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# Allocating airport slots: a combinatorial auction mechanism

**Nicolas Gruyer and Nathalie Lenoir discuss the current allocation of slots on congested European airport. In their eyes the system of grandfather rights constitutes an obstacle to the effective liberalisation of air transportation undertaken in Europe. In this article they propose to use a market mechanism, based on temporary utilisation licences. In order to allocate those licences, the proposed system is based on a combinatorial auction mechanism where a percentage of licences would be reallocated each season. A secondary market would also be set up in order to reallocate slots during a season. Since combinatorial auctions involve a complex optimisation procedure, we describe how it can be made to work in the case of auctions.**

By Nicolas Gruyer and Nathalie Lenoir

Air transportation has been liberalised in the European Union in 1997, after a few years of transition. It seems, however, that so far, the effects on competition are not as important as they have been in the USA, after the deregulation in 1978.

One of the key factors impeding competition in Europe is the lack of airport capacity at major airports for takeoffs and landings. Because of this capacity shortage, in Europe authorities decided to limit the number of takeoffs and landings to a specified number per hour at certain airports corresponding to the runway capacity. A slot is then defined as "... the scheduled time of arrival or departure available or allocated to an aircraft movement on a specified date at an airport co-ordinated under the terms of regulation...". In Europe, airport slots are allocated following the "grandfather rights" rule, which is the historic rule prevailing before liberalisation. According to this rule, an airline using a slot during one season keeps it for the following season, as long as the slot has been properly used ("use it or lose it" rule). Available slots are given as a priority to new entrant airlines. But since very few slots become available each season, this leads to a very conservative allocation. This rule enables stability in the market but by preventing entry of new airlines, it falls short of the regulators expectations to promote competition in the airline industry. In

the following article, we consider the situation from the point of view of the European Community and we assume that the objective is to favour efficient slot utilisation and competition<sup>3</sup>.

It is therefore vital, from the European commission point of view to study alternative allocation rules, either administrative or market based rules, to prevent the liberalization process from stalling.

## Objectives of a slot allocation

Today, the European procedure for assigning slots on saturated airports is characterised by the fact that it is free of charge. Among the disadvantages of this procedure, the most obvious is the disproportion between the demand for slots and the slots that are actually available. Because of the information asymmetry between the authorities in charge of assigning slots and the airlines, it is difficult to assess which airlines will use the slots in the best manner as far as society is concerned.

In view of the currently imprecise legal aspect, some organisations - including airports - turn to the state for a more precise definition of who owns the property rights for slots. If such a question exists, and if it is up to the State to settle it, then the ques-

tion is meaningless: Slots belong to the state de facto, and the state is entitled to give them away or sell them if it wants to. In view of the capital strategic importance of this type of asset, we feel that it is increasingly important that the state should retain these property rights and simply grant rights of use for certain specified periods.

Whatever system is used to allocate slots, it has to be judged by the benefits it brings to the economy. More precisely, the air services resulting from this allocation provide some

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level of "social welfare" to the customers and to the rest of the economy (including some profit to the airlines). The first objective of a slot allocation is therefore to maximise the

benefits brought by the allocation to the economy. However, assuming that the state decides that airports - for example - should benefit from the advantages connected with the use of slots, it would be preferable to set up a system which aims to assign the slots in an efficient manner, and then to enable the airports to benefit from the corresponding income, rather than giving them the property rights directly.

Due to the complexity of the problem, any administrative-type procedure is likely to lead to an inefficient situation in which certain slots are not allocated to airlines which are capable of valorising the situation.

Slots are efficiently allocated when used by the airlines that can generate maximum social benefit from them. We can consider, in a competitive situation, that if an airline thinks it will make large profits by using a slot, this fact tends to indicate high demand and low costs, and therefore a high profit is a reliable indication of a large social benefit. In order to approximate this optimum, we can then target the intermediary goal of maximising the profit airlines derive from the use of a slot, which is linked to the willingness to pay for the slot by the airline. A market mechanism with prices for slots would achieve this requirement, as long as the price reflects the willingness to pay for the slot.

