Aviation Baggage Screening Strategies

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SUMMARY

Aviation Baggage Screening Strategies: To Screen or Not to Screen? This is a problem of decision-make and optimization.

In resolution of this problem with various tasks in order, the proposed 7 tasks (Tasks 1-4 and 6-8[5-7]) are fully finished stepwise through developing some models and analyzing different results. In this paper, several valuable results were obtained illustratedly and demonstrated briefly.

In task 3 a very valuable and widely applicable conclusion are made as follows: In order to schedule the departure of flights, a project worthy to be extended is to keep the same passengers in the departing group during a peak hour and for the departure interval of 1h. This is already verified in our *Model of Two Scheduled Fligh*. In that case, not only the number of EDSs can be reduced quite much but also the SRO index can be increased in a fair content through adjustment of security-screening rules. It is suggested that different security-screening rules should be designed for the different situations particularly for different checking periods.

For solving the novel problems appeared in task 7, on earth the optimal combination where how many bags should be checked by either EDS-screening or ETD-screening. Firstly, the third project (80%EDS/20%ETD) should comprehensively to worthy being prior to be employed among the proposed four projects. Finally through comparison studies it is found that about 58% bags should be checked by EDS-screening while the remained around 42% bags should be checked by ETD-screening.

1 ASSUMPTIONS：

1.Only consider the situation when the airplane flights in a peak hour, and do not consider the interaction effect among the time units (assume the effect is tiny and can be omitted).

2.Suppose that it is equitable for every passenger to check-in, no exception exists.

3.Assume there will not be the cancelled flights in the peak hour.

4.Consider that a peak hour justly is a clockwise hour.

5.According to Appendix A, most passengers typically arrive for their flight between forty-five minutes (45min) and two hours (2h=120min) prior to their scheduled departure time. In order for each passenger to take the airline in time, Aviation Baggage Screening(ABS) using an EDS can be done once the passenger arrive at the airports. Obviously we can suppose that the ABS time is 1.5(=2-0.5)h or 90min (120-30) for any flight to depart during a peak hour, which is subtracted by 30 min(=0.5h), a period needed for passengers to check-in.

6.In this period of 1.5h, the number of passengers (NOP) is not uniformly distributed o the basis of their individual situation. To simply the problem, assume 1/4, 1/2 and 1/4 passengers arrive at the airport in the first, second and final 30min, respectively. This can be shown in Figure 1, where the integrated area expresses the NOP.

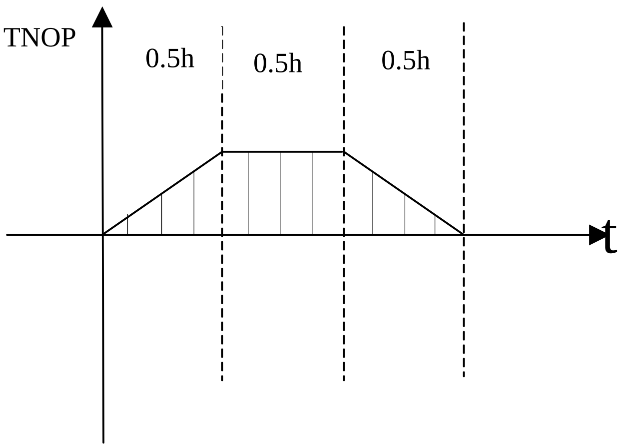

Figure 1

7.In general, suppose that each passenger take two bags to be screened.

8.When designing their flight schedule, only the benefits of the airline are considered while the complains of the passengers are omitted.

2 PROBLEM ANALYSIS

The problem aims at strengthening airline security by safety inspect. We have been tasked to determine the number of EDSs required and hwo to schedule the departure of different types of flights within the peak hour.

The flight type and the number of flights of each type have been described. According to the historical data in appendix,we can compute the numer of all passengers within the peak hour.As a result,the number of all checked bags call be fixed.Two things has to be considered here:One is that the appointed EDS can't examine other scheduled flight when it detects its corresponding flight within the determinate time; the other is that all the EDSs can examine all the passengers mixed.Therefore,the former need to compounding flight type and seek the least number of EDS,the latter requires considering the connection between the passengers' flux and time.

It is known that the inspecting accuracy can be improved by adding ETD. EDS and ETD can examine bags in glide form and we can calculate the number of ETD.We can justified the cost of such a policy in light of the value that it provides.

3 MODEL OF ONE SCHEDULED FLIGHT （task 1）

At first, it is necessary to account the number of required EDSs during the peak hour, which is the key problem. Now only one scheduled flight during a peak hour is involved. As mentioned above, three time stages were divided for the passenger flow. The most crowed period, i.e. the middle 30 min, is the neck-controlled stage. The number of EDSs required for this 30min period is the desired number of required EDSs.

Since the Peak Hour (PH) when the flight seats are highly occupied is examined, Take five percentage (5%) higher than the average for the occupation coefficient of the flight seat (OCFS), which should be in agreement with the practical situation. The occupation coefficient of the flight seat is seen in Table 1.

Table 1. The occupation coefficient of the flight seat

Number of Flight Seats	Historical OCFS	OCFS Average	OCFS during a peakhour（PH）
≤85	70%～100%	85%	90%
128～215	60%～100%	80%	85%
350	50%～100%	75%	80%

Now, the calculation process is demonstrated, as an example, by computing the numbers of passengers and EDSs required during the peak hour (PH) at airport A, which are the followings.

