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Research Article

Runway Capacity Enhancement Analysis of End-Around Taxiway at Istanbul New Airport

Emre AYDOĞAN [a,*], Cem ÇETEK [b]

[a] *Department of Air Traffic Control, Eskisehir Technical University, Eskisehir, Turkey*
[b] *Department of Air Traffic Control, Eskisehir Technical University, Eskisehir, Turkey*
** Corresponding author's e-mail address: emreaydogan@eskisehir.edu.tr*

ABSTRACT

This paper analyses the capacity effects of End-Around Taxiway at Istanbul New Airport which is planned to serve for 150 million passengers per year with the 6 independent runways when it is constructed completely. The new airport will be in service with its two independent and two dependent parallel runways after the first phase of the construction. The airport has also end-around taxiways to increase the runway capacity. End-around taxiways allow the aircraft continue to their taxi movements without the runway crossing. The runway crossing decreases the runway capacity since the crossing aircraft blocks the runway. The effects of runway crossing problem on the runway capacity are analysed in this paper. Istanbul New Airport first phase configuration is modelled with Simmod discrete event simulation tool in two different scenarios which are named baseline and alternative. The baseline scenario represents the new airport without end-around taxiways. The alternative scenario represents the same condition with end-around taxiways. The capacity problems of runway crossing are analysed and it is enhanced with the end-around taxiway usage. The analysis shows the runway capacities with and without runway crossing.

Keywords: *Air Traffic Flow and Capacity Management, Runway Capacity, End-Around Taxiways, Perimeter Taxiways and Discrete Event Simulation.*

İstanbul Yeni Havalimanında End-Around Taksi Yollarının Pist Kapasitesine Etkisinin Analizi

ÖZET

Bu çalışmada tamamlanmasıyla 6 bağımsız pisti ile yıllık 150 milyon yolcuya hizmet vermesi planlanan İstanbul Yeni Havaalanı'nda yer alan End-Around taksi yollarının pist kapasitesine olan etkileri incelenmiştir. Yeni hava alanı ilk etapta 2 bağımsız ve 2 bağımlı pist konfigürasyonu ile hizmete alınacaktır. Havaalanında aynı zamanda pist kapasitelerini arttırmak için End-Around taksi yolları da bulunmaktadır. End-Around taksi yolları uçaklara kullanılan pisti kat etmeden taksi imkanı sunmaktadır. Pist kat edişler kullanılan pistin kapasitesini azaltmaktadır. Bu çalışmada pist kat edişlerin pist kapasitesine olan etkisi araştırılmıştır. Çalışmada İstanbul Yeni Havaalanı Simmod kesikli zamanlı simülasyon ortamında temel ve alternatif senaryolar ile modellenmiştir. Temel senaryoda yeni havaalanı End-Around taksi yolları bulunmadığı varsayımı ile modellenmiştir. Alternatif

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senaryoda ise aynı durum End-Around taksi yolları varken modellemiştir. Bu sayede pist kat edişlerin kapasiteye olan olumsuz etkisi incelenmiş ve bu olumsuz etkinin End-Around taksi yolları ile iyileştirildiği görülmüştür. Analizler pist kat edişler varken ve yokken pist kapasitelerini göstermektedir.

Anahtar Kelimeler: *Hava Trafik Akış ve Kapasite Yönetimi, Pist Kapasitesi, End-Around Taksi Yolları, Çevrel Taksi yolları, Kesikli Zamanlı Simülasyon.*

I. INTRODUCTION

Air traffic volume has been increasing rapidly around the world. The total number of flights that were carried out in 2017 is 10.6 million with an increment of 4.4% compared to 2016. The overall delay per flight during the 2017 is 12.31 minutes with an increase of 9% with respect to 2016 [1]. Istanbul Ataturk Airport (LTBA) is the third of the top 20 ranking for average daily delay in 2017 according to Eurocontrol Reports [2]. The occurred delay in Ataturk Airport is mainly caused by the airport capacity as it is also stated in the report. DHMI, the air navigation service provider of the Turkey decided to build the new airport in Istanbul. It aims to increase the capacity of Istanbul for the future air traffic demand with this new airport.