In reality, the social benefits may not be maximised when profits are maximum, for different reasons: there can be conditions of limited competition, when an airline on a market has some market power, and uses that situation to raise prices, resulting in a decrease in social welfare. The allocation system chosen should therefore address this problem by preventing the building of market power. Moreover, what is optimal at one point in time, may not remain so for long: the allocation should also be capable of evolving, in order to re-allocate the slots to the most efficient use. The second objective of the allocation is therefore to find an equilibrium between the adaptability of the system to changes in demand or market conditions, and a stability necessary to the good functioning (return on capital) and development (investment incentives) of the airlines.

This brings us to recommend that the grandfather rule should be progressively dropped, that airlines should be given temporary licences to use slots (5 to 10-year licences, for example), and that they should be allowed to sell those licences. Progressively, of course, because we must not upset the stability of a system which - although not perfect - does have the advantage of working. Limited-period licences would encourage airlines to sell off the slots that they do not really need

- or that other airlines could make better use of - rather than keeping them for the future.

The fact that market mechanisms enable governments to raise funds generates criticism towards those mechanisms. However, it is necessary to raise revenues in order to achieve efficiency, since the revenues raised are the indication of the market value associated with the asset.

### Choice of a market mechanism

The most basic way of selling a temporary licence to use slots consists in setting a price (possibly variable, depending on the time of day of the slot) whilst retaining the current procedure. Initially, this would reduce the demand for slots and consequently the risk of mistakenly attributing slots to companies which do not valorise them as much as others would. But this solution, which is the easiest to implement, only partially solves the problem of asymmetrical information, and it does not solve the problem of entry barriers. It can still considerably improve the efficiency of allocation.

Economists tend to prefer the auctioning solution, which has the advantage (when well designed) of revealing private information held by airlines and favouring the possible entry of new airlines on airports. In this context, an auction would aim to assign a slot to an airline which considers that it can obtain the highest profit in exchange for a part of that profit. Moreover, it is perfectly possible to design the auction in such a way that it takes into account factors that could appear to be important from a social point of view (for example to reserve slots for regional services as it is done today).

However, the results can be catastrophic if the auction is not properly designed. As regards auctions, several mechanisms can be designed, with different properties. Concerning slots, there are specific issues to be addressed by the auction mechanism chosen. We believe that the most important of these issues is the aggregation problem: a specific combination of slots has more value for an airline than the sum of the individual values of slots. The hub and spoke organisation of networks, with arrival and

departures concentrated in time, makes it important for an airline to have certain sets of synergetic slots.

With simple auctions, where assets are auctioned separately, airlines may fail to obtain all the slots they need and may end up with an inefficient allocation (from the point of view of their operations).

In order to reduce or solve the aggregation problems, two main designs can be used: the first one is a simultaneous, multiple rounds auction (SMRA). The Federal Communication Commission (FCC) has used it for the spectrum auctions in the USA, with reasonable success. Basically, it allows firms to bid on individual assets, the auctions are held simultaneously for all assets, and repeated as long as necessary so that nobody wants to change its bid. Assets are only allocated at this point. This mechanism alleviates the aggregation problem, but does not solve it entirely, because auctions are simultaneous but still separate. Bidders can not bid on bundles of slots and therefore may still face some aggregation problems.

Another way of solving this problem is the use of combinatorial or "package" bidding where bidders can bid on multiple bundles of slots. They obtain a whole package or nothing. By enabling bidders to bid on packages, this kind of mechanism eliminates the aggregation problem entirely.

Since we feel that the aggregation problem is an important issue with the slot allocation, we shall turn to a combinatorial bidding procedure, although this kind of auction is more difficult to implement.

### A proposed auctioning system

Considering the advantages and disadvantages that we have discussed, we feel that the following mechanism could provide some interesting results.

The assets for sale are defined as licences to operate slots for a period of  $n$  years ( $n$  being between 5 to 10). Every  $k$  year,  $(100 k/n) \%$  of the slots are put up for sale (10 to 20 %, corresponding to the duration chosen if the auction takes place every year). Airlines bid on bundles of assets. After the auction, the airlines are entitled to sell their licences.

