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Transportation Research Procedia 14 (2016) 3761 – 3770

Transportation Research Procedia

www.elsevier.com/locate/procedia

6th Transport Research Arena April 18-21, 2016

Incentive-based slot allocation for airports

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Abstract

The demand regulation for airport infrastructures is managed, depending on the location within the world, typically by slot allocation schemes. Slot allocation for the biggest part of the relevant airports is organized in accordance with the IATA Worldwide Slot Guidelines, IATA-WSG. In Europe, Regulation 95/93 including its amendments as local rule with relation to IATA-WSG builds the basis for airport slot allocation. Key element of the slot allocation according to this principle is the fragmentation of the declared capacity into time niches, better known as airport slots. A weak spot with this is the usage of the capacity estimation which has to cover a full scheduling season. Those having been allocated a slot are allowed to make use of the airport infrastructure in general. Demanding airlines without a slot for this airport may request spontaneously a free slot, if available. If not applicable, additional demand's requests are waived. This system limits the serviced demand and assures thereby a reliable level of service at service process stations, e.g. the runway, apron, or terminal. From a strategic point of view this capped demand may cause economic losses due to waived additional airport charges also in situations with capacity well above the average expected value, which was used to calculate the official declared capacity. A second problem with resource usage efficiency arises instead of conservative calculations regarding the available capacity by the variance in resource usage by slot holding airlines. Delayed use of infrastructure may cause excessive demand in later time frames, instead the slot allocation and its levelling effect. Knock-on delays affect the following turnarounds and may destabilize network-wide connections. Especially for the resilience of door-to-door managed networks, process stability is a key ingredient for success. Arrival and departure deviations in aviation may preclude sustainable co-modality by its variability. Both primary as well as secondary delays may jeopardize connections between different or same modes of transportation, and the affected passenger may be stranded at least at the mode's transfer point. By introducing an incentive to avoid primary delays and by foreclosing the propagation of secondary delays within networks, an increase in level of service like process stability or punctuality is realizable. The research topic was to evaluate possibilities to increase resource usage efficiency by changing the methods of slot allocation. Therefore, a priority-based

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Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)
doi:10.1016/j.trpro.2016.05.461

system was created and verified by a simplified microscopic simulation model. Priorities were allocated in advance, representing different categories of resource availability estimation. A second extension to the system was given by a performance-based component. The preselected priority was allocated to the demanding aircraft with up-/downgrades depending on its own punctuality. Despite the increased data exchange volume needed to realize this resource allocation scheme in reality, benefits in resource efficiency and turnaround stability are clearly observable. Different priorities in scheduling are an incentive to schedule with different levels of availability of infrastructures already during strategic planning, whereas the vehicle-oriented performance-based prioritization in operations is suitable to avoid any secondary delay propagation and to increase the system's fairness.

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)

Keywords: slot allocation; prioritization; capacity; punctuality; resilience

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1. Introduction

The introduction of priorities when granting usage rights at slot-constrained airports is assessed in the following in terms of its efficacy in improving resource utilization. The background to this is the theory that, at both the strategic and operative levels, the creation of incentives for an efficient use of limited airport infrastructure has a certain amount of potential to optimize the use of the scarce commodity "airport slot". The need for efficiency improvements at the world's busiest airports is the subject of numerous investigations. The topic of inefficiency of the current primary allocation is addressed (e.g. in nera 2004), and solutions for variants more common to the market are examined, such as congestion pricing (Madas and Zografos 2010) or the legalisation of secondary slot trading, through which airlines can swap their slots and negotiate prices for them (Pagliari 2001). An efficiency--increasing differentiation of the resource "slot", the availability of which has never been questioned in research so far, is introduced here. The provision of service at the infrastructure is mathematically described by queuing theory. The special case of applying priorities in service provision depends on the nature of the waiting discipline and how the formation of a prioritisation system affects capacity. The theory will therefore be briefly addressed (2.) and then the alternative primary allocation procedure is explained (3.). Following that, performance-based operational priority allocation is presented (4.). Using the example of a generic service provision model, the effect of alternative resource allocation is demonstrated in contrast to the conventional method (5.).

