# Sector Traffic Balancing Using Tactical Demand Tailoring

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***Abstract*— The aeronautical traffic capacity is approaching its limits. This is especially true for airports where airports are constrained to resources such as runways. Consequences of full capacity traffic can be translated to delays and safety issues such as higher collisions risks. One important part of traffic are points where traffic is routed, such as transfer of flights to different ANSPs, sector changes, and merging to meter fixes for landing. There are cases where some entry points to sections are close to maximum capacity, while other entry points to the same section have more capacity. Within the framework of FF-ICE, this paper presents the operational idea of Tactical Demand Tailoring, which consists of balancing traffic by re-routing traffic hours before the arrival of aircraft to a given congested section. This paper proposes the conditions that must be met for TDT to be operationally feasible, and it discusses the potential benefits to increase capacity at overloaded parts of the airspace. Results showed that flights exist under the current flight conditions that can be re-routed to increase capacity. On average, these re-routes result in an approximate 1.9% increase in flight track length. Furthermore, a real-world case study conducted at the Terminal Manoeuvring Area of Schiphol Airport demonstrates that the implementation of Tactical Demand Tailoring effectively mitigates delays.**

***Keywords-component; Traffic Management, Delays, Operations, airports, Balance Runways, Capacity***

## I. Introduction

Different modernization projects have risen in the last decade such as NextGen in the United States, and SESAR in Europe aiming to move toward performance-based navigation that will provide a safe, secure, efficient, and environmentally sustainable air transport system into the future. ICAO is also working on diverse initiatives, such as replacing the flight planning system using concepts such as the Flight and Flow – Information for a Collaborative Environment (FF-ICE) which is under development changing from when flight planning was a paper-based (not digital) and human-interpreted system without decision support tools and intended to support the vision articulated in the Global ATM Operational Concept [1]. These initiatives have been put into place also to increase cooperation between the many different parties operating in European airspace.

With this modernization in Air Traffic Management (ATM), diverse solutions are popping up to help balance the demand for tactical operations taking into account key factors such as available airside capacity of the origin and destination airports.

Within the framework of FF-ICE, this study introduces the concept of Tactical Demand Tailoring (TDT) as an innovative approach to mitigate the challenge of balancing demand in air traffic management. TDT is currently undergoing evaluation by Air Traffic Control the Netherlands (LVNL) with the objective of enhancing operational balance and capacity at airports or airspace sectors. Its primary aim is to minimize delays through the dynamic re-routing of aircraft during tactical operations.

In order to achieve an operational balance with low delays, it is required to achieve a functional system considering ground infrastructure, trained human resources and enough airspace, [2]. Therefore, the TDT approach considers that tactical influence over traffic flow is expected to allow flow management controllers and the European Aircraft Navigation Service Providers (ANSP) to influence the incoming direction of traffic flow into their area of operations allowing to balance the demand on the sectors and in the runways of the origin and destination airport. This concept can be applied to any point in the airspace where re-routing can help mitigate delays such as changing sectors.

Currently, whenever the capacity of a given airspace sector is higher than its safety limit, an Air Traffic Flow Management (ATFM) air regulation is issued to reduce traffic in the affected sector. This regulation can be translated as ground delays to release pressure on the sector. The Network Manager (NM) is the arbiter of delay in Europe. Nevertheless, the ANSP's can also be an initiating party for ATFM-delay. The ANSP issues a capacity reduction, and the NM then fairly distributes the delay to the flights in question. TDT aims to influence the decision of the ANSP's, and not that of the NM. Studies such as [3] have shown that airborne holding delays could reduce the total delay cost in Europe.

Some studies have addressed this capacity problem using Air Traffic Flow Management Rerouting Problem (ATFMRP) such as in [4] where a two hierarchical ATFRMP model taking into account airway capacity, and conflict-free trajectories., and [5] addressing airways has been carried out. In [6], the output by

CASA was improved leading to a reduction of 55% on average in the number of flights delayed more than 15 minutes.

In [7] different separation minima were studied and a queueing model to increase airspace capacity and reduce delays taking into account automation levels was developed . In a further study, the authors determined that the airspace capacity in airports can be increased by 10% helping to reduce delays [8]. Using multi agent reinforced learning to traffic images, in [9], a way to reduce ground delays and maximize the use of airspace sectors was developed.

