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AIRLINE OVERBOOKING PERFORMANCE
MEASUREMENT

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AIRLINE OVERBOOKING PERFORMANCE MEASUREMENT

by

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ABSTRACT

Since the "product" of an airline cannot be stored, the value of every seat which is left empty upon departure is lost forever or "spoiled". In order to compensate for the economic effects of passengers holding a confirmed reservation who fail to show-up, airlines overbook, i.e. accept more reservations than physical seats are available under the assumption that sufficient no-shows will occur. Even though airlines have overbooked their flights intentionally for decades, very few efforts have been made to measure the economic success of overbooking. As revenue maximization becomes more critical to the profitability of an airline, it is even more important to review the balanced tradeoff between denied boardings and spoilage.

This thesis outlines the major philosophies of the currently applied overbooking models and illustrates further the common overbooking performance measurement approaches. As all of these models demonstrate significant shortcomings, a new model, the *Revenue Achievement Model*, is introduced. This new approach is based on a purely economics driven philosophy. Along with the Revenue Achievement Model, the different definitions of spoilage, oversales and other key values for the overbooking performance evaluation are reviewed and defined anew in an attempt to standardize the terminology.

It is shown that the Revenue Achievement Model is more consistent with today's overbooking models than other overbooking performance measurement models. It matches the economic objectives of the airlines and shows superior qualities in comparing flights on a single flight level as well as evaluating the aggregate performance for large samples. The proposed methodology enables also to obtain a target performance index which allows a quantification of the objectives of overbooking. Finally, the impact of system overrides by revenue management analysts is analyzed and methods are suggested to evaluate their actions.

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Abbreviations and Notation

AU	Authorization Level
AU _M	Manual Authorization Level
AU _R	Recommended Authorization Level
AVL	Availability
BKD	Bookings
bkr	Booking Rate
CAB	Civil Aeronautics Board
CAP	Cabin Capacity
CRS	Computer Reservation Systems
DART	United Airlines' Space Planning Model
DB _§	Costs of Denied Boarding
DINAMO	American Airlines' Revenue Management Model
DOT	US Department of Transportation
ENABLS	Delta Air Lines' Revenue Management Model
PAX	Passenger
PAX _C	Confirmed Passenger
PAX _S	Standby Passenger
PI _{RAM}	RAM Performance Index
PI _{ROA}	ROA Performance Index
PI _{Target}	Target Performance Index

RAM	Revenue Achievement Model
ROA	Revenue Opportunity Approach
SPL _{\$}	Costs of Spoilage
STD	Standby's
SU	Show-Ups
suf	Show-Up Factor
sur	Show-Up Rate
TDB ₁	True Denied Boarding/1st
TDB ₂	True Denied Boarding/2nd
TSP ₁	True Spoilage/1st
TSP ₂	True Spoilage/2nd
VDB	Visible Denied Boarding
VSP	Visible Spoilage

Chapter 1

Introduction to Overbooking and Revenue Management

The "product" of an airline, the transport from A to B at a specified time in the future, is a very perishable service which cannot be stored. Once the aircraft leaves the gate, the revenues which could have been generated by every empty seat are lost. The limited number of seats which are marketed by the airline represent therefore a fixed product "inventory". Since the costs to carry an additional passenger in a seat which would have otherwise been empty are relatively small (an additional meal, airport handling fees if applicable and a negligible amount of fuel), all additional revenues above these incremental costs contribute towards the total profit generated by this particular flight. It is therefore of critical importance to control the number of seats to be sold at a specific price. Revenue management systems determine, based on historic data and demand forecasts, the number of seats to be offered at a certain fare in order to maximize the generated net revenues.

However, even if a flight is sold out in the classical interpretation, i.e. the number of bookings reached the cabin capacity, it is almost certain that this flight will depart with several vacant seats. This is caused by passengers canceling their reservation at short notice prior to departure (not allowing the airline enough time to sell the seat again) or by passengers failing to show-up for the flight at all. Given that these seats could have been sold to other passengers, the *spoilage* of seats represents a lost opportunity for the airline to generate revenues. In order to compensate for these effects, airlines take reservations in excess of the cabin capacity, i.e. overbook the flights, the assumption being that enough no-shows will occur so that seats will be available for every passenger showing up. The corresponding problem is obvious. Due to the large variance of the number of no-shows, it can happen that more passengers show up than seats are provided, so that passengers with confirmed reservations are *denied boarding*. A denied boarding may be *voluntary*, when the passenger consents not to board for some type of compensation. Otherwise the denied boarding is *involuntary*, when the airline refuses to accommodate the passenger on the flight. It is

evident that sophisticated mathematical models have to be applied in order to minimize the negative effects of overbooking in general and to avoid involuntary denied boardings as much as possible. Together with other inventory control optimizations, mature overbooking approaches have become an integral part of *airline revenue management*. According to P. Belobaba [1], revenue management consists of two major parts - pricing and seat inventory control. The process of airline overbooking and the determination of an optimal *authorization level*, i.e. the optimum number of reservations to be accepted, is therefore an essential precondition for the effective control of how many seats are available at any given time and location for a certain fare.

Although deep-discounted non refundable fares were introduced over the last decades, the percentage of no-shows increased steadily [2] and passengers seemed to be even more encouraged to no-show a flight. The airline industry claims therefore that it is essential for their operations to accept more reservations than seats are available in order to compensate for last minute cancellations and passengers who fail to show up. Without the balancing factor of overbooking, many flights would more frequently depart with empty seats for which there was a demand. American Airlines [3] claims that this would result in lower average load factors and the need to charge the public significant higher fares. They further estimate that 15% of seats on sold-out flights would be spoiled if no overbooking is applied. By using overbooking models, this has been reduced at American Airlines to 7% in 1980 and only 3% of seats were spoiled in 1990 because of the implementation of a new overbooking model [4]. American Airlines approximated that in 1990, if it was able to implement overbooking perfectly compared to no overbooking control, the additional revenues would have been \$250 million. In reality, they estimated that 90% of this revenue opportunity or, \$225 million has been realized due to sophisticated overbooking [4]. It is evident that this amount of additional revenue potential is a crucial factor which can help to improve the profitability of the airline industry.

Therefore, most major airlines, which have the required computer reservation system facilities, put a lot of emphasis not only on overbooking but on revenue management in general. The availability of seat inventories is carefully controlled by automated algorithms as well as by analysts. The authorized overbooking level limits the total number of acceptable bookings at any time. This authorization, which is supposed to be set so that the objectives of the airline are met, is either determined by an appropriate model (as presented later on) or set by a revenue management analyst. While the analysts decides by his personnel judgment and his experience, the overbooking model is based on mathematical models that use historical data. The fundamental input requirement for most overbooking models is a distribution which describes the show-up rate, its mean and variance.