2. Relation to queuing theory

Queuing theory describes the relationship between arrivals at a service station, clearance of these and the resulting system performance parameters, such as the average waiting time per customer or the number of customers in the system. The simplest case involves a First In First Out (FIFO) strategy, according to which the service is provided in the order of arrival at the service station. A waiting strategy can, however, also allow certain characteristics to influence the ranking in the queue. With non-preemptive priority (PRIO-NP), selected customers receive higher priority in resource allocation than the other customers. However, higher-priority customers must wait until the customers who are currently in the clearance process have been dealt with. The effect of this prioritisation system, known as "Head of the Line (HOL)" is therefore limited to the waiting area in the queuing system and, once initiated, the process in operation is not interrupted (see Gnedenko and König (1984), chapter 6). This strategy is usually applied in allocating take-off and landing permission at airport runways. Here, arriving aircraft regularly receive a higher priority than departing aircraft because space for aircraft on final approach is very limited while departing traffic can safely wait at the edge of the runway until a gap in the stream of landing aircraft appears.

For non-preemptive multi-class queues with poisson-distributed arrivals and randomly distributed service provision times at a service station (M/G/1) and unlimited queuing space (loss-free system; all customers waiting for service, no one is turned away), there is an analytic solution (cf. Hideaki Takagi: Queue with priorities. in Hazewinkel (1987) and Allen (1978)). The assumption of poisson-distributed arrivals with negatively exponentially distributed interarrival times may not necessarily correlate to real occurrences at the airport but it is close enough, especially considering that the influence of the arrival distribution related to the comparison between non-prioritised and prioritised cases is of lower importance.

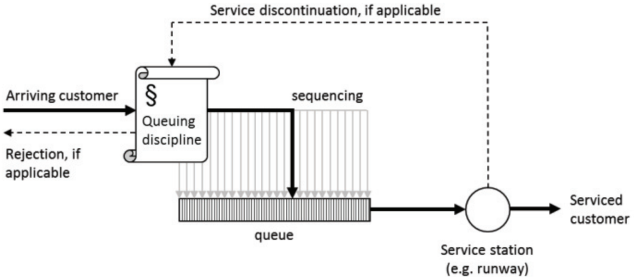


Fig. 1. Queuing system.

The P of different classes of prioritisation are assigned via their indices $p = 1, 2, \ldots, P$, where p is the priority rank and rank 1 promises the highest priority. The arrival process of class p has negatively exponentially distributed intermediate arrival times and the average rate λ_p. The first $(1/\mu)$ and second $((1/\mu)^{(2)})$ moment of the possibly differing service provision times for each class p are named b_p or b_p^2. The capacity utilisation at the service station for class p customers results from

$$\rho_p = \lambda_p b_p \tag{1}$$

and the total capacity utilisation due to all customers correspondingly results from

$$\rho = \sum_{p=1}^{P} \rho_p \tag{2}$$

Stationarity is fulfilled as a stability criterion when $\rho < 1$ is true in formula (2). If it is a PRIO-NP queuing discipline combined with a FIFO service strategy, the expectation value for the waiting time for class p customers results as follows:

$$E[W]_{FIFO} = \frac{1}{2(1-\rho)} \sum_{k=1}^{P} \lambda_k b_k^{(2)} \tag{3}$$

As no priorities are recognised under the FIFO regime, formula (3) applies irrespective of class p. If the service discipline changes to a prioritised service strategy (PRIO-NP), however, there is a dependency between allocated priority p and the expectation value for the waiting time $E[W_p]$. Due to the fact that, when using a priority-based service discipline in air traffic, resource consumption is a focal point and alternatives to the existing procedure have little chance of implementation if they increase the use of resources, prioritisation faces a fundamental interrelationship which is derived from Kleinrock (1975). According to this research, a service discipline is work--conserving when two conditions are met. First, the service station should never be idle when customers are waiting in the system. Second, the service discipline has no effect on the service duration or the arrival time of any customer. Kleinrock formulated Kleinrock's conservation law on this subject:

$$\sum_{p=1}^{P} \rho_p E\left[W_p\right] = \frac{\rho}{2(1-\rho)} \sum_{p=1}^{P} \lambda_p b_p^{(2)} \tag{4}$$

This law states that the intensity-weighted sum of the average waiting times in a non-preemptive queueing system is always constant, regardless of the service strategy. With the introduction of priorities p, irrespective of the number, the total cost of waiting times does not change in this sense.