Another option to reduce delays can be re-routing airborne as shown in diverse studies. In [10], a systematic model for in-flight tactical re-routing reduced ATFM delays on a route subjected to adverse weather conditions was presented. It describes two forms of re-routing: dynamic and statical. The first option is easier to implement and the second one is better to reduce delays.

Others as [11], via a systematic analysis of different routes through a section of airspace, showed benefits from the tactical re-routing of airborne traffic. In [12], the potential for an algorithmic approach to in-flight re-routing was presented. The approach considered constraints in an airspace such as meteorological conditions, en-route capacity constraints and special airspace activity. It was shown that although re-routing might reduce the amount of flown track miles, travel time or fuel usage might not decrease accordingly as meteorological conditions across different route segments might vary.

In other works such as [13], a predictor of operational acceptability for route changes during a flight was developed using data mining techniques. Results indicated that the operational acceptability of a proposed re-route is becoming increasingly predictable and is expected to require human input as time progresses. In the work of [14], operationally acceptable re-routes for air traffic management when a weather event is encountered were generated. This study pointed out that metrics to determine a re-route operationally acceptable included the re-route distances, and how consistent a new route was when compared against historical routing.

However, all these efforts might still be insufficient to unload specific areas and times when capacity is pushed to its limits. Many independent ANSP's work together to form a continent-wide air traffic network in one of the world's busiest sections of airspace. The efficiency of this network is, partially, determined by the level of cooperation between ANSP's. Projects such as the Single European Sky program have been put into place to increase cooperation between the many different parties operating in European airspace.

This paper proposes a novel approach to address the demand and capacity balance issue in a practical and operational manner. A criterion was developed to evaluate diverse city pair routes to determine their feasibility for re-routing flights to alternative runways with more capacity to balance traffic. This work explores the potential benefits of the TDT re-routing approach at the airborne early stages of flights. The main contributions of this paper are to 1) describe the TDT concept for en-route aircraft, 2) evaluate the added flown nautical miles to a flight by re-routing, and 3) show preliminary capacity benefits by presenting case studies on Amsterdam Schiphol Airport (EHAM).

The rest of the paper is organized as follows. Section II explains the TDT concept, Section III explains the methodology implemented to fulfil the objectives. Results and discussion are provided. Finally, Section IV, ends with conclusions and future work.

## II. THE TACTICAL DEMAND TAILORING CONCEPT

The TDT concept consists of the tactical, in-flight alteration of the flight plans of aircraft approaching the airspace of an ANSP, or a Terminal Manoeuvring Area (TMA). This in-flight re-routing could be used to redirect traffic from a pre-planned congested airspace to a less congested airspace as in Figure 1.

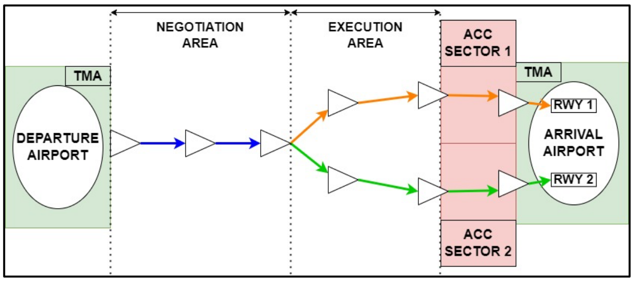


Figure 1. Schematic illustration of Tactical Demand Tailoring

In Figure 1, two different possible routes from one city-pair are shown, the orange and the green one with a common overlapping at the beginning of the trajectories shown in blue. A given aircraft can be assigned to fly the congested "green" route and later, while airborne, can be asked to switch to the less congested orange route. The point where the routes diverge is called the 'divergence point'. As the divergence point is closer to the destination airport, the window in which TDT can be applied increases. This provides the receiving ANSP with more tactical or 'short-term' influence over arriving traffic.

The proper re-routing of traffic, for example in arrivals, might help balance traffic and even help network managers reduce the number of ATFM delays, and its associated environmental benefits at European levels due to more balanced use of the airspace. As it will be discussed in Section III and IV, the selected flights to perform the re-routing are selected based on their feasibility.

