Modelling of Composition of Baggage Screening Systems at Airports

U. Vandebona and **P. Thananupappaisan**

School of Civil and Environmental Engineering, University of New South Wales, Sydney, Australia

Abstract: An optimisation framework for the selection of baggage screening options for airports is explored in this paper. Typically, airports deal with large volumes of baggage and screening may be required because of number of reasons. These reasons have been identified in this project with the focus on recognising the range of appropriate screening devices. Cost and performance characteristics of these systems are summarized in the paper. As a first step, a method for determination of the composition of screening systems is demonstrated using the cost minimisation approach. Further analysis accounts for the range of performance measures such as cost, throughput, efficacy and user preference of the screening system. Field surveys conducted during this project have provided an initial insight about properties of user perception in the context of baggage screening.

Keywords: *Modelling; Airport; Baggage screening; X-ray; Explosive detector; Sniffer dog*

1. INTRODUCTION

Baggage screening at airports has become a topical issue in recent time. Nevertheless, baggage inspection industry has a long history. Baggage screening has been a longstanding phenomenon in long distance travel, particularly across geopolitical boundaries.

Inspection of accompanied property is an important part of implementation of customs regulations. This is seen as important to the economic well being of the particular jurisdiction. In some countries, quarantine regimes and prevention of transport of contrabands may trigger the baggage inspection requirement.

In the context of air travel, baggage handling and inspection is a specialised process. (Taylor, 1998; Wells, 2000). This project attempts to investigate possible screening configurations and optimum compositions of screening methods.

2. BAGGAGE FLOW RATES

A survey at Sydney airport in early 2002 has shown that inbound international passengers carry an average of three bags per two passengers. (Thananaupappaisan, 2002). This is excluding hand luggage items. The survey has also shown that domestic passengers carry slightly less than one bag per passenger. It is acknowledged that these baggage rates are likely to be different at other airports. However, these rates provide a means of making approximate estimates of baggage flow rates at airports. It is important to know estimates of baggage flow rates in the selection of screening systems that may be suitable.

The field survey was conducted at three locations of the airport in Mascot, Sydney in November 2001. An observer counted the number of bags and corresponding number of passengers during this survey. The data collection related to the international terminal was conducted at two locations: at the check-in counter and arrival lobby. The survey covered total of 150 passengers at each site. The observations also covered the size of the bags as reported by (Thananupappaisan, 2002). However, the size distribution of bags is not included in this paper. The data collection at the domestic terminal was performed at the baggage claim area. Again 150 passengers were covered. It was discovered that some domestic travellers did not carry any baggage.

The survey covered roughly equal proportion of males and females as shown in Table 1. Some family groups contained children as well. About 6% of the sample of domestic travellers covered in the survey represented children.

Table 1 shows that departing international travellers carry about 1.38 bags per person. Arriving international passengers carry a slightly higher number of bags at 1.55 bags per passenger. These counts do not include small handbags, purses and clothing items carried on hand. As expected, domestic travellers carry less number of bags than international travellers.

At above rates of bags per passenger, the inbound baggage handling system of the Sydney airport could be able to handle about 2000 bags per hour during the day. At this stage of modelling, only the average baggage flow rate is considered.

Table 1. Baggage count survey

	International Outbound	Inbound	Domestic Inbound
Passenger count			
Male	80	74	83
Female	68	73	63
Child	2	3	4
Total	150	150	150
Bag count	207	233	142
Average per person	1.38	1.55	0.95

3. SCREENING METHODS

There are five main categories of target products subjected to baggage screening. These product groups are explosives, weapons, animals, plants and narcotics. Preventing the ability to bring along explosives and weapons is a primary concern of security agencies. Dobson and Payne (1987) has catalogued a substantial list of events that show terrorist attacks on airliners that has taken advantage of lapses of vigilance on weapons and explosives. In general, security processes rely on detection of explosives and weapons to pinpoint an imminent threat.

Screening transport of animals and plants in passenger luggage is a primary concern of customs and quarantine officials. On the other hand, the illegal movement of various types of drugs has become a worldwide problem for law enforcement agencies.

Passengers are much familiar with handheld scanning devices used by security personal and walkthrough portals available to screen individuals. Some of these methods have come to prominence with the heightened security consciousness of transport operators. A recent paper by Smith (2002) highlighted the high level activity in the areas of research and development related to transport security. An insight into modern tools being developed to outsmart sophisticated troublemakers has been reported by Dawson (2002).

There are four main types of baggage inspection methods identified by Thananaupappaisan (2002). They are (a) Screeners (b) X-ray devices (c) Explosive detection systems and (d) Sniffer dogs.

3.1. Screeners

Screener is a person manually inspecting belongings of travellers. This is a labour intensive and time consuming method. For example, average of the inspection time for a bag is about 4 minutes (Table 2). Also the efficacy of this method is not necessarily higher than other methods available. However, this is one of the most widely applied methods.