For each priority class p, for which $1 \leq p \leq P$ applies, the expectation value for the waiting time in a completely stationary state with $\rho < 1$ is calculated as

$$E[W_p]_{PRIO-NP} = \frac{1}{2(1-\sigma_{p-1})(1-\sigma_p)} \sum_{k=1}^{P} \lambda_k b_k^{(2)} \tag{5}$$

where the following applies

$$\sigma_p = \sum_{k=1}^{p} \rho_p \tag{6}$$

The difference in the expectation values for waiting times for service provision for two prioritisation categories forms the most important parameter of priority-based service provision. According to this, the following also applies

$$E\left[W_p\right]_{PRIO-NP} < E\left[W_q\right]_{PRIO-NP}, \; if\, p < q. \tag{7}$$

As the statements from queuing theory only apply during stationary conditions, statements cannot be made on the full capacity load case with $\rho = 1$ or on any forms of overload with $\rho > 1$. When examining priority-based queuing systems, division into different priority classes does make it possible, however, to determine the average waiting times of those customer classes whose share of the arrival stream only leads to a semi-stationary capacity utilisation in the period examined when the total demand reaches or exceeds the maximum capacity. Accordingly, the expectation value for waiting times for customers with class p prioritisation with $1 \leq p \leq P$ is defined by

$$E\left[W_p\right]_{PRIO-NP} = \begin{cases} \frac{1}{2(1-\sigma_{p-1})(1-\sigma_p)} \left[\sum_{k=1}^{q-1} \lambda_k b_k^{(2)} + \left(1-\sigma_{p-1}\right) \frac{b_q^{(2)}}{b_q}\right], for\; 1 \leq p \leq q-1 \\ \infty, for\; q \leq p \leq P, and\; q = inf\{k\colon \sigma_k \geq 1\} \end{cases} \tag{8}$$

All the customers with priority classes $p = 1, \ldots, q-1$ are served with increasing average waiting times until service. Within the $q - ten$ class, the resource can serve only as many customers as can be served before complete saturation of capacity is reached. The remaining customers from class q and all further customers from low-priority classes can no longer be served.

3. Strategic allocation of airport slots

The first component of the alternative allocation commodity consists in a diversification of the object available for use, i.e. instead of the universal slot granting resource usage rights at the airport there are various categories of slot each with associated attributes. The attributes may be of varying interest to the diverse multitude of potential customers. The varying interest across the spectrum of customers is due to differing individual usage functions. The degree of prioritisation in the provision of service at the resource should be taken here as the attribute. This prioritisation becomes relevant whenever, instead of the expected capacity, only a reduced usable resource level is available and competing demands arise.

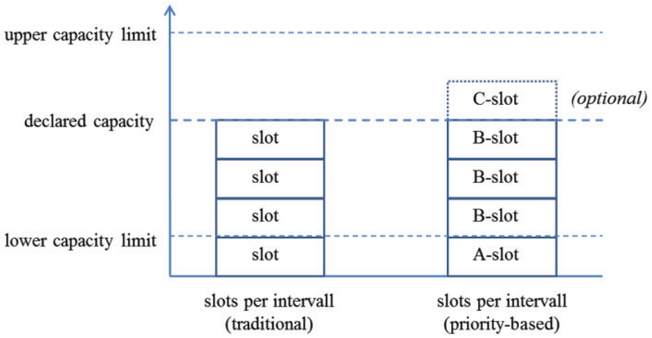


Fig. 2. Capacity discretization: traditional vs. priority-based.