The increment of the traffic amount without causing any extra delay can be possible with the simultaneous increment of air traffic management capacity. The air traffic management capacity composed of many factors such as airspace capacity, airport capacity, runway capacity, ground service capacity and air traffic service capacity etc. [3]. Airport and the runway capacity are the key parameters since all flights should start and finish at the airports. Airport capacity is affected by the number of gates, runways, ground service facilitation etc. The runway capacity is also affected by the runway and taxiway configuration. Istanbul New airport is tried to be designed with such capacity considerations. İstanbul New Airport is going to have 6 independent runways and end-around taxiways for each runways when it is completed. The end-around taxiways were designed to increase the capacities of runways with avoiding runway crossing during the operations. The new airport construction is scheduled to be completed in 4 phases [4]. The all planed phases (P1a, P1b, P2, P3 and P4) can be seen in Figure 1. The phase 1 is divided into two sub phases which are phase1a and phase 1b. The phase 1a is planned to be completed with 2 dependent and 2 independent parallel runways in 2018.

İstanbul New Airport is planned to be in service by 2018 after the completion of phase 1a. At first, two independent runways are going to be used arrival-departure, departure-arrival or the mix configuration. For all configurations, the arrival aircraft should taxi to the gates and the departure aircraft should taxi from the terminal buildings to the departure queue. These taxi movements generally require at least one runway crossing by the arrival or departure air traffics depending on runway usage configuration. The runway crossing can be eliminated with the end-around taxiways.

The end-around taxiways are specially designed taxiways that are built around the end of the runway. These taxiways allow the aircraft taxi without interfering with operations on the runway [5]. The end-around taxiways are also called perimeter taxiways. End-around taxiways not only increase the runway throughput but also decrease the potential runway incursion risk with eliminating the runway crossing. There are many analysis and applications were carried out about the end-around taxiways.

Dallas/Fort Worth international airport has been using the end-around taxiways since 2008. The entire analysis for the end-around taxiway application at Dallas/Fort Worth airport is carried out by Shan A. and Louise [6]. There is also another study that focuses the benefits of the end-around taxiways at Dallas/Fort Wort airport [7]. The usages of end-around taxiway in Atlanta, Dallas and Detroit are also analysed [8]. The environmental impact of the end-around taxiways is another point of interest for the researches [9]. These researches show that end-around taxiway is a useful method to avoid runway crossing. It has also remarkable effect on reducing delay, fuel consumption and exhaust emissions.

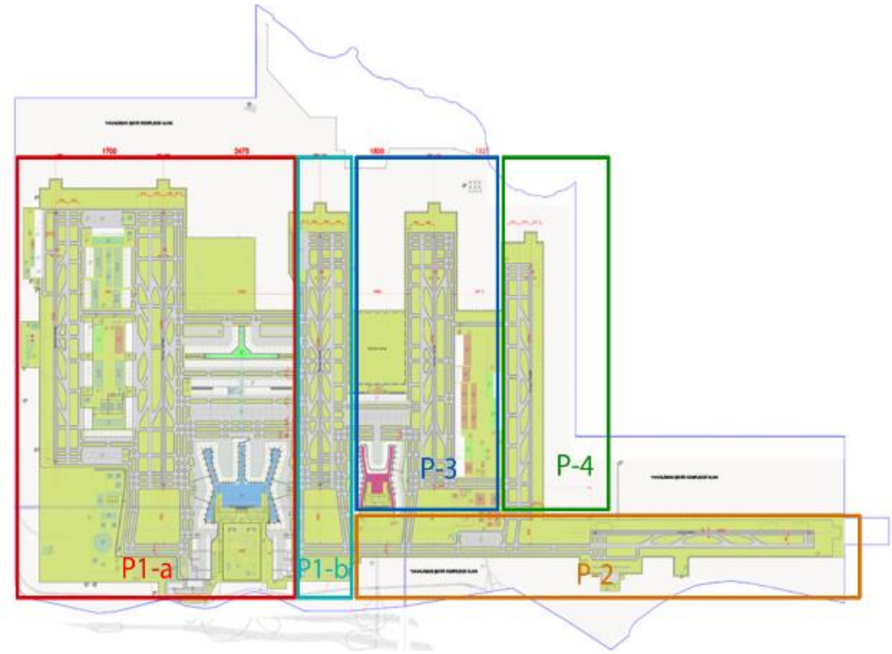


Figure 1. *The Construction Phases of İstanbul New Airport* [4].