A significant drawback of using screeners is the inconvenience and embarrassment caused to passengers. However certain target items may always require physical inspection. The range of dutiable goods and prohibited items is quite large and variable they can be outside the focus of the screening devices readily available. Thus human screeners have to play a backup role to the screening equipment installed.

Another disadvantage is the relatively large amount of time required to deal with certain equipment carried by travellers. Equipment related to electronics, communications and photography often require detailed attention of the screening personal.

United State House of Representatives (2000) has reported that tests of screeners revealed significant weaknesses in their ability to detect threat objects located on passengers or contained in their luggage. In 1987, screeners missed 20 percent of the potential dangerous objects in Federal Aviation Authority tests. Also, a wide discrepancy of screener accuracy has been observed in a joint screener testing program conducted by the Federal Aviation Authority (Dillingham, 2001).

3.2. X ray

These devices adopt the x-ray technology perfected in the medical field to see through outer layers of baggage and belongings within. Recent x-ray devices view items from number of different angles and it is claimed that these devices can detect even a thin copper wire behind a steel plate. Also, there are methods perfected to distinguish between plastics and metal.

Attempts have been made to devise a system that is automatic, needing no video screens and human operators. These automated systems would sound an alarm when a suspicious image is found (Moore, 1991).

Table 2. Capacity, efficacy and cost of baggage inspection methods

Method	Capacity Bags/hr	Efficacy %	Price US$	Cost US$/hr
Screener	15	75	6/hr	6.00
X-Ray	720	85	1,000,000	22.83
EDS	180	80	400,000	9.13
Sniffer Dogs	100	93	100,000	8.56

Source: Thananaupappaisan (2002).

Federal Aviation Authority specifies a minimum flow through rate of 10 items per minute for airport applications. Most commercial X-Ray devices at airports handle about 12 items per minute (Table 1). X-Rays applied to checked baggage are ‘film unsafe’ compared to the ‘film safe’ devices used for hand luggage inspections.

3.3. Explosive Detection Systems

These are referred to as EDS in the security industry. These focus on detection of chemicals that can be used in explosives. EDS devices encountered by the general public are generally based on vapour detection methods. These come in a range of forms, from hand held devices to walk-through devices. Handheld devices used at certain airports are known to require about 20 seconds to inspect the average bag. These devices are useful in inspecting a selected number of bags rather than the complete flow of bags.

For inspection of relatively large bag flow rates EDS devices based on thermal neutron activation (TNA) have been developed. However, these use certain level of nuclear radiation, and as such they are unsuitable for screening passengers and carry-on luggage.

3.4. Sniffer dogs

The nose of a dog can detect odours beyond the scope of humans and machines. Sniffer dogs can be trained to distinguish as many as 19,000 different kinds of explosive (Barker, 2002).

A sniffer dog costs about US$ 90,000 (New South Wales Council for Civil Liberties, 2001). The operator should also consider the cost of support personal including handlers. Also there are costs associated with food, medicine and lodging of the animals. Anyhow, a dog may be able to sniff through 100 to 200 bags an hour (Table 2).

An advantage of using dogs is the high level of visibility they seem to exude. Thus, they are seen as an efficient deterrent against criminal elements.

In Australia, there are three types of sniffer dog teams used. One category looks for explosives and weapons. There are seven teams of this type operating in Melbourne, Sydney and Brisbane airports. The second category consists of beagles used by quarantine officials to detect animals and plants. The third consists of black labradors used by customs officers to detect drugs and narcotics (Barker, 2002).

None of the above methods is suitable for commercial scale screening of all possible target products. Table 3 shows types of target products each of the above methods can detect with reasonable degree of success.

4. THE MODEL

The modelling process in this project followed five steps: (a) identification of price of screening methods (b) determination of hourly cost (c) identification of screening system configurations for analysis (d) estimation of total costs and benefits and (e) selection of optimum screening system. The initial focus is in obtaining information about cost elements and computing the operating cost per hour for each screening method. This is based on pricing information obtained from manufactures and vendors. As expected, there is a wide range of prices. Values selected are already shown in Table 1.

The average cost per hour per unit of a particular screening method is computed by considering the initial investment as well as operating and maintenance costs in conjunction with the useful life of the product. It appears that X-ray and EDS devices have a design life of about five years. For the purpose of the analysis here, the productive life of sniffer a dog is selected as four years. Computations here has also assumed an eight hour working day for the sniffer dog. The estimates of the cost per hour were already shown in the last column of Table 2.

The next step involves investigation of the range of options that can be made up by combining screening methods. The objective is to uncover all target products. It is acceptable to have an overlap such that a certain target product is captured by multiple methods. However, it is unacceptable to let any target product to be outside the focus of all of the screening methods adopted.