Let us say that the available airport slots in the simplest case are characterised by two selectable attributes A and B where A has priority over B. Let us also say that the flight schedule is based on the expected value of the available capacity and that the scheduling can be solved without conflict. Due to external influences, however, the capacity is now temporarily reduced. As many customers must be serviced in the interval as permitted by the current capacity. The capacity is now allocated amongst the customers with higher priority (A) and only the remainder is available to the lower priority customers (B). Those customers which cannot be served within this interval must be pushed back to a subsequent interval or turned away. This prioritisation means that B-slot customers are removed from the current interval until such time as the utilised capacity attains a practicable value under 1.

The prioritisation advantage of an A-slot in comparison to a B-slot in the same interval is obvious. It becomes effective whenever the actual capacity of the resource lies below its expected value, but customers are nevertheless arriving at the resource in accordance with their scheduling. Since their scheduling is based on the assumption of expected capacity and/or on the key coordination value, the limited resource availability causes an overload situation.

Timeslots are not commonly differentiated at present which means that the average waiting time at the service station increases in accordance with the system’s own “flow-delay curve” as shown in figure 1 which depicts a typical example situation. If the desired service level, which was used to determine the sizing of the practical capacity, is not observed, then the resource will now be operated with a higher load. The dynamic increase in the average delay per customer however now leads to confusion in the scheduling of customers affected currently and in the future. Chains of knock-on delays are created which can be transmitted across the entire network.

When slots are differentiated, in contrast, the remaining capacity is held exclusively available to customers with higher priority. Only capacity beyond this need is also available to lower priority customers. Since customers were already able to take into consideration this rationing in their planning phase, the constrained resource is used by those customers which represent a particularly high advantage for their organisations. Flights by the same or other airlines on the other hand which generate a lesser benefit may not use the resource until sufficient capacity once again becomes available.

Due to the prospect of preferential service provision in the case of constraints at the resource, type-A timeslots are the better type for customers when compared with the alternative type-B. This means that it can be expected that the demand for type-B timeslots would be almost zero and that possible advantages arising from product differentiation would also be lost if market-orientated or regularising interventions did not influence demand. How a particular demand for all (both) categories of slots has come about, in other words the balancing out of the primary allocation, is not the subject of this investigation. Similarly, alongside allocation procedures targeting economic balance, there also exist pragmatic solutions for regularising interventions. So the question would arise as to whether to first allow access to the allocation to those airlines which, for example, had proven themselves to be particularly punctual in the previous season, thus supporting the optimal running of the system. This would be accompanied therefore by the expansion of the existing grandfather rights in the allocation of slots by a performance-driven component in accordance with Regulation EU 93/95. Independent of the actual variant selected, it is however extremely important here to ensure that there is no discrimination and to provide equal access to the priorities for all participants. Figure 2 shows the relationship between alternative airport slots and those used thus far. In this example, the expected capacity value is the planned level of allocable time slots. Using the procedure employed thus far, four timeslots can be allocated per interval. In the alternative allocation model there is a variety of types of time slots each associated with prioritisation characteristics. The category-A time slot with the highest priority is allocated precisely once per interval here. In the example constructed, this timeslot occupies precisely that minimum capacity which is anticipated to be available at any time. The customer of this special timeslot can assume that the resource will be available to him precisely as agreed. Timeslots for which this type of guarantee cannot be given based on statistical analysis are emitted as lower priority resource usage rights. As has always been the case, three type-B timeslots complete the capacity which reigns on days with precisely the expected capacity. The alternative procedure now even allows timeslots to be held available which offer capacity which was considered unusable in the past. In our example, a type-C timeslot (ranked below B) occupies that part of the capacity which is really only available on particular days or at particular times. It is of course an unnecessary option to make available timeslots beyond today’s declared capacity.

4. Performance-based prioritization

The second component of the incentive system involves prioritizing operators operating as per schedule over elements requesting service too early or too late. In order to achieve this, the validity of the preselected prioritisation (A, B) is time-limited by a punctuality condition. Outside of this period of validity, the selected attributes do not apply; instead, they are replaced by new attributes which promise a lower level of prioritisation in comparison to timeslot holders requesting service on time.

