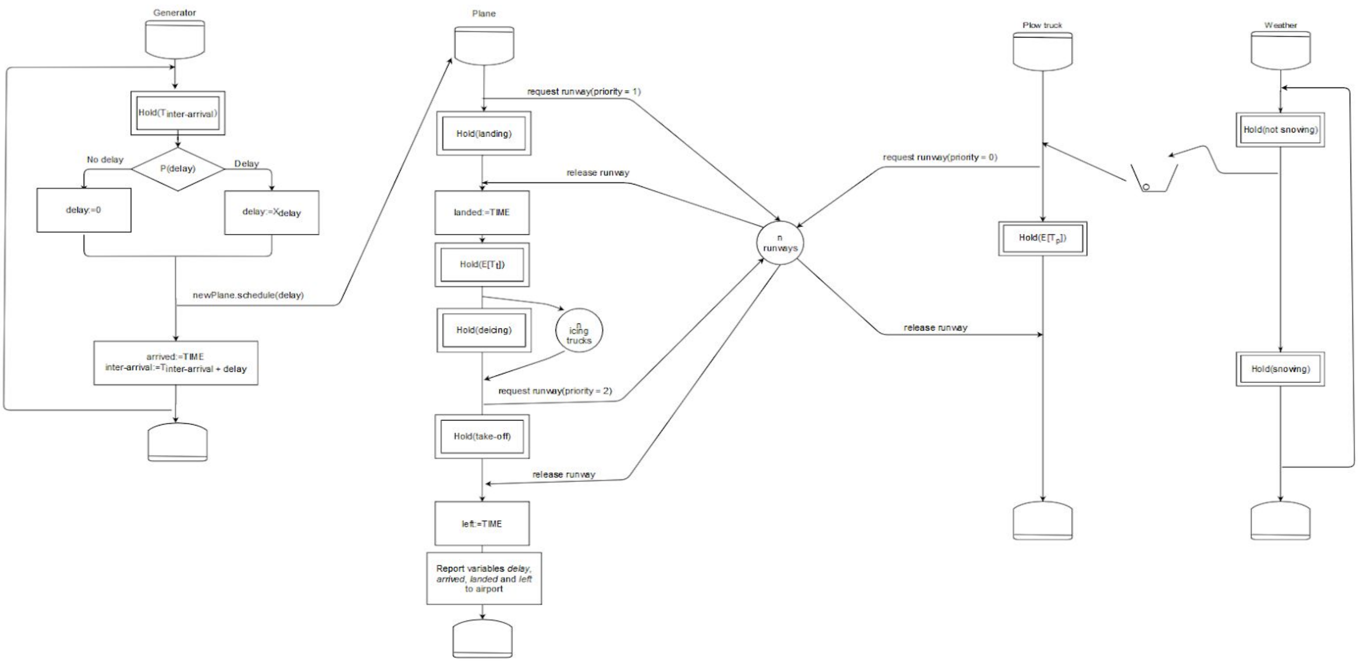
TTM4110 Pålitelighet og ytelse med simulering: Lab 2

Changes to the model from last lab



The model above is the updated activity diagram for this lab.
We have made the following changes:

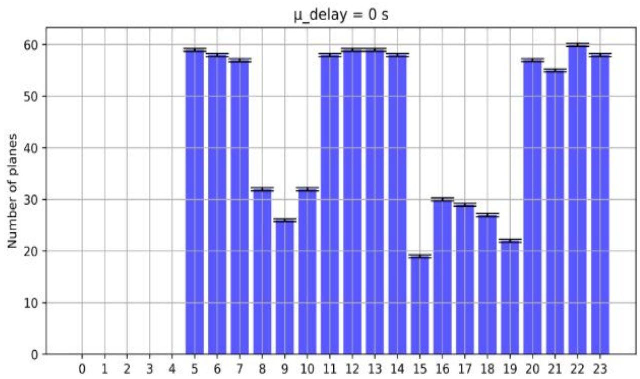
- We moved delay sampling from the Plane entity into the Generator.
- The runway is now a priority resource instead of an entity
- Made a new entity, Weather, to generate snow into a bin
- Changed the Plow truck entity to work with runways as resources and wait for the Weather entity to generate snow
- Added an additional resource in Plane: deicing trucks
- New planes are scheduled with delay

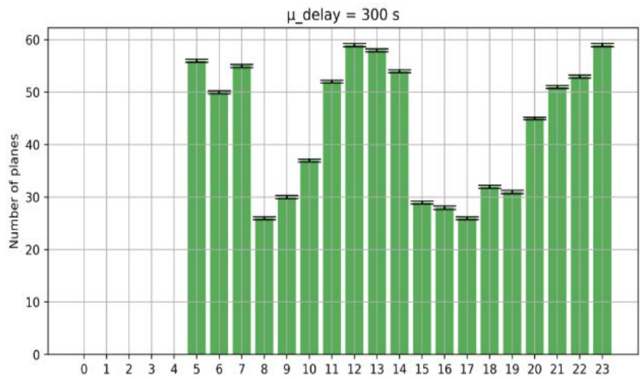
All the graphs in this report are plotted from a dataset generated over one month of simulation time. We separated each dataset into 24 bins, correlated to the hours of the day. The colored bars in the graphs show the means and the black lines show the standard deviations for each bin. Python with Simpy was used for the simulation and matplotlib was used for graphing.