A flight within the European traffic network could potentially be in contact with several ANSPs throughout its flight. Therefore, the TDT concept requires a large cooperation between different parties. Some of these parties would include neighboring ANSPs, and the Airline Operations Control Centre's (OCC's). This approach assumes that the different stakeholders within the European network collaborate to make this re-routing possible. This study assumes that the ACC's where fights are re-routed can accommodate additional traffic, i.e., the adjacent ACC has sufficient capacity to handle the traffic in question. Otherwise, the re-routing is not possible.

## III. Case Study Description

Due to the particularities of Dutch airspace, i.e., the size, and entry point of the traffic, the runway configuration and usage, etc. different ATFM measures are analyzed. The size of Dutch airspace is relatively small, time wise probably it accounts to around 30 minutes from a given flight. This means that controllers operating in this area have limited influence over the landing sequence of EHAM arrivals.

Flights at the final stage to EHAM must be navigated into a sequence before a safe landing can be conducted. This sequencing of arrivals is done by manoeuvring these aircraft within EHAM's TMA. It can be said that this sequence begins at the Approach Fix (IAF) waypoints, which are linked to specific runways. Figure 2 shows an operational situation where two runways are available: 18R and 18C using a three-IAF system linking each runway to an IAF, i.e., ARTIP to 18C, SUGOL and RIVER to 18R.

While this IAF system provides structure to the EHAM arrivals, it also limits the number of arrival routes that an aircraft can take. Also, when entering AMS-FIR, arriving air traffic does not always present itself in equal amounts from each direction causing unbalanced runway and sector utilization.

Under imbalances, re-directing traffic from the designated IAF to another IAF leading to the other runway can help correct the imbalance (Example, re-route from SUGOL to ARTIP). However, it is not as simple to re-route a flight just before arriving at one IAF location to the next as there are certain restrictions and limitations in the way, such as ATC routes and constrictions to airspace (military areas and areas with unfavourably high navigation charges).


Figure 2: EHAM IAF locations and common arrival tracks when landing on runways 18R & 18C

Rerouting with TDT outside the AMS-FIR could be helpful. This study case is used to evaluate the potential benefits of TDT on runway utilisation balance.

### *1) City Pair Identification Cluster*

The identification of city-pairs potentially viable for TDT were selected using real flight data retrieved from LVNL. City-pairs from this dataset were evaluated according to the following criteria.

Criteria 1: *Flights regularly flying to EHAM during inbound peaks.* Flights with higher amounts of traffic are considered more favourable for the application of TDT. This is due to the potential effect that applying TDT to flights from these airports might have on the division of traffic over AMS-FIR-entry points or ACC sector traffic loads. Airports responsible for larger shares of arriving traffic to EHAM have a larger impact on the balance of traffic arriving to AMS-FIR.

Criteria 2: *Select airports based on geographical-time location to EHAM*. Firstly, the distance or approximate flight time from EHAM and to the selected airport is considered. Airports located too close (around 1 hour) or too far (more than 6 hours) from EHAM are not considered suitable city-pairs. Airports relatively close to EHAM are not suitable for the application of TDT as a re-clearance to a new FIR-entry point would result in an inefficient route. Aircraft located too far away from EHAM are also not suitable for the application of TDT due to the relatively low amounts of traffic originating from these airports.

As mentioned, most of the suitable airports might not produce enough flights to create an impact in operations on their own. E.g., an airport with only one or two flights to EHAM per week. Nevertheless, this airport could be located close to other suitable airports in the same region (Example, Spain and Portugal airports). So, the traffic from multiple airports was gathered into a cluster sending traffic at the same time (peak). Considering all flights from the cluster might produce enough traffic to impact the operation of LVNL if TDT was to be applied.

### *2) Individual Flight Feasibility Selection*

All the flights from airports in each cluster were then analysed to form a final selection of suitable city-pairs inside that cluster. This individual city-pair evaluation was performed using an analysis of the route's aircraft fly from origin to EHAM. The next criteria served as guidelines:

Criteria 1: *A suitable city-pair shows different and frequent routes entering the AMS-FIR from different directions and uses different IAFs for their approach*. This is a key element as the objective is to re-balance the runway utilization. In this case, the aircraft can be sent to a more available runway. Having different routes also indicates a level of flexibility in the operation where airlines can operate different routes from the same city-pair.

