the wrong aircraft being turned on to a separation indicator because of the significant impact this could have on the wake turbulence encounter risk for the aircraft being turned on out of arrival sequence order.
- Automatic monitoring and alerting for an aircraft not being turned on to the intended final approach localiser because of the significant impact this could have on the wake turbulence encounter risk for the aircraft being turned on to the wrong final approach localiser.

2.1.11 Reduction to the 2.5NM Minimum Radar Separation on Final Approach

It is proposed that the current 3NM and 2.5NM minimum radar separation on final approach be applied on the initial deployment of the TBS.

However, the 2.5NM minimum radar separation on final approach constrains the efficiency with which the spacing minimum pairs can be delivered to the TBS on final approach.

For the future, but outside the scope of this Initial SPR, it is proposed that a 2NM minimum radar separation is applied during the landing stabilisation speed phase of final approach to the runway threshold.

For the future, but outside the scope of this Initial SPR, it is also proposed that a reduced minimum radar separation below the 2.5NM minimum radar separation is applied during the procedural airspeed phase of final approach when both the lead and follower aircraft are established on the final approach glideslope.

P6.8.3 is to address reducing the minimum radar separation on final approach.

2.1.12 Operational Roles and Responsibilities

The TBS concept operationally impacts Tower ATC, Approach ATC and the Flight Deck.

2.1.13 Other Related Issues

The benefits from the TBS concept will be impacted by the consistency of the arrival flow demand into the initial approach fixes, and the flow of arrivals on to intermediate approach. The benefits will also be impacted by the consistency of the expedited runway vacation behaviour of the lead aircraft of spacing minimum pairs.

The intermediate approach controllers require the display of the indicators on their radar displays so as to provide visual feedback on the appropriateness and consistency of the presentation of aircraft on intermediate approach.

There are expected to be requirements to collect sensor data, radar data, weather data, and wake related reports from flight crew and controllers, in order to ensure the continued safe operation of TBS. This may include the requirement for more systematic and system supported monitoring of wake turbulence encounter risks.

[1] In EC 6th Framework project RESET.

2.2 Description of Operational Services

As stated in the 6.2 DOD for Step 1, X.2s have raised some issues concerning Processes and Services (P&S) methodology and they should be taken into account by B4.1 Enterprise Architecture (EA) study. The conclusion of this study may have an important impact on the way process models are being developed today. Service development can only start once the necessary inputs and guidance will be made available to federating projects by B4.3.

The 6.2 DOD presents only high-level processes and services based on the initial set of B4.2 models.

According to the Section 7.3.3 of 6.2 DOD [3], there are currently no P&S allocated to OFAs (OSEDs). However, the DOD maps the TBS concept to the high-level process called Surface In. The 5.2 DOD [9] shall map the TBS OFA into the process called Descent.

2.2.1 Accident types impacted by the change

Using the TBS OSED and a list of pre-existing hazards the following accident types were identified to be impacted by the TBS concept:

- Wake induced accidents
- Mid-Air Collision (MAC)
- Runway incursion
- Controlled Flight Into Terrain (CFIT)

The scope of this initial SPR is limited only at the main safety impact area - Wake induced accidents part of the AIM.

2.2.2 Safety barriers impacted

For the purpose of Initial SPR[2], we define the services as the main barriers in the 16.6.1 Wake Induced Accidents risk model.

- Strategic conflict management – Separation minima
- Separation provision – Wake spacing management, Wake avoidance
- Collision avoidance – Wake recovery

2.2.3 Functional model

The initial functional model (Figure 6) was developed with aim to identify the key functions to be used in the next steps of the safety assessment process. Additional functions were also identified as background mitigation tasks and human tasks (Figure 7).

[2] In the absence of processes and services from WPB and X.2 DODs.

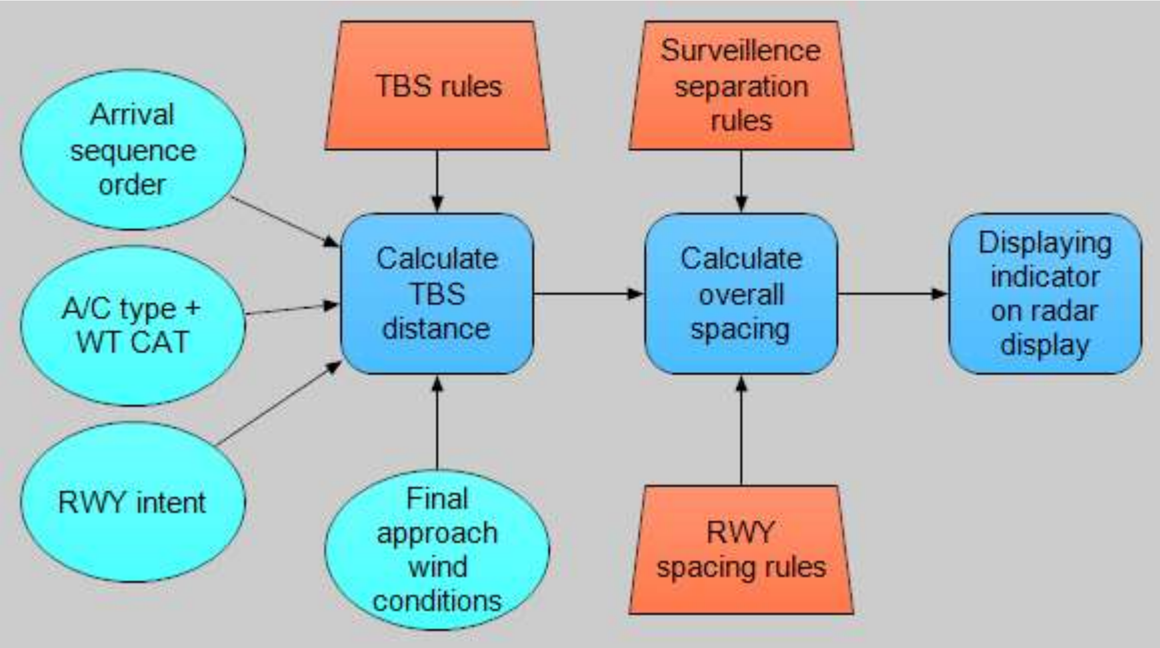


Figure 6: Functional model for TBS

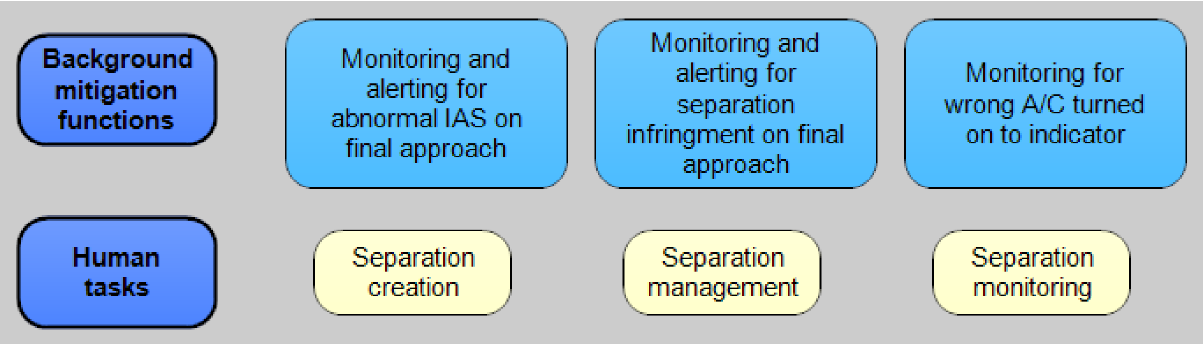


Figure 7: Background mitigation tasks and human tasks

2.3 Description of Operational Environment

For a comprehensive description of the operational environment, refer to the TBS OSED [2], section 3. The section 3 in the OSED describes the following elements of the operational environment in detail:

- Separation standards
- Aerodrome characteristics
- Traffic characteristics
- High-level principles, limitations, assumptions
- Roles and responsibilities
- Constraints

3 Requirements

3.1 Safety acceptance criteria

One of the first actions after identifying the nature and scope of TBS OFA is the setting of safety targets that define what is considered acceptably safe for the change being introduced. This should also permit validation of the expected safety impact on ATM provision.

In P6.8.1 Phase 1 TBS project, it is envisaged to define safety targets at two different levels:

1. Safety target related validation objective – as identified in the validation plan [4]
2. Safety acceptance criteria (SAC) targets defined as per SESAR Safety Reference Material [5].

3.1.1 Safety target related validation objective

A list of validation expectations was defined in the TBS Validation plan [4]. This list was also used for definition of validation objectives. One validation objective focused specifically on safety target is:

OBJ-06.08.01-VALP-0010-0010 – Wake Turbulence Encounter Risk

The aim of this objective is to assess the impact of TBS on the Wake Turbulence Encounter risk on final approach.

The risk of an ATM related accident (incl. fatalities) due to wake turbulence (WT) on final approach with TBS in all wind conditions shall:

- Be reduced as far as reasonably practicable.
- Remain acceptable to controllers, ANSP, pilots, airlines and airports;
- Not exceed 3.2e-9 per flight (this figure is provisionally derived from SESAR 16.6.1 AIM Risk model (Wake induced accidents) and subject to revision in December 2011).
- Not exceed the current level when current DBS are applied in low wind conditions [**SAC1**].

Be mitigated through controller procedures for monitoring and recovering from time based separation infringement risk on final approach.

3.1.2 Safety Acceptance Criteria target for TBS OFA

In SESAR, due to the multitude of operational projects involved and to the necessity to be able to predict and assure that overall safety targets should and are being met (by validation) at the different concept development steps, it is essential that these targets are identified and described based on a common framework. In SESAR, this framework is supplied by the Accident Incident Model (AIM).

The AIM risk model provides a set of templates (one for each accident type) that all operational projects can use to identify where and how the operational improvements they are making will impact the safety of ATM provision.

The method involves the identification of the base events in the risk model that would be impacted and thereby the measurable accident precursors that would be either increased if safety was reduced, decreased if safety improved or unchanged in the case of operational changes that should not impact safety. The targets set by this method are called safety acceptance criteria (SAC).

In SESAR it is a **16.06.01 activity to support OFA projects in the identification of these SAC targets**. SACs are set during the scoping and change assessment activities that are part of the safety planning process. The AIM models are used by safety experts (within 16.06.01 and OFA projects) with the assistance of operational and technical experts on the changes involved.

The AIM model, as shown in **Figure 8** below, is a set of accident risk models based upon ECAC incident data and developed using operational experts.

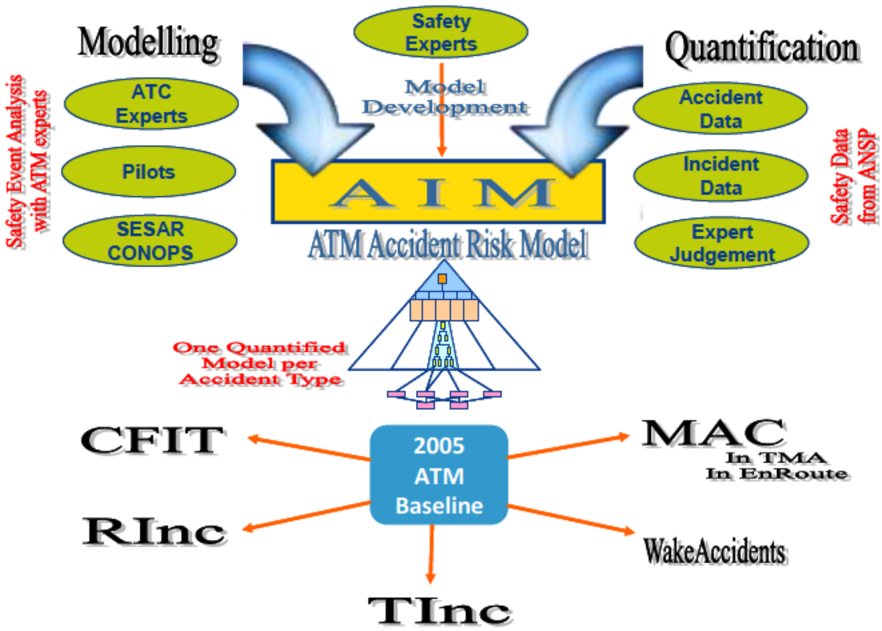


Figure 8: AIM – high-level view

This AIM model has been used in the production of Step 1 validation targets published by B4.1 [Ref 10]. According to this target document, there should be no increase in the number of accidents with respect to 2005 irrespective of traffic increase.