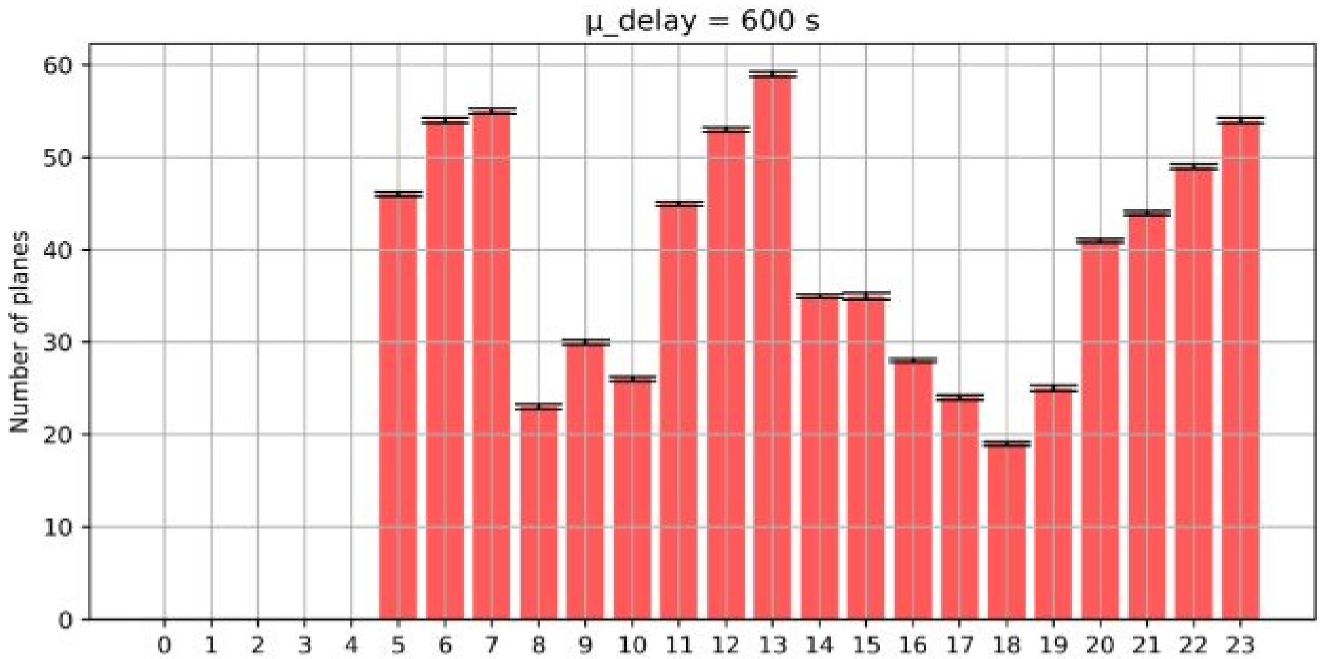
Part II.a: Simulating arrivals

Assumption: Arrival-intensity gives the expected number of planes per hour.

The following graph has the number of planes along the y-axis and the arrival time along the x-axis. This is to illustrate how the delay pushes the arrivals back. For the first graph (blue), we expect 0 delay. As such the number of planes is decided by the guard timer for the high intensity periods and by the intensity during the low intensity periods. When comparing the first graph to the second (green) and third (red), we can see that as the delay rises, the number of planes during the high intensity periods get lower. This is due to the planes being delayed into another bucket and thus flattening the graph.