The next step is to compute overall cost of such systems able to match the baggage flow rate of the airport. This step and proposed methods for selection of the appropriate screening system are explained in a later section.

5. SCREENING SYSTEM COMPOSITIONS

For the purpose of this paper we adopt the term screening method to mean a particular type of screening, such as EDS. The term screening system is adopted to mean a combination of such screening methods. Table 3 allows us to construct combinations of above methods necessary to uncover the total range of target products. For example screeners are not suitable when the objective is the detection of explosives. Thus, if screeners are employed, we also need

Table 3. Focus areas of baggage inspection methods

Method	Explosives	Weapons	Animals	Plants	Drugs
Screener		yes	yes	yes	yes
X-Ray		yes	yes	yes	
EDS	yes				yes
Sniffer Dogs	yes		yes	yes	yes

EDS or Sniffer dogs to supplement the screening system. A list of possible combinations of inspection methods is prepared as shown in Table 4. For example, (a) screeners and EDS and (b) screeners and sniffer dogs options mentioned in the previous paragraph are listed as options 1 and 2. The last five options have redundancy. In other words, those options may screen a certain category of product by more than one inspection method.

As the capacity of each system is reasonably easy to establish it is possible to estimate the count of each category required for a given baggage flow rate. Number in each category, is simply the average baggage flow rate divided by the service capacity indicated in Table 2. More specifically, the number of units required in inspection method i is given by:

$$N_i = B / C_i \quad \text{.. (1)}$$

Where B represents the baggage flow rate and C_i denotes the handling capacity of a unit of the inspection method i.

6. COST OF SCREENING SYSTEM

The count of number of units from each screening method allows us to estimate the total cost of the system. To enable comparison of costs, the estimates are made in cost per hour basis. Thus the cost is given by:

$$C = \Sigma c_i N_i \quad \text{... (2)}$$

Table 4. Inspection method combinations

Option	Screener	X-Ray	EDS	Sniffer Dog
1	✓		✓	
2	✓			✓
3		✓	✓	
4		✓		✓
5		✓	✓	✓
6	✓	✓	✓	
7	✓	✓		✓
8	✓		✓	✓
9	✓	✓	✓	✓

where c_i denotes the cost per hour of a unit of the inspection method i.

Computed values of cost per hour of each of the inspection system options for an airport with 1000 bags per hour to inspect is shown in Figure 1. From the total cost point of view, options 3, 4 and 5 are much superior (low cost) to the other options. These options cost about US¢ 10-20 per bag inspected. According to these calculations, the estimated cost of baggage inspection at Sydney international airport is in the range of A$ 400 – 800 per hour. In contrast, the more expensive options cost an exorbitant US$ 4-6 per bag. This is at least a 20 fold increase of the baggage inspection expense.

Recall that option 5 has three baggage inspection methods and thus include a certain degree of redundancy. In that context, option 5 may be the superior option of the three low cost options considered. However, this option is rarely applied perhaps because this option relies solely on technology. This issue will be discussed later in the context of user perception.

All high cost options use screeners. Screeners are employed at many airports. At small airports, it may be argued that the reason for this is the inability to muster the large upfront cost required for other inspection devices.

7. VISIBILITY INDEX

A reliable measure of benefits of screening systems is not readily available. It is acknowledged that catching offenders is of value

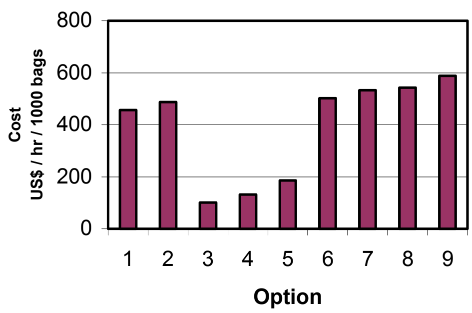

Figure 1. Cost of baggage inspection options

Table 5. User perception

Method	Reliability	Accuracy	Equity	Overall average
Screener	71.40	7.305	70.90	71.8
X-Ray	89.65	88.67	90.48	89.6
EDS	85.40	84.45	84.75	84.9
Sniffer Dogs	73.67	74.45	73.55	73.9

to the law enforcement agencies and the community in general. However, for many travellers (and operators), the obvious outcome from the screening process is the delay and irritation. This lack of tangible benefits has made planners view screening systems as mainly a legal and social obligation.

Thus, it is important to appear that the airport has a good security system. In this context, the 'appearance' becomes an important performance indicator. It may be possible to equate this to 'professionalism' and other similar concepts. However, there is no formal method to account for such a concept. Thus, we introduce the concept referred to here as 'visibility index' method. This is a measure that reflects how users perceive the effectiveness of the inspection system. In this connection what we need is a visibility coefficient for each category so that the overall visibility level of the inspection system could be estimated.