The interpretation of the this overall SESAR safety target is that, for any specific point in the future, there should be no increase in the expected annual number of accidents with an ATM contribution. In the case of collisions, this requires the probability of collision per encounter to reduce in proportion to the square of the traffic increase. In other accident types and with risk metrics directly proportional to the amount of traffic, a reduction equal to the traffic increase would be sufficient to meet the objective.

The table below shows the risk reductions required per Influence Factor with respect to the Do Nothing Case, i.e. a 40% increase in capacity and demand (as per Capacity KPA target for Step 1) with no SESAR improvements. Together, the individual risk reductions equate to the 29.6% overall reduction required to prevent a rise in the risk per year of a fatal accident with ATM contribution.

	MAC-ER	MAC-TMA	R-Inc	T-Inc	CFIT	Wake Induced	TOTAL
TOTAL	-4.5%	-4.3%	-8.6%	-0.3%	-10.6%	-1.2%	**-29.6%**
Proportion	*15.3%*	*14.4%*	*29%*	*0.9%*	*35.8%*	*4.1%*	***100%***

According to the 16.6.1 safety team, the TBS OFA is expected to reduce effectiveness of the following safety barriers (as identified in the AIM model):

Wake induced accidents:

- Tactical wake management – by 5%
- Pre-tactical wake management – by 2.5%

Mid-air-collisions:

- Tactical conflict management – by 0.81%.

These values can be further cascaded down to specific functions under each barrier and assessed by project team. However, in order to correctly interpret these safety targets, P6.8.1 project team members needed to clarify the targets with safety experts in 16.6.1. Several issues have been identified in the review of the AIM – Wake induced accident module. It was agreed, that this module needs to be updated. An expert input workshop is already planned with 16.6.6 for 7th December 2011. An outcome of this workshop shall lead to revision of the wake turbulence related safety targets (TBS

OFA and Dynamic vortex separations OFA). Once the new updated validation targets for Safety KPA are available for TBS OFA, they will serve as the main input for the safety assessment.

3.2 Success safety objectives

The success objectives are within the context of the TBS tool support and the displayed Indicators operating as intended correctly displaying the separation or spacing constraint of each arrival pair for supporting:

1. The final approach controller turning aircraft to merge on to the final approach localiser adhering to the separation constraints that apply on final approach
2. The final approach controller monitoring for separation infringements and carrying out timely intervention actions
3. The Tower runway controller monitoring for separation infringements and carrying out timely intervention actions

The Indicators are provided within the context of the current runway centre-line distance markings and so the final approach controller and Tower runway controller are still able to assess the spacing between aircraft independently of the Indicators.

The TBS rules are applied on final approach. The final approach controller is required to apply the current DBS rules on intermediate approach prior to merging on to final approach and so is expected to be aware of the DBS that applies between each arrival pair during intermediate approach. The final approach controller is also expected to be aware of the prevailing headwind conditions on final approach and the expected impact of the headwind conditions on the TBS distance between each arrival pair.

The current minimum radar separation will remain as a constraint on final approach and the final approach controller and Tower runway controller are expected to remain aware that is this is the minimum separation that can be applied between non-wake pairs.

The final approach controller is required to apply spacing practice when merging aircraft on to final approach such that the distance spacing compression on final approach that is experienced in the prevailing conditions is proactively managed. The separation and spacing constraints represented by the Indicator are required to be respected from aircraft being turned on to merge on to the localiser until the aircraft crosses the runway landing threshold to touchdown.

Within the above context the following are success objectives for normal conditions:

1. Each aircraft is turned to merge on to final approach observing the separation and spacing minimum constraints represented by the Indicator
2. Each aircraft is merged on to final approach with the appropriate spacing for the distance spacing compression that will be experienced to the aircraft in front in the prevailing conditions, until the aircraft in front crosses the runway landing threshold to touchdown, for observing the separation and spacing minimum constraints represented by the Indicator

Within the above context the following are success criteria for abnormal conditions. Abnormal conditions include aircraft emergencies, unplanned runway changes, sudden change in runway visibility, unforeseen runway closure, sudden significant change in final approach wind conditions and failures (human or technical) external to the TBS concept:

1. In abnormal conditions where it is no longer possible to continue the approach on to the landing runway, and it is not possible to switch to a parallel runway, the arrival aircraft on final approach are directed on to a missed approach
2. In abnormal conditions where it is no longer possible to continue the approach on to the landing runway, and it is possible to switch to a parallel runway, the arrival aircraft is switched to the parallel localiser
3. In abnormal conditions that unexpectedly induces additional distance separation compression, timely controller intervention is carried out to prevent separation infringement or when possible, to restore separation as soon as possible when there is separation infringement

4. In abnormal conditions that unexpectedly induces additional distance separation compression such that unrecoverable infringement results, the follower arrival aircraft is directed on to a missed approach

3.3 Failure safety objectives

A functional hazard assessment will need to be done on success safety objectives to derive failure safety objectives and safety requirements. This can't be done for the initial SPR due to needing to mature the AIM - Wake induced accident model. A workshop is already planned for 7th December 2011 to update the AIM with 16.6.1 team and a group of wake turbulence experts.

A set of Failure Safety Objectives may be established in relation to quantified degrees of separation or spacing infringement, for example:

1. Up to 0.5NM infringement
2. 0.5NM to 1.0NM infringement
3. Over 1NM infringement

The steps in the quantified degrees of separation or spacing infringement may be dependent on the changing risk impact on each of the accident types identified as being impacted by TBS in §2.2.1.

These infringement scenarios will need to be considered for all arrival pairs, both the pairs requiring wake turbulence separation above the 2.5NM minimum radar separation, and spacing minimum pairs. For spacing minimum pairs there may also be a need to consider the application of reduced separation in the vicinity of the aerodrome below the 2.5NM minimum radar separation.

The Failure Safety Objectives are to be considered within the context of the TBS tool support and the displayed indicators, considering all of the operational performance scenarios:

1. Operating as intended correctly displaying the separation or spacing constraint for each arrival pair.
2. Not operating as intended and incorrectly displaying less that the required separation or spacing constraint for some arrival pairs
3. Not operating as intended and incorrectly displaying more than the required separation or spacing constraint for some arrival pairs

The quantified degree of incorrect operation of the displaying of the indicators may need to be taken into account when establishing the Failure Safety Objectives, for example:

1. Up to 0.5NM divergence
2. 0.5NM to 1NM divergence
3. More than 1NM divergence.

The Failure Safety Objectives are to be considered in the context of the combined controller/pilot spacing performance in relation to the displayed indicators:

1. The spacing performance distribution from over spacing to under spacing in relation to the displayed indicators.

The Failure Safety Objectives for normal operations may then be expressed in the form of the following (term quantified means that values are yet to be determined in the future safety assessment process):

1. The percentage of TBS wake turbulence separation pairs turned on to merge on to final approach with <quantified> wake turbulence separation infringement shall be <quantified comparison with the percentage of DBS wake turbulence separation pairs with <quantified> wake turbulence separation infringement observed in current operations.
2. The percentage of TBS wake turbulence separation pairs with <quantified> wake turbulence separation infringement on final approach to the runway landing threshold shall be <quantified comparison with> the percentage of DBS wake turbulence separation pairs with <quantified> wake turbulence separation infringement observed in current operations.

3. The percentage of TBS spacing minimum pairs turned on to merge on to final approach with <quantified> minimum radar separation infringement shall be <quantified comparison with> the percentage of DBS spacing minimum pairs with <quantified> minimum radar separation infringement observed in current operations.
4. The percentage of TBS spacing minimum pairs with <quantified> minimum radar separation infringement on final approach to the runway landing threshold shall be <quantified comparison with> the percentage of DBS spacing minimum pairs with <quantified> minimum radar separation infringement observed in current operations.

The Failure Safety Objectives for normal operations will need to take into account the operational performance scenarios of the displayed indicators and establish quantified objectives for each scenario:

1. The percentage with the indicators operating as intended correctly displaying the separation or spacing constraint for each arrival pair, considering the combined controller/pilot spacing performance in relation to the displayed indicators
2. The percentage with the indicators not operating as intended and incorrectly displaying less that the required separation or spacing constraint for some arrival pairs, for each quantified degree of incorrect operation of the displayed indicators, considering the combined controller/pilot spacing performance in relation to the displayed indicators.
3. The percentage with the indicators not operating as intended and incorrectly displaying more that the required separation or spacing constraint for some arrival pairs, for each quantified degree of incorrect operation of the displayed Indicators, considering the combined controller/pilot spacing performance in relation to the displayed indicators

These Failure Safety Objectives can then be considered in the context of the FHA considering:

System failures when the indicators are not operating as intended:

- Calculating the TBS Distance Failures
  - Arrival sequence order dependency failures
    - Missing arrival aircraft
    - Late arrival aircraft inclusion
    - Wrong arrival aircraft sequence order
    - Late arrival aircraft sequence order change updates
    - Incorrect tracking of missed approach aircraft
    - Late tracking of missed approach aircraft
  - Wake category/aircraft type dependency failures
    - Incorrect category
    - Incorrect aircraft type
  - Runway intent dependency failures
    - Incorrect runway intent
    - Late notification of changes of runway intent
    - Incorrect tracking of late runway switch aircraft
    - Late tracking of late runway switch aircraft
  - Glideslope wind conditions aloft or ground speed wind effect dependency failures
    - Unavailability – default to zero wind effect conditions (so that TBS greater than DBS)
    - Out of date or stale information – revert to zero wind effect conditions (so that TBS greater than DBS)
    - Incorrect wind conditions aloft or ground speed wind effect with current information
      - Up to 10kt more mean ground speed wind effect
      - Up to 10kt to 20kt more mean ground speed wind effect
      - Greater than 20kt more mean ground speed wind effect
      - Up to 10kt less mean ground speed wind effect
      - More then 10kt less mean ground speed wind effect

    (Note: 10kt ground speed wind effect error equates to ~0.25NM when converting 96s to a TBS distance)