Criteria 2: *Trajectory Overlapping*. Each different city-pair routes identified in criteria 1 must contain a significant amount of overlap in the first part of the flight (see Figure 1 – blue line). If the two routes diverge in the first stages of the flight, then switching from one route to another would result in inefficient operations as the aircraft flying large distances to intercept the track of the other route.

### B. *Track Length Change Computation due to TDT*

Re-routing flights may deviate flights from their optimal trajectory increasing flight distance. This implies an increase i fuel burn, CO2 emissions, and costs.

The TDT suitable city-pairs would have multiple routes along the city-pair, each passing over different IAFs when approaching EHAM. For each city-pair, 10 flight tracks were selected. Where available, 5 tracks were selected that use one IAF and 5 that use another. Routes heading to one IAF are referred as route 1 and trajectories heading to the other are referred as route 2.

The following steps are followed to compute the track length change:

1. Calculate the average track length for route 1.
2. Calculate the average track length for route 2.
3. Subtract the length of route 2 from the length of route 1 to provide the change in track length.
4. Obtain the difference percentage.

This comparison only evaluated excluded other potential influences on their operation such as navigation charges, exact fuel consumption, and extra load to the air traffic controllers.

### C. *Capacity Balancing Potential Benefits Analysis.*

It is of interest to evaluate the added flexibility by TDT suitable city. This is evaluated with a metric expressed as the number of flights from a given cluster per inbound peak that could have been re-routed to approach EHAM for landing passing a different IAF. The importance of this metric becomes evident when studying its impact on balancing runways in a practical example in the Results section.

## IV. RESULTS

In this section, the outcomes of applying the methodology guidelines to select remote airports serving EHAM airport to apply the TDT concept are presented. Initially, the selected airports and the incremental track mile from the implementation of the TDT concept are introduced. Subsequently, a detailed illustration of the TDT concept impact on runway balancing and AFTM delay reduction. Finally, a brief discussion of the operational challenges is provided.

### A. *Potential City-Pair Clusters*

The assessment of remote airports suited for the TDT was carried out applying the criteria from Section IV.A.1. Regular traffic from to EHAM based on their geographical location such as the United Kingdom area, Southwest European area, Nordic area, and the Southern Area. From those areas, the most suitable one for the application in this paper was the Southern Area. Table 1 shows which remote airports were found to be potentially suitable for the TDT.

Once the clusters are identified, the individual flight feasibility was analysed using the criteria described in Section IV.B.2. The individual track analysis of the departing airports from Table 1 revealed three categories of potentially TDT suitable airports: city-pairs suitable for the application of TDT, city-pairs unsuitable for the application of TDT, and city-pairs suitability dependent on the flight plan filed in for that specific flight.

As an example of a suitable city pair from Table 1 is the route Amsterdam Airport (EHAM) - Bari Karol Wojtyła Airport (LIBD) is shown in Figure 3 while Figure 4 presents the example of a non-suitable city-pair on the route EHAM – Milan Malpensa Airport (LIMC).

TABLE I. POTENTIALLY SUITABLE AIRPORTS FOR APPLICATION OF TDT

| Airport name | ICAO-code |
|---|---|
| Bari Karol Wojtyła Airport | LIBD |
| Catania–Fontanarossa Airport | LICC |
| Olbia Costa Smeralda Airport | LIEO |
| Milan Malpensa Airport | LIMC |
| Turin Airport | LIMF |
| Genoa Cristoforo Colombo Airport | LIMJ |
| Milan Linate Airport | LIML |
| Bologna Guglielmo Marconi Airport | LIPE |
| Verona Villafranca Airport | LIPX |
| Venice Marco Polo Airport | LIPZ |
| Rome Fiumicino Airport | LIRF |
| Pisa International Airport | LIRP |
| Florence Airport | LIRQ |
| Porto Airport | LPPR |
| Lisbon Portela Airport | LPPT |
| Geneva Airport | LSGG |
| Zurich Airport | LSZH |

Figure 3: Tracks between LIBD & EHAM passing ARTIP (righ routet) and RIVER (left route)

Flights between Bari and EHAM show that the flights on this city-pair tend to use a mixture of two routes, using two different IAFs, ARTIP (right) and RIVER (left). This Figure shows that the routes between this city-pair, regardless of which of the IAF's is used, contain a large amount of overlap diverting at a certain point over Germany. This indicates that LIBD-EHAM is a city-pair with high suitability for the application of TDT. The LIBD-EHAM city-pair will continue to the final selection of city-pairs suitable for TDT.

