AIRPORT FLEXIBILITY: A FIRST GLIMPSE ON THE EXTERNAL FACTORS

Liliana Magalhães, Universidade Técnica de Lisboa, Instituto Superior Técnico, CESUR, liliana.magalhaes@ist.utl.pt

Vasco Reis, Universidade Técnica de Lisboa, Instituto Superior Técnico, CESUR, vascoreis@ist.utl.pt

Rosário Macário, Universidade Técnica de Lisboa, Instituto Superior Técnico, CESUR, rosariomacario@ist.utl.pt

ABSTRACT

The future is not foreseeable and forecasts fail most of the times due to unpredictable changes on the circumstances. Airport operators need to anticipate a range of possible scenarios that might occur to face these changes. Flexibility represents the ability to change the function of a certain feature in an efficient and feasible way according to the needs. The first objective of this work is to identify the external factors that drive the need for airport's flexibility. It is important to know the main drivers for flexibility in order to understand which factors affect airports' development. We developed a survey to worldwide airports where airport practitioners were invited to rate a set of eight factors, being: demand, economic cycles, technology developments, regulation, financial resources/capacity, land use restrictions, environmental issues, and geopolitical stability. This survey also collects the main flexible options available at the airports which is the second objective of this work. Results indicate that the most common flexible options are the available land for expansions, utilization of available land for non-aeronautical activities, easiness of changing the design and layout of retail areas within the terminal, swing gates and available spaces at the terminal. The external factors rated as more important in the survey are: demand, financial capacity and technology developments.

Keywords: Airport flexibility, Airport planning, External factors, Flexible options.

INTRODUCTION

The traditional way of planning airports does not prepare this infrastructure to compete in the current or future market conditions. Master plans perform poorly since airports around the world operate in an increasingly uncertain environment (Kwakkel et al., 2010). Future airport traffic volumes are volatile and have a high uncertainty associated which is expected to increase in a free-market regime. The aviation industry lies on a greater market mobility of

carriers and freedom to establish linkages and alliances. Carriers enter and exit markets, change the frequency of services, the size of aircrafts and also the airports where they operate. They form partnerships, alliances, and take equity positions in other national and global carriers. These factors generate a high impact on airport's demand and utilization. Hence, traffic forecasts are likely to become non-reliable and weaker. The discrepancies between forecasts in airport master plans and actual traffic volumes increase as the horizon of the forecast becomes more distant.

Airlines are able to change their network structures overnight. The oil price, flu epidemics, and financial and economic woes further add to the volatility of aviation demand development. Combined with tensions between economic and environmental impacts, this turns airport strategic planning into a challenging task. Additionally, low-cost carriers have been growing and contribute to increase the dynamic of aviation market due to their strategy of minimizing costs (de Neufville, 2006). These carriers change their routes with high frequency, creating new ones and promoting to develop regional airports. Also, they require specific features at airports in order to fulfill their goals (e.g. quick turnaround times and simple passenger terminals).

Moreover, the current economic turmoil has generated an uncertainty in the level of investment in airport infrastructure. There are favourable demand forecasts for short and long-term, suggesting a growth in air transport but uncertainty remains. It is not obvious how to expand the airport's capacity (Burghouwt, 2007).

Flexibility allows airport planners to deal with the volatile market environment and associated uncertainty of future traffic demand and composition. Infrastructures with a long life-cycle such as airports should be embedded on flexibility in order to be adaptable to change the functions and processes accordingly with external conditions with a minimum costs. As de Neufville (2008a) points out:

> "airport planning paradigm is shifting from the traditional pattern, which is determined by high standards, established customers and long-term forecast, to that of recognizing great uncertainty at forecasts, broad range standards and potential for a rapidly changing customer's base."

It is important to notice that building an airport so large that can deal with higher future demands just because we have the money to do so, as for instance Dubai Airport, does not mean to be flexible. Being flexible is related with exploring an infrastructure until its operation limit to maximise the investment.

The first objective of this work is to present a first glimpse on all the external factors that drive the need for flexibility. The second objective is to understand the main flexible options available at airports. We start with a literature review on airport flexibility to collect the external factors that directly or indirectly have driven the need for flexibility. Then, we select several airports with flexible options to extract the external factors that drove their need for flexibility. Additionally, we perform a survey to worldwide airports managers to capture their importance rating on the identified external factors and the most common flexible options.

The objective of questioning on flexible options at airports is to characterize the planning level at which they are more common: strategic, tactical or operational. Flexible options at strategic level are related with actions that require more than a season to be accomplished. Options at tactical level represent actions that occur during a season period. Lastly, at operational level the options are used on a week or even daily base. Furthermore, they also point out other external factors that they consider relevant and were not mentioned.

Airport Flexibility – The Concept

Flexible Strategic Planning, as Burghouwt (2007) calls it, emerged during the 1990s as a branch of strategic management. The theoretical roots of this concept can be traced back to the late 1950s.

Flexibility has been applied in other fields besides airport infrastructures. For instance, de Neufville and Scholtes (2011) present several examples of application of flexibility in engineering design (e.g. bridges, oil platforms, parking garage). The use of flexibility or adaptability in building design of residential and non-residential buildings is a widely used concept (Till and Schneider, 2005; Schneider and Till, 2007). Moreover, it also have been largely used in manufacturing systems and studied by several authors (Suarez & Cusumano, 1991; Taylor, 1991; Schulz et al., 2000; Ross et al. 2008). However, the need for flexible design in airport terminals is a recent recognition (de Neufville, 2008a; de Neufville and Belin, 2002; Edwards, 2005).