        - Approach tracking algorithm dependency failures
            - Incorrect tracking of aircraft on to their base and intercept legs
            - Incorrect tracking of aircraft on to their intended final approach localiser
            - Incorrect tracking of aircraft on to a missed approach
            - Incorrect tracking of a late runway switch on to a parallel runway final approach localiser
        - Calculation algorithm failures
            - Look up of TBS time incorrect
            - Conversion of TBS time to TBS distance incorrect
            - Commencing calculation late
            - Not re-calculating when required
            - Re-calculating when TBS distance to remain stable
        - Interface failures
            - Incorrect TBS distance being provided for calculating the overall spacing
            - Late in updating the TBS distance to calculating the overall spacing
    - Calculating the Overall Spacing Failures
        - Minimum surveillance (radar) separation dependency failures
            - Changes to in-trail separation not being notified correctly
                - Incorrect separation
                - Late notification
            - Changes to not-in-trail separation not being notified correctly
                - Incorrect separation
                - Late notification
        - Runway spacing dependency failures
            - Changes to runway spacing not being notified correctly
                - Incorrect spacing
                - Late notification
        - Aircraft capability and approach procedures related separation constraint dependency failures
            - Not being notified
            - Incorrect notification
            - Late notification
        - Arrival sequence order dependency failures
            - Missing arrival aircraft
            - Late arrival aircraft inclusion
            - Wrong arrival aircraft sequence order
            - Late arrival aircraft sequence order change updates
            - Incorrect tracking of missed approach aircraft
            - Late tracking of missed approach aircraft
        - Runway intent dependency failures
            - Incorrect runway intent
            - Late notification of changes of runway intent
            - Incorrect tracking of late runway switch aircraft
            - Late tracking of late runway switch aircraft
        - Approach tracking algorithm dependency failures
            - Incorrect tracking of aircraft on to their base and intercept legs
            - Incorrect tracking of aircraft on to their intended final approach localiser
            - Incorrect tracking of aircraft on to a missed approach
            - Incorrect tracking of a late runway switch on to a parallel runway final approach localiser
        - Calculation algorithm failures
            - Commencing calculation late
            - Not re-calculating when required
            - Re-calculating when TBS distance to remain stable
        - Interface failures

            - Incorrect Indicator distance being provided for displaying on the radar display
            - Late in updating the Indicator distance being provided for displaying on the radar display
    - Displaying the Indicator on the Radar Display Failures
        - Approach tracking algorithm dependency failures
            - Incorrect tracking of aircraft on to their base and intercept legs
            - Incorrect tracking of aircraft on to their intended final approach localiser
            - Incorrect tracking of aircraft on to a missed approach
            - Incorrect tracking of a late runway switch on to a parallel runway final approach localiser
        - Display algorithm/logic related failures
            - Late in commencing the displaying of an Indicator
            - Incorrect calculation of Indicator display position relative to the lead aircraft target update position
            - Incorrect updating of the Indicator position
            - Late in removing an Indicator

4 Traceability matrix

Not applicable for the first release of this document.

Requirement Identification	Requirement title	Functional block Id < xxxxx >	System Function Identifier	Information Service or Application Service Identifier
TBD	*TBD*	*TBD*	*TBD*	*TBD*

Table 1: Requirement traceability matrix

5 References and Applicable Documents

5.1 Reference Documents

The following documents were used to provide input / guidance / further information / other:

[1] AIM Model
[2] TBS OSED
[3] 6.2 DOD
[4] TBS Validation plan
[5] SESAR SRM
[6] B.4.1 Performance Framework
[7] B.4.3 Architecture Description Document
[8] 16.6.1 Safety Reference Material
[9] 5.2 DOD
[10] B4.1 Validation targets – Step 1

Appendix A Quantitative safety performance objectives for definition of TBS separation minima per WT category pair

A.1 Introduction

This appendix presents a set of Complementary Cumulative Distribution Function (CCDF) curves – in other words frequency and severity curves of potential WVE - for each wake turbulence category pair. These curves are computed using LIDAR wake vortex data collected at London Heathrow airport (between October 2008 and December 2010). The curves are provided as initial set of evidence satisfying the identified safety target for both **Wake separation minima (without infringement) – Appendix A.3 and Wake spacing management with 0.5 NM separation infringements – Appendix A.4.** These curves will be updated and further explored in the course of the full safety assessment process planned for 2012. It is perhaps worth highlighting, that for the Super Heavy wake turbulence category (J) we do not seem to meet the safety acceptance criteria using the selected risk assessment approach, we do not have sufficient number of wake vortex tracks to use in the analysis. This will lead to alternative assessment methods, such as wake vortex modelling, for example in the Wake4D modelling package.

A.2 Methodology

A.2.1 WVE risk assessment scenarios

In the initial safety assessment work, the WVE risk comparison was performed by assessing the likelihood for a wake to be alive (=survival) in the flight path at the spacing at ICAO Distance Based Separation minima in low wind (0 to 5 kt total wind) vs. TBS separation minima in all wind conditions.

A.2.2 Approach for in-trail WVE risk quantification

Quantification of the WVE risk can be performed by measuring the wake turbulence which is alive in a defined specific area and timeframe of a reference scenario at a given location and in given conditions (to be reasonably pessimistic to maximize the risk). The WV strength can be characterized by the WV circulation[3], expressed in m^2/s, and corresponds to the circular velocity of the rotating air masses. WV circulation can be measured via a dedicated Light Detection and Ranging (LIDAR) too. The combination of WV measurements with corresponding aircraft, flight and weather data allows to deduce frequency distribution of WVE strength for the reference baseline case, a likelihood distribution of potential WVE for the reference TBS cases, and to generalize the results applicable for the whole specimen final approach segment, aircraft types, flight and weather conditions.

The comparison and WVE risk quantification was performed on a WT category basis (J,H,M,L), to assess the reduction of separation minima. The quantification for a specimen operational environment was done through data from a local specific operational environment (London Heathrow) but is also valid and representative for the specimen one.

A.2.3 Principles of WVE risk curve comparison

Once WV are measured in a certain spatial area, and we are able to determine the strength associated to a given age corresponding to the time / distance spacing between the generator and encountering aircraft in given weather conditions, we can plot the (logarithmic) distribution of frequency (per follower aircraft approach) of each strength value.

The principles of WVE risk curve comparison are illustrated further below.

- Distribution frequency vs. circulation strength plots for baseline case

[3] This metric was used in the A380 and WIDAO safety cases

WVE risk curve plotted for the baseline case (DBS in low wind conditions) will define the maximum acceptable WVE risk (blue continuous line), defined by the distribution of likelihood of WV strength (using WV circulation as metric)

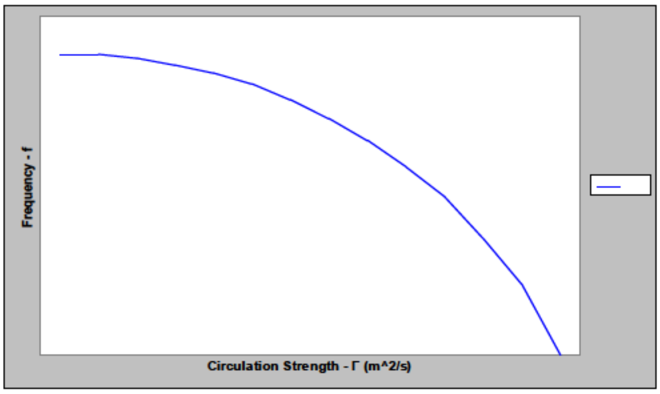


Figure 9: Schematic illustration of Log Vortex Frequency (f) vs. Circulation Strength (Γ) Plot

- Create TBS plots and compare to the reference criterion

The WVE risk curve plotted for the TBS cases (red line) will then be compared to the WVE risk curve for the baseline DBS case (blue line). To demonstrate that the likelihood of potential WVE for each given strength value is always lower or equal than the baseline the risk curves must not cross; the red TBS curves must remain within the boundary of the blue baseline curve.

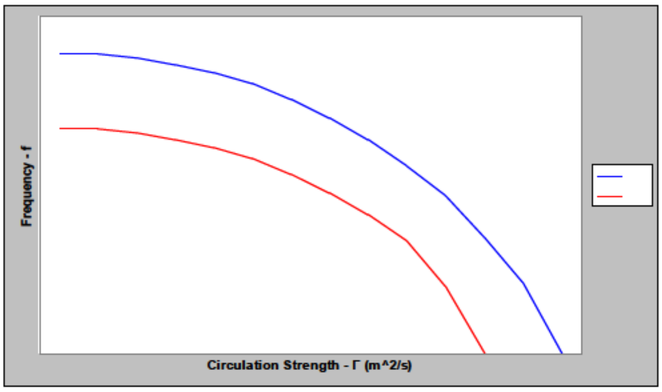
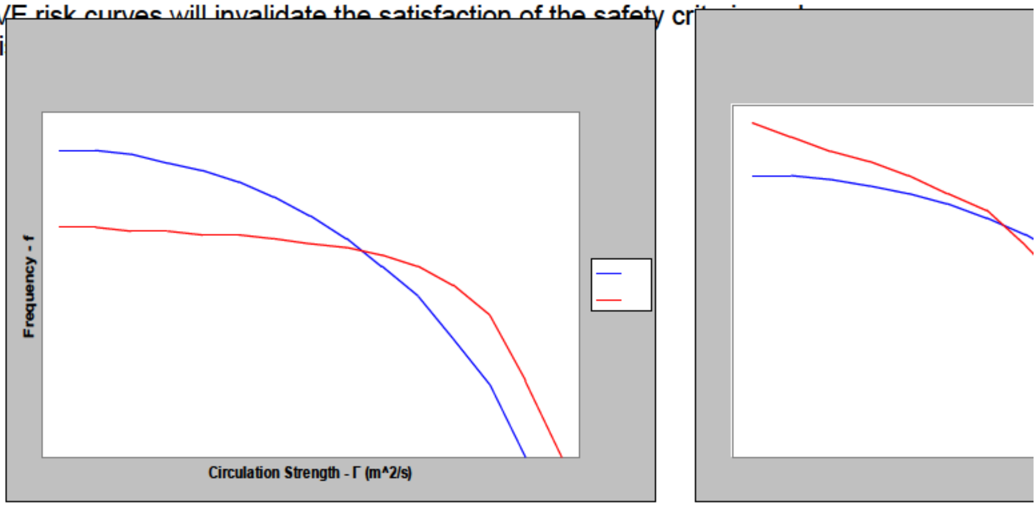


Figure 10: Schematic Example of Comparison of Baseline vs. New Concept Plot

Any crossing of the WVE risk curves will invalidate the satisfaction of the safety cri
will require additional ri