In practice, if slots are defined as they are today, it will not be possible to set up this type of mechanism for selling slots because the number of combinations of assets increases exponentially with the number of assets put up for sale, and the optimum becomes too complicated to compute. For this reason, in order to reduce the number of assets to sell, on each airport, the slots are grouped by the auction organiser into a certain number of groups which appear to be coherent from a historical point of view (the most probable coherent grouping being seasonal grouping). Another solution is to define slots inside time windows : Within a time window, there would be many slots, but they would all be the same from an auctioning point of view. This reduces considerably the number of different assets to be auctioned, even with only a 15-minute time window (but there would now be many identical assets to sell).

Then, iterated Vickrey-Clarke-Groves<sup>1</sup> auctions are held on all the saturated airports, possibly with distribution constraints (for example: at least 4 different airlines must obtain more than a certain quantity of slots, or at least a certain percentage of slots is distributed to new entrants on the airport). The bids of the previous rounds are made public, and are sus-

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<sup>1</sup> Among the mechanisms invented by economists to allocate rare assets, the Vickrey-Clarke-Groves mechanism has a remarkable property: Whatever the strategies of the other buyers, the optimum strategy of any given buyer consists in bidding, without lying, the maximum value that he/she would be ready to pay for any bundle of assets.

To obtain this result, it is simply necessary for each buyer to have a reliable knowledge of the value that the auctioned asset or combination of assets will have for him/her if ever he/she were to obtain them.

The Vickrey-Clarke-Groves mechanism allows for combinatorial bids: Bidders can submit bids for multiple combinations of assets rather than just individual assets.

For further details concerning this mechanism, the reader can refer for example to the book by V. Krishna

tained during subsequent rounds. A rule for continuing the auction and a rule for closing it (similar to those used for auctioning the Hertzian spectrum in the United States) are set up, and the bids concerning the first rounds of the auctions can only apply to individual slots.

Payments are determined on the basis of a monthly amount to be paid, calculated from the bids made by the airlines, using the rule of payment of a VCG mechanism with constraints. These payments are weighted according to the air transport activity level, on the basis of a rule announced at the beginning of the auction.

Some of the slots might not be auctioned, in order to be able to allocate them using other criteria. For example the government could keep slots for specific routes, as is already done currently.

After the auction a secondary market would be set up, ensuring efficient reallocation throughout the season. Since the organiser of the auction had to group the slots into groups of seasonal slots, the secondary market would enable airlines to obtain part season slots. Care should be taken as to the design of this market, in order to ensure that no building of dominant position could happen, as was the case on the US market for domestic slots.

Since slots at different airports can be complementary, the ideal solution would be to hold a single global VCG auction, covering the slots of all saturated airports. But this would not be possible, if only for technical reasons concerning the combinatorial explosion. There is nevertheless still the possibility of holding separate auctions on each airport. It would be preferable to hold these auctions simultaneously, in several rounds, so that the airlines can adjust their bids on one airport based on the results obtained on the other airports. It would require a European coordination.

## Conclusion

The auction mechanism we propose is one among many possible (auction) mechanisms, but it has interesting properties in terms of efficiency and flexibility. Adding constraints to the allocation is always possible without distorting the optimal strategies of the bidders, which are to announce their true values for each bundle of assets, implying that an efficient allocation is obtained.

Some points were not discussed here, like the acceptability of this system, or the way to address the problem of market power, or the implementation of the auction; they are however discussed in the full version of this paper (see bibliography).

Several parameters of the mechanisms also remain to be specified, like the duration of the license, or the time window defining the slot, but overall, this mechanism should allow for a much more efficient use of the slots than today. Ideally, such a mechanism should be implemented at the largest possible level, in order not to distort competition between airlines, and so they can constitute coherent sets of slots between congested airports.

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- In general an interesting issue and an interesting article, but it can be more concrete. Some more examples, empirical prove and facts.

This article is based on: Auctioning Airport Slots (ATRS, 2003), Nathalie Lenoir and Nicolas Gruyer. The whole article is available on the LEEA website and highly recommended by Airlines. Laboratoire d'Économie et d'Économétrie de l'Aérien, École Nationale de l'Aviation Civile: [www.enac.fr/recherche/leea](http://www.enac.fr/recherche/leea)