The numbers of passengers during the peak hour (PH) at airport A is calculated as follow as:

$$(34\times10+46\times4+85\times3)\times0.9+(128\times3+142\times19+194\times5+215\times1)\times0.85+350\times1\times0.8=4609$$

and when each device can examine 185 bags per hour, the numbers of required EDSs during the peak hour (PH) at airport A is accounted as:

$$(4609\times0.2+4609\times0.6\times2)/(2\times185\times0.5\times0.92)=38$$

Through calculation, the numbers of passengers during the peak hour (PH) at both airports A and B can be obtained, see Table 2 for details, where Min, Max and Ave refer to the minimum, maximum (fully occupied) and average values of the occupation coefficient of the flight seat (OCFS), and PH stands for the value of OCFS during the peak hour.

Table 2. Numbers of passengers during the peak hour (PH) at both airports A and B

	Passengers at airport A	EDSs at airport A	Passengers at airport B	EDSs at airport B
Min	3281	27	3548	30
Ave	4339	37	4665	39
PH	4609	38	4954	41
Max	5396	45	5781	48

4 TASK 2

Beyond question, it is the most important to undertake security for every airport. As for the safety, it is involved an awfully crucial concept, that is, the probability (p) of hiding a jeopardy, that leads to a disaster, for each bag taken by some passengers. Aviation misadventure and/or misfortune will take place in the following two cases: $p=p_1+p_2$, one due to the uncertainty of baggage screening and its probability is noted as p_1; another due to the situation of undone screening and its probability is given as p_2. For anyone, either airport A or B,

$$p_1= (20\%\times s+60\%\times 2s)\ \times p\ \times\ (1-98.5\%)\ /2s=1.05\%p$$

and

$$p_2=(20\%\times s+20\%\times 2s)\ \times p/2s=30\%p$$

where s is the total number of passengers during a peak hour.

A safety probability (PSRO) is defined for the measure of security-related objectives (SRO) and PSRO =1-31.05%p. There exist the two constraints: one is due to p mentioned above, which can be controlled by us; another is due to the limited number of EDSs, which permit one bag or more bags (i.e. both two bags) of some passenger not to be screened. In other words, how many passengers will be checked without screening their any bag, and how many passengers will be checked through screening their one or more bags. An obvious problem is that the probability of aviation misadventure due to not screening of baggage is much greater than that due to the uncertainty of baggage screening. Although the p value is very small, the loss of aviation misadventure is extremely colossal once it takes place. Accordingly, the number of EDSs is increased as possible in order to realize that every bag is screened. Besides, it justly is the problem to be resolved finally.

Under the premise conditions of limited current instruments, it is proper for to optimally adjust some rules to realize our best security-related objectives of the airlines and then to make some conclusions. Now Airport A is still taken as an instance. The some calculation results are given in Table 3.

Table 3, The some calculation results for Airport A

Not check	Check one bag	Check two bags	The number of EDSs	SRO
20%	20%	60%	38	1-31.05%p
15%	25%	60%	40	1-28.59%p
15%	15%	70%	42	1-23.66%p
10%	20%	70%	44	1-21.2%p
10%	10%	80%	46	1-16.275%p
5%	10%	85%	49	1-11.35%p
0	0	100%	55	1-1.05%p

From Table 3, it is not difficult to know that SRB will obviously be increased as the number of EDSs is increased; and when the number of EDSs is not so large, the number of EDSs is raised from 38 to 49 and accordingly the value of PSRO is from 1-31.05%p to 1-11.35%p; while the number of EDSs is raised to 55 then all bags can be screened. Simultaneously, it is not difficulty to find that when only 2 EDSs are raised, the PSRO value is obviously increased by the attitude of 2~5%. Therefore, it is reasonable to express that the money is is very necessary to be spent for increasing the EDS machines, and besides 100% screening of checked luggages will be certainly realized. To this goal, each airport is required to exert oneself.

As for the further adjustment of security-screening to be more reasonable, this will be discussed in deeper later in the answer the task 4.

5 TASK 3

5.1 MODEL OF MULTI-FLIGHT SCHEDULE

To test whether schedule of the flights departure is legitimate, we preliminarily consider the two reasons: one is high screening coefficient of EDS instruments, another is low even no passengers-delay. At first, totally 46 airplanes were roughly divided into three groups departing at different time, i.e. time t_0, t_0+0.5h and t_0+1h, during a peak hour. In order to reduce the effect of overlapping between the neighbor groups of airplanes on security examination since when the former departing flights, known as f1, arrive their peak period, the later departing flights, known as f2, begin their baggage screening. The overlapping can easily make passengers delay. So we divide the passengers into two groups: one group consists of more passengers (here taken as more than or at least equal to 1800 persons) and another cluster fewer passengers (here taken as 500~ 1000 persons). These two groups of passengers are asked to check-in alternatively and the above-stated situation can be avoided.