The research on the use of flexibility to improve airport's competitiveness is relatively scarce. The concept of flexibility has been studied by few authors and no universal concept was accepted so far. Moreover, only few authors present their own definition of this concept. de Neufville (2008a) defines flexibility, from a design perspective, as a:

> "group of technical features that enable the owners to change, easily and inexpensively, the configuration of their facility to meet new needs".

Edwards (2005) also presents a definition for flexible design. According to this author, flexible design:

> "is intended to respond specifically to changing situations and operations".

This definition is different from the previous one since it does not refer anything about expenses or easiness of changing. It is more related with the ability to change without considering the way of doing it. Burghouwt (2007) sees flexibility as the same as re-adaptability, and defines flexibility as:

> "the ability to make continuous adjustments in constantly changing conditions."

For Gil & Tether (2011) flexibility is associated with design and closely connected with risk management. Shuchi et al. (2012) see flexibility as the same as adaptability and they define flexibility or adaptability as:

> "the ability to adapt to the environment without making any permanent change to the environment".

Despite the few definitions presented some similarities can be observed. For all the four definitions authors use the word "change" or a variation of it such as "changing". One can conclude that for all authors flexibility is associated with some sort of change. For two of the authors flexibility is an ability to adapt or adjust. Our understanding is that a response, as Edwards (2005) defines flexibility, or even "features that enable the owners to change" as de Neufville (2008a) defines it, are particular abilities of a system. Based on this, one can conclude that all authors see flexibility as an ability of the airport.

From our point of view, flexibility can be defined as the ability to have an infrastructure as mutable as possible to adapt to future needs with minimal investment. The issue of minimal investment is crucial since the benefits of flexibility are closely linked with optimizing financial investments, reducing the idleness of the infrastructure. Additionally, flexibility can be applied at strategic and operational development levels. These levels represent different options of flexibility with different scopes of action. For example, land saving to expand is an option of strategic level (that maybe will not ever be used), and moveable walls to change terminal's configuration is an operational option since it is used frequently. Moreover, not only the options have different scopes at each level but also the results produced are very different.

IDENTIFICATION OF EXTERNAL FACTORS

We adopted a two-tier approach to identify the external factors driving the need of flexibility, being: review to the literature and case studies on airports known to be flexible. A total of eight factors were gathered, as follows:

1. Demand;
2. Economic cycles;
3. Technology developments;
4. Regulation;
5. Financial resources/capacity;
6. Land use restrictions;
7. Environmental issues, and;
8. Geopolitical stability.

Literature Review on Airport Flexibility

Through a literature review some external factors were identified. The external factor that is pointed out by more authors is **demand**. For de Neufville and Belin (2002) peaking at different times and uncertainty in the type of traffic are the primary drivers motivating use of multifunctional facilities which implies the use of flexibility. This multifunctional use is assured by flexible options such as moveable walls. Additionally, Burghouwt (2007) states that airports suffer mismatches between demand and supply can face overbuilding or underbuilding, if they cannot deal with uncertainty in a flexible way.

Bonnefoy et al. (2010) mention airports can meet future demand through multiairport systems. This is a flexible option by which two or more significant airports can serve commercial traffic of a metropolitan region, surpassing the capacity constraints. Herein it is another allusion of demand as an external factor that motivates airport flexibility. Moreover, Butters (2010) states that the most flexible airports have a series of components for capacity increase, each of which has specific characteristics and can be developed independently or combined. An example of these components is terminal extensions that allow the independent expansion of parts of the terminal. For instance, the growth of international traffic may require an extension that domestic traffic does not need, so it will be possible to expand only one part of the terminal.

In de Neufville (2008a) the author presents a study of flexibility associated with the concept of low-cost airports for low-cost airlines. As he mention, economic deregulation of aviation and the rise of low-cost airlines are changing airport planning and low-cost airlines are becoming significant factors on it. Low-cost airlines drive the development of secondary airports and cheaper airport terminals. As the author notes:

> "they catalyze 'low-cost airports' around the 'legacy main airports' built for the 'legacy airlines'."

This evidences that **regulation** is one of the external factors that drives the need for flexibility. The influence of deregulation is stated in other works of this author such as de Neufville (2008b), de Neufville (2006), de Neufville and Weinberg (2003). Regulation changes are not controlled by airport managers and they can change dramatically the airport's operations or layout. Moreover, Butters (2010) states that rigid master plans do not cope well with new or changing requirements, resulting in inefficient or constrained airports that no longer support commercial operations effectively. The restrictions that the 9/11 attack originated in passengers' control are an example of this.

Shuchi et al. (2012) present evidences of **technology** as an external factor that drives the need for flexibility. The authors pointed out technological advances as important drivers of changes at airport's layout or terminal such as the introduction of the new larger Airbus 380 and e-passport. Magalhães et al. (2012) explains this factor with more detail and adding that nowadays the space for check-in counters is much less do to online check-in service.

Other technology uncertainties able to drive the need for flexibility are presented by Kwakkel et al. (2010). The authors mention the Air Traffic Management technology and also the engine technology related with noise and emissions. These two areas are constantly improving due to innovations and discoveries in their fields. That is the reason why they perform such an important uncertainty source.