İstanbul New Airport is planned to be built with end-around taxiways for all runways. In this way the runway crossing is eliminated to increase the runway capacity. In this study, the end-around taxiways' effect on the runway capacity of the İstanbul New Airport will be analysed. The analyses aim to clearly show the effectiveness of the end-around taxiway at the future's biggest airport in the world. All analyses were carried out according to the phase 1a final configuration. The analyses include with and without the end-around taxiway configuration of phase 1a.

II. MODELLING AND SIMULATION

The modelling parameters and the methodology will be explained here to clarify the analysis. All simulation analyses were carried on İstanbul New Airport based on its plan [4]. The all flight data in these analyses is generated data according to previous year's traffic flow information of Istanbul Ataturk Airport.

A. MODELLING OF AIRPORT

Modelling of İstanbul New Airport was carried out by Simmod Pro, a discrete event simulation tool [10]. Two scenarios were generated for the airport model. The first one is the baseline scenario which represents the two independent runway without end-around taxi ways. At this model the runway 36L was used as arrival and 36R was used as departure configuration. Since the terminal building is located right side of the 36R the arrival air traffics at 36L must cross runway 36R. This situation brings extra delay for the departure air traffics at the runway 36R. The baseline scenario model can be seen in Figure 2.

The second one is alternative scenario which is similar to the baseline scenario except it has end-around taxiways connecting 36L to the terminal buildings. In this model, arrival traffics of runway 36L can continue to their taxi movements without crossing runway 36R. This situation enhances the capacity of the runways since it eliminates runway crossing delay. The alternative scenario model can be seen in Figure 3.