This problem is made of an integer programming one. In case of Airport A, an optimization model can constructed as the followings:

Objective function: $\max = \sum_{i=1}^{3}[X(i)A]$

$s.t:$

$$\sum_{i=1}^{3}[X(i)A]-4609\le 0$$
$$\sum_{j=1}^{8}x_{1j}=15$$
$$\sum_{j=1}^{8}x_{2j}=15$$
$$\sum_{j=1}^{8}x_{3j}=16$$
$$\sum_{i=1}^{3}x_{ij}=R(j)(j=1,2,\cdots,8)$$
$$X(1)A\ge 1800$$
$$500\le X(2)A\le 1000$$
$$X(3)A\ge 1800$$

Where all variables are taken as an integrate greater than zero: $x_{ij}\ge 0$. Among the above equations, A is an 8×1 matrix with 8 rows and 1 column or a column vector with 8 elements: A=[34×0.9；46×0.9; 85×0.9; 128×0.85; 142×0.85; 194×0.85; 215×0.85; 350×0.8]; R is also an 8×1 matrix with 8 rows and 1 column or a column vector with 8 elements: R=[10 4 3 3 19 5 1 1]; and X is an 3×8 matrix with 3 rows and 8 columns with 24 elements, here x_{ij} stands for the number of airplanes in the *i*th fly group at the jth departingtime, and X(1), X(2) and X(3) refers to the first, second and third row respectively.

Resolution was done for Airport A by using the LINGO7 software and the results were given in Table 4A. In similar way, the resolution results were obtained for Airport B, which were listed in Table 4B.

Table 4A. The type and its number (in the break) of departing airplane with corresponding number of passengers for 3 different flying groups at various departing time (Airport A).

Flying group	Departing time	Number of passengers	The type and its number (in the break) of departing airplane
1	t_0	1843	4（1），5（13），6（1）
2	t_0+0.5h	941	1（9），2（1），3（1），4（2），6（2）
3	t_0+1h	1825	1（1），2（3），3（2），5（6），6（2），7（1），8（1）

Table 4B. The type and its number (in the break) of departing airplane with corresponding number of passengers for 3 different flying groups at various departing time (Airport B).

Flying group	Departing time	Number of passengers	The type and its number (in the break) of departing airplane
1	t_0	2229	4（1），5（8），6（7）
2	t_0+0.5h	908	1（3），2（6），3（6），4（1）
3	t_0+1h	1817	1（5），3（1），4（3），5（1），6（3），7（2），8（1）

A better manner may be the followings: further ramifying will be done for the three departure groups in a very similar way as above-mentioned. Also, Airport A is taken as an example, three departure periods are further divided into total 9 smaller departure periods among the three ordering periods, i.e., from t_0 to t_0+0.12h, from t_0+0.18h to t_0+0.3h and from t_0+0.36h to t_0+0.48h, respectively. Accordingly, each flight group with individually 15 or 16 airplanes was further divided into three subgroups. Simultaneously, we also divide the passengers for the subgroup into two clusters: one consists of more passengers (here taken as more than or at least equal to 720 persons) and another consists of fewer passengers (here taken as less than 250 persons). These two groups of passengers are asked to check-in alternatively and the above-stated situation can be avoided. These alternative allocations with more and fewer passengers can mostly decrease the times of passengers delay. The results for total 9 departure subgroups are given in Table 5.

Table 5. The type and its number (in the break) of departing airplane with corresponding number of passengers for 9 different flying groups at various departing time (Airport A).

Flying group	Departing time	Number of passengers	The type and its number (in the break) of departing airplane
1	t_0	725	5（6）
2	t_0+0.06h	351	4（1），5（2）
3	t_0+0.18h	769	5（5），6（1）
4	t_0+0.24h	218	4（2）
5	t_0+0.3h	509	1（2），2（1），3（1），6（2）
6	t_0+0.36h	215	1（7）
7	t_0+0.42h	755	1（1）， 5（6）
8	t_0+0.48h	307	2（3）7（1）
9	t_0+0.54h	763	3（2），6（2），8（1）

Repeat this treatment process，all 46 airplanes can further subdivided into 27 departure subgroups; and in this case an almost ideal results can be obtained. Of course, for Airport A, all 46 airplanes can finally subdivided into 46 departure subgroups, that is each airplane can finally regarded as each departure subgroup. Here only the results of 9 subgroups were given due to the limited time and space.

５.2 MODEL OF TWO-FLIGHT SCHEDULE

In above discussion of *MODEL FOR MANY-FLIGHT SCHEDULE*, it is not difficult to find the practical time for security screening is no longer 1.5h after the airlines are divided into the departure groups or subgroups. If the airlines are divided into two-flight departure groups instead of multi-flight departure groups, then the airplanes will depart at time t_0 and at t_0+1h, and the corresponding total period for security screening can be d asserted as from t_0-2h to t_0+0.5h. Certainly, this is the maximum period for security screening, which can then be called the *maximum efficient period for security screening T*.

Before establishing the mathematical model, two viewpoints should be declared as the follows:

First, if and only if the *maximum efficient period for security screening T* is fully utilized, then the number of EDSs can be reduced as possible.

Second, on behalf of not delaying passengers, the number of EDSs required for the period of most passengers, which is the most involved time-period, during the peak hour can be accounted and this number is finally the number of EDSs required at least to consequently undertake security screening.

Finally, the higher the utilization efficient of the security-screening instruments, the less the number required.

Let us firstly consider the simple problem that all airplanes is divided into two departure groups. For the sake of making the most use of the *maximum efficient period for security screening T*, the airplanes should depart at both time t_0 and time t_0+1h. The numbers of passengers for each group can be described in the following scheme (see Figure 2 for details).