As mentioned before, the total number of bookings is limited by the authorized overbooking level at any time. Due to the dynamic nature of the booking process, a continuous control and review of the authorization level is necessary. Compensation actions are taken to adjust for unforeseen changes of the passenger "behavior", e.g. exceptional high or low cancellation. This fine-tuning becomes even more important closer to departure. The following abstracts covers briefly the historic development of the overbooking problem and explains the progress of the overbooking models and the adopted policies by the airlines. Since the detailed modeling approaches towards overbooking are not of great importance to assess the overbooking performance, only the main strategies and policies are discussed.

1.1 Historic Development

The phenomena of no-shows and late cancellations are not new. In the 1950's the incentive to abuse the flexibility offered by the airlines was even higher when passengers who made reservations could cancel them or even no-show without economic penalties. In order to compensate for these negative effects, airlines decided to overbook their flights deliberately rather than relying on passenger wait lists. Even if the airlines did not admit to overbooking intentionally, it was common practice throughout the industry [2]. The reservation limits were determined on the basis of the recent cancellation and no-show history as well as the judgment of reservation office supervisors.

In 1961, a CAB report [5] revealed that the leading US carriers were faced with a significant no-show rate of 10% relative to the system wide number of passengers who boarded the flights. The introduction of a penalty scheme by the end of 1961 lead to a reduction of no-shows. This scheme penalized passengers who failed to show up by paying an amount of up to 50% of the ticket value but not more than \$40. The penalty was collected if another reservation was made or the tickets were handed in for redemption. Along with the penalty for no-shows the airlines were required to pay exact the same amount of money to reserved passengers denied boarding in the case of oversales, i.e. if more passengers with a confirmed reservation show up than the airline is able to accommodate on the flight. Although this system was at least partially successful, the CAB permitted its expiration after 1963 mainly because the airlines were concerned about their public relations [2]. Later on, the CAB introduced the penalty scheme again with significantly higher penalties for the airlines which were increased even more by the CAB in 1978. The new scheme also required the airlines to ask for volunteers before passengers were involuntarily bumped. Furthermore, the CAB encouraged the airlines to introduce new models which help to find passengers to volunteer for denied boarding.

K. V. Nagarajan [6] proved in a survey, that a considerable number of passengers are happy to volunteer for denied boarding in exchange for a very small amount or even no compensation at all. Thus, the scheme of penalizing the airline for bumping passengers involuntarily, was slowly replaced by the procedure of asking for volunteers who are willing to wait for the next flight in exchange for a relatively small remuneration.

The basic idea of the scheme to penalize and remunerate, even if changed over the years, is still applied for certain fare types by today's airlines. Depending on the restrictions of the purchased ticket, fees have to be paid in order to change a reservation and some tickets cannot be redeemed at all if they are not used for the booked flight. Passengers denied boarding are compensated with travel vouchers, and expenses for hotels, meals etc. might be covered. But many high fare tickets (first, business and even full economy fare) allow changing of reservations on short notice, cancellation of bookings and not showing up for the flight without economic penalty. Thus, the spoilage of seats on flights which were *fully booked* is still a major issue in the airline industry.

1.2 Overbooking Models and Policies

Meanwhile, different approaches were taken to optimize the overbooking level depending on the objective of the airline. The earliest published optimization model was developed by M. J. Beckmann in 1958. It minimizes the loss due to denied boardings and spoilage under the assumption of a very simplified environment. A more exact formulation of the problem was suggested by L. Kosten in 1960. Applying the same policy of minimizing costs due to oversale penalty and opportunity costs for non-utilized seats, his model considers the interspersion between reservations and cancellations. Furthermore, the maximum number of reservations to be accepted depend on the time left upon departure [7].

Costs of Overbooking

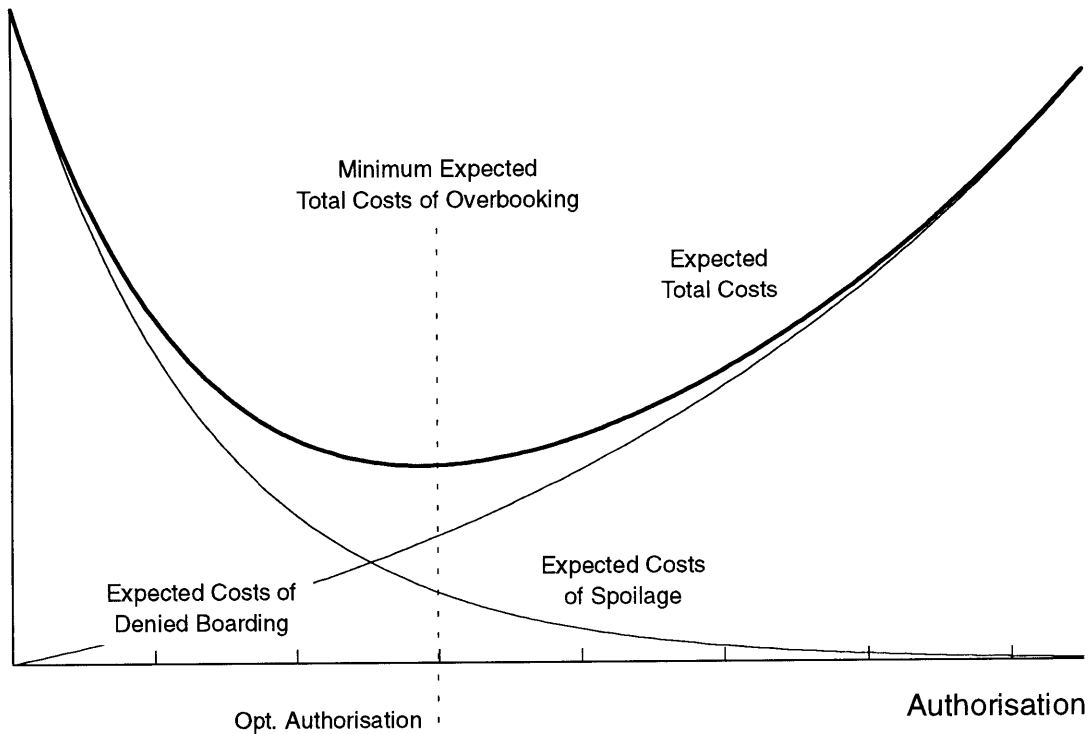


Figure 1.1 Minimum Expected Total Costs

The basic concept of the cost minimization model can be explained by Figure 1.1 which shows the considered cost curves over the cabin capacity. It is evident that every accepted booking in excess of the cabin capacity raises the probability of denied boardings. The more bookings are accepted, the higher is the number of expected denied boardings with an associated increase of the related costs. While the costs of denied boardings increase with an increasing number of bookings, the opposite is evidently true for the costs of spoilage. Thus, the total costs can be obtained by summing the expected costs of oversales and spoilage. The minimum of the summed curve determines the optimal authorization level, i.e. the optimum number of bookings to be accepted.