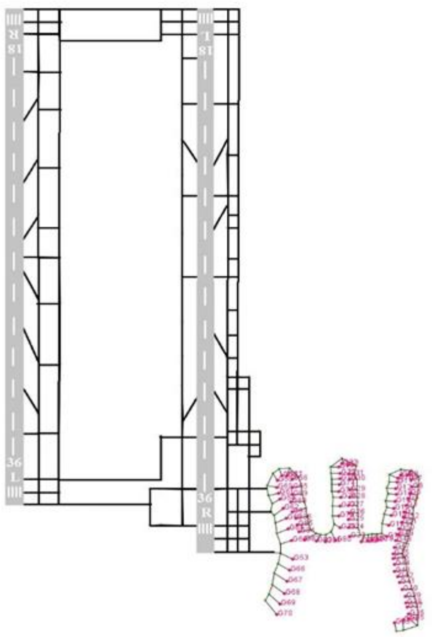


Figure 2. *The Baseline Scenario Model*

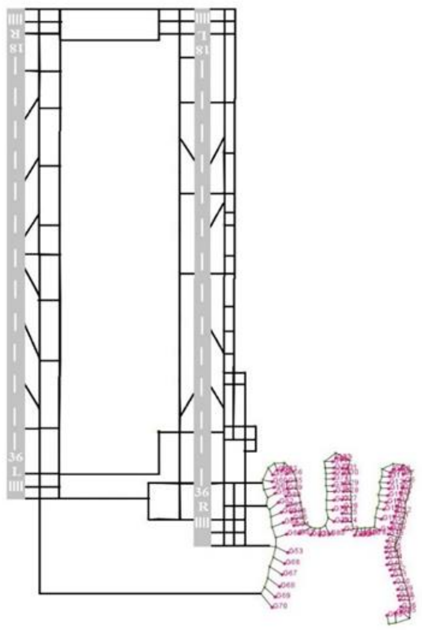


Figure 3. *The Alternative Scenario Model*

The simulated air traffic is generated exponentially for the 180 minute-simulation time. The total number of traffic is 198 aircraft which have 99 arrivals and 99 departures for the specified period of time. The aircraft can be categorised based on their simulation entry time at the Figure 4. The first and the last 44 aircraft injected to the simulation are called warm-up and cool-down traffic, respectively. The remaining 110 aircraft are referred to as the simulation traffic. Figure 4 also shows the aircraft categorization based on the simulated aircraft type. There are 3 types of aircraft model used during the simulations. Learjet 35, Boeing 737 and Boeing 747-400 are used as light, medium and heavy respectively. The category distribution of aircraft can be seen in Figure 5 for both arrival and the departure runway. The all parameters are taken the same for the baseline and the alternative scenarios. In this way the simulation focuses on the effects of the end around taxiways.

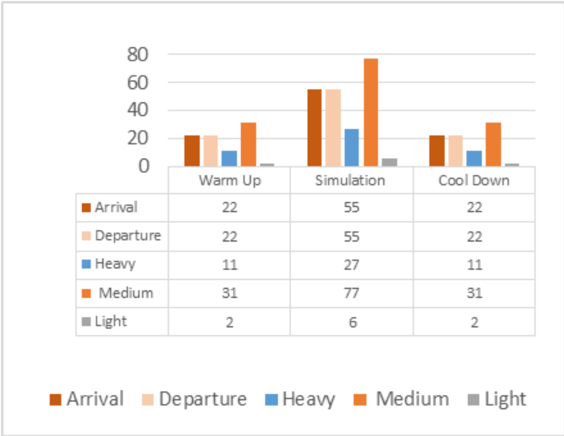


Figure 4. *The Traffic Distribution of Simulations*

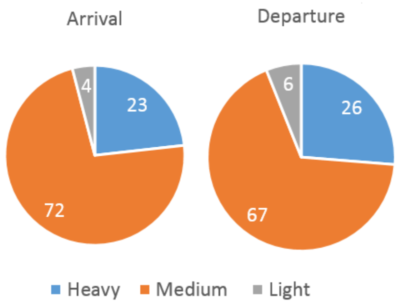


Figure 5. *The Number of Aircraft Distribution for Arrival and Departure Runway*

A. SIMULATION RESULTS

The simulation analyses were carried out between the time intervals of 12:00-15:00. The results will be given in hourly periods at these time intervals to represent the behaviour of the baseline and the alternative scenario much more precisely. The first result is the air traffic demand and flow at these time intervals can be seen in Figure 6.

The air traffic demand and flow statistics for the baseline and the alternative scenario are divided into arrivals and departures. The demand shows the number of aircraft that are scheduled to arrive or depart at the given time interval. The traffic flow shows the number of aircraft that are actually completed its arrival or departure at the given time interval. The shifted traffic represents the number of aircraft that are unable to complete its arrival or departure at scheduled time interval and shifted to the next time interval. The number of the traffic demand is the same for both scenarios. As it can be shown in Figure 6, the arrival traffic flow is the same for baseline and alternative case. It is not a surprising result because the arrival traffics is independent of the departure traffics. Arrival traffics have only additional taxing delay because of runway crossing at the baseline case during their taxi movement after their landing time. Although the taxing time of the arrival aircraft is different between the baseline and the alternative case the arrival traffic flow is the same for both scenario.