Part II.b: Simulating arrivals in nice weather

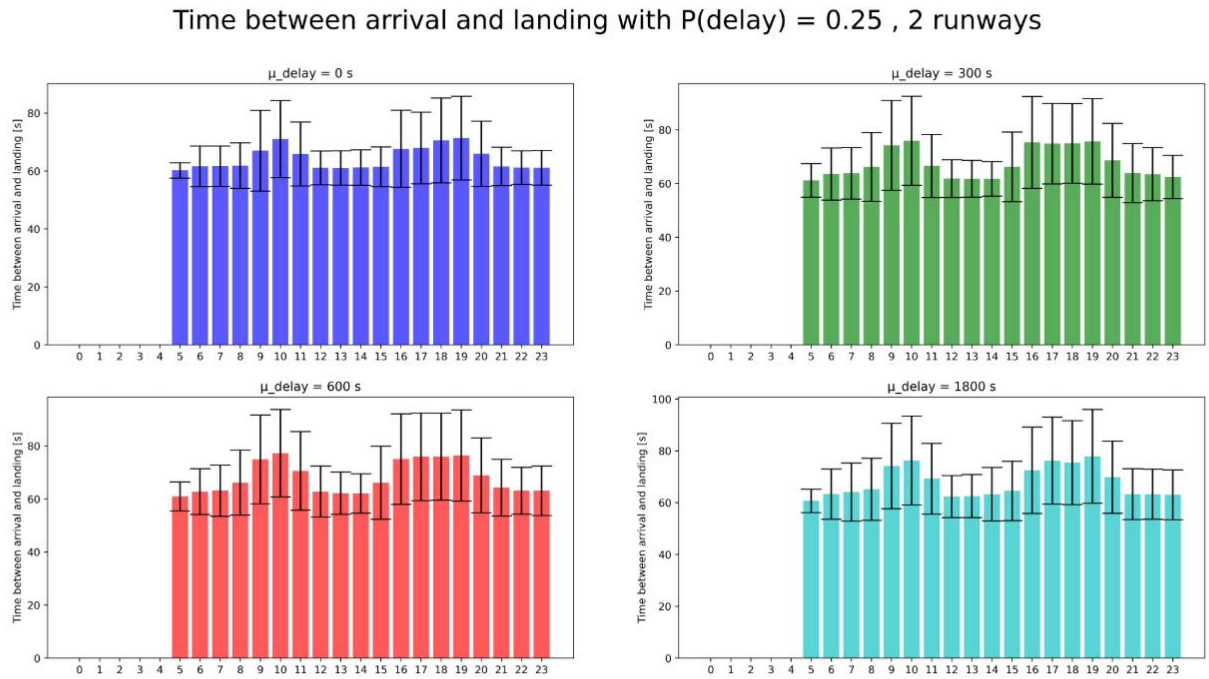
By comparing the graphs below we can see that the delay has a minor effect on time spent waiting for runways, both for landing and takeoff. The graphs for landing planes are pretty flat as the airport has the resources required to handle them. However, the planes waiting for takeoff are congested due to having a lower priority than the planes seeking landing. This has two main effects:

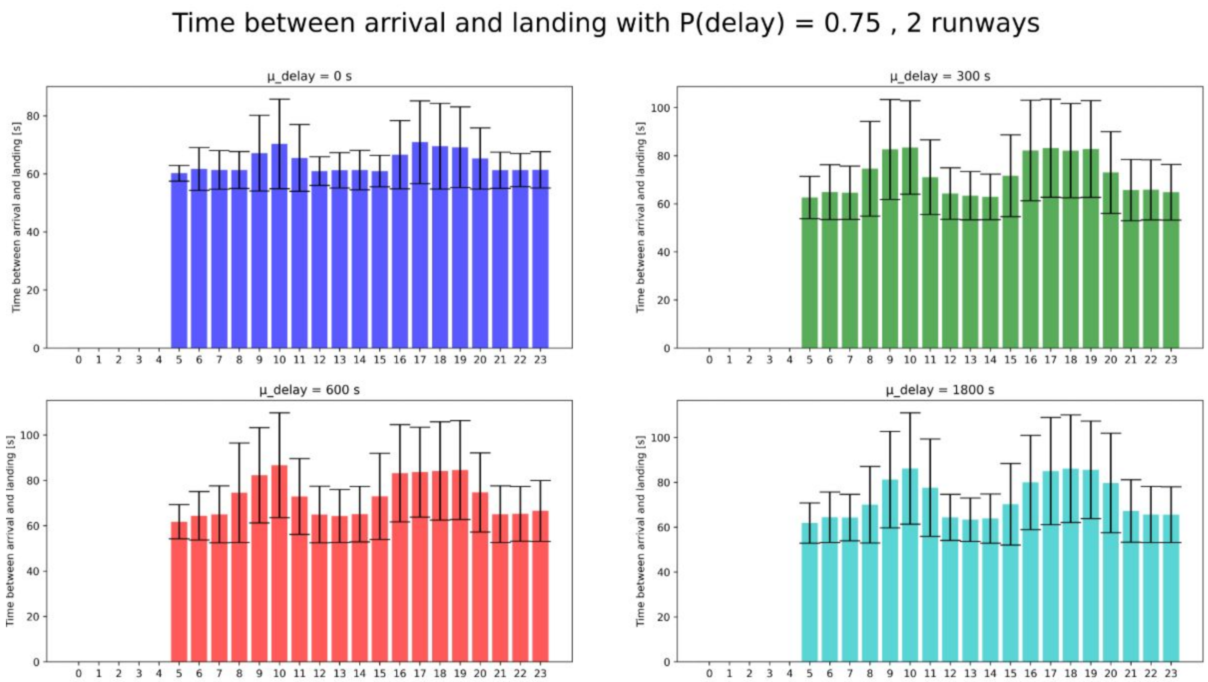
1. The planes have to wait much longer for takeoff than for landing
2. The planes seeking takeoff are affected much more by the current arrival intensity than planes seeking landing.