Table 1. Priority allocation depending on pre-selection and own on-time performance.

Pre-selected priority	Request for service within punctuality window?	
	yes	no
A	A	α
B	B	β

Building on the above example, timeslots are allocated with the attributes A and B. If a customer arrives at the resource after the agreed punctuality interval has expired then that customer loses his preselected prioritisation A or B and until the start of service provision is given timeslot attribute α (instead of A) or β (instead of B). However, the preselected higher prioritisation of the previous A-timeslot is retained for customers requesting service early or late only in relation to equally unpunctual B-timeslots. If the customer arrives too early at the resource then he is only ranked as ‘unpunctual’ until the beginning of its validity period. If he has not, despite his lower priority, already been serviced at the resource then this customer gets back his preselected priority without the threat of downgrading by the beginning of his servicing at the resource. The incentive system overall thus consists of the preselected relative prioritisation of customers conducted at a strategic level and a component recognising individual punctuality which is allocated to each case in operation. The first selection possibility accommodates the various user interests of the customers and opens up entirely new possibilities in the allocation of user rights through the differentiated definition of the in-reality fluctuating infrastructure capacities. The latter reduces resource usage caused by ‘unpunctual’ demand by creating additional incentive to operate on time. The system thereby operates to a large extent independently of the type of primary allocation of usage rights. Once in operation, the system regulates itself through its incentive functionality and through the priorities planned in advance.

An alternative resource allocation model such as the one presented here demands implementation by the institutions involved in the operation. The allocation of resources in the aviation industry is generally carried out by ground-based advisory bodies. Undoubtedly, in order to implement the concept, the present computer-aided air traffic control systems must be enabled to process the prioritisation information. Data exchange is of particular importance at the interface with the centralised air traffic flow management of the CFMU (Eurocontrol’s Centralized Flow Management Unit).

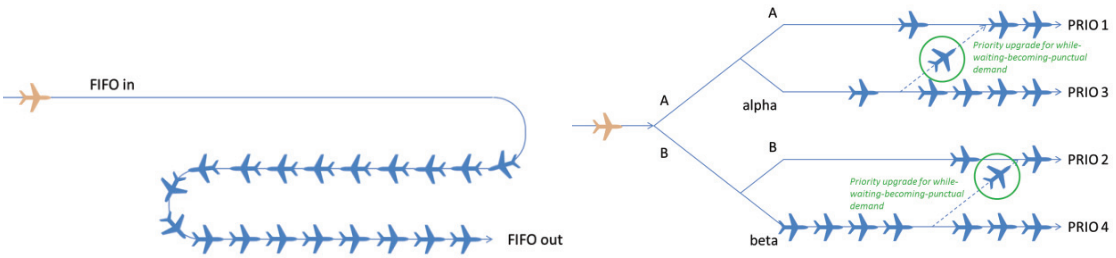


Fig. 3. (a) FIFO queue; (b) PRIO queue.

At the CFMU the airspace timeslots can be allocated taking into account the schedule times and the prioritisations at the resource triggering the adjustment. So when the destination airport is suffering from resource constraint, for example due to reduced capacity as a result of weather events, those flight plans which in the planning phase registered a lower requirement for resource availability can be adjusted in a targeted manner. Flight plans with higher priorities are then able to operate without hindrance at least in the context of the remaining available capacity.

Alongside the pure communication and processing of information concerning timeslot categories, this innovation can bring with it further operational changes. It is indeed expected that the hoped-for determinisation of the traffic can lead to an effective reduction in waiting times and queue lengths. However, it must also be taken into account in the future that waiting procedures must be retained. The current holding pattern (two minute circle with straight sections) and trombone (extended parallel approach) procedures have proven their suitability over many years for the current procedure which is primarily based on the FIFO waiting discipline.