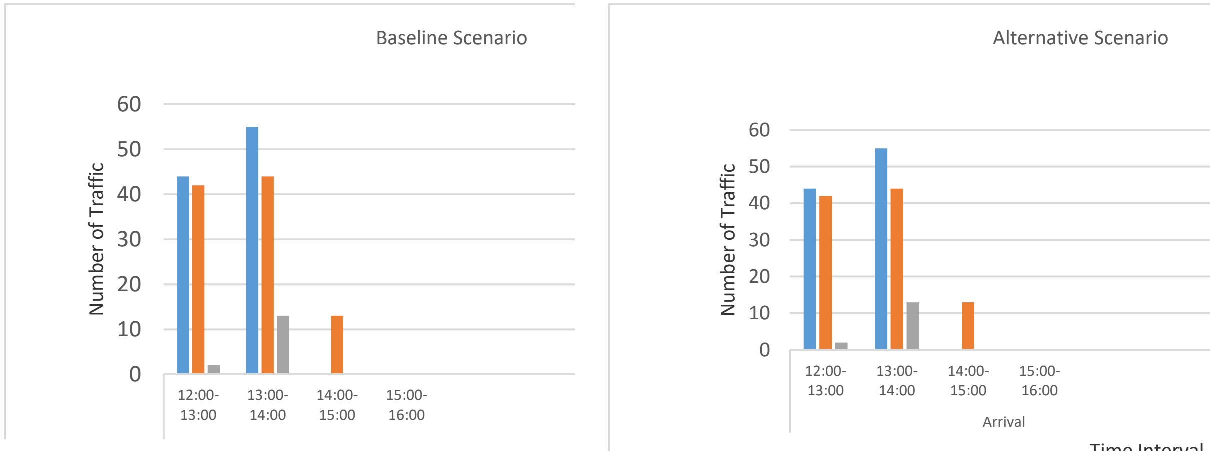


Figure 6. *The Air Traffic Demand and Flow of Baseline and Alternative Scenarios*

For the departure aircraft, the traffic flow is different in two scenarios. The departure traffics have to wait for runway crossing of the arrival traffics at the baseline case. This condition brings additional queue delay that causes the decrease of the hourly traffic flow number. As it can be seen in Figure 6 baseline scenario has less departure traffic flow for the same time interval than the alternative scenario. Even though the departure traffic flow between time interval 14:00-15:00 in the baseline case seems to be higher than the alternative case, it does not mean the baseline case has a higher air traffic flow since most of the flight in this time interval are the shifted traffic from the previous time interval. Because of that the number of shifted flights is also important to see the air traffic flow versus demand for both scenarios. The number of shifted departure traffics for the baseline case are higher than the alternative case.

Another remarkable results of the analysis are the travelling and delay time of the scenarios that can be seen in Figure 7. The travelling time is the time passed for the traffics during their normal operations including arriving, landing, taxing and un-boarding for the arrivals and boarding, taxing and departing time for the departures. The delay time is the time which is other than the listed ones above and caused by any kind of delay such as holding delay, taxi delay, departure and queue delay. The travel time and delay analysis is also divided into arrival and departure as the previous analysis.

The travel time for the arrivals is increased at the alternative scenario as compared with the baseline scenario. The main reason for this increment is the extra taxi distance caused by the end-around taxiways. The travel time shows the alternative case is worse than the baseline. In fact it is not true when the delay time is also included in comparison. Even though the travel time for the arrivals is increased in the alternative case, the delay amount is decreased substantially. This can be easily seen in the total delay time for the arrivals.

The travel time for the departure traffics is the same for the baseline and alternative cases. The delay time for the departure traffics shows the effectiveness of the end-around taxiways. There is a remarkable decrease of the delay time for the departure traffics at alternative scenario compared to baseline case. This remarkable decrease of the delay is achieved by the end-around taxiways that eliminates the runway crossing.

Figure 7. *The Travel and Delay Time of Baseline and Alternative Scenarios*

The number of delayed aircraft can be shown in Figure 8 as grouped according to amount of delay. The delay amount is grouped into 4 different interval which are less than 5 min, 5-10 minutes, 10-15 minutes and more than 15 minutes. As it is shown, the delayed aircraft more than 15 minutes in the baseline case is nearly eliminated at the alternative case. The delay amount is decreased from 15 minutes and distributed in 5-15 minutes interval at alternative scenario. The main reason for such a decrease is the elimination of runway crossing at the alternative scenario. The departure air traffic's queue delay and the arrival air traffics' taxi delay are decreased by the help of end-around taxiways. This result is another indicator of effectiveness of the end-around taxiways.