Burghouwt (2007) mentions another external factor: **investment**. Although this factor can be seen as internal, for most airports investment is provided by Third Party fellows so it can be consider an external factor. This author proposes for a good flexible strategic planning the creation of real option, backcasting and contingency planning in order to protect the investments. In fact, real options are also suggested by de Neufville & Belin (2002) to deal with long-run (years) uncertainty. According to these authors, real options analysis is needed to assess the value of flexibility provided by buffer spaces which is a common flexible option. As they explain, an option represents the capability of doing something at the owner's discretion without being obligated to do so. Looking at flexible space, it is an option because it provides the ability to use a facility in an alternative way sometime in the future, but not the obligation.

By using real options, airport practitioners can manage the level of investment with more efficiency. They can build a terminal with the ability to be expanded but instead of building with total capacity they do only a small part of it. By doing this they can save investment resources to apply in other fields.

Case Studies on Airport Flexibility

Looking at airport case studies one can see that the presence of the factors mentioned above and also others not pointed out yet. Niagara Falls International Airport is a good example of application of the latest advances in flexibility design. Due to its location near the most powerful waterfall in North America – Niagara Falls – airport design include the use of transparency to improve the wayfinding and the use of local geologic materials (Roulston, 2010). Clearly there was a concern or we might say a pressure related with **environmental issues** which is identified as another external factor. Due to the proximity with this natural resource, it may be possible in the future to adapt airport operations based on environmental restrictions.

The terminal is a modest structure with the ability to reconfigure its parts to "swing" from international to domestic operations with the simple opening and closing of moveable walls. This feature reflects a concern with uncertainty on demand and investment at the same time, since airport management board is not spending more money than necessary on the terminal to handle current demand, but they are embedded the infrastructure with ability to adapt or even expand. When passenger volumes grow beyond current capacity, as the airport operator expects they will, an expansion scheme of the terminal and apron has been designed as part of the initial project where the end of the building can be easily expanded without compromising the design purpose (Roulston, 2010).

Dublin International Airport is also an example of a flexible airport. It has a series of components for capacity increase, each of which has specific characteristics and can be developed independently or combined. This evidences an influence of investment and also demand. Figure below presents the diagram of Dublin International Airport.

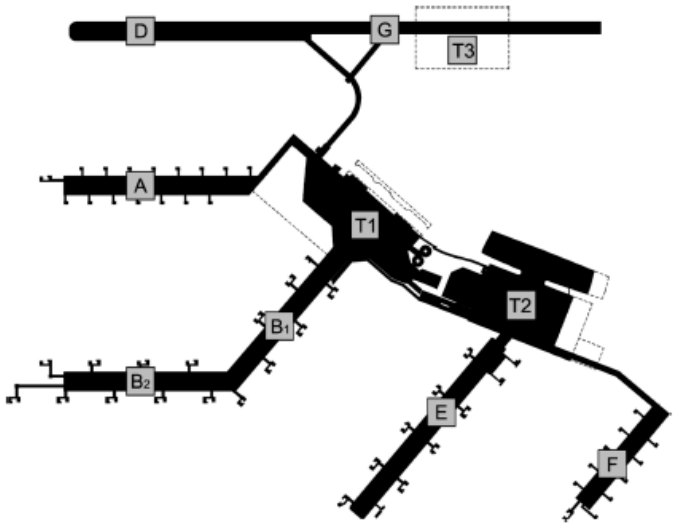

Figure 1 - Diagram of Dublin International Airport (Butters, 2010)

According to Butters (2010), terminal extensions are planned to Terminals 1 and 2 but can be developed independently following an increased traffic demand. Piers are provided in three areas to respond to different traffic scenarios (Figure 1). Central Apron Piers A and B will balance the growth of legacy and low-cost carriers. Pier G and F will support higher volumes of both types of traffic. It is also planned to develop, if needed, a hub for Atlantic sector for which land are already saved. The reason for this is **land use restrictions** that constantly block airport development through expansion. Here, flexibility is assured through land saving in order to avoid land restrictions in the future that will require more investment and will be time-consuming. Land use restrictions represent another external factor driving the need for flexibility at airports. This factor is related with regulation but it is a specific type of it, not related with international air transport directives that we already mention.

Land use restrictions were also faced by Frankfurt International Airport managers. Airport was facing capacity constraints due to the runways' congestion so airport managers decided to go for a third runway in 1973. Nevertheless, the project spawned massive protests by residents and environmentalists being the main point of conflict the increasing noise and pollution and the cutting down of protected trees in the Frankfurt City Forest. It took more or less ten years in courts to approve the runway construction but immediately after the approval the works begin and in less than four months the runway was ready and opened in 1984. The runway is perpendicular to the other two which makes its use limited. This information was mostly obtained during an interview with Sascha Schmitt, Senior Project Manager of Retail and Properties of Frankfurt International Airport, on 9th January 2012. The flexible option of land saving would have avoided the juridical procedure.

Athens International Airport is an example of land saving to avoid land use restrictions to future expansion. Technically, only half of the airport project was built since it is planned to construct another terminal from the beginning but current demand does not require an expansion so investment in new terminals and runways is stopped. Nevertheless, there is already space for it that is currently being use for solar panels to collect energy for the airport. This is an improvement of land saving flexible option by optimizing the use of land. This information was obtained during a meeting with Stratos Papadimitriou, Chairman of the Board of Directors of the airport, on 13th January 2012.