or

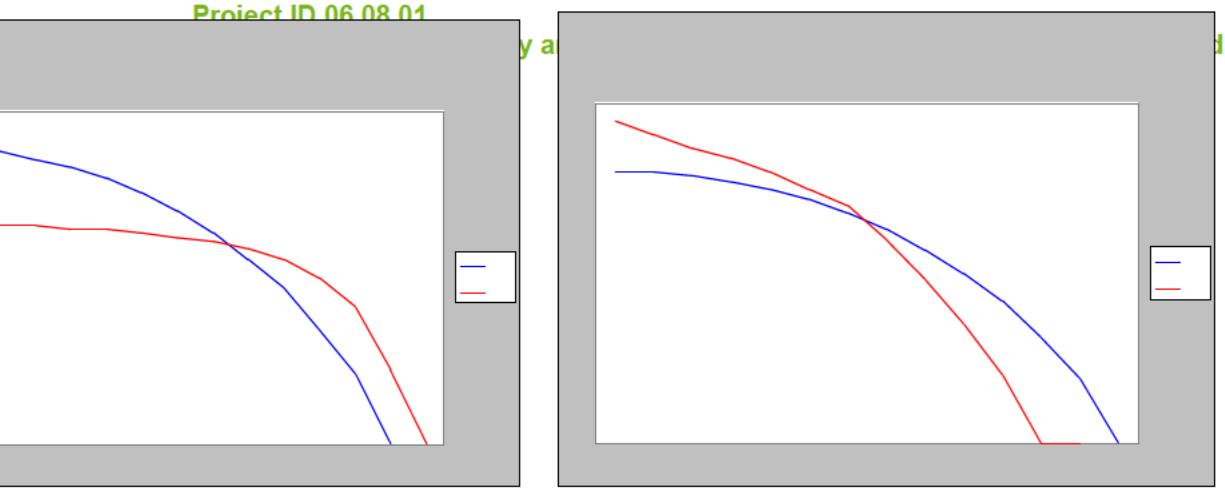
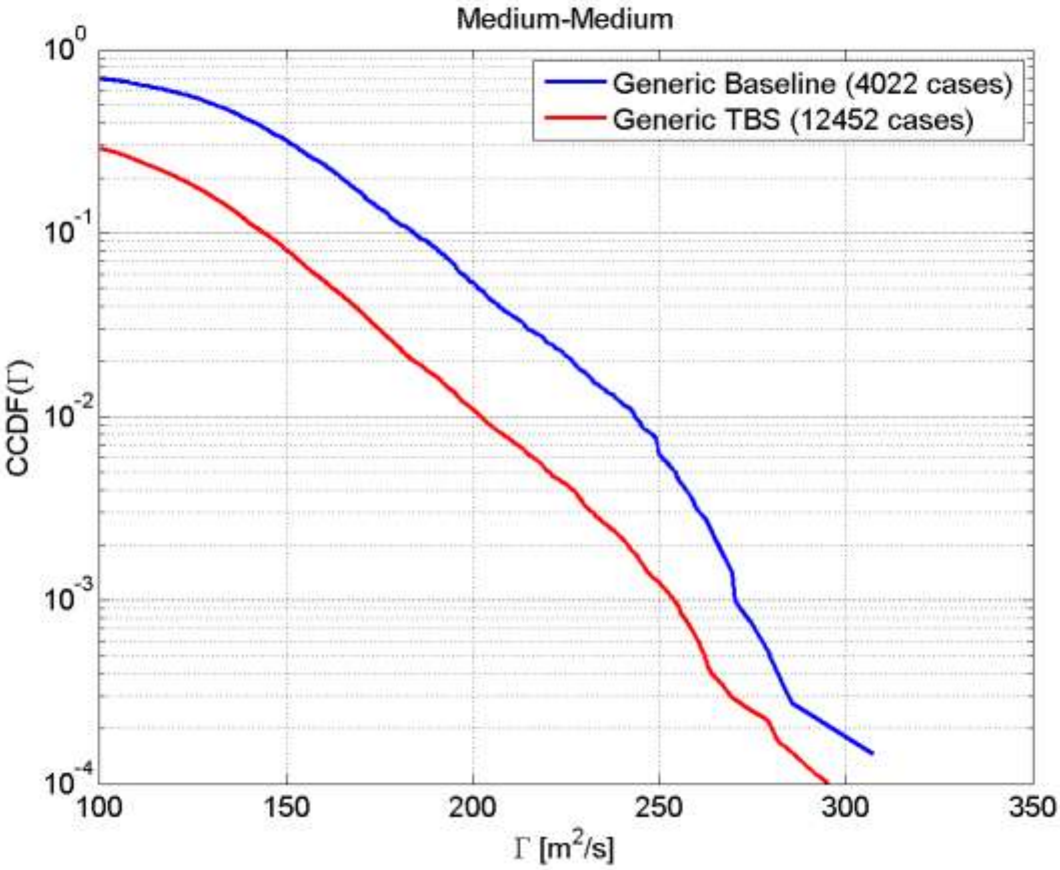


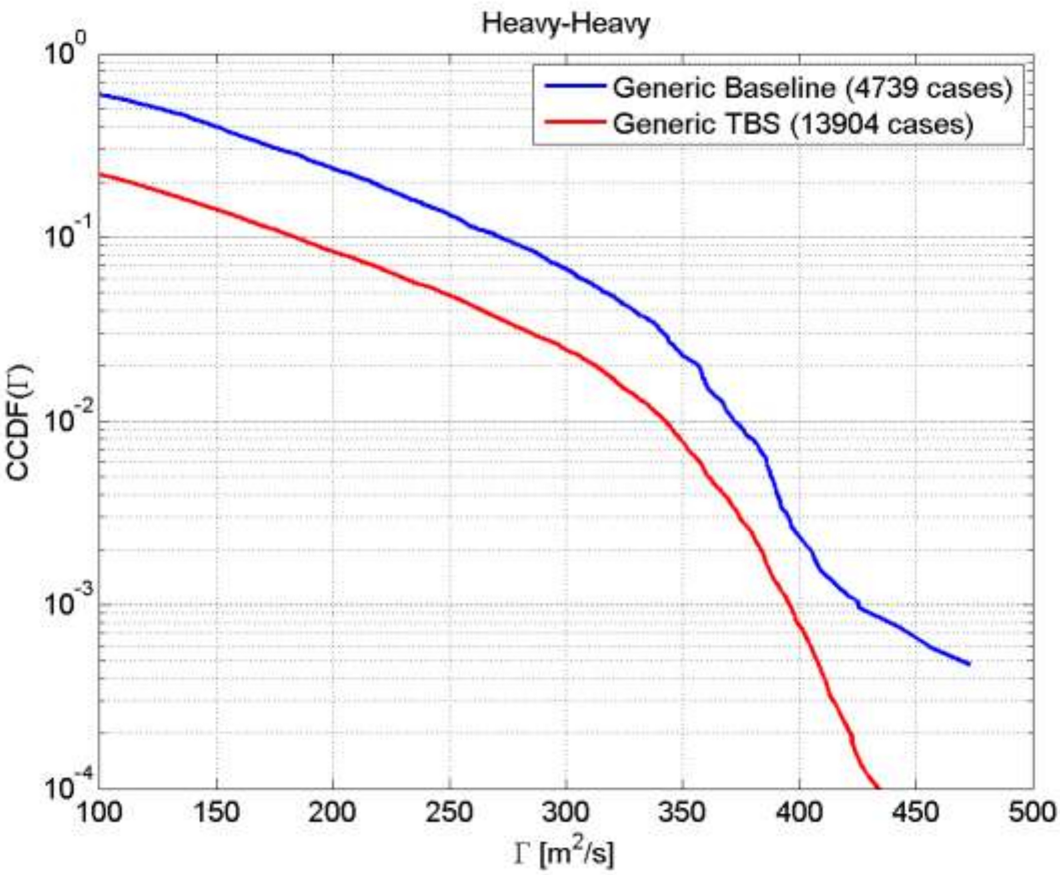
Figure 11: Schematic Example Results which would not meet the Safety Criteria

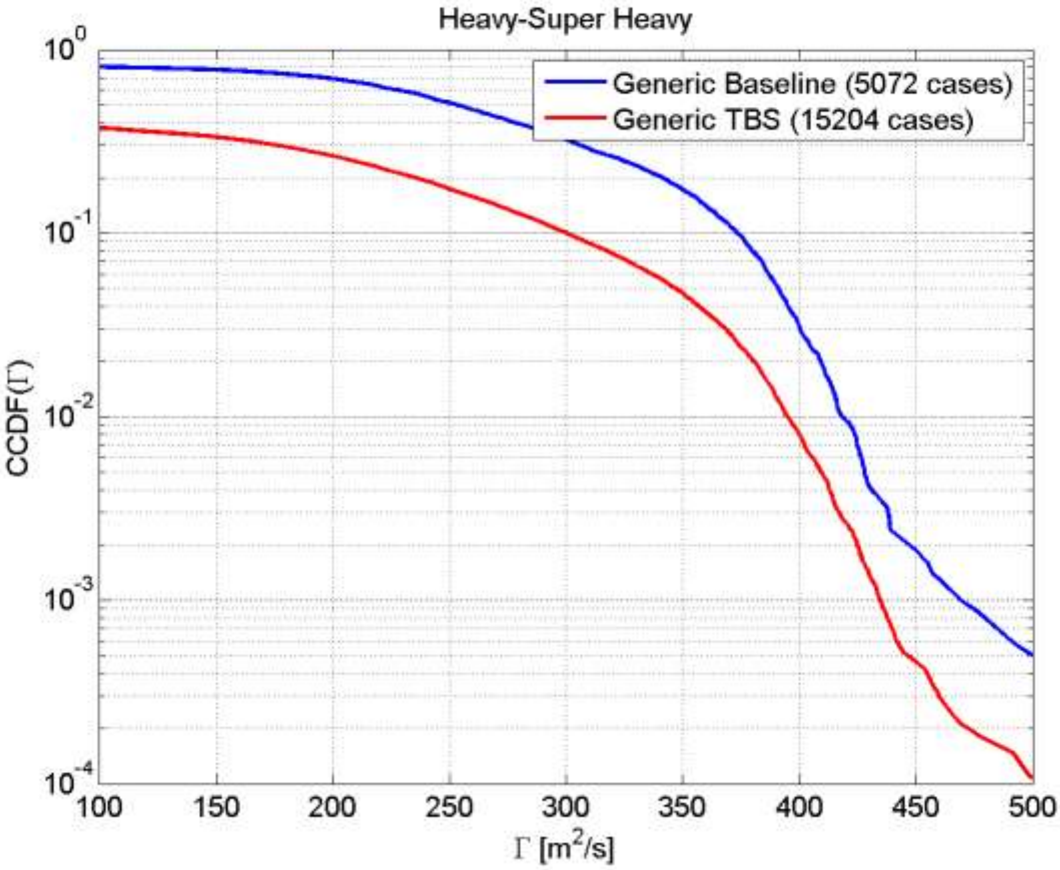
A.3 Wake separation minima (without infringement)

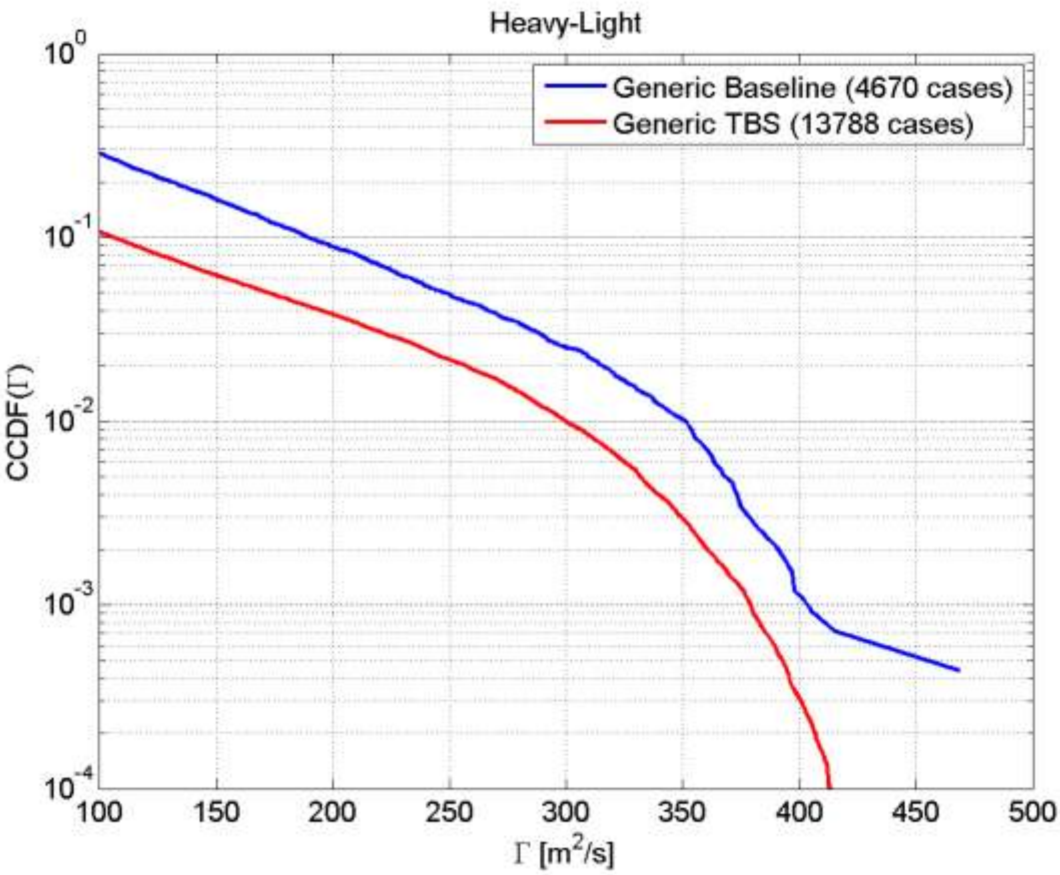
The CCDF curves for the following scenario:

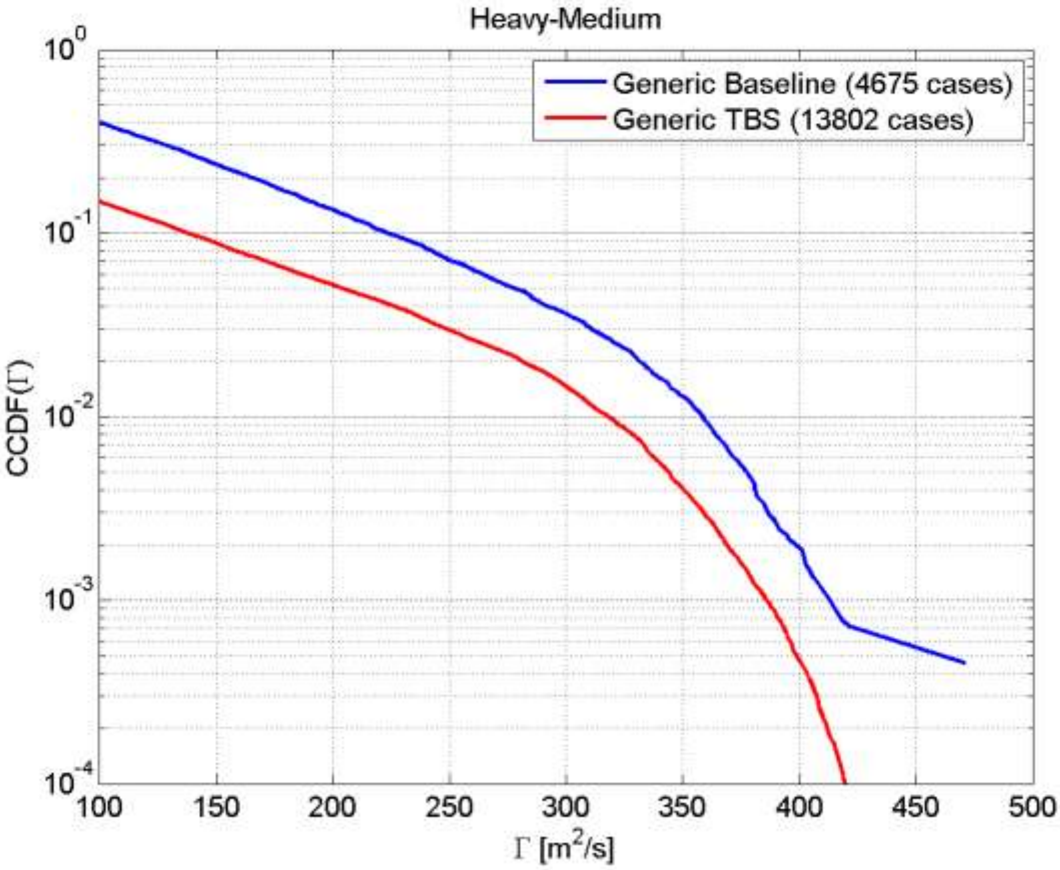
- DBS in low conditions (0 to 5 kt total wind)
- TBS without separation infringement in all wind conditions (-5 to 50 kt total wind).

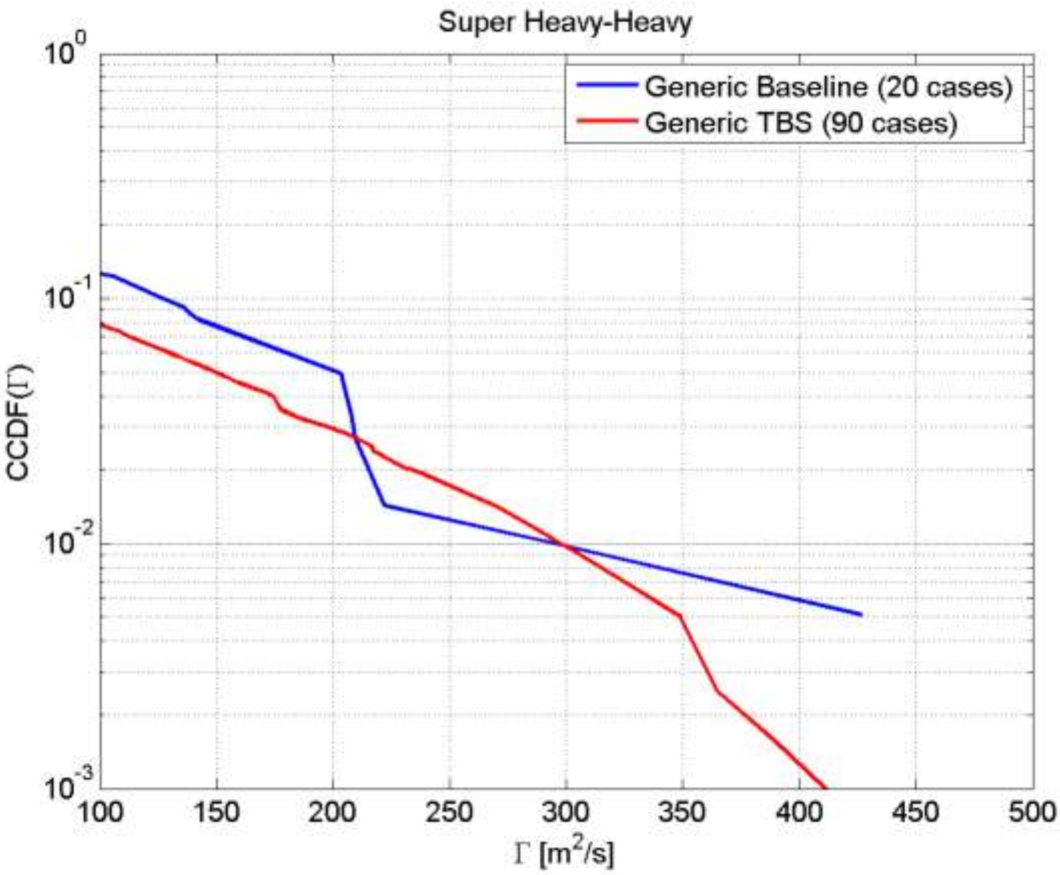

Medium-Medium
Generic Baseline (4022 cases)
Generic TBS (12452 cases)
CCDF(Γ)
Γ [m²/s]
10^0
10^-1
10^-2
10^-3
10^-4
100
150
200
250
300
350


Heavy-Heavy
Generic Baseline (4739 cases)
Generic TBS (13904 cases)
CCDF(Γ)
Γ [m²/s]
10^0
10^-1
10^-2
10^-3
10^-4
100
150
200
250
300
350
400
450
500

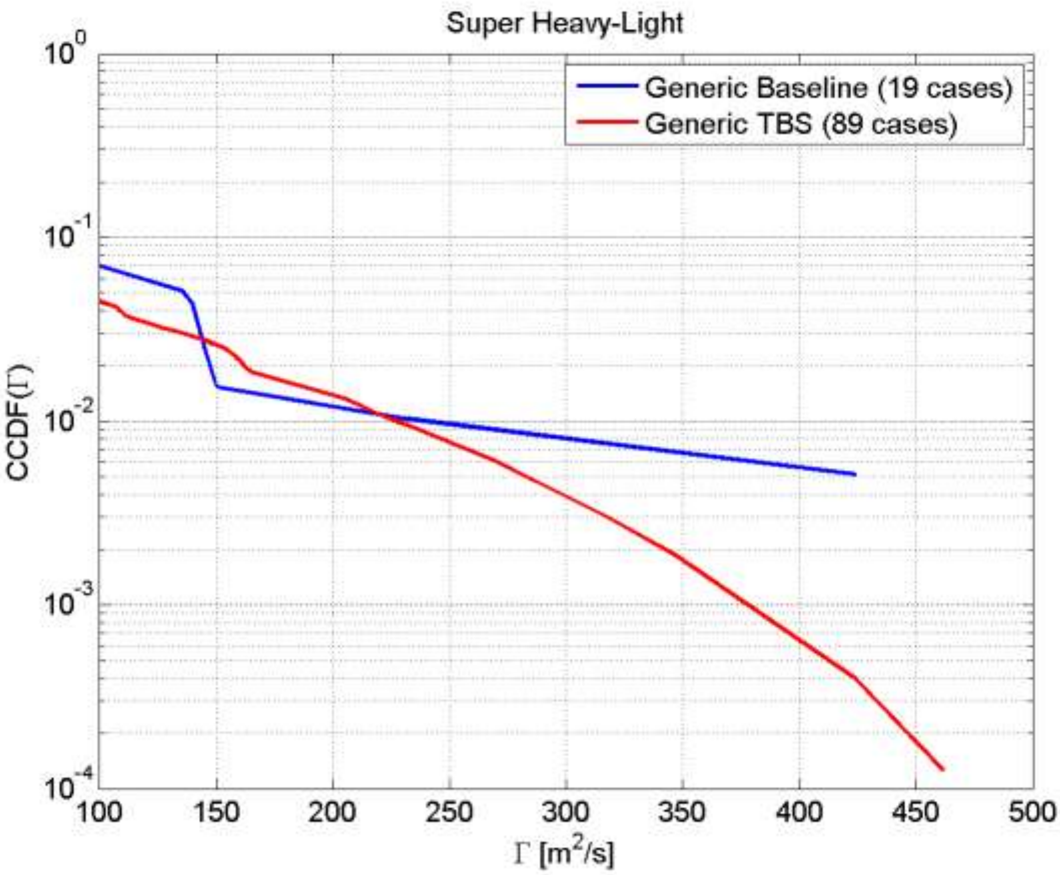

Heavy-Super Heavy
Generic Baseline (5072 cases)
Generic TBS (15204 cases)
CCDF(Γ)
10^0
10^-1
10^-2
10^-3
10^-4
100
150
200
250
300
350
400
450
500
Γ [m²/s]