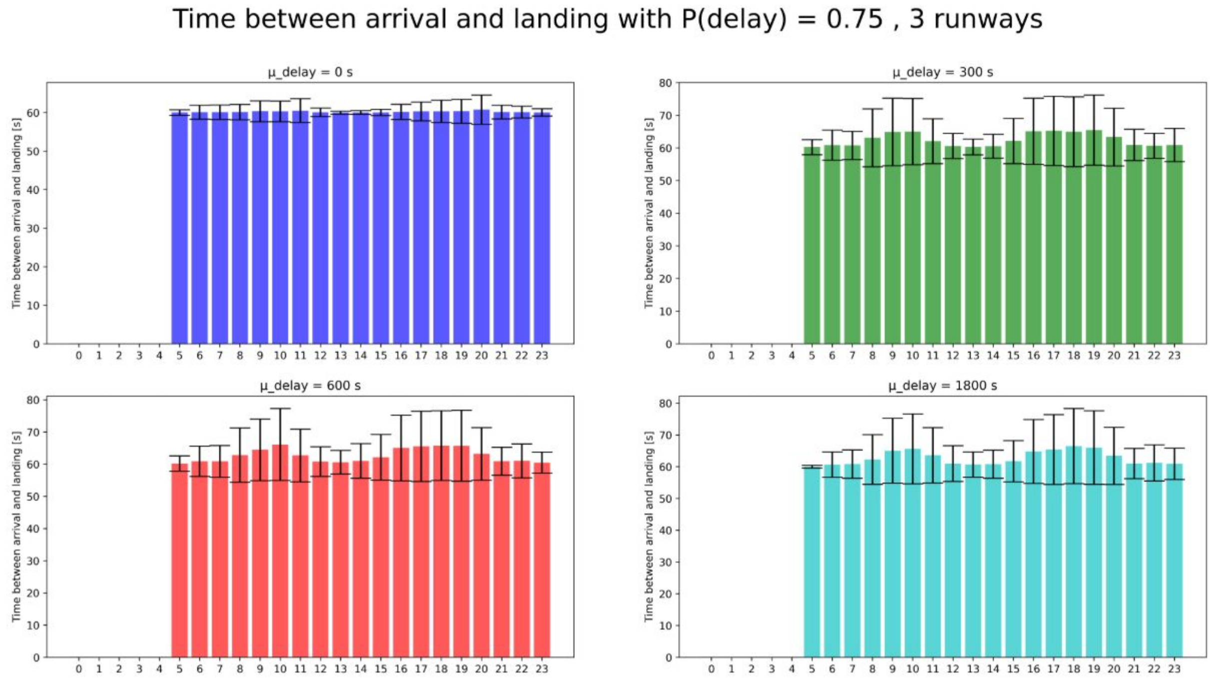
However, by examining the graph plotting time between arrival and takeoff, we can see that the delay is not that critical to the airport's performance. This is due to the fact that while delay will create spikes of activity, the airports ability to handle traffic is unchanged and the spikes of activity will average out with times of less activity. As such, delay will affect short term performance, but will average out over longer periods.

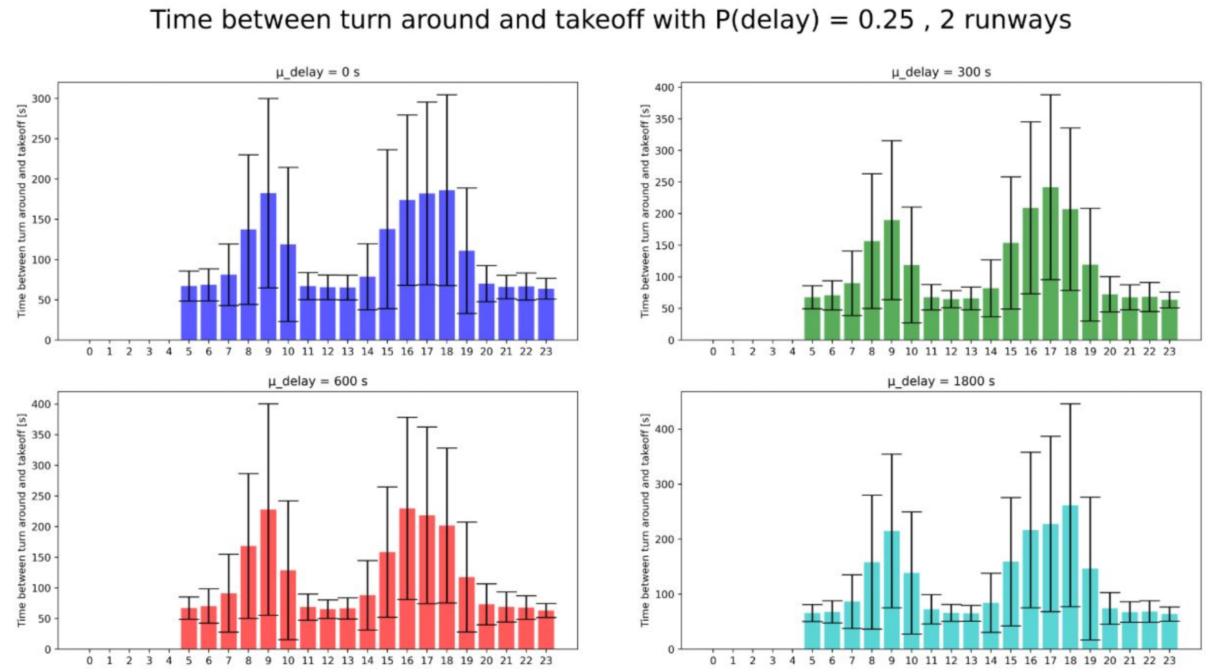
The final graph for this section is a graph showing the consequences of reducing the amount of runways to 1. This has a severe effect on the airports ability to handle traffic and makes the time between arrival and takeoff jump to more than 10 hours. As such, the main takeaway from this section is that the biggest decider for long term performance is the airport's innate ability to handle traffic.