Thananaupappaisan (2002) has made an attempt to measure the user perception through a survey at the Sydney international airport in July 2002. Opinions of one hundred travellers (57 male, 43 female) were considered. The survey used two interviewers. The interviews focused on three aspects of the baggage screening systems. The interviewers obtained a user selected score in the range of 0-100 to reflect the perceived level of reliability, accuracy and equity. Reliability covers the ability to work continuously without failures. The accuracy focuses on the ability to perform without making errors. Equity relates to the ability to operate in a non-discriminatory manner without prejudgement.

Table 5 summarises results of the survey. The average rating is calculated from the survey sample of 100 respondents. The average of unweighted ratings is shown in the last column.

Based on Table 5, X-ray has the highest trust from the respondents. The reason may be familiarity and also experiences of being stopped by X-ray machines for trivial reasons. Explosive detector systems are ranked second. This may have been influenced by recent events emphasising terrorism related news.

It is now possible to compute an index to reflect the level of alertness visible to the users. The visibility index computation would be similar to the calculation of cost. For example, the system visibility index is given by:

$$V = \Sigma \rho_i N_i \qquad \text{...(3)}$$

where ρ_i = visibility coefficient of a unit of inspection method i.

Equation 3 uses the count of items of a particular method in computing the overall level of the index. It can be argued against the simplistic nature of this formulation. However, at this stage there is insufficient information to justify a more complex form of accounting for the variables involved. Thus the above formulation is selected for the purpose of this analysis.

The overall average of the user perception already shown in the last column of Table 5 is adopted as the visibility coefficient for the purpose of this analysis. It is possible that these visibility coefficients are affected by socio-cultural background of users and transportability of these coefficients needs further investigation. At this stage these coefficients are applied as indicative values. This allows the computation of level of visibility under different options as shown in Figure 2.

Figure 2 has a shape similar to the histogram shown in Figure 1 with few differences in the rank of options. Preliminary attempts to combine these visibility values (Figure 2) and cost estimates (Figure 1) using a simplex method type optimisation have been unsuccessful and need further research. However, it is important to note

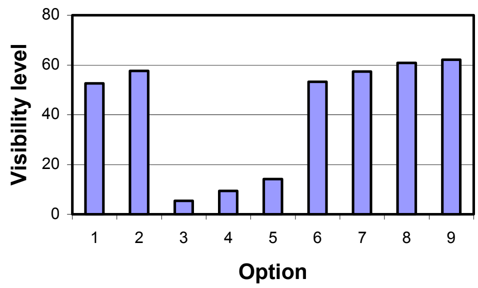

Figure 2. Level of visibility

Table 6. Properties of security system options

Option	Visib-ility	Capacity	Capital cost	Cost /hr	Space need
1	High	Low	Low	High	Large
2	High	Low	Low	High	Large
3	Low	High	High	Low	Small
4	Low	High	High	Low	Small
5	Low	High	High	Low	Small
6	High	High	High	High	Large
7	High	High	High	High	Large
8	High	Low	Low	High	Large
9	High	High	High	High	Large

that options that provide high level of visibility are not those that will be selected by cost minimisation. This is because cost minimisation selections lead to low visibility levels. Application of different types of inspection methods and having large number of units raise the level of visibility. Invariably, that leads to a high level of cost.

Many factors influence the choice of a screening system. Table 6 attempts to provide some guidance based on the method followed in this project.

It is possible to estimate the space allocation requirements based on the count of units in each screening method and footprint size. Space calculation equation is similar in structure to equation 3 and is not repeated here. The small range (0.7 – 0.9) of visibility coefficients used in this project has given rise to the apparent co-relatedness of the space requirements and visibility indices. Thus, in Table 6, low visibility options are associated with low space requirements, whereas high visibility options are associated with large space allocations for screening systems.

8. CONCLUSIONS

A system consisting of screeners and explosive detection equipment is the recommended bag screening system for small airports according to the modelling process described in this paper. This screening system option is recommended because of it needs a relatively low capital investment. Medium size and large airports could consider Option 3 (X-ray, and explosive detection equipment). This system has the lowest operating cost and is suitable to for high flow rates of bags. John F. Kennedy Airport in the U.S.A. and the international airport in Sydney are examples that use X-ray and explosive detection technology as the primary source of screening for security purposes. An increased sense of vigilance is achieved by using screeners and sniffer dogs for random checks at these airports.

Knowledge about capacity and cost of unit of each inspection method allows the selection of the screening equipment composition that would result in the minimum cost. However, it is seen that cost minimisation solution is deficient in its ability to account for real selections made. To allow for this discrepancy, a concept referred to as visibility index is proposed in this paper to account for perceived benefits of screening systems. It is seen, that space allocated may be adopted as a proxy variable to account for the perceived level of anticipated benefits.

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