As de Neufville (2008a) points out, Vancouver International Airport provides a good example of flexible design at the terminal. To handle with the shifting travellers who require different processing procedures such as Canadian, transborder to the United States and other international traffic, airport terminal is basically a large open hall divided by interior glass panels into spaces that can be connected in different ways by escalators and passages – moveable walls. Airport is easily adjusted to short and long-term shifts of traffic – for short-run operators open and close doors between various sectors and for long-run they displace panels. This is an example of how the type of demand influences daily operations at the terminal, driving the need for a flexible option. Shuchi et al. (2012) also mention this airport as a good example of flexible design due to its ability to accommodate both short and long-term shifting patterns in traffic.

Amsterdam Schiphol International Airport is, according to Shuchi et al. (2012), an example of an airport still running successfully with the addition of new terminal buildings. Figure 2 presents a view of Schiphol airport where it is possible to see its continuous growth in terms of terminals and piers.

Figure 2 - Schiphol Airport View

Schiphol has been successfully adapted and expanded to respond to the continuous increase of demand. Maurits Schaafsma also said, during an interview on 11th January 2012, that gradually this airport evolved to an airport city with a strong cooperation with the City Council of Amsterdam. Despite some complaints against the airport development, they have weekly meetings with the City Council that allow discussing and solving these issues. This

cooperation gives to airport managers a strong position to discuss land use restrictions and environmental issues. Moreover, this also creates a **geopolitical stability** that is important for airport investors. This factor may not influence directly the need for flexibility but has repercussions in investment which is one external factor driving the need for flexibility already identified.

Another important external factor is **economic cycles**. To illustrate the importance of this factor we present the case of the New York City's John F. Kennedy International Airport (JFK) that opened in 1962. TWA terminal, called "Bird in Flight" was a monumental infrastructure but it proved over time to be functionally deficient as a passenger terminal due to its radial and compact layout. The main reason for the terminal close in 2001 was the fact that American Airlines bought TWA since the last was bankrupted, and the terminal does not serve the requirements of the new client (Shuchi et al., 2012). Airports' clients – airlines – are subject to economic cycles and as explained before, they can change its structure or routes overnight, so it is important for airport managers to not limit the infrastructure too much. Flexibility can help airport managers to deal with uncertainty on economic cycles.

Modular terminals represent the most easy and cheap way to deal with adaptations or expansions to meet demand or economic cycles. Shuchi et al. (2012) provide a good example of this type of cost-effective terminals – Southampton Airport (UK). The terminal form facilitates future expansions that could be easily achieved without disruptions on the existing operations. According to the authors, the adopted form provide an economical solution with a target price 50% of the unit rate usually required on the development of terminals' gateways. This is a way to prepare to future changes in air transport whether they are related with demand, economic cycles, investment, technology developments or others.

Shuchi et al. (2012) present another example of a modular technique offering quick construction of building elements at a lower cost – Bangkok Suvarnabhumi Airport (Thailand). The principle is the simple and flexible design concept of using a series of large modular terminals, each served by airside corridors with aircraft gates in both sides. According to Richard de Neufville, Bangkok airport expansion is not based on the initial master plan. This author defends that master plans are by definition not flexible, they are the opposite of it. This information was obtained during an interview on 8th March 2012. This case is an example of how technology developments (modular terminals), airport management board decisions (to skip the original master plan), uncertainties in demand or economy (building a terminal as flexible as possible) and investment issues (cheap and functional terminal) lead a new approach on airport development.

SURVEY METHODOLOGY

We conduct a survey with two goals: understand the available flexible options at airports and collect airport practitioners'' rating the external factors collected from the literature. This survey will mainly help us to present a first glimpse on airport industries' opinion regarding the importance of the external factors that are leading the need for flexible options, despite the question regarding the flexible options available at the airports.

The airports were chosen based on the Airport Benchmarking Report for 2009 provided by Air Transport Research Society (ATRS, 2009). From the 149 airports presented at this report we released this survey for 100 since it was not possible to contact more airports. The survey was released on the internet and the airports were notified by e-mail for the first time on 15th September 2012. The chosen airports are located in Europe, Asia, North and South America, Africa and Oceania. The survey sample for this work was captured until 4th February 2013. The survey is still available on the internet on the following link: http://goo.gl/gg95r

The survey is in English to expedite its disclosure worldwide. The survey was built through the Google Drive Form service. This is a free service which gathers the necessary features for our needs. We decided that an online version will be more appealing than a paper one. Moreover, the disclosure on paper will require additional investment and time.

Survey Structure

The survey has two main parts besides the general information about the person that is responding. The first part is related with flexible options. Then, we present a list of options so that airport managers can select the ones that they have. Additionally, they were invited to add others that were not listed.

Several flexible options were presented:

1. **Strategic level**: available land for expansions, utilization of available land for non-aeronautical activities (e.g., solar panels, warehouses), utilization of modular terminals for easier expansion, linear form of terminals, open space terminal: minimum load bearing walls, open space terminal: high roof span of the terminal;

2. **Tactical level**: easiness of changing the design and layout of retail areas within the terminal, easiness of changing the functions within the terminal (e.g., convert check-in areas in retail areas), movable partition walls at terminal, available spaces at terminal;

3. **Operational level**: swing gates between international and domestic terminals, moving systems: check-in counters, airline counters, security areas, signalling and advertising, luggage belts.