Graphs for Part II.b:

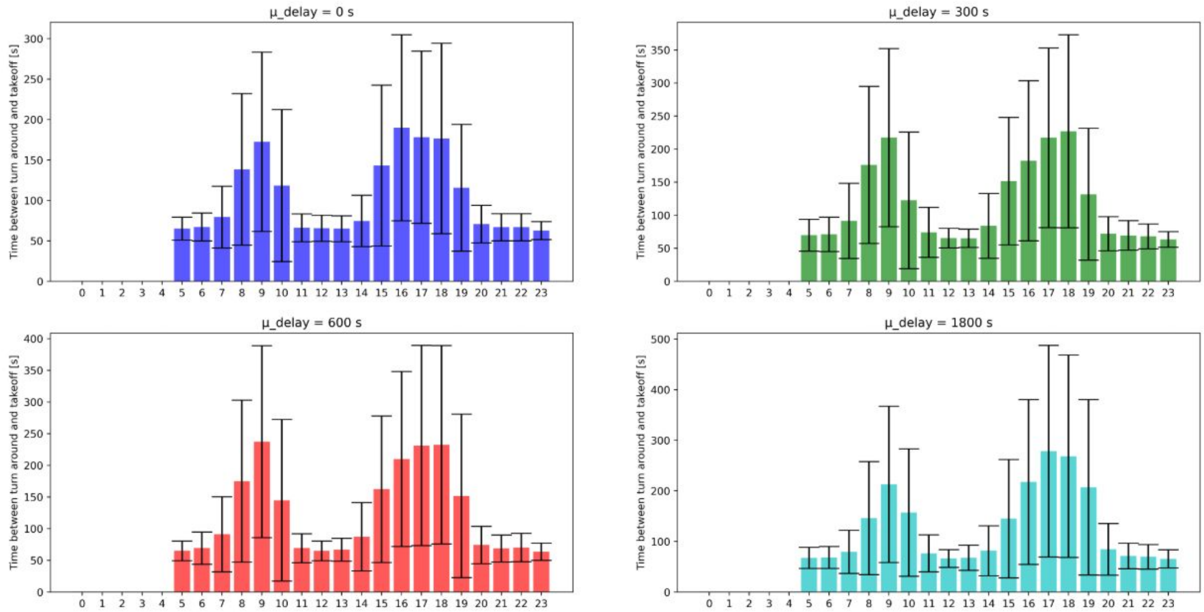




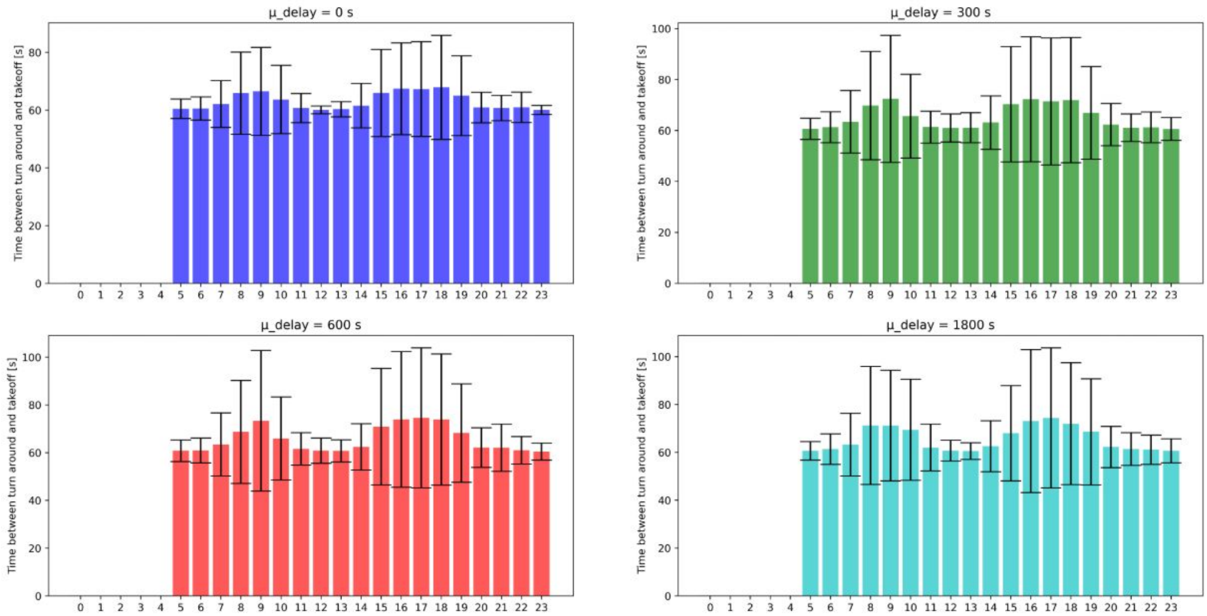

Time between arrival and landing with P(delay) = 0.75 , 3 runways
μ_delay = 0 s
μ_delay = 300 s
μ_delay = 600 s
μ_delay = 1800 s
Time between arrival and landing [s]