Average delay amount for the baseline and the alternative cases can be seen in Figure 9. The delay amount is categorised as air, ground, gate delay and departure queue delay. The air delay represents the holding delay to ensure the required separation minima and waiting for the runway for landing clearance. It depends on the executed separation minima and the arrival traffic density.

The ground delay consists any delay that is carried out airside of the aerodrome such as taxi delay and departure queue delay. The gate delay shows the amount of time required to get a serviceable gate for the operation.

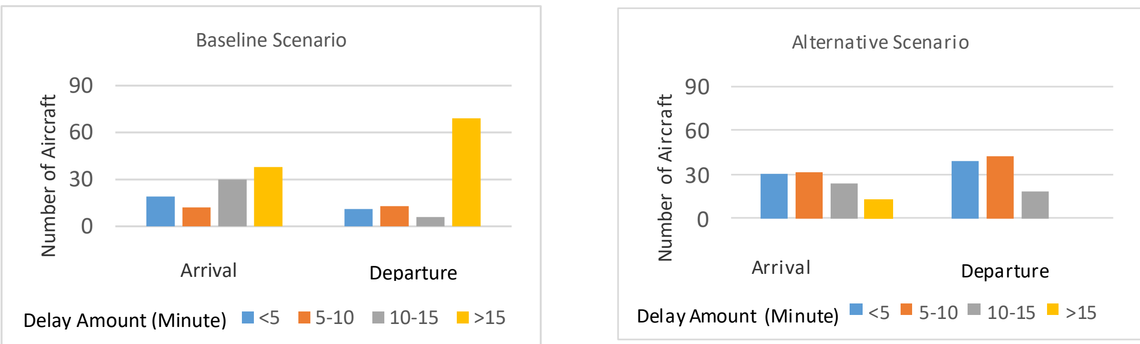
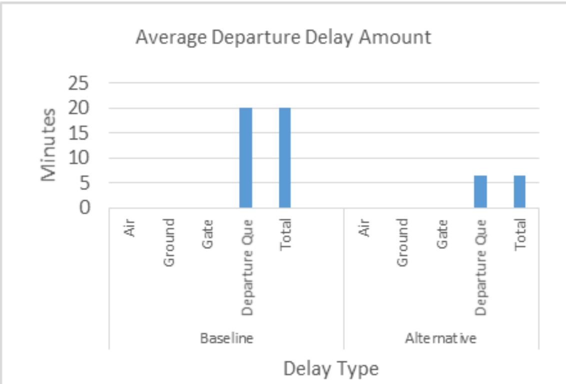


Figure 8. *The Delayed Traffic Distribution of Baseline and Alternative Scenarios*

The gate delay is zero for arrival and departure runways in both scenarios since there is enough gate for operations. The departure queue delay is the amount of delay for the departure traffics caused by runway occupancy due the any reason such as departing aircraft on the runway or arrival air traffic runway crossing process. In the analysis of the average arrival delay amount, the air delay is the same for baseline and alternative case. As it is mentioned previously it is an expected result since the arrival air delay mainly caused by the separation requirements. The average ground delay of the arrival traffics becomes zero in the alternative case while it is 4 in the baseline case. The runway crossing delay for arrival traffics is eliminated with the end around taxiways alternative case. Because of this reason the ground delay is decreased to zero. In the analysis of the average departure traffic delay there is no air delay since the departed air traffics ejected from the simulation. The only delay source for the departure air traffic is departure queue delay. It is decreased from 20 minute to 6 minutes. The departure traffics in the alternative case have much more less departure queue delay as compared to baseline case. In the alternative case the departure traffics are able to take off without waiting for the runway crossing arrival traffics as opposed to baseline case.

The total average delay for the arrival traffics decreased from 12.34 minutes to 8.1 minutes in alternative case as compared to baseline. This equals approximately 53% decrease in the arrival delay. The total average delay for the departure traffics decreased from 20.10 to 6.34 minutes. This is a valuable result that equals approximately 68% decrease in departure traffic delay. The main reason for these enhancements is the usage of end-around taxiway. The end-around taxiway results to eliminate the runway crossing. In this way the arrival traffics continue their taxi without waiting for the runway crossing. Similarly the departure traffic becomes able to take off without waiting for the runway crossing air traffic.