Holding patterns are normally stacked one above the other in several levels in order to provide room for several waiting aircraft. A maximum of one aircraft operates at each level guaranteeing separation. An air traffic controller instructs each pilot individually to leave the holding pattern, for example by giving permission to begin the final approach. The order in which this is done depends on the local strategy which is however normally the FIFO strategy. This may mean that from the point of view of air traffic control it may be useful to define a variety of holding pattern areas which remain reserved for the various timeslot categories. Within these holding patterns areas the FIFO strategy could then again be used. It could then also be useful to reserve a separate holding pattern area for customers arriving earlier than expected since these customers' prioritisation category may still change once the punctuality conditions have been reached.

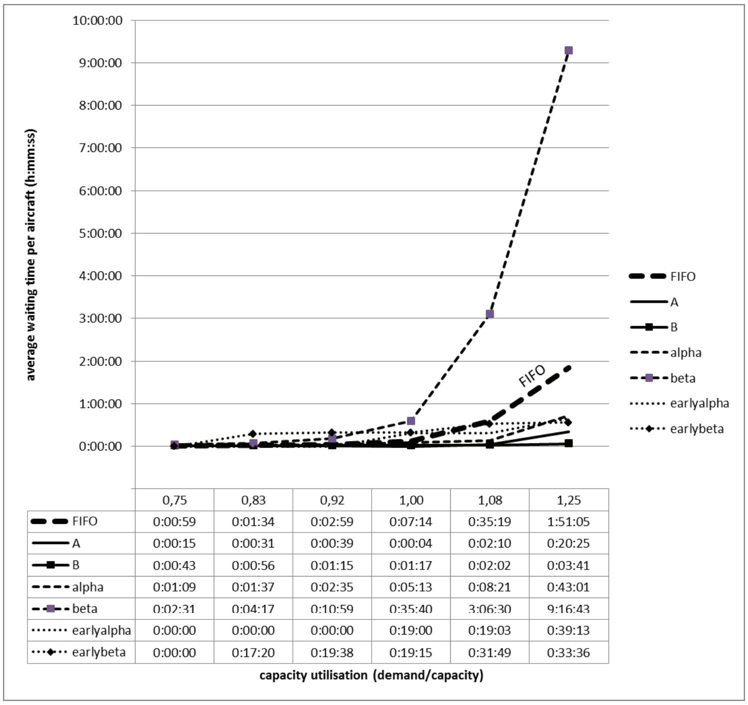
5. Trial with real data

Using real data generated from ADS-B data and comparing them with flight schedule data from a large international airport it was possible to analyse deviations from scheduled flight operations. 330,711 datasets were available from this airport. The longest delay (Actual Time of Arrival ATA – Scheduled Time of Arrival STA or Actual Time of Departure ATD – Scheduled Time of Departure STD) within this dataset was 23 hours 45 minutes, the earliest operation took place 16 hours 39 minutes earlier than scheduled. On average the deviation from the scheduled value was 16 minutes 58 seconds; correspondingly 15 minute punctuality at the point of service request after servicing at the runway stood at only 66%. The deviations between scheduled and actual usage time of the runway are extracted from the available real data. Deviations are taken at random from this data set and applied to each individual flight event in the simulation. In the period from 06:00 to 22:00 inclusive the flight schedule of the purely generic, simulated airport contains precisely 961 evenly distributed timeslots each of which was allocated precisely one flight event. This is equal to a declared capacity of 60 movements per hour whereby times after 22:00 hours may also be used but not allotted. The actual demand is derived from the conflict-free flight schedule by overlaying the deviations. In the simulation, type A and type B timeslots are alternately allocated in the flight schedule (961 timeslots in total, of which A: 481, B: 480). Using its own punctuality limit (here +/-5 mins: not be confused with 15 minute punctuality) the simulation decides whether a customer arrived at the runway within or outside of his validity time window for guaranteeing his strategically allotted priority if the runway were immediately available. Each flight event is thus granted a priority for consideration in servicing. Punctual (+/- 5min) customers with type A or B timeslots receive priority A or B; customers with type A or B timeslots arriving too early or too late receive priority alpha or beta. In accordance with the prioritisation sequence "A before B before alpha before beta" a sequence is now created using the prioritisation categories which looks for the next possible handling opportunity after arrival of the customer. This means that a sequence is first formed with all priority-A customers and then subsequently customers with diminishing priority.

