**(P2)**

**Time and efficiency play a vital role in air transportation.** Therefore, it's necessary to build a model that provides the best strategy for different types of aircrafts and on various occasions.

**This flowchart demonstrates the process of boarding. The main factor that causes the queue is passengers’ stowing their luggage.**

**Our model can be divided into three parts: Math Model, Optimisation in a mathematical account and Program.**

**(P3)**

Assumptions should **make our model discrete** but also **plausible**. This is the main reason for making most of the **seemingly impulsive hypothesis** afterwards. We omitted the subsidiary assumptions, and you can refer to them in the essay.

In Model A, we would **consider the single-aisle case and combine them with other aircrafts based on their similarity.** The luggage assumption’s justification will appear in the sensitivity analysis. **The time wasted while passengers try to stuff extra luggage into their seats is qualitatively equivalent to that spent while stowing extra luggage.**

**We also assume that passengers always walk at the maximum possible speed.**

**(P4)**

**As for the velocity, we assume that the velocity in a particular cell remains constant.** **This assumption enables us to simplify the calculation for the velocity (for it was only used when calculating distance) and wouldn't cause much inaccuracy,** which will not dramatically affect the total time, as shown in the graph. This is partly because **the basic timestep is only , a short time** that wouldn't influence the velocity and distribution of passengers much. Therefore **the velocity in a certain timestep wouldn't change much,** so it can be seen as a constant.

**(P5)**

The three types of variables are: **Constant A**, which refers to the static constants that reflect properties of the model; **Constant B**, which refers to the properties of an aircraft or a strategy; **Variables, describing properties of passengers,** will be for different initial sequences of passengers.

**(P6)**

**In the model, the definition of time and velocity differs from SI. We make these changes to make the calculations simpler.**

**(P7)**

Here is how we calculate the total time systematically. The loop here indicates that we calculate the total time based on recursion. According to the discreteness of our model, the process of calculating total time can be reduced to finding a recursion formula for any passenger-based variable. We chose (velocity) as that variable out of simplicity and authenticity concerns.

**(P8)**

Before turning the spotlight on the analysis, we’ll first construct the space of cells and coordinates as shown on the slide.

**(P9)**

So far, we are only looking into the regular cases where passengers move freely without being blocked. There aren’t scenarios of contradictions such as equals infinity in this case.

**(P10)**

First, we’ll calculate the velocity according to the density. The density defined in the model is as shown on the slide. The visibility range is taken as because is proper and realistic. It also decides the time step (if taken as , the time step can be or sec), reducing the complexity of the simulation.

**(P11)**

Next, we use Greenshields speed-density linear model to develop the relation between and.

**(P12)**

After that, we use dot products of vectors to calculate distribution according to density, as the slide shows.

**(P13)**

Additionally, the distribution has correspondent associations with the velocities by using partial summation.

**不大正常 页码和讲稿长度不同**

**(P14)**

Therefore, we get the result.

Notice that previous calculations have shown that real-time speeds are associated with a linear bound. And we’ll also use two methods to justify our deductions: first on the next slide and then in the Sensitivity Analysis part.

The recursion formula clearly displays the linearity. ( can be understood as the real-life speed.)

**(P15)**

As mentioned before, now we’ll come to the second scenario: when someone is causing a queue.

We divided the task into two parts: stowing luggage and offering seats. The first is trivial (but we’ll later add *discompliance* factors to this in the SA).

**(P16)**

Offering seats can be calculated as shown mathematically – using permutation and the preservation of order.

Here is the schematic diagram for this procedure.

**(P17)**

Now we’ll show the formula for the interconversion of states. The formulas here are further improved compared to our essay.

**(P18)**

Here are the ideal formulas. It preserves linearity.

**(P19)**

Deletion is relatively trivial according to programmatic views.

**(P20)**

Here we give the results. The weights can be calculated by accumulating all the and selecting the element. This can be easily done with matrix multiplications.

**(P21)**

After obtaining all these indicators, we will calculate the total time.

**(P22)**

This part will focus on the modelling approach to optimising (or minimising) the total time. Our work can be divided into inspiration from our previous calculations and strict mathematical proof.

We’ll raise *parallelity* to describe how many of the aisle cells are occupied. The higher the parallelity, the more efficient the system is and the faster the strategy is. The formulae of parallelity are shown in the slide.

**(P23)**

We’ll prove the intuitive idea proposed in the previous slide.