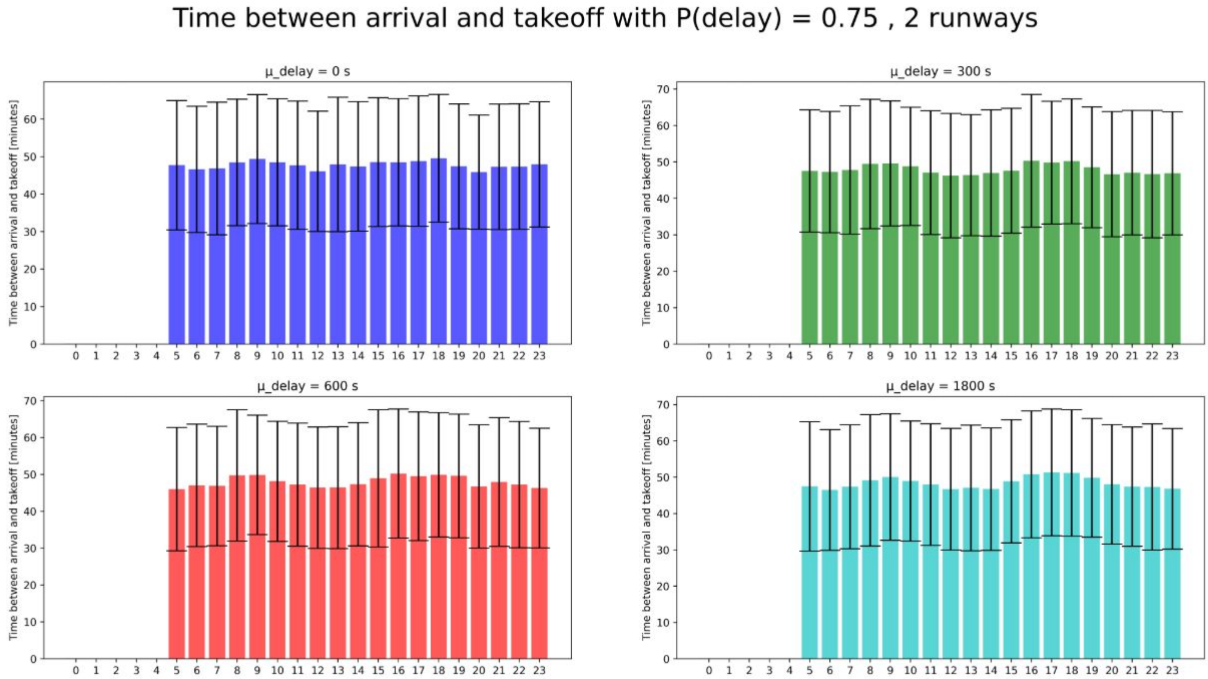

Time between turn around and takeoff with P(delay) = 0.25 , 2 runways
μ_delay = 0 s
μ_delay = 300 s
μ_delay = 600 s
μ_delay = 1800 s
Time between turn around and takeoff [s]

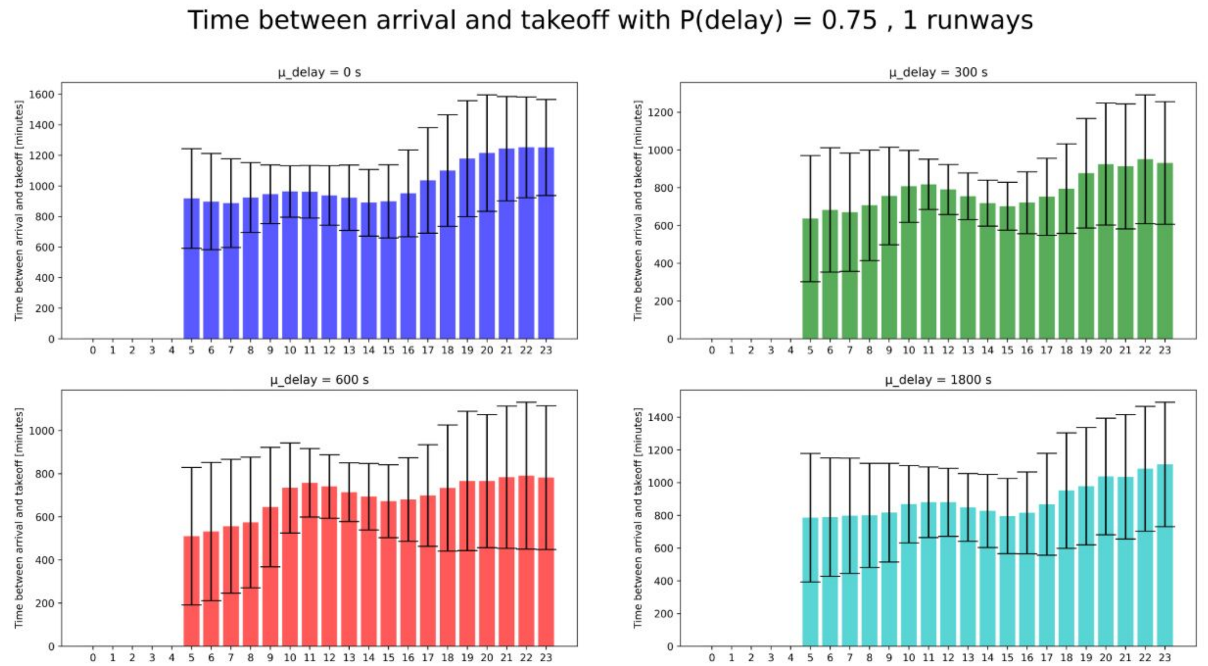
Time between turn around and takeoff with P(delay) = 0.75 , 2 runways