Using this method it regularly occurs that there is a gap between two handling procedures in which no other service request can be accommodated. This resource usage with strictly asymmetric resource distribution would be in conflict with the desire to increase resource usage efficiency. A strategy was therefore introduced which has increased flexibility, making it suited to reducing this resource usage without at the same time eliminating the effects of prioritisation. The strategy used allows customers to claim a gap for themselves if, e.g., the gap has at least 10% of the capacity actually required for servicing the customer. The size of the gap is sufficient for trialling as an optimisation method but does not make available an overall optimised result. For this it would be necessary to apply an optimisation algorithm which would for example optimise all of the waiting times. However, optimisation of this kind is not necessary to prove the effectiveness of the allocation procedure, particularly as this optimisation could further improve a less strict FIFO procedure.

After this sequence-building procedure, each flight event is allocated a runway usage time. Some of the customers, who had received a downgrading of their priority by arriving too early at the resource, can now receive a runway usage time beginning after the start of the validity time window for the allocation of full priority. Since in these cases punctual arrival at the take-off and landing runway can only be validated by the passage of time, the algorithm takes into account this demand for subsequent reinstatement of the better priority. To achieve this a recursive process is required which defines for each individual affected the position in the sequence above which the higher priority ought to lead to the higher value sub-sequence in the asymmetric sequence generation process. Since this place cannot be calculated in advance – a portion of the affected individuals will for example be serviced ahead of schedule despite having a lower priority – the start of the changed priority is now sought by object within the existing sequence. The entire sequence formation is repeated from this point in time. It is possible that too much advantage may be given to an individual in the ascending ranking of customers by the individual pushing themselves in between customers of equal ranking as a result of pushing the second highest in the ranking into a gap which is actually too small and thus possibly being serviced more quickly than an originally more punctual arrival. In order to avoid this the customer must wait for at least as long as the last customer of equal ranking had to wait. So those gaps in the sequence which are at least equal to this waiting time after upgrading of the individual's own priority are considered first.

As a result (see figure 3) there is now in the simulation the expected upgrading of the A-customer and a downgrading of the B-customer, in each case in respect of the expected waiting time in the case of the FIFO variant. The average value across all aircraft is approximately equal to that of the FIFO strategy which was predicted by the independence from the queueing discipline. Within each respective prioritisation class however an average waiting time applies which is independent of prioritisation. If we take a detailed look at the data, we can clearly see that, as in figure 4a, the distribution of waiting times for each prioritisation category is broken down still further. It is those customers with the attribute "beta" which are most strongly affected by the increase in waiting times when capacity usage levels increase. Since "beta" customers are those which in the primary allocation were allocated the second-ranking category of slots and in addition themselves request servicing outside of their planned time window, these customers must compete for runway usage with the lowest priority. Those aircraft which are ready on time for take-off or landing and therefore have priority class A or B have the best chance of being serviced promptly. In between there are a few customers who were at the runway too early but who whilst waiting were nevertheless granted an upgrade to a class similar to their primary allotted priority class in order to maintain fairness. These sampled waiting times, which vary considerably depending on the case, document the priority ranking from a purely qualitative point of view. However, apart from the distribution of waiting times to the individual customers which is unusual in terms of the FIFO strategy because it is asymmetric, the introduction of this procedure alone does not result in any useful advantage in relation to the waiting times. It is far more the impact of this differentiation which leads directly to measurable advantages in comparison to the current system using the FIFO strategy. Firstly there is the clear increase in punctuality. Since the 15 minute punctuality measure is an industry standard which classifies all processed aircraft into the two categories "punctual" and "not punctual" and the alternative algorithm provides advantage to those aircraft which still have any chance of retaining punctuality, this leads to stable punctuality levels even in cases of heavy overload. The price of this is the increasing waiting times for all those who were given lower priority. Nevertheless, this selection makes sense because in the case of overload, by definition not all customers can be serviced, but when using the FIFO system all aircraft must wait for similar waiting times. A second and no less important effect is the presumed incentive effect of aircraft operating punctually – i.e. according to schedule. In reality there may be reasons why an aircraft cannot operate to schedule. The introduction of priorities in servicing at the runway would however counter these reasons with a price. The price, i.e. the consequences of not arriving at the service station on time, can then be weighed strategically or at the latest operationally against any possible advantage of requesting servicing too early or too late. Working on the hypothetical assumption that the distribution of deviations from the schedule used in this simulation would be reduced by 20% overall and the total flow of customers would thus spontaneously deviate from the schedule to a lesser extent, then a further positive effect of prioritisation on capacity can be seen. It was possible to maintain punctuality achieved in periods of overload at an even more stable level without reducing the number of customers.