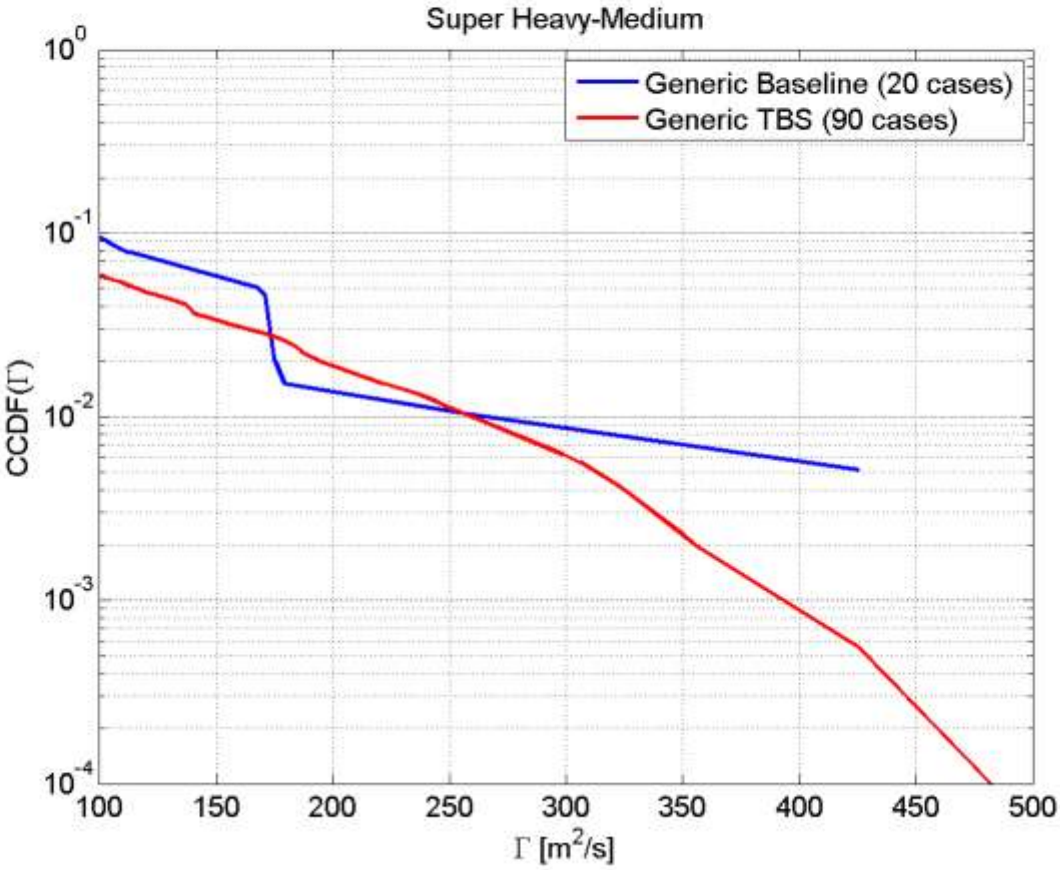

Heavy-Light
Generic Baseline (4670 cases)
Generic TBS (13788 cases)
CCDF(Γ)
10^0
10^-1
10^-2
10^-3
10^-4
100
150
200
250
300
350
400
450
500
Γ [m²/s]

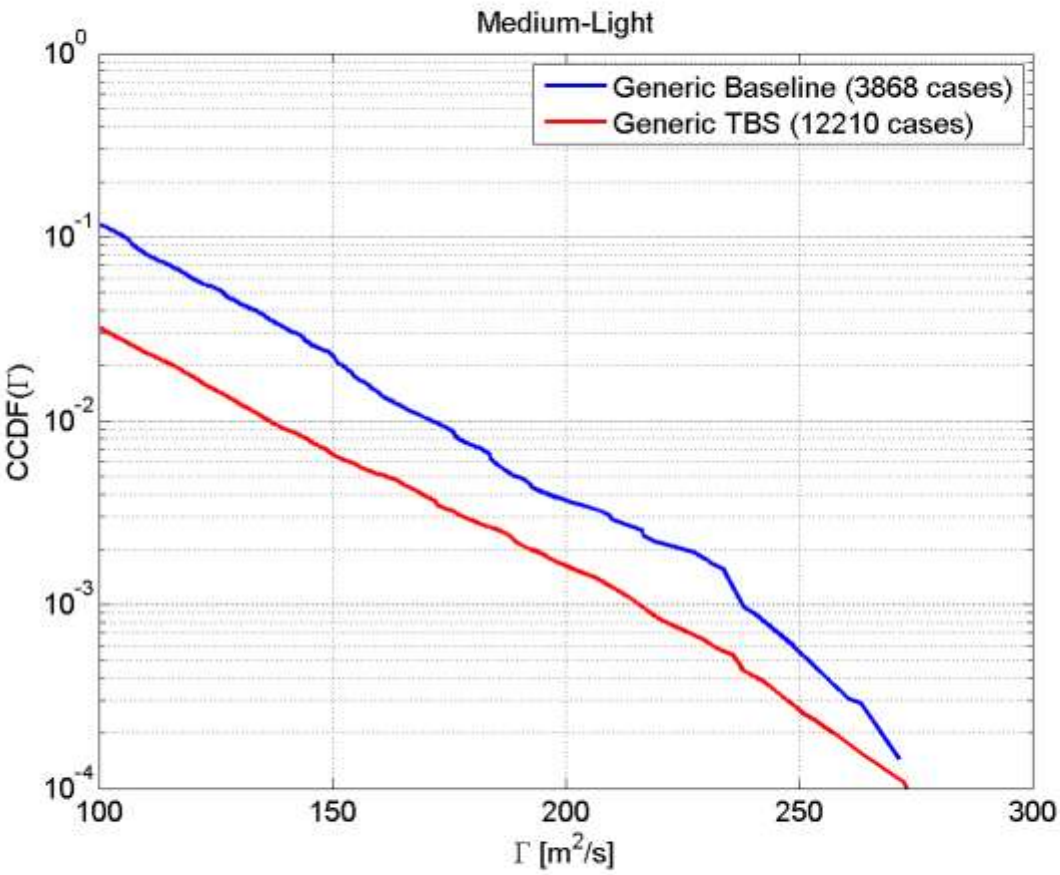

Heavy-Medium
Generic Baseline (4675 cases)
Generic TBS (13802 cases)
CCDF(Γ)
Γ [m2/s]


Super Heavy-Heavy
Generic Baseline (20 cases)
Generic TBS (90 cases)
CCDF(Γ)
Γ [m2/s]


Super Heavy-Super Heavy
Generic Baseline (25 cases)
Generic TBS (109 cases)
CCDF(Γ)
Γ [m²/s]
10^0
10^-1
10^-2
10^-3
10^-4
100
200
300
400
500
600
700


Super Heavy-Light
Generic Baseline (19 cases)
Generic TBS (89 cases)
CCDF(Γ)
Γ [m²/s]
10^0
10^-1
10^-2
10^-3
10^-4
100
150
200
250
300
350
400
450
500

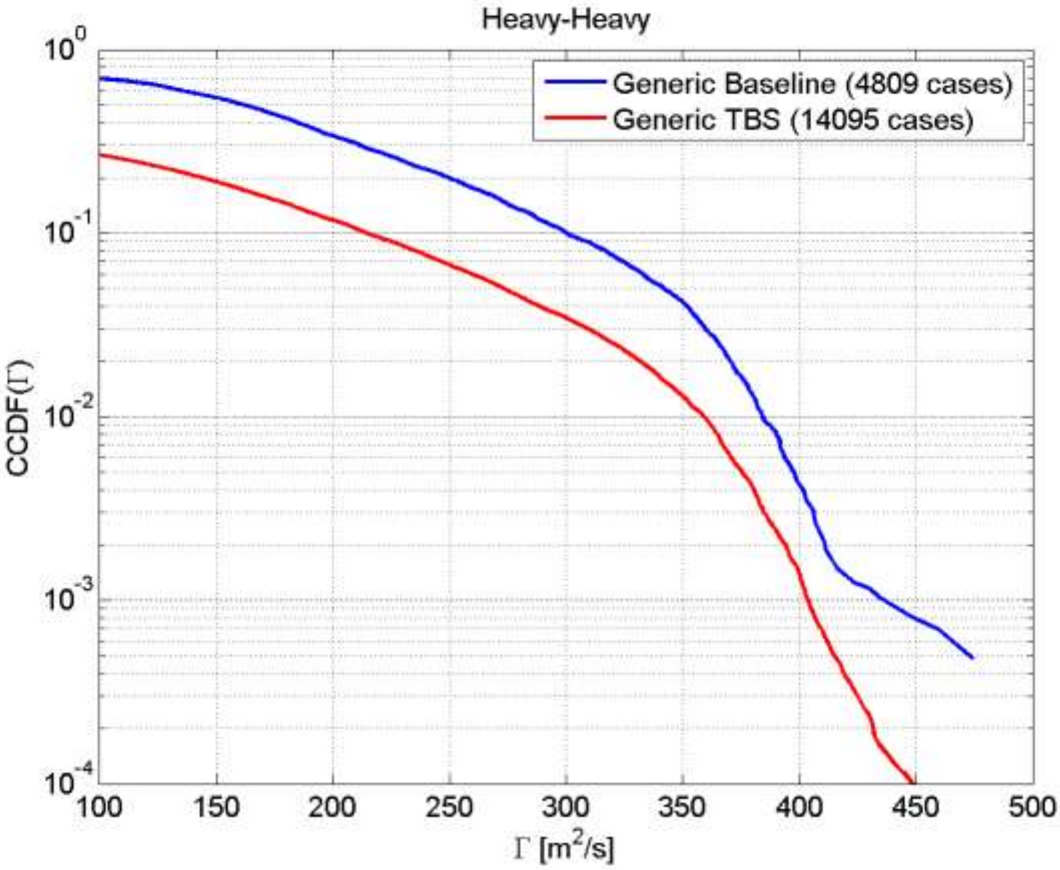

Super Heavy-Medium
Generic Baseline (20 cases)
Generic TBS (90 cases)
CCDF(Γ)
Γ [m²/s]
10^0
10^-1
10^-2
10^-3
10^-4
100
150
200
250
300
350
400
450
500

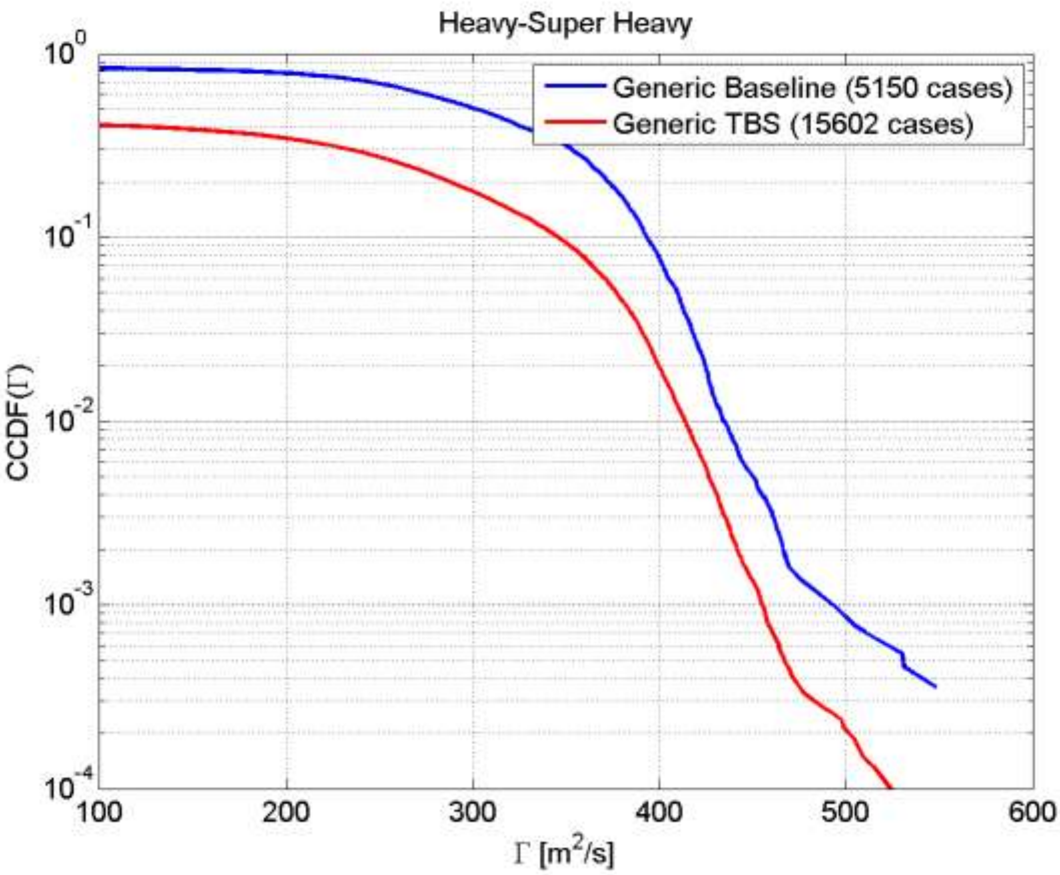

Medium-Light
Generic Baseline (3868 cases)
Generic TBS (12210 cases)
CCDF(Γ)
Γ [m²/s]
10^0
10^-1
10^-2
10^-3
10^-4
100
150
200
250
300