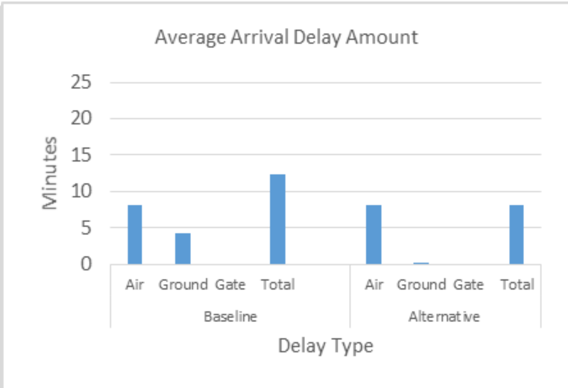


Figure 9. *The Average Arrival and Departure Delay Amount of Baseline and Alternative Scenarios*

The last data for the analysis is the hourly maximum departure queue length for the departure traffics which can be shown in Figure 10. In the baseline case the maximum departure queue lengths are 7, 20 and 30 for time intervals between 12:00 and 15:00. In the same intervals, the maximum number of aircraft waiting on departure queue in alternative case are 6, 9 and 12. The departure queue length is increased with the increased number of traffic in both case. The queue length in baseline case is increased more rapidly than the alternative case.

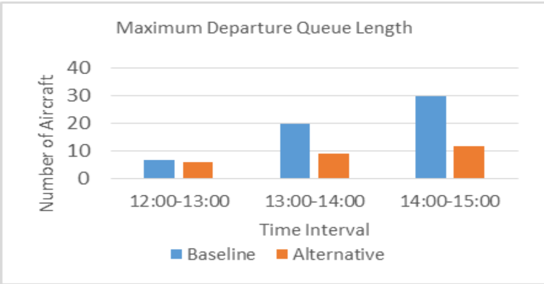


Figure 10. *The Maximum Departure Queue Length of Baseline and Alternative Scenarios*

III. CONCLUSIONS

In this study the effects of the end-around taxiways over the runway capacity are analysed using the discrete event simulation technique. İstanbul New Airport is modelled with its final configuration of phase 1a. Even though, the study takes İstanbul New Airport as a sample, the results of the analysis show the general effectiveness of the end-around taxiways. End-around taxiways take place of runway crossing for the arrival or departure traffics depending on the runway configuration. In this study arrival traffics used end-around taxiways since the runways were configured as 36L arrival and 36R departure runway. Analysis and the simulation results show that end-around taxiways decrease the delay caused by runway crossing procedure. Runway crossing brings additional delay for both the arrival and the departure air traffics in the baseline case. In the alternative case the delay amount caused by the runway crossing is eliminated by the usage of the end-around taxiways. The end-around taxiway usage decreases the total arrival delay from 1221 minutes to 798 minutes. This equals approximately 34% of decrement in arrival delay. While the total amount of departure delay in baseline case is 1990 minutes, it is just 636 minutes in alternative case. It is equal a 68% decrease of delay mount in alternative case as compared to baseline case. These decrement of delay amounts mean that available capacity of the airport is increased. Such capacity increase effect can also be surveyed with the number of traffic flow comparison between the baseline alternative cases. In parallel to the decrease in delay, the maximum departure queue length is also decreased. It is a useful result for the airports that have shorter holding points. According to the analysis it can also be inferred that the end-around taxiways must have more environment-friendly operations with regard to the runway crossing for high traffic demand. The end-around taxiways allow continuous taxi movements for the traffics. The runway crossing causes the interruption of the taxiing traffics. Even though the end-around taxiways bring additional distance to travel, the fuel consumption of taxi movement at end-around taxiways must be less than the runway crossing in high traffic demand. However in low traffic demand runway crossing method may have less fuel consumption than the end-around taxiways because of its additional distance for taxi movements.

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