Time between turn around and takeoff with P(delay) = 0.75 , 3 runways




Time between arrival and takeoff with P(delay) = 0.75 , 2 runways
μ_delay = 0 s
μ_delay = 300 s
μ_delay = 600 s
μ_delay = 1800 s
Time between arrival and takeoff [minutes]


Time between arrival and takeoff with P(delay) = 0.75 , 1 runways
μ_delay = 0 s
μ_delay = 300 s
μ_delay = 600 s
μ_delay = 1800 s
Time between arrival and takeoff [minutes]

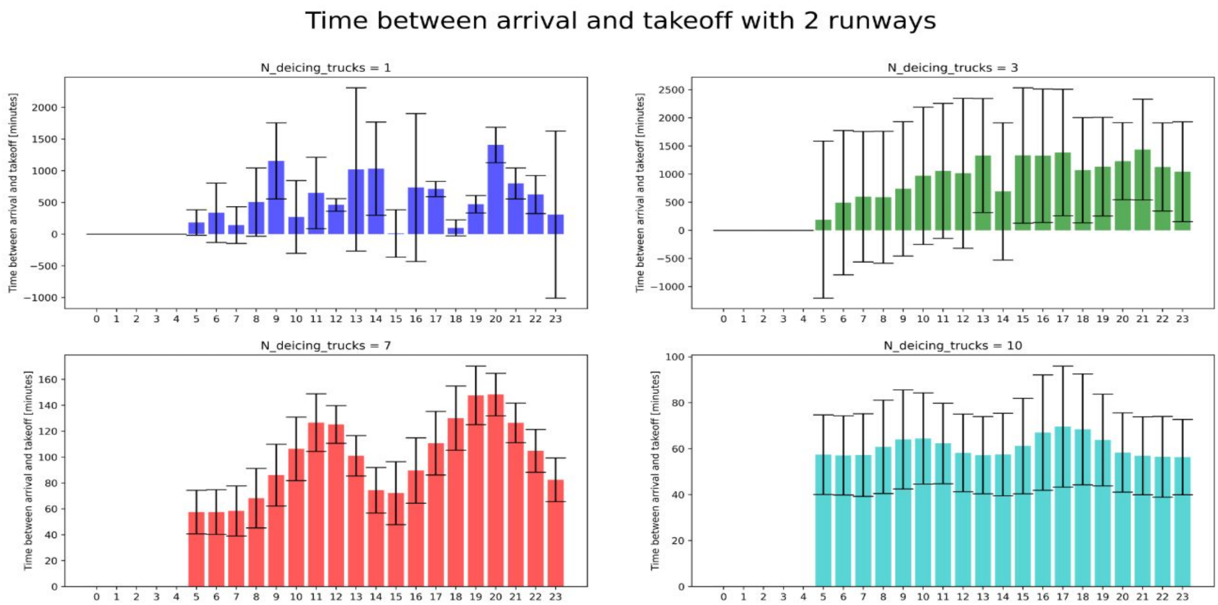
Part II.c: Simulating arrivals in bad weather

We made the following assumptions for Part II.c:

1. The snow weather's intensity does not change during a snow event.
    a. This should have a negligible effect on the results and simplifies our program.
2. The time a deicing truck require to deice a plane is constant
    a. We are unable to find anywhere that states how to generate the time a deicing truck requires to deice a plane. As plow trucks are assumed to take constant time, we feel that this is a fair assumption.