First, based on the model, we can do these analyses as shown.

**(P24)**

The linearity of our model preserves these properties.

**不大正常 页码和讲稿长度不同**

**(P25)**

Secondly and mathematically, we’ll also prove this with two significant claims. Claim One, shown on the slide, is about the optimality of all cells being occupied. Claim Two will be helpful when dealing with more complicated aircraft.

**(P26)**

**Disembarking can be seen as the reverse of boarding**. **Therefore, the best strategy should be similar to boarding: to reach the highest parallelity.** However, as there are no offering cell procedures, the passengers have already been in an ideal queue, thus spending less time than boarding because of higher parallelity.

**(P27)**

Besides the total time, passengers’ **satisfaction** is also an essential factor to consider. In real-life experiences, dissatisfaction mainly comes from queuing and offering seats. And according to the strict sequence, some fellow passengers may be split, causing dissatisfaction. **The total dissatisfaction index is the weighted sum of the three factors.**

**The weights of the factors are respectively 1, 250 and 10. The reason for 1 is for standardisation, and the others are based on real-life experiences and unite magnitudes to make the ultimate dissatisfaction index combine the three factors.**

**(P28)**

**These are the results of our simulation.**

This is a comparison between different methods. **We can see that Steffen Sub-Perfect is the fastest and back to front is the most satisfactory plan.**

**(P29)**

**We use compliancy index to measure the sensitivity in figure. It shows the predictability of changes in the model, and the function to compare with is a relationship proved by our model.**

**(P30)**

**Case one is a longer stowing time. We use a random model – sigmoid model, as shown in the slides – to distribute the discompliance of passengers in a relatively realistic method, due to its speciality.**

**(P31)**

**These are how we determine whether the model is stable or unstable based on how the graph looks.**

**(P32)**

**This is how longer stowing time affects our plan based on variance.**

**(P33)**

**We can conclude that random boarding is the most sensitive while front-to-back seems not sensitive.**

**(P34)**

**Next, we analysed the queue-jumping situation and concluded that both methods are sensitive, meaning queue-jumping significantly impacts total results.**

**(P35)**

**Last but not least, we researched on the reduction of passengers and found out that random boarding is the most sensitive (see the distribution of points) while back-to-front is not so sensitive.**

**(P36)**

These are the major conclusions drawn from our sensitivity analysis: **Random is far more sensitive than front to back, because randomised sequences can result in immeasurable effects. Back-to-front is the best overall because it is the least sensitive and has better time and satisfaction.**

**(P37)**

Then we will apply our model to different aircrafts, and we will start with the development of coordinates. For the Flying Wing aircraft, as we've already divided it into four blocks, we define the intersection point of the main aisle and the th block aisle as , and the th block aisle as its -grid.

**(P38)**

And for the TETA aircraft, we define the entrance cell on the left as , and the direction of the two aisles as the x-grid. **The seats with a negative -coordinate are the first class.**

**(P39)**

**This is Claim Two, which helps us find the best strategy for the two kinds of aircrafts.**

**不大正常 页码和讲稿长度不同**

**(P40)**

**Here are the main ideas when we apply the model to different aircrafts.** Two Entrance Two Aisle and the Flying Wing are two kinds of multi-aisle aircrafts, and we found that **they can be divided into smaller individual parts similar to ordinary one-aisle aircrafts.**

**(P41)**

To optimise the whole plan, we need to **apply it to both the boarding sequence inside groups** and **the between-group sequences. The details are included in the pseudocode of the essay.**

**(P42)**

To ensure that every cell is used, we arranged **a few inner group passengers to fill empty blocks.**

**(P43)**

**The graph shows our best strategy for Two Entrance Two Aisle aircraft.**

**(P44)**

**To conclude, as for the strengths of our model, we considered various situations and used programs to simulate the process. As a result, the model can be accurate because of the multiple situations considered, with universality and efficiency due to the usage of programs.**

**And for the weaknesses, we introduced many variables, some of which are a bit abstract, making our model complex. And the strict boarding sequences make it difficult to operate.**

**(P45)**

**Last but not least, we write a letter to provide the airline executives with some suggestions**. First, we **point out two critical factors: hommization and efficiency**. **Secondly, we draw a simple chart to illustrate our plan** and **offer some simple tips**. **Airline executives need to prevent passengers from being stuck in aisles, provide them with enough space to place their luggage, and avoid queue-jumping.**