A different approach was proposed by H. R. Thompson in 1961. Rather than minimizing the inherent costs of overbooking, his model limits the probability of denied boardings. Thus, by ignoring all costs of oversales, a pre-set risk limit of denied boardings (probability of one or more excess passenger) constrains the upper booking limit at any time, as shown in Figure 1.2.

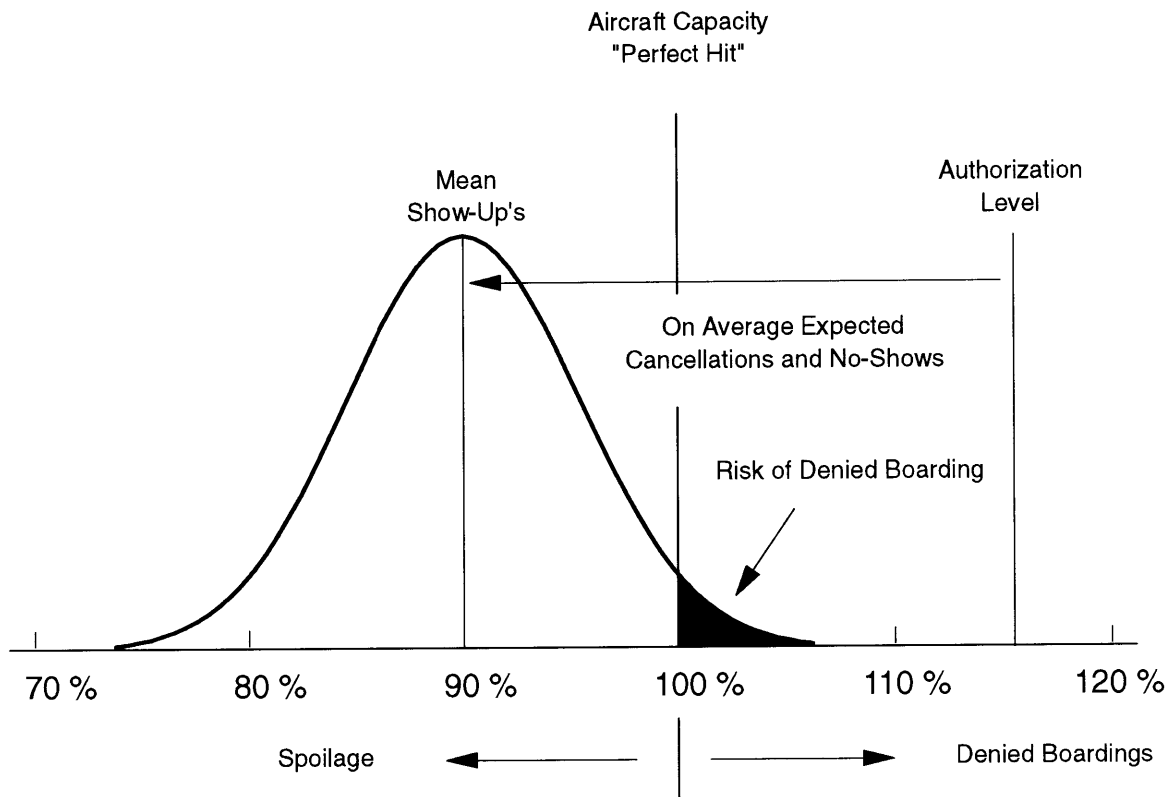


Figure 1.2 Probability Limitation of Oversales

Assuming that the number of show-ups follow a specified distribution, the probability of exceeding a given number of show-ups can be determined. A standard normal distribution with a mean show up rate μ and a standard deviation σ , was used in Figure 1.2 to illustrate this relationship. While the white area under the curve characterizes the likelihood that the number of show-ups do not exceed the cabin capacity, the shaded sector describes the opposite case. The "probability-tail" which represents the chance of having show-ups in excess of the cabin capacity can be interpreted as the risk of denied boardings which is limited by a pre-set policy target.

The same aim of limiting the probability of denied boardings was pursued by C. J. Taylor. His model, published in 1962, is similar to the Thompson approach but treats cancellations, no-shows and passenger groups much more accurately [7]. Furthermore, he considers the proportion of denied boardings per fixed number of booked passengers as an alternative constraint to the risk limitation. A simplified version of the Taylor model was implemented with American Airlines by M. Rothstein and A. W. Stone 1967 [8]. The model suggested by M. Rothstein in his doctoral

thesis in 1968 [7] finally combines the two policies discussed above. Subject to the constraint of a particular ratio of denied boardings per boarded passenger, his approach maximizes the revenues gained from the flight.

In 1972, K. Littlewood [9] presented a new model to forecast and control passenger bookings as used by BOAC. His approach to determine the overbooking level is still based on the proposal of M. Rothstein and A. W. Stone, but examines the reservation process in greater detail. Again, the maximum number of bookings to be accepted is constrained by a pre-set probability value of expected denied boardings.

Another interesting contribution towards the problem of airline overbooking policies is the research done by E. Shlifer and Y. Vardi as published in 1975 [10]. Within this report, a model is proposed which was implemented by El Al to develop an appropriate booking policy for an airline. Again the principals of the Taylor approach were used by Shlifer and Vardi to examine the implications of applying three criterion concurrently on different types of flights (single-leg flights carrying a single type of passenger, single-leg flights carrying two different types of passengers and two-leg flights). In each case the most conservative of the following criterion is applied: (1) limiting the probability of denied boardings, (2) constraining the ratio of expected oversales over the expected number of boardings and (3) maximizing the expected net revenues from the flight. Thus, not only the probability of exceeding a pre-set rejection level combined with the objective of maximizing revenues is considered but also the probability of rejection at all. If involuntary denied boardings have to be avoided, in particular the latter issue is an important measure in order to maintain a certain "perceived" service standard. For instance, the number of expected rejections could be limited by the number of expected voluntary denied boardings. Thus, no involuntary denied boardings occur and passengers do not get upset about the service.