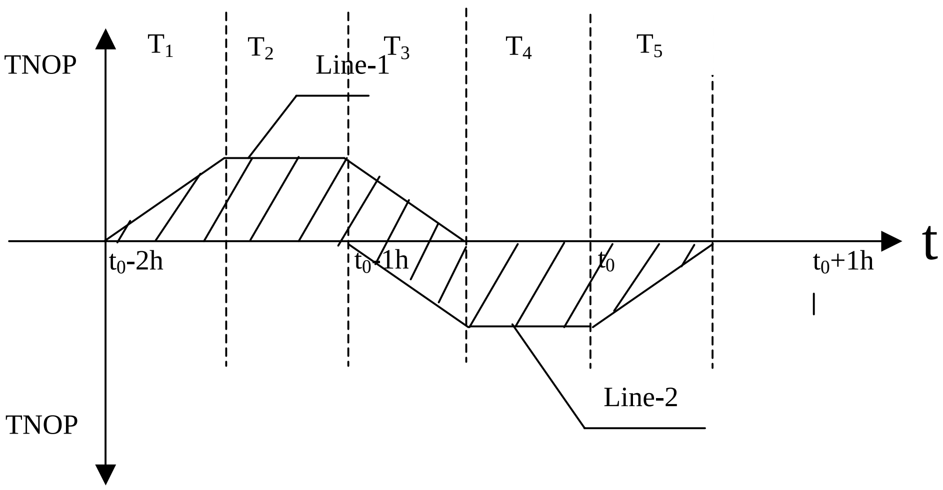

Figure 2

Here line-1 represents the numbers of passengers with security-screening for the first group and line-2 indicates the numbers of passengers with security-screening for the second group.

It is not difficult to find that, if the numbers of passengers for both the first and second groups are the same, then the utilization efficient is the highest. There are 5 time-periods of 30min, among them the time-periods of highest utilization efficient are T_2, T_3 and T_4; though in both periods, T_1 and T_5 , the utilization efficient of EDSs are high enough, by the way, it is inevitable. Certainly, the most concerned time-periods are those during which the largest numbers of passengers are check-in, because that justly is the key to determine whether the passengers are delayed or not.

When the airplanes are divided in three groups when departing at different time t_0, t_0+0.5h and t_0+1h, respectively, which can be described in Figure 3.

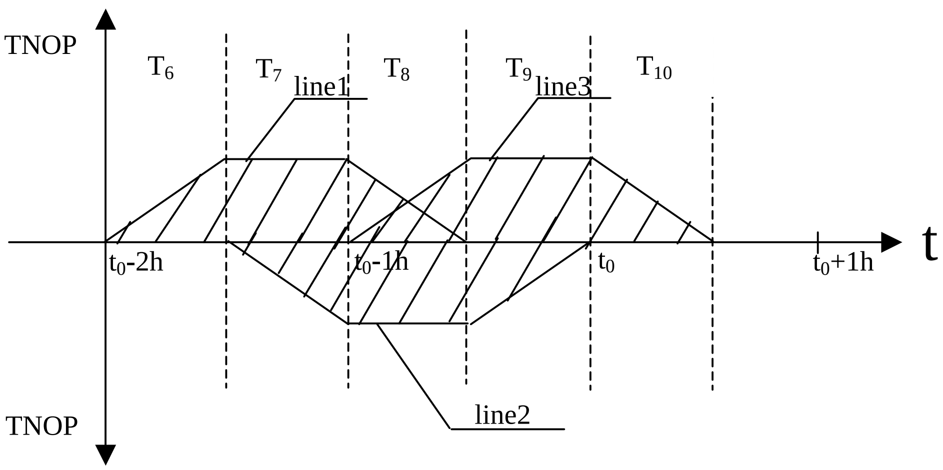

Figure 3

Here line-1 represents the numbers of passengers with security-screening for the first group, line-2 indicates the numbers of passengers with security-screening for the second group and line-3 indicates the numbers of passengers with security-screening for the third group.

As for the divided 5 scheduled periods, obviously the period segment T_8 is the involved time-period with the maximum numbers of passengers, which seems to be the more interested one for passengers not to delay because the security-screening has finished for the first departing airlines. At that time, the EDS machines can make passengers not delay. It is quite easy to understand that the highest utilization efficient for EDS instruments can be obtained at the period T_8. But for the whole time-period of 2.5h, the integrated utilization efficient is not so high. In the event that integrated utilization efficient of EDS machines is increased, the numbers of passengers in the second group should be decreased. The fewer the passengers are, the higher the efficient is. When the number of passengers is zero, the utilization efficient is the greatest. In the same way, it is not difficult for us to understand that if the departing groups are increased, the numbers of passengers in the third group during the corresponding period T_3 should be increased and then the integrate utilization efficient of the EDS machines is whereas reduced. Therefore, for two departure groups with 1h interval, it will be the best manner to keep numbers of passengers in each group in the same or almost agreement with one another; and the integrate utilization efficient of the EDS machines is the greatest and the required number of the EDS machines is the smallest.

For this case, the number of EDSs required can be accounted as:

$$4609/8\times2\times(20\%+60\%\times2)/(0.5\times0.92\times185)=19 \text{ for Airport A}$$

and

$$4954/8\times2\times(20\%+60\%\times2)/(0.5\times0.92\times185)=21 \text{ for Airport B}$$

which numbers are reduced by a certain degree (A from 38 to 19 and B from 41 to 21).