Nevertheless, in order to simplify the survey structure and its comprehension we did not present the options separated by planning levels but as a single list. The division by planning levels is only used in the discussion and presentation of the results.

The second part is the external factors' rating. Respondents were asked to rate the external factors identified in the previous section by choosing one option among "not important", "low importance", "indifferent", "important" or "very important".

RESULTS AND DISCUSSION

We collected 19 responses from the following airports: Edmonton International (YEG), Athens International (ATH), Wellington International (WLG), Detroit Metropolitan (DTW), Willow Run Airport (YIP), Brussels International (BRU), Memphis International (MEM), Reno-Tahoe International (RNO), Amsterdam Schiphol International (AMS), Zurich International (ZRH), Vancouver International (YVR), Portland International (PDX), Lisbon International (LIS), Trudeau-Montreal International Airport (YUL), Nashville International Airport (BNA), Louisville International Airport (SDF), Jacksonville International Airport (JAX), Austin-Bergstrom (AUS) and Stockholm-Arlanda Airport (ARN).

Some of airports were contacted through privilege contacts but for the majority we used general e-mails. Moreover, some of the airports were contacted through online formularies. Since most of the contacts were made by general channels the answers to the survey did not match the expected number. Lastly, some Chinese airports reply that they are not allowed to disclosure information. However, the results are relevant to understand this aspect of airport flexibility where so far the knowledge was not grouped.

External Factors

Here we present the rating results for the external factors provided by the survey. We asked airport managers to rate the external factors identified before through the following notation:

1. Very important = 5
2. Important = 4
3. Indifferent = 3
4. Low importance = 2
5. Not important = 1

None of the external factors were rated as being not important. However, as Figure 3 presents, some factors are seen as more important than others. Demand is the external factor that was rated by more airports as very important. Financial resources/capacity is the second one rated by more airports as very important. Additionally, one can notice that technology developments and environmental issues were not highly rated as very important, but most airports consider it as important. Geopolitical stability is the external factor that presents the lower rating results which is consistent with the few evidences found in the literature regarding this factor.