In 1979, the model to determine the optimum overbooking level as presented by R. Gerbracht and applied by Continental Airlines [11] was again cost driven. Due to the increase of penalties for denied boardings by order of the CAB, the effect of oversales on generated revenues was becoming much more severe. While it was important to achieve even higher overbooking levels in order to compensate for the constantly increasing number of no-shows, it was "becoming very expensive to go too far in that direction". The proposal therefore only focused on costs occurring due to spoilage and denied boardings. A pre-set value not to be exceeded either for the number of expected denied boardings or the probability of a denied boardings were not considered. This can easily be justified by the enforced high penalty/fare ratio of 2/1. Thus, the statistically expected net revenues were maximized by matching the predicted marginal costs of denied boardings with the predicted

marginal costs of empty seats as function of a particular probability distribution of no-shows (dependent on the O-D market, the season, day of operations etc.). Due to the high costs of a denied boarding it is obvious that the adopted overbooking policies were less aggressive and more in favor of spoilage. In order to avoid incidents of high oversales, more spoilage was accepted.

However, not the definition of the airline objectives (revenue maximization and service level preservation) and the mathematical formulation are problematic but the practical application. Specifically, the required input data for the overbooking model are difficult to provide. In particular the probability distribution of the no-show rate is crucial to maximize the net revenues as stated by J. L. Gascó [12] in 1980. It is therefore not surprising that all of the more elaborate approaches discussed above are mainly focused on a realistic modeling of the booking and cancellation process.

The most recent publications also emphasize the same objective of maximizing the net revenues while maintaining a desired service level. An interesting exception was the model applied by United Airlines until 1986 [13]. Within their philosophy the most desirable objective was, of course, to achieve a "perfect hit" for every flight. In order to pursue the "perfect hit" policy, all methods and objectives were used to minimize the spoiled seats and denied boardings on an equal basis. The overbooking authorization was determined independent from the costs of seats light, (i.e. spoilage) or denied boardings by matching the mean of the number of show-ups with the aircraft capacity. Then, the authorization can be obtained easily by dividing the aircraft capacity by the mean μ of the show-up rate ($0 < \text{mean show-up rate} < 1$). This very simplified approach is a special case of the models discussed before and fails to incorporate different costs or desired service standards. The model, however, evaluates denied boardings in the same way as spoiled seats, and the probability of an oversale is equal to the probability of a seat light because of the match of aircraft capacity and mean show-up rate. It represents therefore the optimal solution for the maximum revenue case if the ratio of denied boarding penalty and costs per empty seat is equal to one.

This "special" approach as adopted by United Airlines is visualized in Figure 1.3. Again, the show-up distribution is assumed to be standard normal. The mean of the distribution matches the aircraft capacity exactly by definition. The "risk" of a denied boardings equals the risk of spoilage with a probability value of 0.5. Thus, the expected ratio of spoilage and denied boardings is equal to one.

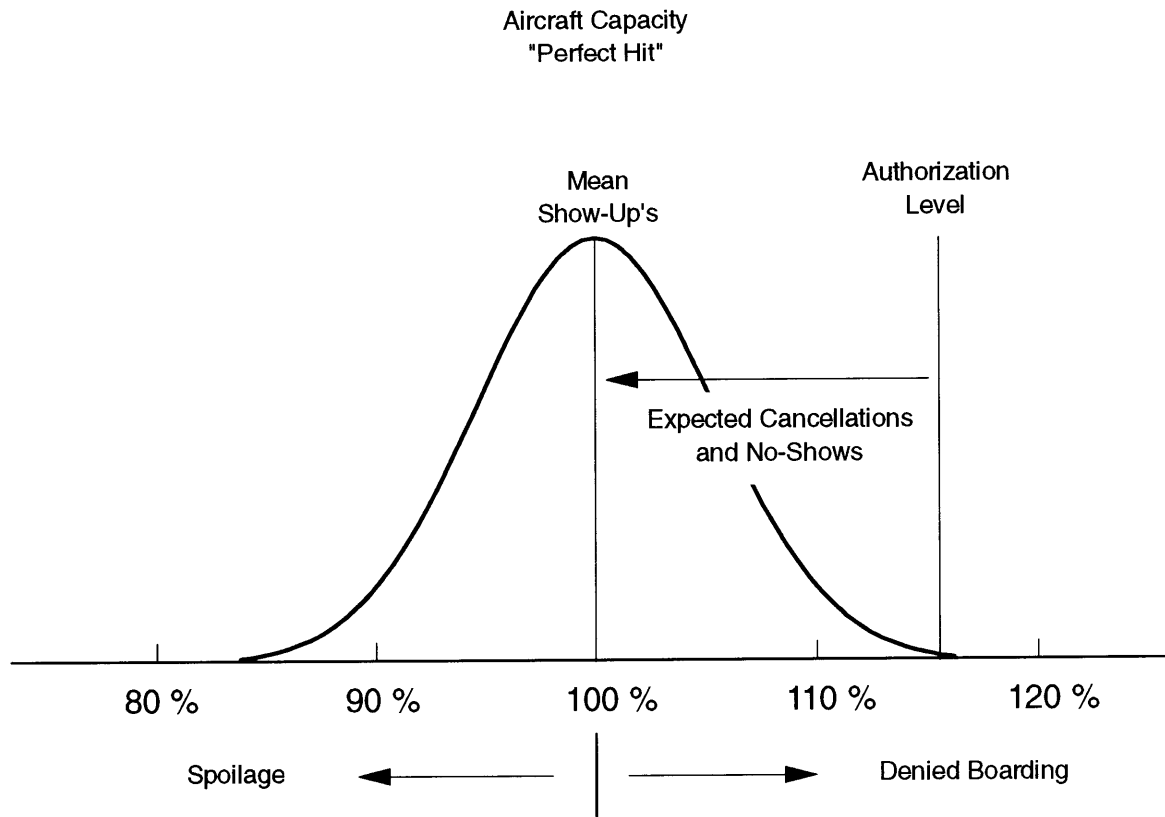


Figure 1.3 "Perfect Hit" - Overbooking Policy

Later, United Airlines obviously realized that it is more important to maximize the expected revenues and implemented the new space planning model (DART) in 1986 [13]. Once again, the overbooking level represents an economic trade-off between the costs of empty seats and the costs of denied boardings in accordance to the service and revenue objectives of the airline. Based on this simple revenue maximization approach, more advanced booking techniques were implemented by United Airlines as presented by N. B. Ashby [14] in 1989. While the overall objective of revenue maximization still applies, the entire process from booking a seat to departure of the flight is modeled more realistically within the refined model. Main features are the uncertainty added to no-show rate, cancellations, demand and late demand as well as two types of denied boardings (voluntary and involuntary) and a multiple cabin aircraft.