On the other hand, the flight LIMC to EHAM shown in Figure 4 is an unsuitable city pair. Flights along this city-pair mainly use two routes. One route makes its approach to EHAM via ARTIP, initially heading north into German airspace. The other group makes its approach to EHAM via RIVER, initially heading Northwest into French airspace. The two different routes show no overlap between them as they diverge almost immediately after departure. The lack of overlap in these tracks indicates this city-pair not suitable to apply TDT. Transitioning from a RIVER route to an ARTIP route, or vice versa, would be undesirable due to an increase in track miles flown. This causes LIMC and airports following this pattern to be excluded from the selection of city-pairs.

Finally, a flight plan dependent city pair can be seen with the airport LICC to AMS in Figure 5.

Similar to LIBD, LICC also operates both RIVER and ARTIP as preferred IAF's. However, unlike LIBD, flights from LICC are observed to take more than one route to the same IAF. Namely, this is the case when flights from this airport approach using RIVER as IAF. The middle and right sections of Figure 5 show the different approach routes taken by these flights when an approach is made using RIVER.

The middle section shows the route when passing Switzerland on the north side and the right section shows the route when passing Switzerland on the south side. This fluctuation in routes indicates that multiple routes to the same IAF are viable for the operator. When the operator has filed for a route over to ARTIP, it is sure to have filed for a route northbound of Switzerland. If a filed route passes RIVER, it is not immediately clear if the filed route passes north of Switzerland or south of Switzerland. As shown in figure 5, the route to RIVER passing north of Switzerland has a large overlap with the route passing ARTIP, overlapping all the way until passing the Austrian-German border, making it a suitable city pair.

However, if the flight filed for a route to RIVER passing in the South of Switzerland, its route would diverge from a route to ARTIP nearly immediately after take-off making this city pair unsuitable for the TDT application.

The different routes to RIVER will be indicated using the RIVER North (RIVER N) for the route northbound of Switzerland and RIVER South (RIVER S) for the route southbound of Switzerland.

Operationally, when a flight is filed for an approach over ARTIP, it could be re-routed using TDT for an approach to RIVER by instructing the flight to change its planned route from an ARTIP route to a RIVER N route. The flight would remain on its planned course until reaching the point of divergence near the Austrian-German border and pick up the RIVER N route before or at the divergence point.

Figure 4. Ttracks between LIMC & EHAM passing ARTIP and RIVER

Figure 5: tracks between LICC & EHAM passing ARTIP and RIVER

Nevertheless, when a flight has filed for a RIVER N route, and LVNL would prefer this aircraft an approach using ARTIP as its IAF, the option of applying TDT becomes dependent on what route the operator has filed for this flight. If the filed route is a RIVER route, applying TDT for an ARTIP route is possible. The operation would continue as described above when changing from an ARTIP route to a RIVER N route.

However, when a route has been filed for a RIVER S route using the most left route in Figure 5, diverging the aircraft for an approach to ARTIP becomes much less convenient. This is because the RIVER S route diverges the ARTIP route nearly immediately after take-off. Re-routing will mean a significant change for the crew and many added extra miles. This means that when LVNL desires to apply TDT to a flight from LICC filed for a route passing RIVER and wanting it to approach using ARTIP, it must first be verified if the filed flight plan overlaps as in the two most eastern routes. City-pairs such as LICC-EHAM will continue to the final selection of city-pairs suitable for the application of TDT.

After classifying the routes, Table II shows the remaining 11 suitable city pairs (67%) for this cluster.

TABLE II. AIRPORTS SUITABLE FOR THE APPLICATION OF TDT

| Airport | ICAO-code |
|---|---|
| Bari Karol Wojtyła Airport | LIBD |
| Catania–Fontanarossa Airport | LICC |
| Milan Linate Airport | LIML |
| Bologna Guglielmo Marconi Airport | LIPE |
| Verona Villafranca Airport | LIPX |
| Venice Marco Polo Airport | LIPZ |
| Rome Fiumicino Airport | LIRF |
| Florence Airport | LIRQ |
| Porto Airport | LPPR |
| Lisbon Aiport | LPPT |
| Zurich Airport | LSZH |

## *B. Track Length Change Comparison due to TDT*

An analysis of the change in track length for all previously selected city-pairs is shown in Table III following the methodology in sub-Section IV. B.