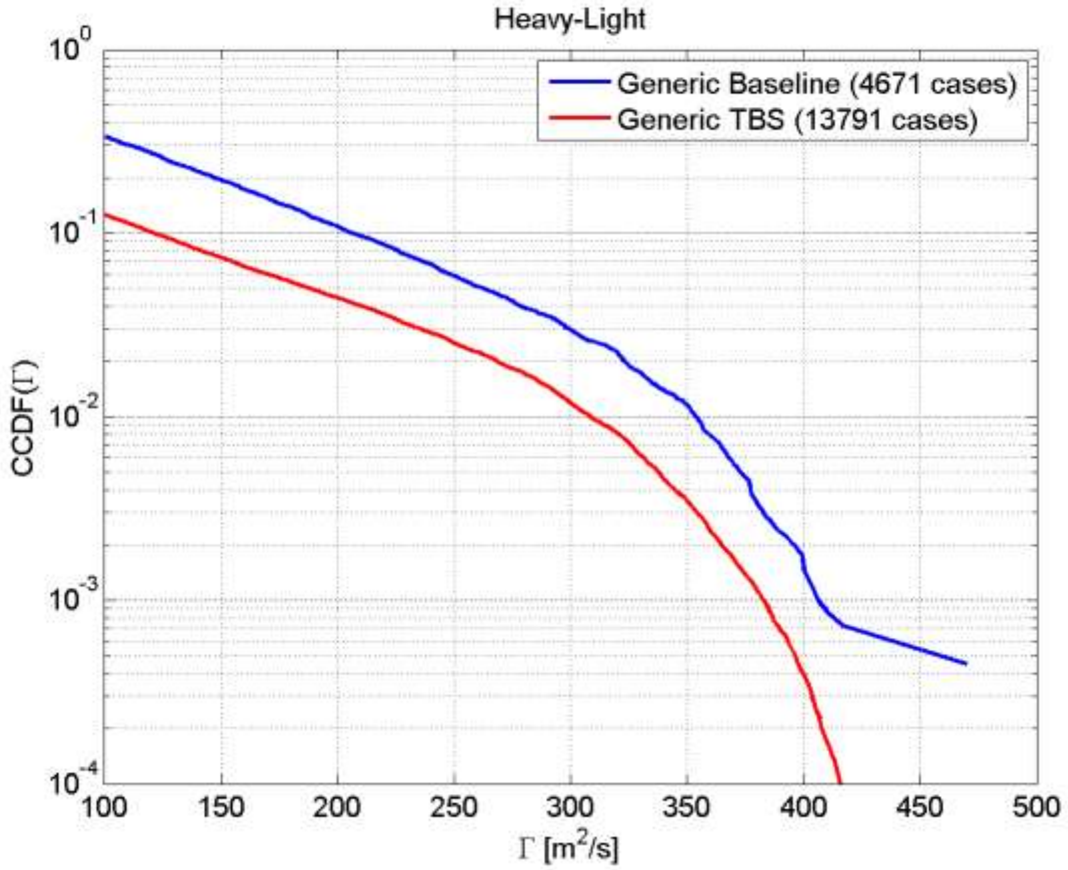
A.4 Wake spacing management with 0.5 NM separation infringements

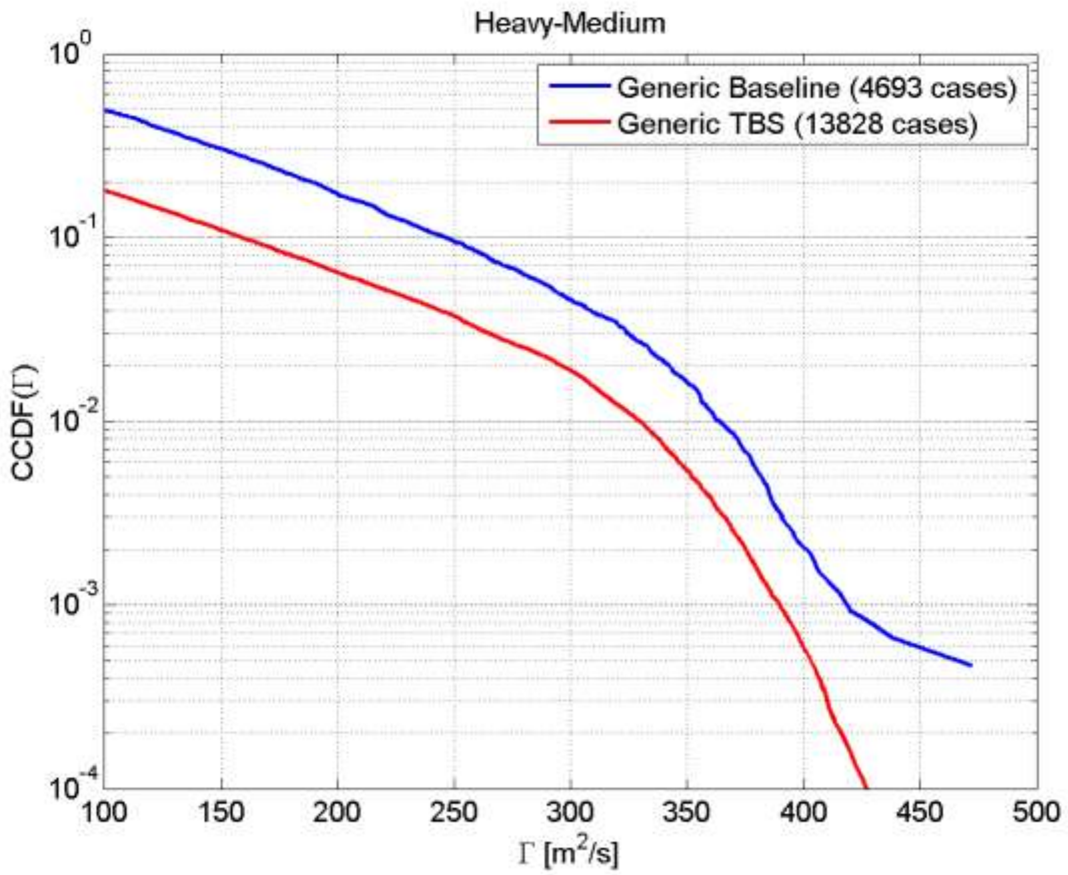
The CCDF curves for the following scenario:

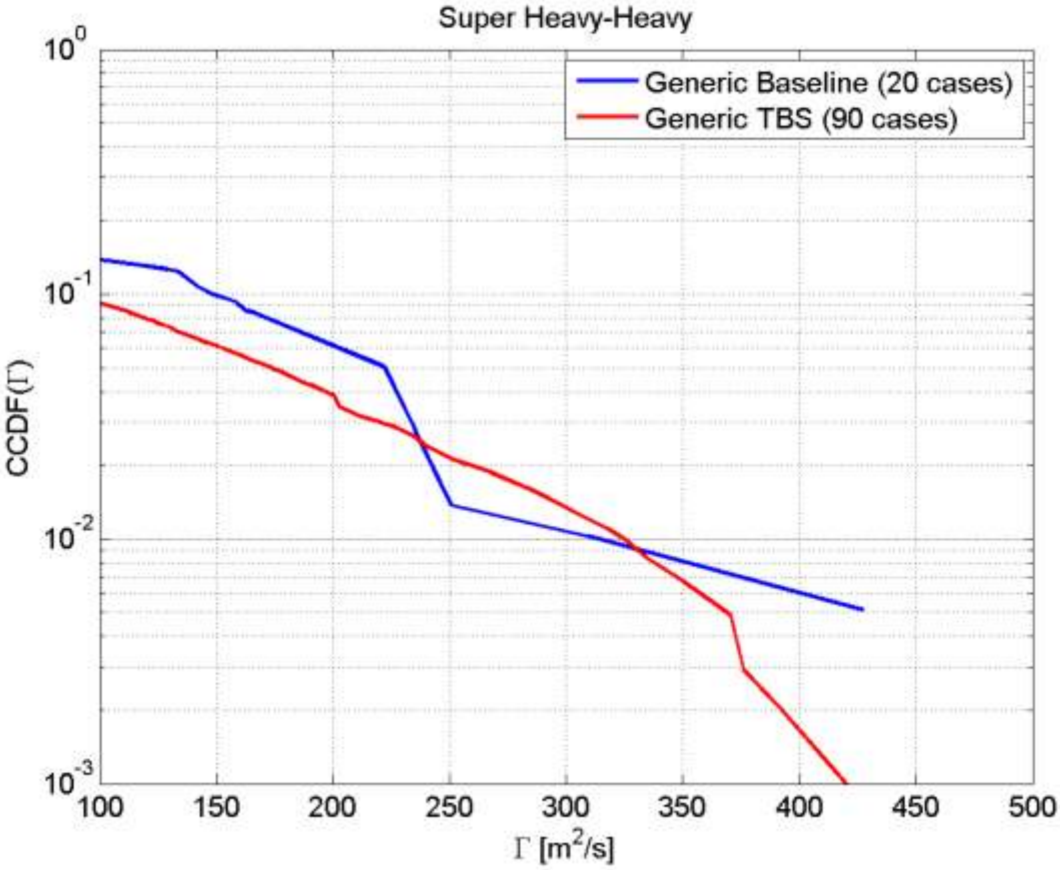
- DBS with 0.5 NM separation infringement in low conditions (0 to 5 kt total wind)
- TBS with 0.5 NM separation infringement in all wind conditions (-5 to 50 kt total wind).


Heavy-Heavy
Generic Baseline (4809 cases)
Generic TBS (14095 cases)
CCDF(Γ)
10^0
10^-1
10^-2
10^-3
10^-4
100
150
200
250
300
350
400
450
500
Γ [m^2/s]

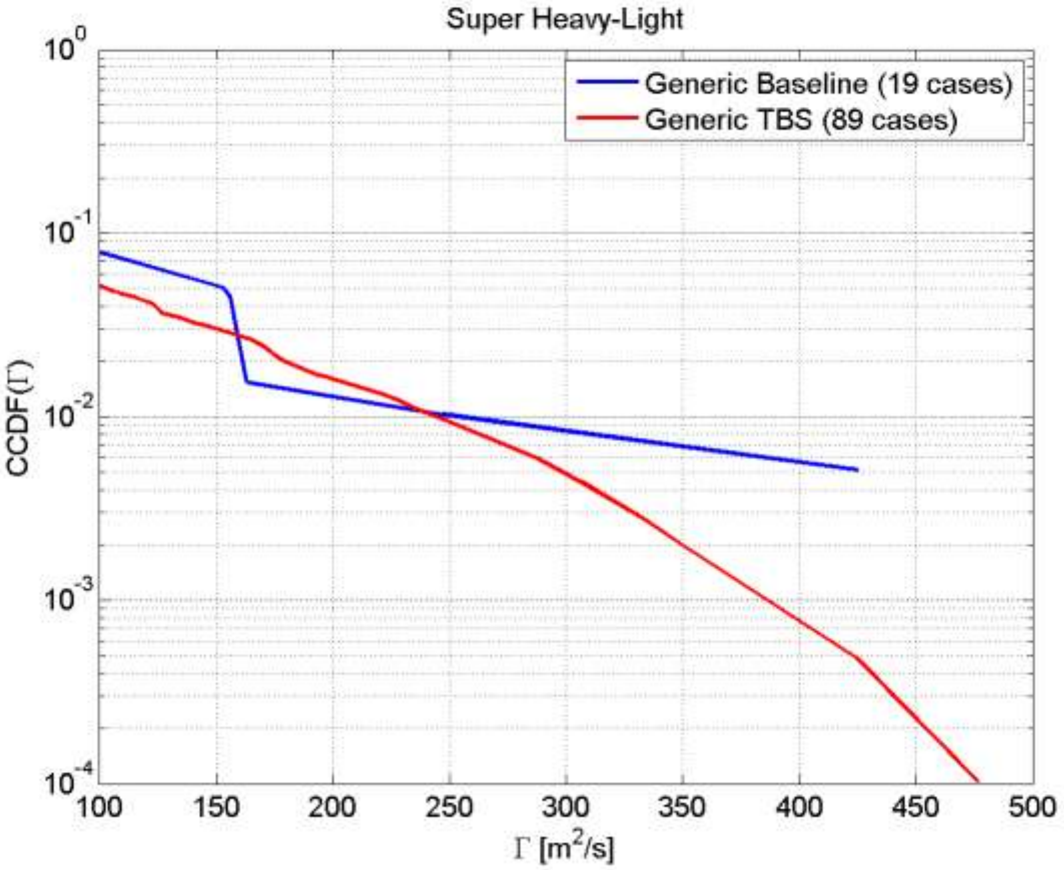

Heavy-Super Heavy
Generic Baseline (5150 cases)
Generic TBS (15602 cases)
CCDF(Γ)
10^0
10^-1
10^-2
10^-3
10^-4
100
200
300
400
500
600
Γ [m^2/s]