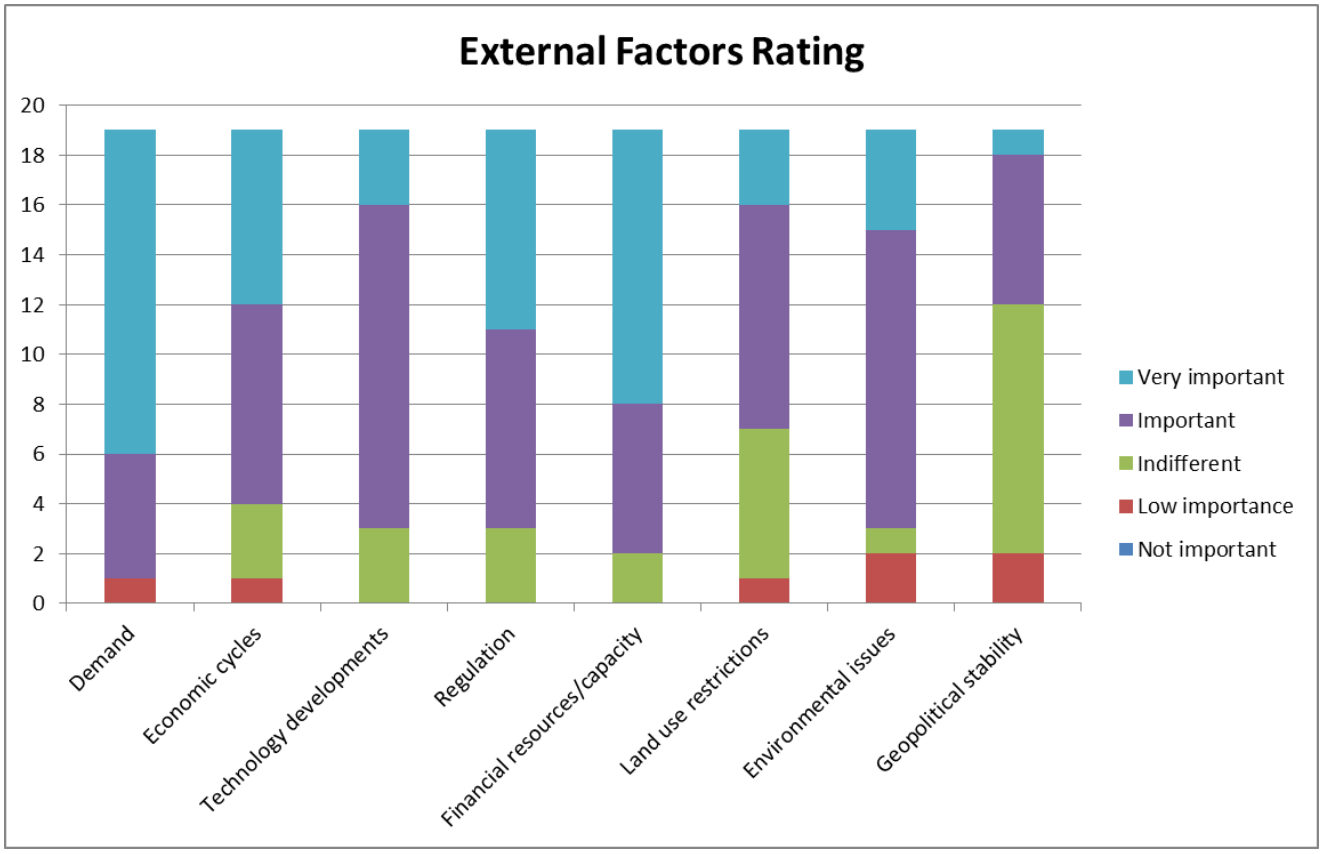

Figure 3 - Number of responses by external factor

Technology developments are seen by the majority of airports as important. In fact, Portland, Edmonton and Montreal consider technology development as very important. Only for Brussels, Austin and Arlanda airports this external factors is rated as indifferent. For Wellington, Lisbon and Brussels regulation factor is seen as an indifferent external factor. Nevertheless, for the others the opinions are equally divided between important and very important.

Eleven airports consider financial resources/capacity as a very important external factor and six consider it as important. Nevertheless, for Brussels and Vancouver airports this external factor is considered as indifferent. It is important to notice that none of them consider it as of low importance or even not important. This factor is mentioned in the literature as one of the most important ones since the available investment determines airport's capacity to evolve.

A part from Memphis, Lisbon and Nashville airports, land use restrictions seems to be less important than the previous factors since seven of the airports consider it as indifferent or of low importance. This is not surprising for airports like Schiphol where they have a good relation with the City Council or Athens where there is already saved land for future expansions. Nevertheless, twelve airports consider this factor important or very important and the majority are located in North America.

The majority of the airports consider that environmental issues are important or very important. These results are consistent with the tendency found in the literature.

Nevertheless, for Athens this factor is seen as indifferent and of low importance for Wellington and Reno-Tahoe airports.

The obtained results evidence that geopolitical stability is not considered as highly relevant in driving the need for flexibility. Especially, when compared with the other factors. Only Schiphol, Edmonton and Montreal marked it as important and Jacksonville as very important. The other airports rated it as indifferent and for Reno-Tahoe and Vancouver this factor is considered of low importance. The results are consistent with nowadays situation where boarders are stable and there is a high geopolitical stability, especially in the countries that answered to this survey.

Table 1 presents the average ranking for the rating of each external factor. The maximum rankin is 5 for all external factors and minimum ranking varies between 2 and 3. As expected demand presents the higher average value, followed by financial resources/capacity, and geopolitical stability the lower average. All factors have supporters of its high importance but for geopolitical stability only Jacksonville marred it as very important. The minimum rating is never lower than 2. This evidences that none of the external factors were considered as not being important.

Table 1 – External factors' average ranking

	Demand	Economic Cycles	Technology Developments	Regulation	Financial Resources/ Capacity	Land Use Restrictions	Environmental Issues	Geopolitical Stability
Average Ranking	4.57	4.11	4	4.26	4.47	3.74	3.95	3.32

It is also important to mention that two more external factors were pointed by Schiphol airport: changes in passenger/consumer expectations and changes in the business model of airport company. The first one is strongly related with the ability of airport terminals to adapt to demand, but instead of quantity it is the type of demand. This is the typical situation between low-cost and legacy carriers' consumers, especially those who travel in business class, needs since they are very different types of passengers. Airports have to be able to serve the all type of consumers that airlines can bring to them, unless the airport defines a specific business model. There airports that affirm that their business is only cargo and other which only deals with low cost carriers. If an airport defines a specific business model, this conditions the terminal specifications and the need for flexibility changes – it becomes more specific.

Lastly, Nashville airport also pointed out two more external factors: availability and cost of natural resources and air carrier consolidation. The availability and cost of natural resources

conditioned the prices and airlines dynamics, making them move to different airports if they decide to restructure their routes to optimize costs. Our understanding is that this market's dynamic is a specific example of demand consequences, as well as air carrier consolidation.

Available Flexible Options

Here we present the results obtained in the first part of the survey, regarding the flexible options available at airports. Figure 4 presents the collected answers organized by planning level: strategic, tactical and operational.

The most common flexible options are available land for expansions, utilization of available land for non-aeronautical activities (e.g., solar panels, warehouses), easiness of changing the design and layout of retail areas within the terminal, swing gates and available spaces at the terminal. Available land for expansions is quite famous especially in airports surrounded by urban developments, which is the case of AMS, LIS, YEG, WLG, DTW and RNO. This option represents an insurance against future constraints on airport expansion due to unavailable land. The utilization of available land for non-aeronautical activities is the most common option and represents a way to generate more income. The easiness of changing the design and layout or retail areas within the terminal and available spaces at the terminal are both an output of terminal's building option that, as mention before, represent a safety way to deal with future uncertainty. Swing gates between international and domestic terminals represent a relatively simple option that allows more freedom to manage airport's arrivals and departures.

Airports present a mixture of flexible options at different levels. One can notice that for the three levels we obtained representative results but some options are clearly more common than others. For instance, at operational level swing gates are much more used than moving systems. This option was marked by airports such as LIS that has capacity constraints and also by airports such as AMS which traffic is almost 50000 million passengers. This may evidence that one simple option as swing gates help to deal with capacity constraints and optimize operations for high levels of traffic.