Of course, the proposed model only considers the benefit of the airlines, rather than that of the passengers. Surely, it can properly be adjusted according to the concrete situations. If aviation is at the peak hour or the other crowded period such as the golden week and wanderlust vacation, there would be better a certain interval such as 1 h, between the neighbor departure airlines in order to undertake passengers to check-in on time without delaying due to security-screening. In the ordinary circumstances, the airlines may be increased in the different periods, particularly other than the peak hours, in the seek of passengers.

6 TASK 4

Based on our calculation analysis, what we can recommend to Mr. Sheldon and the airlines about checked baggage screening for the flights during the peak hours at our two airports are suggested as follows:

In respect that is convenient to passengers, it is as soon as possible to do security screening individually once the passengers arrive at two airports. Based on the postulated hypotheses as stated above that baggage screening begins before the departure and will then take 1.5h except the interval of 30min from check-in to flight departing. From the three simply divided groups of our *MODEL 2*, one can calculate the scheduled departure and know that the corresponding security screening begins at 2h before and end at 30min before departure. Furthermore, for Airport A when 9 subgroups are divided, similar conclusions are also made in the same way. Here, there is a worried problem, which make passengers delay. Our already made MODEL 2 is not so well done; a good method by worthy of recommendation is designing some one or more EDSs as the special EDSs for particularly used at the moment that the flights will soon depart, for instance, only in 30min later.. In this way, not only the high utilization efficient of EDSs can be achieved but also the passengers later arriving at airports will not delay due to baggage screening.

For some possible passengers delay, it may take the better made Model 3. When the airlines are divided into two-flight departure groups security screening can still be done as mentioned above. In our case, passenger delay is unnecessarily worried to occur because various possible passenger-delays are considered into our model.

Now the remained problems may be if our security-screening systems can be adjusted according to different numbers of passengers during the different periods before flight departure. The current rule based on the historical data is that according to what airlines claim for flights other than “shuttle” service, 20% of the passengers do not check any luggage, 20% check one bag, and the remaining passengers check two bags. Based on our analysis, different baggage screening should be designed for different cases, such as different numbers of passengers and different time-periods prior to their scheduled departure time. For our MODEL OF TWO-FLIGHT SCHEDULE the airplanes will depart at time t_0 and at t_0+1h, and the corresponding total period for from t_0-2h to t_0+0.5h, a quite reasonable analysis has been done already.

As for the divided 5 scheduled periods, the time-periods of highest utilization efficient utilization efficient of EDSs are T_2, T_3 and T_4; while the inevitable ones lower utilization efficient of EDSs are T_1 and T_5 , respectively. Therefore, proper adjustments can be done. For the inevitable periods lower utilization efficient of EDSs, T_1 and T_5 , it is fully reasonable to do all, or al least most, checked luggage screening, which lead to not only high utilization efficient utilization efficient of EDSs but also great security-related objectives of the airlines.

For airport A, in the intervals of both T_1 and T_5, when the biggest utilization efficient of EDSs is achieved, all current EDS machines can perfectly perform luggage screening with the number of bags being $19\times 0.5\times 0.92\times 185=1617$, while in the practical baggage screening the number of bags being $4609/(2\times 4)\times 2=1126$. That the former is obviously greater than the latter demonstrated that the EDS machines are enough for security screening. So during this period, all checked luggage screening can be done. Whereas in the three intervals, T_2, T_3 and T_4, luggage screening is not done with the numbers of bags being $[4609/(2\times 4)\times 2\times 2-1617]\times 3=2064$, the not-screening rate can be estimated to be $2064/(4609\times 2)\times 100\%=22.4\%$. For this case, the security-related objectives of the airlines can roughly be estimated as

SRO（A）=1-[（1-22.4%）×（1-98.5%）×p+22.4%p]=1-23.56%p.

Similarly, for Airport B, in the intervals of both T_1 and T_5 with the biggest EDSs utilization efficient utilization efficient, all checked luggage screening can be done, the not-screening rate being 21%,and the security-related objectives of the airlines can around be estimated as

SRO（B）=1-22.18^5%p.

Postulate the flight depart times, both t_0 and t_0+1h, the new rules can be employed, which is stated as follows:

Two bags of all passengers that arrive at the airport form t_0-2h to t_0-1.5h and from t_0 to t_0+0.5h d are both checked through security-screening, while from t_0-1.5h to t_0 any bag of 20% passengers that arrive at the airport is not checked and one bag of 20% passengers that arrive at the airport, so-called “check one bag” cluster, are either checked through security-screening.

Besides, it is also found that when the above adjustment is done on both the flight departure and the security-screening rule, security-related objectives of the airlines can further be increased in a content, by SRO been located from 1-31.05%p to 1-23.56%p or 1-22.185%p for Airports A and B respectively. If only the numbers of the EDS machines is solely increased, the SRO value is increased from 1-31.05%p to 1-23.56%p, Just mentioned above (see *task 2 for detail*), so about more 4 EDS machines will be required. Surely, in order to increase the SRO value, it is prior to use mathematical knowledge through the optimization or modeling to realize the anticipated goals and the desired aim is not realized yet, it is required to purchase new apparatus as less as possible.

7 TASK 6

Our models are quite simple and well applicable due to its no escpecial requisition. For its application to all 193 airports in the Midwest Region even 429 ones in the whole United States, it can be assumed the flights and security situations of each airline and/or airport are very similar or even almost the same. An evident hypothesis can be made: the same 8 Flight Types in Table 1 of Appendix A are already to be used during the Peak Hour. Once given the number of flights, the number of seats and all other related information, THE NUMBER OF EDSs can be gotten through our *ONE SCHEDULED FLIGHT MODEL* and *TWO SCHEDULED FLIGHT MODEL* mentioned above according the same security-screening rules and individual numbers of airlines or flights.