Results showed that this change is nearly negligible for most analyzed city-pairs. Except for two city-pairs from Portugal, no change in track length exceeds 2,5%, with most city-pairs having a change smaller than 1%. Thus, increase in NM flown by applying TDT is unlikely to outweigh its potential benefits to the whole operation. Even considering these two cases, the change to track length is of 1.9 % on average.

TABLE III. TRACK LENGH ANALYSIS OF SUITABLE CITY-PAIRS

| Airport | ICAO-code | Change to track length (%) |
|---|---|---|
| Bari | LIBD | 0.80% |
| Catania | LICC | 0.10% |
| Milan Linate | LIML | 1.40% |
| Bologna | LIPE | 1.30% |
| Verona | LIPX | 0.40% |
| Venice | LIPZ | 0.70% |
| Roma Fiumicino | LIRF | 0.30% |
| Florance | LIRQ | 1.50% |
| Porto | LPPR | 6.20% |
| Lisbon | LPPT | 5.80% |
| Zurich | LSZH | 2.40% |

## *C. Estimating the capacity balancing potential of TDT*

The found suitable city-pairs for the application of TDT combined with historical LVNL traffic data was used to create an estimate of how many aircraft could be re-routed during an inbound peak.

Re-routing 3 to 4 flights inside one inbound peak from one approach direction to another could have considerable benefits to the operation. One of these benefits is the amount of ATFM-delay produced by capacity regulation issued by LVNL over its IAF's. This will be presented next via a realistic example where a ATFM-delay capacity regulation over the IAF ARTIP was issued and could have been avoided by applying TDT.

On the 15th of May 2022, regulations reducing traffic flying over ARTIP to 30 aircraft per hour between 12:50 and 14:00 was issued at 10:11. This was decided given the predicted traffic over ARTIP obtained at 10:10 as in Figure 6.


Figure 6: Predicted Traffic Over ARTIP at 10:00

In Figure 6, each bar in this graph represents the traffic inside 20-minute window, with a 5-minute change to this window from one bar to the next. The highlighted bar in this graph shows that on this day between 12:55 and 13:15, approximately 18 aircraft were expected to fly over ARTIP exceeding the advised limit for this waypoint (15 flights per 20 minutes). If traffic predictions exceed this value, it does not necessarily mean that a regulation is issued but serves more as support for the flow controller to make a decision. Another tool indicated that this amount of traffic would likely result in a delay for some of the 18 flights planned to fly over ARTIP in this 20-minute window. This means that, if no action is taken, too much traffic will be approaching ARTIP in this time window. This would require the air traffic controller of the ACC sector preceding ARTIP to manifest an in-flight delay for some of these flights.

To avoid this, at 10:11, the flow controller on duty issued a capacity regulation over ARTIP for a maximum of 10 aircraft per 20 minutes. This regulation led to several aircraft scheduled to pass ARTIP during the restricted period to receive an ATFM delay. The regulation resulted in a total of 90 minutes of ATFM delay.

The delayed flights were effectively pushed back to enter AMS-FIR at a later point in time. This reduced the demand of traffic over ARTIP, but also resulted in a change to the expected traffic demand for EHAM arrivals, from the traffic without regulation as in Figure 7 and with regulation as in Figure 8

Figure 7 shows the forecasted inbound traffic to all EHAM, before the regulation over ARTIP was put into effect. It shows that from 12:30 to 13:30 traffic demand roughly matched the capacity of EHAM, indicated with the yellow (partially dotted) line. This capacity changes depending on i.e., active runway configuration. Figure 8 shows the forecasted demand of EHAM inbounds after the regulation over ARTIP was put into effect. The yellow bars are the flights affected by the issued regulation over ARITP. The peak in traffic seen at roughly 13:45 was directly caused by the issued regulation over ARTIP, delaying the arrival of many flights. This peak in traffic exceeded the airport's maximum capacity. This led LVNL to issue yet another capacity regulation. This new regulation was issued at 10:55, restricting traffic flow for EHFIRAM between 14:00 to 16:00 and resulted in a total of 442 minutes of ATFM delay. In this situation, the issuing of a capacity regulation to ARTIP cascaded to create a total of 532 minutes of ATFM delay.