Also, at tactical level the easiness of changing the design and layout or retail areas within the terminal and available spaces at the terminal are more used than easiness of changing functions within the terminal or moveable partitions walls. This may evidence that is easier to change the layout of retail areas among itself than changing the space functions inside the terminal. Available spaces at the terminal were not marked by airports such as LIS that present capacity constraints. This option was marked by airports such as YEG, ATH and BRU that do not present issues with capacity.

Strategic level presents, in general, more supporters than the other levels. Nevertheless, based on the sample size we cannot affirm that this level is more used or applied than the others but the results suggest it. However, a bigger sample is necessary to clarify this tendency.

The results in this part of the survey evidence that airports present some solutions to the main problems pointed out in the literature which require flexible options. Despite the sample size the industry's choice to deal with uncertainty is consistent with the main flexible options presented as options at our survey.

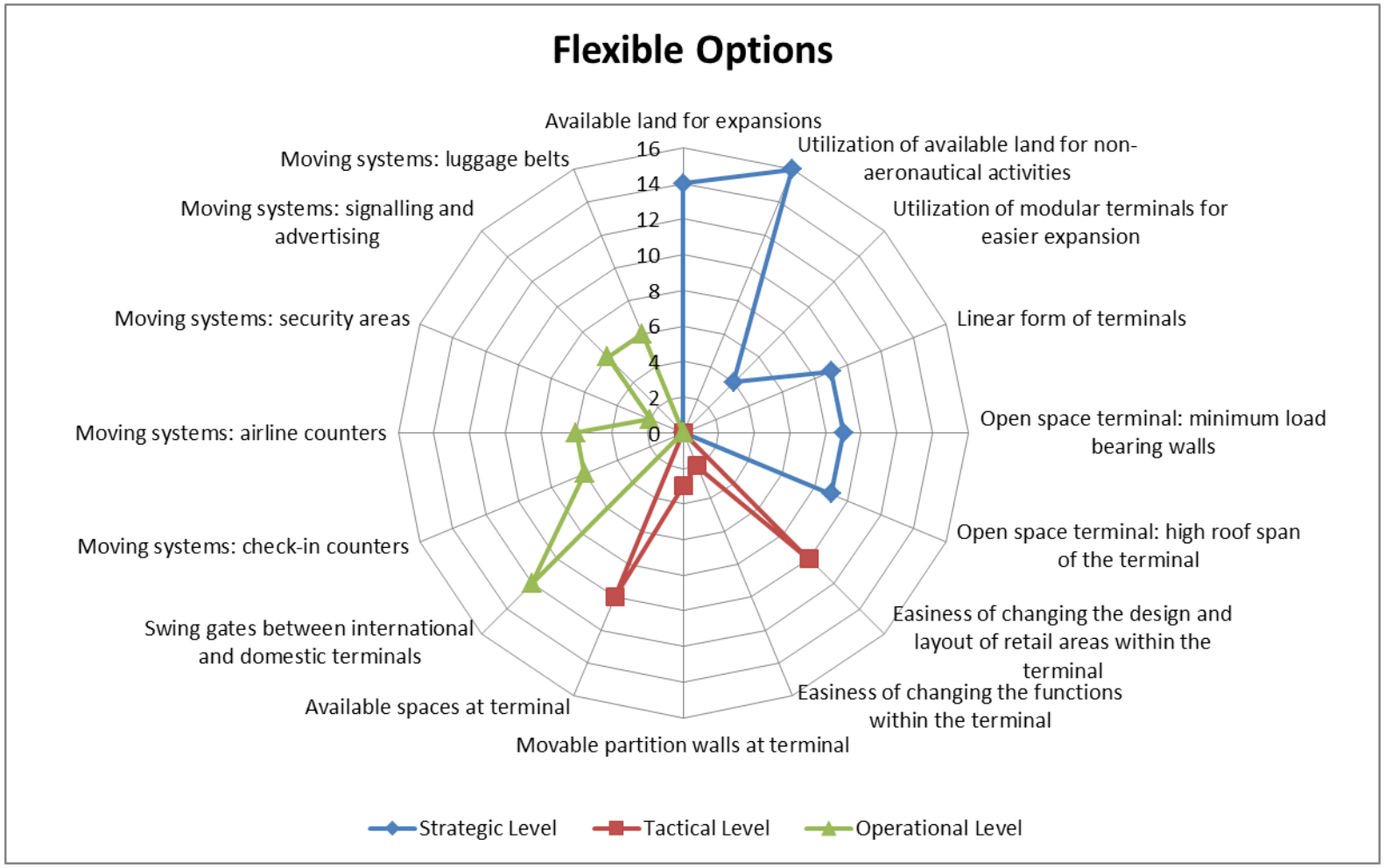

Figure 4 - Flexible Options by Level at the Airports

CONCLUSIONS

This study represents an innovative systematisation on airport flexibility knowledge, especially regarding the external factors driving its need. Studies on airport flexibility external factors seems to be disperse and to the best of our knowledge this is the first merge of what has been published, airport case studies and practitioners' opinion.

From literature review and case studies eight external factors were identified: demand, economic cycles, technology developments, regulation, financial resources/capacity (investment), land use restrictions, environmental issues and geopolitical stability. We conduct a survey to rate this external factors by airport practitioners and the results show that seven out of the eight factors were rated as important or very important by the majority of airports. The external factors consider as more relevant by the airports are demand, financial resources/capacity, technology developments and environmental issues. Only geopolitical stability was not considered highly relevant since twelve out of nineteen airports rated it indifferent or of low importance. Demand and technology developments were the factors that gather more consensuses, the first as very important and the second as important. The fact that airport industry recognizes the majority of the identified factors as important or even very important allow us to conclude that literature is aligned with industry's perception.