For scheduling the departure of flights, a project worthy to be extended is to keep the same passengers in the departing group during A PEAK HOUR and for the departure interval of 1h. This is already verified in our *TWO SCHEDULED FLIGHT MODEL*. In that case, ont only the number of EDSs can be reduced quite much but also the SRO index can be increased in a certain degree through adjustment of security-screening rules. It is suggested that different security-screening rules should be designed for the different situations particularly for different checking periods.

8 TASK 7

8.1 Additional LOCAL ASSUMPTION

1. The same passengers are kept in the departing group during A PEAK HOUR and for the departure interval of 1h.

2. Every EDS machine works well, each ETD machine operate in parallel, the security-screening period is 1.5h, and the distribution of the checked bags is similar as

mentioned as above.

3. The labor cost to operate the ETD machine is 5$.
4. Considering technologies with more modest space and labor costs will emerge in the coming decade, we suppose the current EDS machines are not changed in the future of about ten years.
5. Suppose the current EDS machines still work in the recently about ten years.
6. Assume that 250 dollars will be spent to install an ETD machine, while 5000 dollars for an EDS machine. The cost of Installing is abbreviated as CI.
7. Assume that we do not account the cost of modifying existing infrastructure (CMEI), maintenance costs, power costs and the other miscellaneous costs
8. Suppose that a security-screener works 8 h everyday and fully every months; the labor cost to operate the EDS machine is 5$ per hour.

8.2 EDS/ETD MODEL

First of all, Four security-screening projects can be selected for airports:

1． EDSs check all bags.（100%EDS）

2． ETDs check all bags.（100%ETD）

3． EDSs check the bags taken by 80% of the passengers, ETDs check the bags taken by 20% of the passengers.（80%EDS/20%ETD）

4． In order to reduce high risks, not only EDSs check all bags but also ETDs check the bags taken by 20% of the passengers.（100%EDS/20%ETD）

Suppose an ETD machine can process 45 bags per hour. For Airport A, now project 4 (*100%EDS/20%ETD*) is arbitually taken as an example to illustrate the calculation process.

The number of EDSs is equal to $(4609\times 2/4)/(185\times 0.5\times 0.92) = 28$

The cost to purchase EDS is taken as 28,000,000

The number of ETDs is equal to $(4609\times 2\times 0.2/4)/(45\times 0.5\times 0.92) = 23$

The cost to buy ETDs is taken as $23\times 45000 = 1{,}035{,}000$

The total cost of purchasing EDS/ETD is 29,035,000

The CI and CMEI cost is 100000×28＋5000×28＋250×23=2 945 750

The total labor cost as wage of 10 year is （23×10＋28）×5×8×365×10＝37，668，000

The total fee of the examined airport for 10 years is 69,648,750

Because the accuracy for a device to perform security screening is limited, the rate of the existing hazard without being found is defined as the “inaccurate” rate, and its value is calculated as “inaccurate”＝1.5%×0.3%×0.2＋1.5%×0.8＝1.2009%

All four security-screening projects are shown together with their calculation results in Table 6.

Table 6. All four security-screening projects together with their calculation results

Project of sreening	Purchase cost	CI and CMEI	Wage cost	Total cost	inaccurate
100%EDS	28,000,000	2,940,000	4,088,000	35,028,000	1.5000%
100%ETD	5,175,000	28,750	167,900,000	173,103,750	0.3000%
80%EDS/20%ETD	24,035,000	2,420,750	36,938,000	63,393,750	1.2600%
100%EDS/20%ETD	29,035,000	2,945,750	37,668,000	69,648,750	1.2009%

From Table 6, one can find:

1. When using the first project (100%EDS), the total cost is the lowest, but the “inaccurate” rate is the highest. When effect of the security factor is not large, this project can be taken.

2. When using the second project (100%ETD), the total cost especially the labor cost is too large to be used although the “inaccurate” rate is the lowest. In general airports will not use this project due to its extremely high cost

3. When using the third project (80%EDS/20%ETD), the total cost is quite lowest, but the “inaccurate” rate is fairly low (1.26%), so this project can be taken in most cases. Inversely, when using the fourth project (100%EDS/20%ETD), the total cost is relatively higher, but the “inaccurate” rate is slightly lower. Although the effect of the security factor is large, this project cannot be considered. Comparatively, by using the latter project, more 6,255,000 dollars will be spent whereas the “inaccurate” rate will only be reduced quite a little (only by 0.0591%). Distinctly, this cost is not worth to spending, therefore, the repeated screening is

not so necessary.

4. Consequently, the third project (80%EDS/20%ETD) should comprehensively to worthy being prior to be employed among the above-stated four projects. In the other words, most part of bags should be checked by EDS-screening while the remained bags should be checked by ETD-screening. For most cases, this project is always satisfactory when compared with the other three projects.

Finally, we emerge a novel problem, which is on earth the optimal combination where how many bags should be checked by EDS-screening and how many bags should be checked by ETD-screening.

The proportional rate of bags checked by ETD-screening or EDS-screening can be raised from 0% to 100% by 20% acceleration rate stepwise or reduced from 100% to 0% by -% acceleration rate stepwise. The variation processes and calculation results by using Matlab6.1 software are listed in Table 6.