The same basic principal of balancing the costs of spoilage and denied boardings appropriately in order to maximize net revenues can be found within the overbooking model of American Airlines as presented by B. N. Srikar [15]. As shown in Figure 1.4, the optimum authorization level is determined by matching the marginal expected costs of oversale with the marginal expected costs of seats left. The marginal expected costs are the probability-weighted costs of an additional incident of oversale or spoilage. It is reasonable to accept any additional booking, as long as the marginal expected costs of spoilage exceed the marginal expected costs of denied boarding. In this case, an additional booking reduces the expected marginal costs of spoilage significantly while the respective costs of denied boardings raise slightly. This is true until the equality of both expected marginal costs is reached. Then, any further booking leads to an increase of expected denied boarding-costs which cannot be compensated by the decrease of expected spoilage-costs. The additional booking does not raise the expected net revenues any more but lowers it. Once both marginal expected costs match each other, the optimum number of bookings is reached and the expected, i.e. statistically predicted, net revenues are maximized.

Expected Revenues and Costs

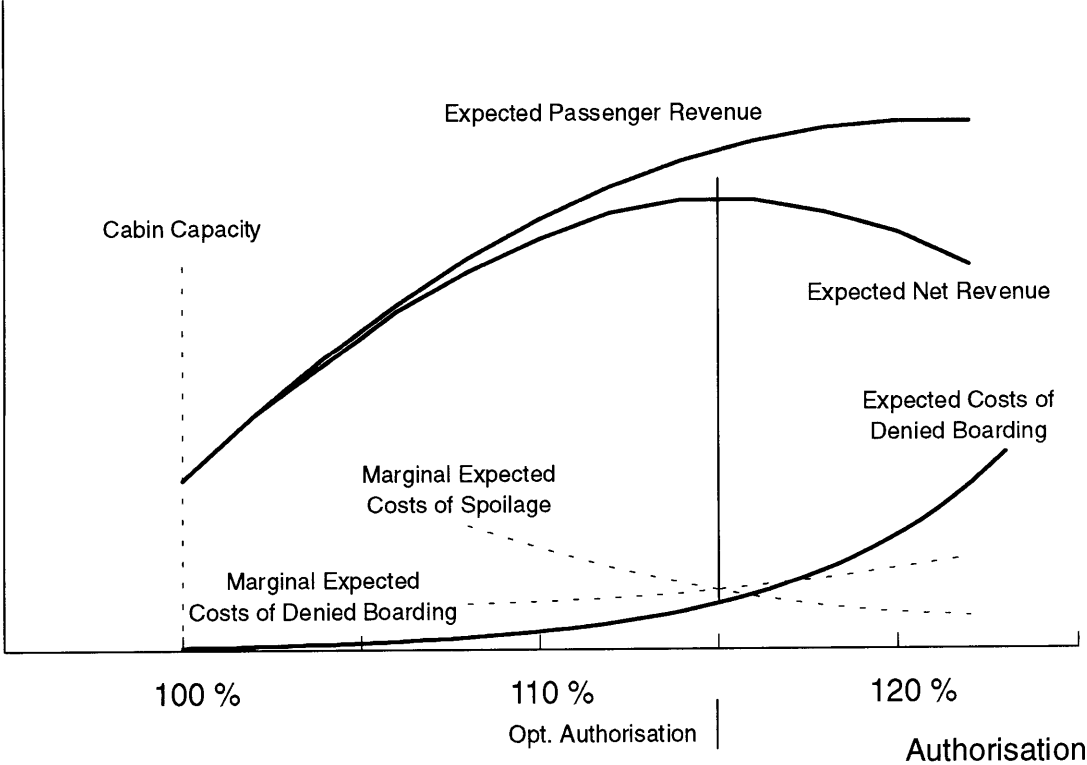


Figure 1.4 Marginal Expected Costs of Denied Boardings and Spoilage

However, the costs of oversales are difficult to establish because of their tangible and intangible components. Srikar claims that both components of the oversale costs should be assumed more accurately as non-linear functions. It is evident that the compensation for involuntary denied boardings should be higher than for voluntary denied boardings. Also the intangible components in the form of goodwill costs and perceived service quality depend heavily on the number of oversales. Further, he argues that airlines might want to penalize themselves more with increasing numbers of oversales because of service policy considerations. In order to overcome these difficulties he uses a "combination of the knowledge of tangible costs with an acceptable service level constraint". The model includes therefore a non-linear estimation of tangible oversales costs, as well as the "old" idea of constraining the number of expected denied boardings. The tangible costs of oversale are still approximated by a relatively simple step function.

Within American's revenue management system DINAMO, which was implemented in 1988, another interesting aspect of revenue management was incorporated, the recapture probability [4]. This is the likelihood that a passenger who cannot get the desired reservation will book on another flight rather than switch to another airline. While the risk of oversales increases with an increasing number of bookings, the additional expected revenue decreases because of the higher expected average oversale costs. It can be therefore beneficial for the airline to reject a booking request in cases of high recapture probabilities even though an incremental net revenue gain is expected. In such a case, the expected revenue increase of an alternative flight exceeds the additional expected net revenues of the highly overbooked flight. Hence, high recapture probabilities lead to lower overbooking levels.

Even though a variety of different approaches to the overbooking problem were have been proposed, as outlined in the previous discussion, the basic concepts and policies to determine the optimum authorization have not changed over the years. Either one or a combination of the subsequent listed objectives is considered by the airlines:

- maximizing net revenues by minimizing the total costs of oversale and spoilage
- balancing the number of spoiled seats and denied boardings (perfect hit)
- never exceeding a pre-set maximum number of expected denied boardings
- maintaining an average ratio of x denied boardings per 1000 passengers

The currently prevalent models pursue two strategies. Either the expected net revenues are optimized by matching the incremental expected gains and incremental expected costs of oversale or the revenues are maximized while a competitive service level (related to denied boardings) is maintained [16].

1.3 Overbooking Performance - What is it ?

Reviewing the different overbooking models used by the airlines, it is interesting to note that very few attempts were made (or published) to assess the overbooking performance of their daily operations. It is even more surprising given the history of the overbooking problem. Although the CAB permitted deliberate overbooking in 1967 as long as it could be "carefully controlled", the expression was never quantified by the CAB. Thus, the airlines determined themselves what they considered to be an acceptable overbooking performance.

Since then the situation has not changed very much. Although the CAB was dispensed from most of its controlling responsibilities with the Deregulation Act of 1978, nowadays airlines are still required to report their "Overbooking Performance" to the US Department of Transportation (DOT). However, the required ratio of denied boardings per 1000 boarded passengers does not mean very much, as outlined below.