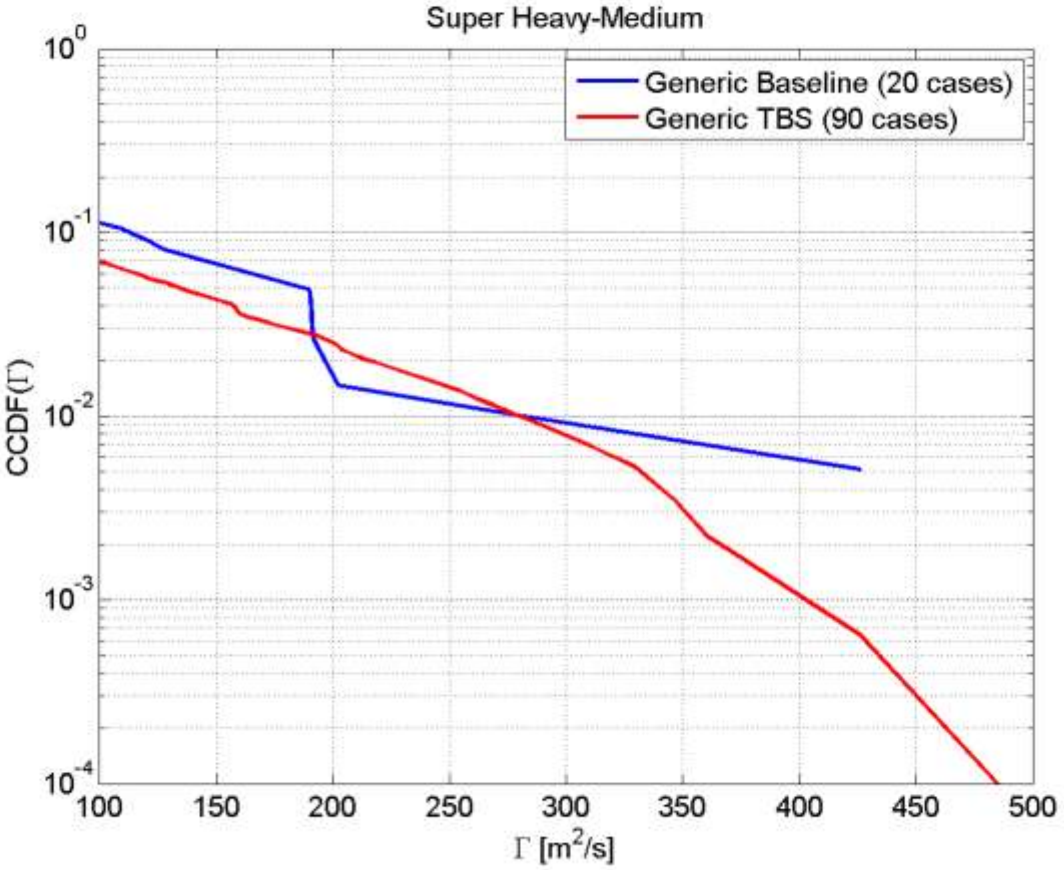

Heavy-Light
Generic Baseline (4671 cases)
Generic TBS (13791 cases)
CCDF(Γ)
Γ [m²/s]

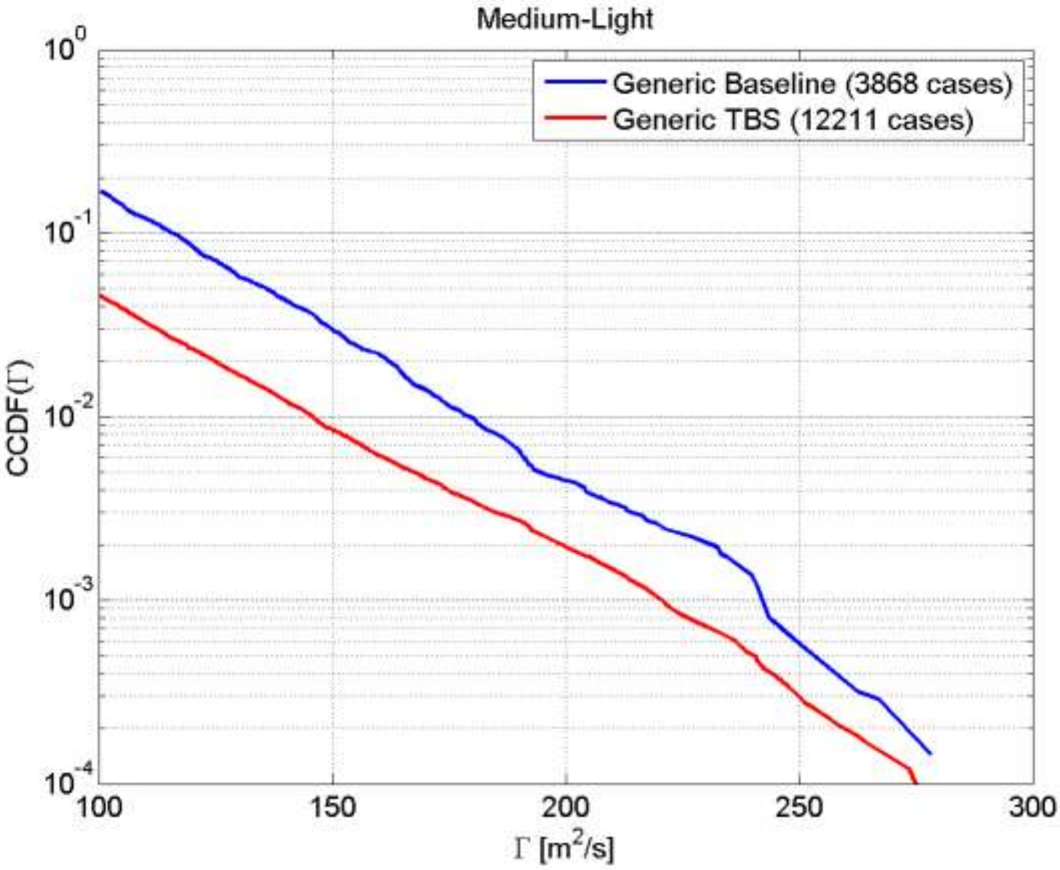

Heavy-Medium
Generic Baseline (4693 cases)
Generic TBS (13828 cases)
CCDF(Γ)
Γ [m²/s]

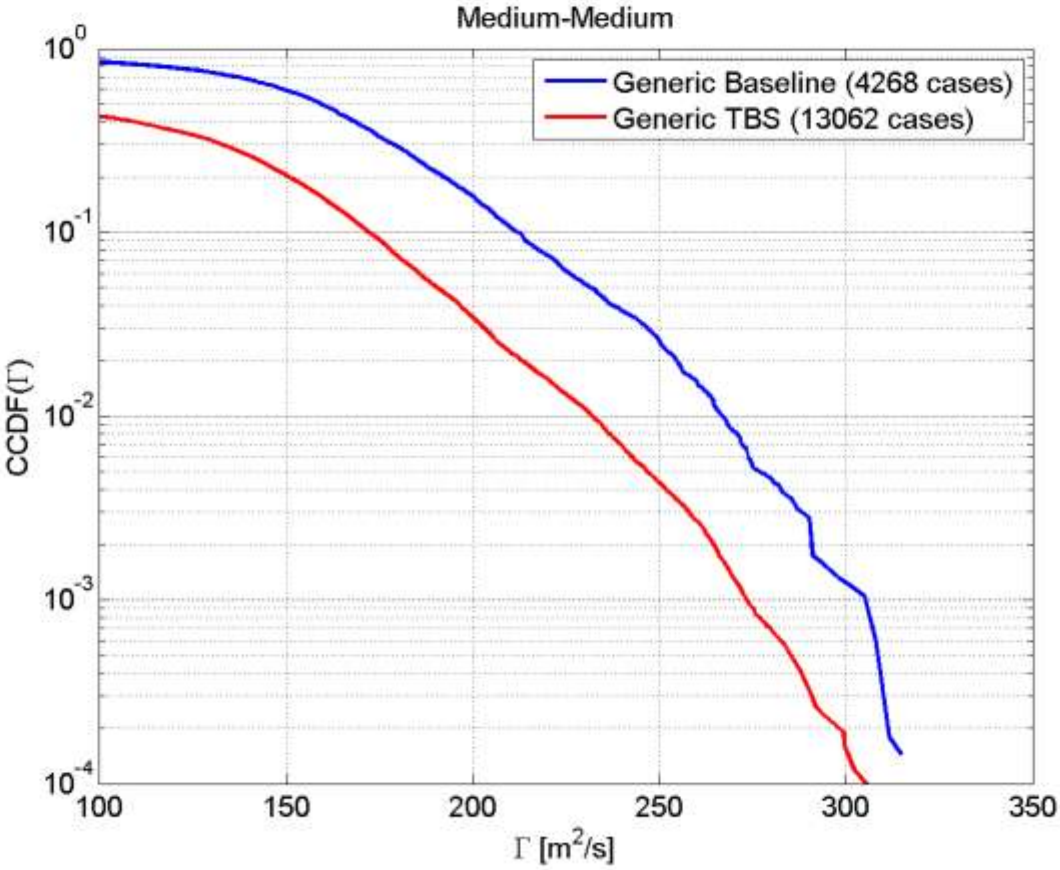

Super Heavy-Heavy
Generic Baseline (20 cases)
Generic TBS (90 cases)
CCDF(Γ)
Γ [m²/s]
10⁰
10⁻¹
10⁻²
10⁻³
100
150
200
250
300
350
400
450
500


Super Heavy-Super Heavy
Generic Baseline (27 cases)
Generic TBS (122 cases)
CCDF(Γ)
Γ [m²/s]
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
100
200
300
400
500
600
700


Super Heavy-Light
Generic Baseline (19 cases)
Generic TBS (89 cases)
CCDF(Γ)
Γ [m²/s]


Super Heavy-Medium
Generic Baseline (20 cases)
Generic TBS (90 cases)
CCDF(Γ)
Γ [m²/s]


Medium-Light
Generic Baseline (3868 cases)
Generic TBS (12211 cases)
CCDF(Γ)
Γ [m²/s]


Medium-Medium
Generic Baseline (4268 cases)
Generic TBS (13062 cases)
CCDF(Γ)
Γ [m²/s]

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