The survey also evidences the most common flexible options at airports: available land for expansions, utilization of available land for non-aeronautical activities, easiness of changing the design and layout of retail areas within the terminal, swing gates and available spaces at the terminal. Flexible options at strategic level present, in general, more supporters than the other levels. However, based on the sample size we cannot affirm that this level is more used or applied than the previous ones but the results suggest it. A higher sample is necessary to elucidate this tendency.

Despite the low number of answers, we were able to collect responses from airports in United States of America, Canada, Europe and New Zealand. The number of participants in the survey is low (nineteen) but the results represent an important step on airport flexibility's studies, especially regarding the external factors since the knowledge on this feature is not organized or systematized. For most of the airports we didn't have privilege contacts so the survey disclosure could have fall in the wrong department and not forwarded.

ACKNOWLEDGEMENTS

We would like to acknowledge to all the airport practitioners that answered to our survey. Without their participation and information this work will not be possible. Moreover, we would like to acknowledge Sascha Schmitt from Frankfurt Airport, Andrea Joerger from Zurich Airport, Maurits Schaafsman from Schiphol Airport and Stratos Papadimitriou from Athens

Airport for the interviews on January 2012 that allows to collect more information about their airports that improved our work.

REFERENCES

Air Transport Research Society (ATRS), 2009. Airport benchmarking report: global standards for airport excellence. Volume 1: Summary report, Centre of Transportation Studies, University of British Columbia, Vancouver.

Bonnefoy, P.; de Neufville, R.; Hansman, R. (2010). Evolution and Development of Multiairport Systems: Worldwide Perspective. Journal of Transport Engineering. ASCE. November.

Burghouwt, G. (2007). Airline network development in Europe and its implications for airport planning. Ashgate, Hampshire, England.

Butters, M. (2010). Flexible airport design. Airport Management, 4, 4, 321-328. July-September.

de Neufville, R., Belin, S. (2002). Airport passenger buildings: efficiency through shared use of facilities. Journal of Transportation Engineering, May/June.

de Neufville, R., Weinberg, R. (2003). "Rethinking Retail Relationships in a Volatile World." International Airport Review, 7, 1, 26-34.

de Neufville, R. (2006). Planning Airport Access in an Era of Low-Cost Airlines. Journal of the American Planning Assocation, 72, 347-356.

de Neufville, R. (2008a). Low-cost Airports for low-cost airlines: flexible design to manage the risks. Transportation Planning and Technology, 31, 1, 35-68.

de Neufville, R. (2008b). "Building Airport Systems for the Next Generation." Journal of the National Academy of Enginnering, The Bridge, 41-46.

de Neufville, R., Scholtes, S. (2011). Flexibility in Engineering Design. Engineering Systems. The MIT Press, Cambridge, Massachusetts, EUA.

Edwards, B. 2005, The Modern Airport Terminal. Second ed. London and and New York: Spon Press, 1-276.

Gil, N., Tether, B. (2011). Project risk management and design flexibility: analysing a case and conditions of complementarity. Research Policy, 40, 415-428.

Kwakkel, J.H., Walker, W.E., Marchau, V.A. (2010). Assessing the efficacy of adaptive airport strategic planning: results from computational experiments. 12th WCTR Conference, July 11-15 Lisbon, Portugal.

Magalhães, L., Reis, V., Macário, R. (2012). Flexible Development of Airports: where we stand now?. Paper presented at AIRDEV Conference. Lisbon, Portugal, 19th of April.

Roulston, P. (2010). Falling for Niagara – Airport Design. Airport World, October-November, 81-82.

Shuchi, S; Drogemuller, R; Kleinschmidt, T. (2012). Flexible Airport Terminal Design: Towards a Framework. Proceedings of the IIE Asian Conference 2012, Furama Riverfront Hotel, Singapore, 348-356.

Schneider, T.; Till, J. (2007). Flexible Housing. Oxford, UK: Architectural Press.

Schulz, A; Fricke, E; Igenbergs, E. (2000). Enabling Changes in Systems throughout the Entire Life-Cycle – Key to Success?. Proceedings of the 10th annual INCOSE Conference, July 2000, Minneapolis, USA.

Suarez, F; Cusumano, M; Fine, C. (1991). Flexibility and Performance: A Literature Critique and Strategic Framework. Sloan School WP 3298-91-BPS, Massachusetts Institute of Technology.

Ross, A; Rhodes, D; Hastings, D. (2008). Defining Changeability: Reconciling Flexibility, Adaptability, Scalability, Modifiability, and Robustness for Maintaining System Lifecycle Value. Journal of Systems Engineering, Volume: 11, Issue: 3, John Wiley & Sons, Pages: 246-262.

Taylor, T. (1991). Evaluating and Selecting Manufacturing Flexibility. S.M.Thesis. Department of Mechanical Engineering, Massachusetts Institute of Technology.

Till, J.; Schneider, T. (2005). Flexible housing: the means to the end. Architectural Research Quarterly, 9 (3/4). pp. 287-296. 9(3/4): p. 287-296.