Consider for instance two airlines A and B. While airline A does very poorly on some flights, experiencing an extremely high number of denied boardings, it does not have any oversales but many empty seats on other flights (due to lower demand, too large aircraft, poor scheduling etc.). Airline B in contrast reports some denied boardings on many flights but does not waste its resources to the same extent as airline A by flying around with empty seats on most of its remaining flights. Assuming further, that system-wide both airlines carry the same number of passengers and deny boarding to the same number of passengers. The result would be an identical ratio of oversale incidents per 1000 passenger. The shortcomings of such a reporting methodology are obvious. Having the same "Performance Index", airline A is doing worse than airline B as far as overbooking is concerned. But not only the economics of airline A are bad, also the perceived service standard is lower. An average of 2 oversales per relevant flight are certainly more desirable in terms of perceived service level than 7.5 denied boardings per relevant flight. Table 1.1 illustrates this problem.

Table 1.1 - Denied Boardings per x Passengers Ratios

	Airline A	Airline B
Number of flights which experienced denied boardings	200	750
Average number of denied boardings per flight	7.5	2
Total number of denied boardings	1500	1500
Total number of passenger	1,000,000	1,000,000
System wide seat capacity	1,600,000	1,300,000
Average load factor	62.5 %	76.9 %
Number of denied boardings per 1000 passengers	1.5	1.5

The main problem however are the economic implications for the airlines itself. Even though they are also interested in maintaining a certain service level, the main objective is revenue maximization. It is therefore essential for them to use all available tools to influence the net revenues gained per flight. With the use of even more refined overbooking models, it is getting more and more important to monitor the performance accurately on a quasi real-time basis in order to detect deviations from the ideal outcome as soon as possible. This could enable the airlines to counteract quickly and efficiently in order to compensate for unexpected changes in the mean show-up rate for example. Most important, however, is the evaluation of the economic achievements due to overbooking. This means that it must be possible to control the success of the trade off between spoilage and denied boardings as predicted by the overbooking model. It is further necessary to evaluate the actual overbooking performance on a single flight level as well as on an aggregate flight level. If booking analysts have overruled the automated recommendations it is of interest if these human overrides were beneficial for the airline. While the purpose of allowing analysts intervention can easily be justified by the need to incorporate common sense and human discernment in unusual situations, it is supposed to be to the advantage of the airline. Therefore, it is essential to compare the actual achieved performance with the theoretical performance which would have been achieved if the automated system's overbooking level recommendation would have been applied. It then can be decided if the system override by the analyst led to a reduction of spoilage or oversales costs for this particular flight or not.

An aggregate evaluation of the overbooking performance on a monthly or quarterly time horizon is necessary to measure the success in trading off denied boardings and spoilage on a long term basis. This helps to detect trends in either direction and prevents the development of "hidden" negative tendencies. Furthermore, useful information can be gained which can give important feedback about the assumed inputs of the applied overbooking model. For instance, any fine-tuning concerning the assumed tangible and intangible costs can be carried out by reviewing the recent overbooking performance. The same applies for all other input parameters of the overbooking model which had an effect on the booking level authorization. The airline must be able to assess the economic impact of their modifications of the overbooking model and the required input data. As such, analytical tools should be made available to assess the impact of any modification made to the overbooking model. If, for instance, a change which was supposed to improve the overbooking situation results in four additional denied boardings for an incremental reduction of one spoiled seat, the trade-off between spoilage and oversale turns out to be worse (assuming a modest spoilage/denied boarding cost ratio less than 4/1). Any variation can only be considered to be successful if the improvement of the spoilage situation was not made at the expense of an extraordinary deterioration of the number of denied boarding incidents. This example underlines the importance to trace the performance and to analyze the spoilage and oversale information concurrently and not separated from each other.

Furthermore, it might not only be important to know the actual performance but also what performance could have been achieved if appropriate overbooking levels were applied. Nevertheless, the use of such an indication must be considered very carefully because of its implications for the level of expectation and the danger of getting "disappointed". Although it is very tempting to calculate a figure which suggests an obtainable perfect outcome, it becomes hazardous if the expectations are set beyond achievable goals. It must never be forgotten that the show-up rate is probabilistic and therefore uncertain. A perfect hit cannot be achieved on every flight.

Additionally the problem of accurate data provision should be mentioned briefly. Whatever tools are applied for the purpose of analyzing the overbooking performance, it is essential to obtain the required flight information in the needed accuracy. Precise evaluations can only be made if the provided data fulfill the precondition of being comprehensive and exact.

It is therefore essential to tackle the problem of overbooking performance measurement systematically in order to find an appropriate tool which helps to evaluate the operations on a daily, monthly or annual basis and report to the airline management. Not only overbooking but also the

entire revenue management system should be treated like a closed control loop. Every change of input data leads to a changed situation which has to be analyzed. The findings must be reported back to the beginning of the chain in order to provide feedback. Otherwise it is impossible to control the revenue management activities properly. Without control it is not feasible to distinguish between profitable, invaluable and even harmful actions. While every simple industrial steering system is designed as a closed control loop, there is even a greater need to apply the same "standards" for complex mechanisms such as those utilized for the purpose of revenue management and overbooking.

Chapter 2

Overbooking Performance Measurement Literature Review

Sophisticated overbooking techniques, which reflect the objectives and policies of the airlines, are an integral part of today's revenue management systems. Although all major airlines apply overbooking models in order to reduce the spoilage of capacity and to maximize their revenues, very few attempts have been made to measure the performance of their actions. Due to its severe economic implications on the net revenues gained per flight, it is essential to monitor the "rate of success" of the applied overbooking technique.

Coupled with the problem of assessing the performance are the questions: What performance can be considered as good ? - and - What could have been achieved ? Furthermore, a much more detailed definition of the objectives of the adopted overbooking policy must be offered than only a statement like "high load factors coupled with low denied boardings" [14]. Although this remark describes the economic goals of the airlines very well in general terms, it does not help at all to evaluate a certain overbooking situation. Any serious attempt to assess the overbooking performance must therefore clarify the goals by using particular key values or target ranges which have to be achieved.

Depending on the pursued overbooking policies of the airlines, different approaches are applied to measure the success of setting a certain overbooking level. These models include monetary evaluations as well as non-monetary performance measurements. A further distinction of the different approaches is the size of the sample which has to be evaluated. Either single flights are analyzed or the success of overbooking is evaluated on an aggregate flight level. In this chapter, the main attempts towards the performance measurement of overbooking levels are illustrated and discussed in greater detail.