Table 6. The calculation results when the proportional rate of bags checked by ETD/EDS-screening can be raised/reduced from 0/100% to 100/0% by +/- 20% acceleration rate stepwise..

Raised/reduced proportional rate checked by ETD/EDS (%)	0－20% (1－80%)	20%－40% (80－60%)	40%－60% (60－40%)	60%－80% (40－20%)	80%－1 (20%－0)
Raised Total cost ($)	28365750	27114750	28365750	27114750	27114750
Reduced “inaccurate” rate (%)	0.24%	0.24%	0.24%	0.24%	0.24%

It is found that when the proportional rate of bags checked by ETD-screening is raised or reduced from 0% to 100% by 20% acceleration rate stepwise and simultaneously the proportional rate of bags checked by EDS-screening is reduced from 100% to 0% by -20% acceleration rate stepwise, the total costs are varied by about 28 million dollars acceleration rate stepwise and the “inaccurate” rates are reduced by 0.24% acceleration rate stepwise. Both variations, either the increment or decrement, of them are kept on an even keel. Roughly it is difficult to judge which projects (80%EDS/20%ETD to 20%EDS/80%ETD) are preferred to the best and maybe all are applicable. Under this condition, comprehensive considerations on both the security and cost and even with their interaction relationship are required to determine which one is the optimal. As is well-known, maybe the security is more important and the increment of security will reduce number of misadventures. So an important relationship is that the loss infected with un-safety due to the misfortunes will be immense, then the additional value should be considered by matching this vast loss. So the optimal project can be determined finally.

Additionally the made decision to use the best project may be related with some important events. For instance, since “9.11 Terror Assault Accident”, the security has been located on first of all for every airport even for many governments. These facts will raise the difficulty to resolve the problem. Based on these facts, the “accurate” rate should be raised to 99.99% at least. Of course, the limitation of money is also considered and in this practical case, the “accurate” rate is taken as slightly greater than 99.0%. This example can be given in Table 8A and B for Airports A and B respectively.

Table 8A. The calculation results with about 99% security-screening “accurate” rate for Airports A

Project of sreening	Purchase cost	CI and CMEI	Wage cost	Total cost	inaccurate
58.3%EDS/41.7%ETD	19160000	1797000	72562000	93519000	0.9996%

Table 8B. The calculation results with about 99% security-screening “accurate” rate for Airports B

Project of sreening	Purchase cost	CI and CMEI	Wage cost	Total cost	inaccurate
58%EDS/42%ETD	20295000	1542750	77088000	98925750	0.996%

It is easily to find the ideal project is that 17 EDSs to check 58% bags and 48 ETDs to check 42% bags through security/baggage-screening for Airports A. The similar results are obtained for Airport B, the optimal project is that 18 EDSs to check 58% bags and 51 ETDs to check 42% bags through security/baggage-screening.

9 TASK 8

this task mainly solve how to best fund future scientific research programs and security system.research areas are the science, technology, engineering, and mathematics (STEM).

Through the analyses mentioned above, it is quite easy to find that mathematics is quite even very important to security system。 The focus for action of mathematics is at reasonable optimization including the interaction effects between two instruments, the improvement of the management system and so on. All of them are needed to use the mathematics knowledge especially mathematical modeling. As stated as problems appeared in *Task 4*, the security is further undertaken, the fewest new machines can be increased to realize our best target. If mathematics knowledge is deeper used to optimize, the optimal results can be obtained without any or with only a little increment of the new machines.

Next, based on the analysis and discussion in *Task 7,* it is found that the science, technology and engineering are also even more important to raise the itself security performance of the screening systems. Mathematics makes the benefit of security system through the optimization although this benefit is finally limited。Compared with mathematics, science, technology and engineering act in quite different ways. Based on *Task 7,* it should be found that if money enough and condition permitted, developing new principle, methodology and techniques from the view of points based on science, technology and engineering is fully possible and make more benefit of security system in a long time. So it would be suggested that most money should be spent to develop science, technology and engineering especially high and new methodology and technology such as e.g. x-ray diffraction; neutron-based detection; quadropole resonance; millimeter wave imaging; microwave imaging and mass spectrometry. Certainly proper amount of money should be spent in Mathematics and optimization。

Additioanlly, there is a small problem is to use our EDS/ETD model to examine the possible effect of changers in the device technology, cost,accuracy, speed, and operational reliability. One of the referenced thought way is continuously adjust the operational reliability accurate or speed, to determine the number of instruments, the total cost, the integrated accuracy and the comprehensive index through their combination. The better project with the most prefect will occur finally. More discussion and deeper approaches will can be made owing to the limitation of space and time.

10 Strengths and Weaknesses

10.1 Strengths

1. The model is established through the psythic of passengers, therefore it is practical. Surely through the *Model of Two Scheduled Flight*, a very valuable and widely applicable conclusion are made as follows: the most important is to undertake security for every airport; the probability of aviation misadventure due to not screening of baggage is much greater than that due to the uncertainty of baggage screening. It should properly be adjusted according to the concrete situations. If aviation is at the peak hour, there would be better a given unity interval, such as 1 h, between the neighbor departure airlines in order to undertake passengers to check-in on time without any delay due to security-screening and with the smallest number of screening instruments.
2. In our *Model of Many Scheduled Flight*, the practical operation can easily finished when the number of passengers is not so large.
3. Not only the number of EDSs can be reduced quite much but also the SRO index can be increased in some fair content through adjustment of security-screening rules. In general, when the number of EDSs is not raised while the SRO index can be increased through employment of novel security-screening rules. Summary

10.2 Weaknesses

1. The benefits of passengers are not considered and only the benefits of the airlines are accounted while the mathematical models are established. Practically, convenience provided for passengers is also a very important target.
2. Some models are still rough, for instance, when considering the delay of passengers through our *Model of Many Scheduled Flight*. Therefore, more complex situation should be regarded in order in improve the proposed models
3. It is a quite sorry for us not to connect the total cost with the security "accurate” rate in the developed *EDS/ETD Model*. This model may be modified through directly adding the colossal loss lead by any misfortune into the total cost by timing a conversion factor. This is not finished due to the limited time.