These regulations could potentially have been avoided by using TDT and re-routing traffic originating from suitable city-pairs. Between 12:55 and 13:15, from the 18 flights predicted to fly over ARTIP, 3 departed from airports suitable for the application of TDT (LIPE, LIRF and LIRQ). Re-routing these flights to approach EHAM passing RIVER instead of ARTIP would have reduced the traffic load over ARTIP from 18 to 15 flights between 12:55 and 13:15. The predicted traffic over RIVER is shown in Figure 9.

Between 12:55 and 13:15 the predicted load over RIVER was of 4 flights. This is well within the advised limits to capacity for this IAF, indicating that the three flights planned for ARTIP could be rerouted using TDT to an approach using RIVER without exceeding the advised limits. The reduction in predicted traffic over ARTIP from 18 to 15 flights between 12:55 and 13:15 might have influenced the decision made by the Flow Management controller on duty. Since the limit for traffic load over ARTIP is defined at 15 flights per 20 minutes, the predicted traffic load reached this limit, but was it not exceeded.

In the case that the TDT approach was used, and the controller had decided not to issue a capacity regulation over ARTIP, then this would have prevented the delayed departure for flights affected by this regulation. This, in turn, would have removed the necessity for the Amsterdam Flight Information Region (AMS-FIR) regulation from 14:00 to 16:00 preventing the 532 minutes of ATFM delays by only approaching to EHAM passing RIVER instead of ARTIP. According to [15], back in 2014, the cost per ATFM minute was about 100 euros. Applying TDT to this case would represent economic savings of €53.200. This cost does not include the potential costs for passengers and losses to stakeholders outside aviation by arriving too late to a destination or appointment.

A data meta-analysis of July 2019 using the suitable airports described showed that, on average, one inbound peak contained up to four aircraft originating from TDT suitable city-pairs.

*D. TDT Challenges*

The implementation of TDT would face operational challenges. These challenges would include establishing some form of communication between interrelated parties. This information sharing would likely have to be automated to some degree, as manually exchanging this information would likely result in a higher demand on operational personnel.

One of the biggest challenges might be that the stakeholders involved are expected to act in their own interest; the commercial aviation industry is partly driven by a sense of competition. Parties might be encouraged to participate by offering pertinent incentives; particularly, airlines can get benefits by exploring alternative routes with a similar performance.