2.1 Non-Monetary Performance Measures

A prevalent non-monetary performance measurement is the straight evaluation of the number of spoiled seats or denied boardings in relation to some passenger figure. Once, the notation of spoilage and denied boardings are clearly defined, it is relatively easy to derive the required data from the raw booking and flight data. Within this approach the number of oversales or seats light is simply related to the number of passengers or the number of affected flights by calculating the relevant ratios. Figures are produced which express either (1) the average number of oversale and spoilage incidents per 1000 boarded passengers, (2) the average number of oversale and spoilage incidents per flight or (3) the ratio of seats light per denied boarding. A proper interpretation of these ratios is difficult and only feasible in correlation to historic performance data. Due to the probabilistic nature of the show-up process, the calculated ratios depend on the considered route, the days of operations, the season etc. While a ratio of 1.5 denied boardings per 1000 passenger, for example, might be the system-wide average, it can be exceeded by far on some routes which experience a high variation of the show-up rate. Hence, the resulting ratios of routes which are well known to be less predictable must be analyzed more carefully than "normal" samples which meet the average assumptions. These measures are therefore rather useful to identify changes of the overbooking performance compared to former achievements than to determine an universal and absolute performance index.

A critical feature is the basis of the comparison. In order to express a meaningful ratio it is necessary to relate the number of seats light or oversales only to relevant, i.e. "closed flights" flights. These are flights where the number of bookings exceeded a certain threshold at the day of departure. This threshold is usually slightly lower than the determined authorization level in order to allow for a certain buffer range. This is required to include also flights which were constrained by the authorization level sometimes during the booking process but ended up with slightly less bookings than actually authorized. Although the data are regularly reviewed by the computer reservation system or an analyst, a flight might have been closed a few days before and does not appear so during the review or at the day of departure because of recent cancellations. In addition to that, every flight that experienced denied boardings should be included even though the authorization level has not been reached at any time.

Another aspect of this comparison which has to be clarified is the relation of the spoilage and denied boarding data to the relevant flights itself. While a ratio could be established by using either the number of flights or the number of boarded passengers, the latter one is logically more correct. Due to the disregard of the aircraft size, a ratio which is based on the number flights

overemphasizes the denied boardings or seats light on large aircraft and vice-versa underestimates overbooking incidents on small aircraft. In spite of this and contrary the fact that all overbooking optimization methods maximize the generated revenues under consideration of the aircraft size, some airlines still use denied boarding and spoilage ratios related to the number of flights. A reason for this might be quality of service considerations. It could be argued that the perceived service level is more closely related to the absolute number of denied boardings rather than the percentage value. Passengers who were left at gate do not care about the size of the aircraft and percentage relations. Even though 8 denied boardings on a 80 seat aircraft are proportional to 30 denied boardings on a 300 seat aircraft, the passenger understanding for this situation is probably not proportional. Nevertheless, the economic objectives are not met. From the economic point of view there is no difference between 8 denied boardings or spoiled seats on a 80 seat aircraft compared to 30 incidents on a 300 seat aircraft respectively. The portion of lost revenues because of compensation payments (or lost opportunity in case of spoilage) is still 10% and exactly this percentage is optimized by the overbooking model.

While these ratios are ideal for comparing a pre-set service level constraint which limits the number of denied boardings, the economic objectives of the airline are assessed indirectly and only to a small extent. Due to the failure to incorporate any costs by using these ratios, it is difficult to analyze the economic implications of overbooking shortcomings. A cost ratio of the spoilage (SPL_g) and denied boarding costs (DB_g) can be implemented by choosing an appropriate goal to be achieved. In order to maximize the net revenues, the cost ratio SPL_g/DB_g should correspond to the performance ratio which expresses the number of denied boardings per spoiled seat DB/SPL (please note the inverse relationship of both ratios). A non-linear increase in these opportunity or oversale costs, because of involuntary denied boardings for example, cannot be considered within this simple evaluation.

Furthermore, an interpretation of these ratios is not easy. Whatever ratio is used for the analysis, it is only relevant if compared with former achievements. In particular the average number of spoiled seats or denied boardings depends strongly on the routes, day of operations, etc. Thus, extreme variations from the system-wide average can occur if only a selected part of the system is analyzed. Therefore, the application of a spoilage/denied boarding-ratio which expresses the number of spoiled seats per experienced oversale is not a very useful tool for analyzing purposes. On the other hand, an independence from the absolute variations is gained by determining a ratio which expresses the number of denied boardings per spoiled seat or vice versa. While, for instance, a sample of flights (A) experience an average of 8 seats light and 4 oversales per flight, another sample (B) could experience an average of 10 spoiled seats and 5 denied boardings per flight.

Although the latter sample appears to be worse in terms of overbooking performance, it turns out, that sample B differs only by a higher standard deviation of the show-up rate than sample A. The amount of spoilage per denied boarding is the same in both cases leading to a ratio of 2/1. The application of a spoilage per denied boarding ratio reveals that both flights were equally balanced in terms of overbooking.

Despite the shortcomings mentioned above, the use of ratios expressing spoilage and in particular oversales in relation to number of boarded passengers seems to be a fairly common tool which is applied by airlines in order to evaluate their overbooking techniques. References to these "overbooking performance ratios" can be found in American Airlines [3] and United Airlines [13] for example.

The same approach was also used by Delta Airlines [17] to analyze the oversale and spoilage performance of Y-class. The main purpose is to evaluate flights which were overbooked in accordance to the recommendations of Delta's ENABLS Revenue Management System in contrast to flights where the automated recommendations were overridden by revenue management analysts. In order to consider relevant flights in terms of overbooking, only "closed" flights are analyzed. These are flights where the final number of bookings exceeded a specific threshold which is slightly smaller than the authorized booking level. Furthermore, flights were excluded for the purpose of their analysis when the authorization level exceeded the actual cabin capacity only by a small number of extra "seats". In order to appraise the success of the system overrides of the ENABLS recommendations by revenue management analysts, the data are now split into three categories. These are (1) all flights with an applied authorization level equal to the recommended one, (2) all cases with an effective authorization level exceeding the recommended overbooking level and (3) all flights with an applied overbooking level less than recommended by ENABLS. In addition to that a further categorization of international, domestic and total flights in the system is applied to acknowledge the different characteristics of domestic and international flights.

The subsequent measurement of the overbooking performance itself is based on the denied boarding and spoilage ratios as discussed above. Thus, the average number of denied boardings and seats light per flight is calculated for each of these categories. Finally, a spoilage/denied boarding-ratio is determined which shows the number of spoiled seats per denied boarding. The comparison of the spoilage/denied boarding-ratio between the different categories allows conclusions about the benefits or costs of authorization changes by revenue management analysts.