	0,75	0,83	0,92	1,00	1,08	1,25
FIFO	0:00:59	0:01:34	0:02:59	0:07:14	0:35:19	1:51:05
A	0:00:15	0:00:31	0:00:39	0:00:04	0:02:10	0:20:25
B	0:00:43	0:00:56	0:01:15	0:01:17	0:02:02	0:03:41
alpha	0:01:09	0:01:37	0:02:35	0:05:13	0:08:21	0:43:01
beta	0:02:31	0:04:17	0:10:59	0:35:40	3:06:30	9:16:43
earlyalpha	0:00:00	0:00:00	0:00:00	0:19:00	0:19:03	0:39:13
earlybeta	0:00:00	0:17:20	0:19:38	0:19:15	0:31:49	0:33:36

Fig. 4. Mean added delay for each priority class.

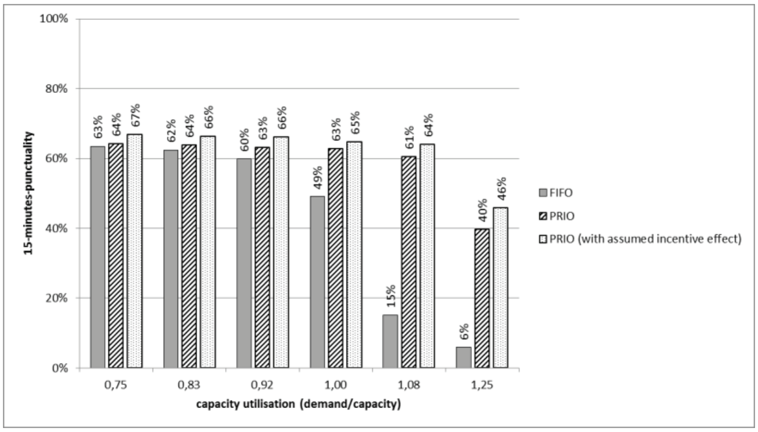


Fig. 5. Resulting 15-minutes punctuality for FIFO and PRIO cases.

6. Résumé

The effects on the quality of service provision when customers request servicing on a runway was investigated in a first test with schedule deviations drawn from real data. It was shown that the introduction of priorities cannot have a negative effect on the performance capacity of the overall system when a neutral waiting discipline variant such as the PRIO-NP procedure is used. The differentiation option produced using this method offers the customer a more efficient tool for ensuring quality of servicing, in particular when the demand-capacity balance has been upset. Strategically allocated priorities differentiate the availability of the resource – in this case the runway – according to their dynamic. The airlines are thus free to prioritise the importance of their flights in advance at a strategic level so that in times of need they are no longer surprised by delays that may occur. Performance-based priority on the other hand takes into account the customer’s own contribution to the overall result and therefore provides incentives for minimising disruptions to the overall operation. Due to the primarily positive effects on punctuality of prioritisation and the stabilisation of punctuality in cases of very high capacity load, a procedure such as this can be recommended for airports with particularly stretched capacities at which even small disruptions in operations can lead to enormous losses in servicing quality due to steeply increasing average waiting times. An alternative consideration would be using the method in connection with airport expansions to increase capacity which were not funded by all customers. A prioritisation model could be used with “dedicated infrastructures” such as these, for example runways which were made available to a particular prioritised group of customers but could be offered to all customers in times of need.

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