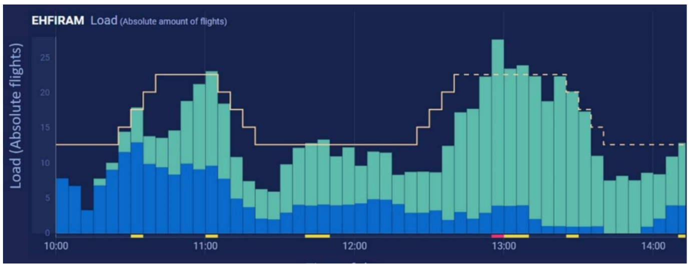

Figure 7: Traffic Prediction for EHAM Arrivals With UNactive ARTIP Regulation

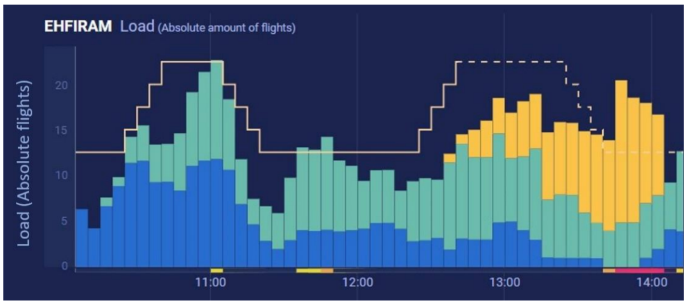

Figure 8: Traffic Prediction for EHAM Arrivals With Active ARTIP Regulation

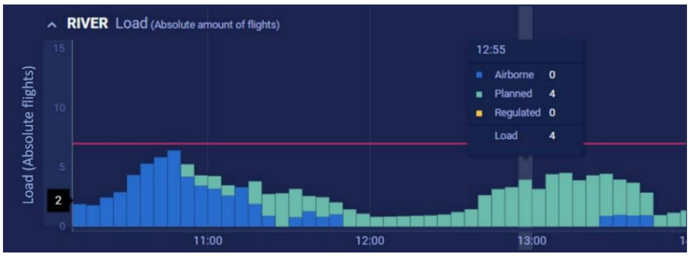

Figure 9. Prediction over RIVER

The information required to be shared to enable an application like TDT by a party is likely to be accessible to its competitors. This would necessitate the identification of what information these parties are willing to share. Currently, it is generally agreed upon by most actors in the aviation sector that operational benefits would arise if interorganisational information sharing is applied. For example, nowadays, airlines do not have all the information to propose an acceptable alternative trajectory to the NM. Likewise, the NM is missing some airline/flight specific information for decision making (ICAO, 2022). Developments for such a network are already underway. One of the networks that could support interorganisational cooperation tools, such as TDT, would be ICAO's concept FF-ICE defines information requirements for flight planning, flow management and trajectory management. Potentially, FF-ICE would allow for live real time information sharing, and hence, updates to be made to the electronic flight plan. It is likely that the airline OCC and/or the flight crew would have to approve of the re-route before it can be executed.

This study assumes that the ACC's where fights are re-routed are able to accommodate additional traffic, i.e., the adjacent ACC has sufficient capacity to handle the traffic in question, else the re-routing is not possible; in addition, the TDT application relies on real time information sharing between different parties operating in European airspace by using the ICAO concept FF-ICE, including the adjacent ACC's.

## V. Conclusion

This paper aims to explain the so-called Tactical Demand Tailoring (TDT) within the FF-ICE framework and the potential benefits of its implementation. For this purpose, the arrival flights rerouting to the AMS-FIR study case was used with the goal of balancing runway and airspace utilization.

A single city pair did not contain enough traffic to influence operations. For this reason, clustering different city pairs from geographical regions could produce enough flights to influence operations. The city-pairs suitable for a re-route analysis resulted in the identification of 11 departure airports to which TDT could be applied.

The analysis of the mile tracks showed that for flights from most of the identified city-pairs, the change to route length is negligible. Often, the change to the length of the route of these flights is on average normally below 2.5% with some punctual cases where the increment was of 5.2% and 6.2% for a total of almost 1.9% of change to track length on average.

Data on traffic from July 2019 showed that, per inbound peak, on average, up to 4 flights originating from TDT suitable city-pairs approach EHAM. This would allow LVNL to influence the direction of approach of these flights to better fit its operation. Changing the direction of approach of 3 to 4 flights could significantly reduce the amount of ATFM-delay produced by capacity regulations issued potentially saving thousands of euros of delay costs and countless human hours. Therefore, TDT would likely benefit the operation of LVNL. Further investments into research on the implementation of TDT should be made.

There are situations when it is not clear if the predicted traffic level will eventually exceed safe limits. When such a situation occurs, a flow controller might be inclined to pre-emptively issue a regulation to the sector capacity, even when uncertain if the traffic might have stayed within safe limits. However, it is assumed that if the flow controller observes that the incoming inbound peak contains about 3 or 4 flights that could be re-routed to a different ACC sector before entering AMS-FIR, then the flow controller might restrain from issuing a sector capacity regulation and instead opt to issue a re-route using TDT.

TDT becoming operational will be dependent on the willingness of parties such as airlines and ANSPs to understand the need to share information regarding operations. Further research should thus be aimed at identifying what information is necessary for TDT, what parties are involved/affected by its application, and if these parties are willing to make this information publicly available.

Efforts to focus on the operational processes with the NM manager, the adjacent ANSP's, e.g., Maastricht UAC and Karlsruhe UAC is also desirable. It is also interesting to analyze different applications as for example ANSPs sector changes.

This concept is exploratory, and the results seem promising as only a low increment of flown miles was recorded. However, further research addressing financial, safety, environmental, commercial, and operational implications for airlines and other related parties is desired.

The current work evaluated conventional routes. It would be desired to evaluate this concept using the 'free-route' concept. In addition, an enhancement on the selection framework is needed to capture in a structured manner the benefits together with clearly defined areas of performance such as punctuality (contribute to the reduction of ATFM-delay), efficiency, and predictability, to mention some.

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