Appendix

Programme Code Sheet

task3	Subsection of the scheduled flight
task7a	Calculating data for each project at airport A
task7b	Calculating data for each project at airport B

task3:

```
MODEL:
MAX=34*0.9*x11+46*0.9*x12+85*0.9*x13+128*0.85*x14+142*0.85*x15+194*0.85*x16
+215*0.85*x17+350*0.8*x18+
34*0.9*x21+46*0.9*x22+85*0.9*x23+128*0.85*x24+142*0.85*x25+194*0.85*x26+215*
0.85*x27+350*0.8*x28+
34*0.9*x31+46*0.9*x32+85*0.9*x33+128*0.85*x34+142*0.85*x35+194*0.85*x36+215*
0.85*x37+350*0.8*x38;

34*0.9*x11+46*0.9*x12+85*0.9*x13+128*0.85*x14+142*0.85*x15+194*0.85*x16+215*
0.85*x17+350*0.8*x18+
34*0.9*x21+46*0.9*x22+85*0.9*x23+128*0.85*x24+142*0.85*x25+194*0.85*x26+215*
0.85*x27+350*0.8*x28+
34*0.9*x31+46*0.9*x32+85*0.9*x33+128*0.85*x34+142*0.85*x35+194*0.85*x36+215*
0.85*x37+350*0.8*x38<=4610;
x11+x12+x13+x14+x15+x16+x17+x18=15;
x21+x22+x23+x24+x25+x26+x27+x28=15;
x31+x32+x33+x34+x35+x36+x37+x38=16;
X11+x21+x31=10;
X12+x22+x32=4;
X13+x23+x33=3;
X14+x24+x34=3;
X15+x25+x35=19;
X16+x26+x36=5;
X17+x27+x37=1;
X18+x28+x38=1;
34*0.9*x11+46*0.9*x12+85*0.9*x13+128*0.85*x14+142*0.85*x15+194*0.85*x16+215*
0.85*x17+350*0.8*x18>=1800;
34*0.9*x21+46*0.9*x22+85*0.9*x23+128*0.85*x24+142*0.85*x25+194*0.85*x26+215*
0.85*x27+350*0.8*x28<=1000;
34*0.9*x31+46*0.9*x32+85*0.9*x33+128*0.85*x34+142*0.85*x35+194*0.85*x36+215*
0.85*x37+350*0.8*x38>=1800;
@GIN(x11);@GIN(x12);@GIN(x13);@GIN(x14);@GIN(x15);@GIN(x16);@GIN(x17);@
```

```
GIN(x18);
@GIN(x21);@GIN(x22);@GIN(x23);@GIN(x24);@GIN(x25);@GIN(x26);@GIN(x27);@
GIN(x28);
@GIN(x31);@GIN(x32);@GIN(x33);@GIN(x34);@GIN(x35);@GIN(x36);@GIN(x37);@
GIN(x38);
END
```

task7a

```
format long g;
a=0.001;
b=0.41;
c=0.42;
x=b:a:c;
etd=x';
eds=1-x';
goumai=45000*ceil(115*x)+1000000*ceil(28*(1-x));
anzh=250*ceil(115*x)+(5000+100000)*ceil(28*(1-x));
gz=(ceil(115*x)*10+ceil(28*(1-x)))*5*8*365*10;
inaccurate=0.003*x+0.015*(1-x);
zfy=goumai+anzh+gz;
table=[x;goumai;anzh;gz;zfy;inaccurate;ceil(115*x);ceil(28*(1-x));x]'
zhen_fy=[];
jian_inaccurate=[];
for i=1:(c-b)/a
        zhen_fy(i)=zfy(i+1)-zfy(i);
        jian_inaccurate=inaccurate(i+1)-inaccurate(i);
end
zhen_fy
jian_inaccurate
```

task7b

```
format long g;
a=0.01;
b=0.38;
c=0.42;
x=b:a:c;
etd=x';
eds=1-x';
goumai=45000*ceil(120*x)+1000000*ceil(30*(1-x));
anzh=250*ceil(120*x)+(5000+80000)*ceil(30*(1-x));
gz=(ceil(120*x)*10+ceil(30*(1-x)))*5*8*365*10;
inaccurate=0.003*x+0.015*(1-x);
```

```
zfy=goumai+anzh+gz;
table=[x;goumai;anzh;gz;zfy;inaccurate;ceil(120*x);ceil(30*(1-x));x]'
zhen_fy=[];
jian_inaccurate=[];
for i=1:(c-b)/a
    zhen_fy(i)=zfy(i+1)-zfy(i);
    jian_inaccurate=inaccurate(i+1)-inaccurate(i);
end
zhen_fy
jian_inaccurate
```

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