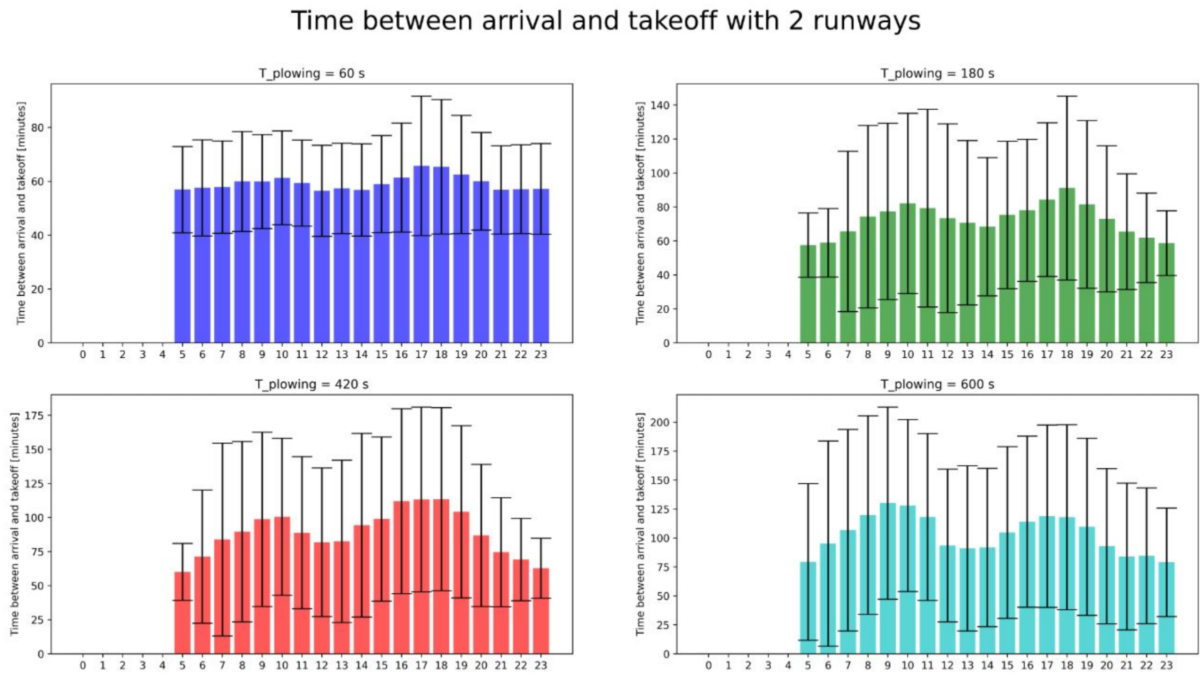
The Effect of Deicing:

Deicing becomes a bottleneck when the deicing trucks are unable to maintain a throughput around the number of incoming planes. Deicing trucks will be able to handle incoming traffic as long as they can handle around 40 planes per hour. During the high intensity hours the deicing trucks will get behind schedule, but they will catch back up during the low intensity hours. This is shown in the third graph. With 7 deicing trucks and 10 minutes per deice they're able to handle 42 planes per hour. This shows in the graph as the time between arrival and takeoff rises during the high intensity hours and decreases as the trucks are catching back up again during the low intensity hours. If the trucks can handle the max intensity of planes per hour, deicing will be more or less irrelevant when looking at long term performance. When looking at the first two graphs we see what happens when the deicing trucks cannot handle the low intensity hours. As the deicing queue just keeps increasing the total delay is catastrophic and the airport would more or less cease to function. If aiming to use the least amount of deicing trucks possible, one should base the amount of deicing trucks on the expected number of plane arrivals that hour. If one uses 10 trucks for the high intensity hours and 5 or 6 trucks for the low intensity hours, the effect of deicing should be tiny and one would free up airport resources for the low intensity hours. We have chosen not to model this as that would require more complex code and we feel that our current graph illustrates the point just fine.



The Effect of Plowing:

When examining the effects of plowing upon the system we can see that the time between arrival and takeoff rises steadily with the time required for plowing. This result is as expected given that the longer the plow truck requires to clear a runway, the longer the runways are unavailable due to snow.



Another takeaway from these graphs is that the average time between arrival and takeoff rises more during high plane intensity hours than during low intensity hours. This is due to the fact that more planes are affected by the runways being closed and it will take longer to catch up again due to the larger queue. This effect can be mitigated by having more plow trucks as the airport would be quicker back to full capacity.

We have chosen to not model how the difference in weather parameters (snow intensity, expected length of snowfall) affects the airport as these factors are out of the airport's control.

Main Takeaways from the Simulation:

1. Delay has a minor effect on the airport's performance. The effects are more major short term, but become less important as the simulation runs longer.
2. The most important parameters are the ones that decide the airport's capacity.
    a. Runways: Allows more planes to land and takeoff simultaneously. More is better, but two or more are required.
    b. Deicing trucks: One should optimally have enough deicing trucks to deice planes as fast as they can arrive, but it is fine to have a few less as they can catch up during hours of low intensity. However, if the deicing trucks are unable to handle the traffic during the low intensity hours, the delay will grow out of control.
    c. Plow trucks: Generally fine with the standard parameters. As the simulation only allows one plow truck per runway having more plow trucks than runways is a waste. One can consider using more plow trucks during hours of high intensity to make sure that the airport's throughput is close to the arrival rate.

Potential Error Sources:

- We had some problems generating proper distributions for both the exponential distribution and the Erlang distribution. As such, we changed the variables until they returned sensible results. This can have skewed the necessity for certain resources such as plow trucks.
- The model has returned a couple of weird plots during the simulations. Whether that is due to a logical error with the model or a hard to track error such as a rounding error is unknown.
- We have also encountered a rounding error when calculating the values for the bins (the bin for 04:00 had data in it). While we fixed this, we cannot be completely sure that rounding does not cause inaccuracies in our data. This error should be inconsequential, but is worth mentioning.