Nevertheless, the main airline objective, revenue maximization, is only minimally reflected by this type of success measurement. Neither the costs of oversale nor the opportunity costs of having empty seats are directly considered by this model. This is a major limitation, if the overall goal of overbooking is supposed to be revenue maximization. The use of these ratios is also limited by the requirement of large sample sizes. Even though it is a usable tool to measure the success in maintaining an average service level on a system-wide basis, it cannot be applied on a single flight basis but only on an aggregate flight level which involves larger sample sizes. No meaningful ratio of spoilage per oversale can be obtained if the sample size is too small.

2.2 Monetary Performance Measures

In order to overcome the shortcoming of dismissing the impact of costs, it is essential to apply monetary performance measurement models. These approaches are by definition more capable to evaluate the economic implications of overbooking. This is achieved by using monetary values to express the negative effects of oversale and spoilage onto the generated revenues. Rather than employing the absolute number of oversold seats or the number of seats left, the respective costs of denied boardings or spoilage are used to measure the success of the revenue maximization. While the costs of spoilage are opportunity costs, i.e. expected revenues which did not materialize, the costs of oversale are more "real". These could either be expenses for overnight accommodations, meals or accommodation on another flight with a competing carrier, for example. In addition, the costs of denied boardings are characterized by an intangible component, passenger goodwill. What is the monetary value of passenger goodwill and "how much" passenger goodwill is lost if the passenger was involuntarily denied boarding? This question becomes a major factor if costs of overbooking are involved and is difficult to estimate. Another uncertain feature are the opportunity costs. Even though the number of spoiled seats is known once the aircraft leaves the gate, the potential loss in revenue can only be estimated by making certain assumptions about the revenue generating ability of the remaining seats. This could be the average revenue per passenger (yield) for this flight or some demand based mixture of sold fare classes, for example. It is therefore another challenge to approximate the occurring costs as accurately as possible in order to evaluate the overbooking performance on a cost basis.

Once rational cost assumptions have been established (which, of course, have to be under constant review), the basis for an overbooking performance evaluation is given which corresponds to the optimization algorithm and therefore the airline objectives. It also underlines that any serious approach towards the measurement of overbooking performance should be cost oriented in some way. If the main objective of the airline is revenue maximization, the performance of achieving this

goal must be assessed and not the perceived service quality deterioration due to denied boardings for instance. It is therefore not surprising that different performance measurement approaches were developed by the airlines which incorporate the economic implications of overbooking.

The following abstract discusses the philosophy and concepts of two different approaches, a cost based ratio model as implemented by United Airlines [13] and the Revenue Opportunity Approach (ROA) which is applied by American Airlines [4], British Airways [19] and Delta Air Lines[18].

2.2.1 Relationship of Oversale to Spoilage Costs

The basic concept of this evaluation philosophy is similar to the one described above in section 2.1. Rather than using the absolute or relative number of denied boardings or spoiled seats, either the opportunity costs due to seats light or the various cost elements of oversales, compensation payments etc., are the basis for the performance measurement. Here, the average costs of spoilage and denied boardings are determined for a selection of flights. Due to its nature that every "non-perfect hit" flight either experiences oversale or seats light (some exceptions may occur in which a flight departs with empty seats while at the same time boarding is denied to late show-ups), it is only feasible to obtain the required cost ratio for a significant sample of flights. This means that the sample must be large enough and that the flights must be comparable. This sample could be, for instance, the same flight number over a weekly or monthly period or any other justifiable sample (justifiable in the sense that only comparable flights, i.e. flights with the same properties are compared). This comparability requirement is extremely important if small samples are analyzed. On the other hand it is self-explanatory that this comparability requirement cannot be enforced on a system wide evaluation. Once the average costs of oversale and spoilage are established, the data can be analyzed. The evaluation itself is identical to the one described before. The experienced trade off between costs of spoilage and costs of oversale can be measured by the ratio which indicates the amount of money spent due to oversale for every Dollar which was "lost" because of spoilage. The objective of balancing the costs of overbooking is achieved if the ratio of spoilage to denied boarding costs is close to one. Any excessive deviation from this balanced ratio illustrates that either the costs of spoilage or oversale are too high, i.e. the overbooking performance is not optimal.

Again, the problem of aircraft size arises if the costs of overbooking are considered on a flight basis as opposed to a relation of the overbooking costs to the total "revenue potential" or total "revenue opportunity". This revenue opportunity value, which will become even more important within the application of the Revenue Opportunity Approach, accounts for the total amount of

revenues which could have been generated. The resulting problem is related to the determination of the costs of spoilage. While the total revenue potential in terms of seats is well defined by the availability, the equivalent monetary "number", expressing the overall revenue opportunity, cannot be derived as easily. The determination of this value is even difficult with perfect hindsight after departure. The revenues which could have been generated by every empty seat can only be estimated by the application of assumptions as outlined before. A more detailed discussion of this problem can be also found in section 2.2.2 covering the characteristics of the Revenue Opportunity Approach.

However, the comparison of average oversale and spoilage costs matches indirectly the controlling needs of the main algorithm of most overbooking models. Remembering that the net revenues are maximized when the average expected costs of oversale are equal to the average expected costs of seats left, it is obvious that a practical match of these costs can be applied to measure a good or bad performance. Although it must be stressed again that the described way of performance measurement is only as good as the estimated spoilage and oversale cost, it is a powerful tool which emphasizes the overall airline objective of revenue maximization.

An enhanced version of the above approach was developed by United Airlines [13] and focuses mainly on the subsequent analysis and presentation of the results. While prior to 1986, United Airline's objective was to minimize the number of spoiled seats and denied boardings, they evidently realized that it was more important to concentrate on the economic aspects of overbooking. Therefore, United's new space planning model DART was implemented, replacing the old approach in which all measures were taken to achieve a "perfect hit" on every flight (see also section 1.2). Thus, the policy of minimizing the number of spoiled seats and denied boardings changed towards the objective of maximizing the expected net revenues. This is achieved by balancing the trade off between the costs of spoiled seats and denied boardings.

United Airlines also recognized that any evaluation approach has to be compatible with the policies and methods used to set overbooking levels. It is therefore obvious that, concurrently with the implementation of the new overbooking model DART, economic aspects of space planning were included into the overbooking performance evaluation model as presented by W. Mainzer [13]. Besides the compatibility requirement, he also concludes that the measurement should be "normalized appropriate to the risks and benefits of space planning" and underlines the need to generate a monetary figure to understand the impact of overbooking on the airline's revenue. The necessity of a normalized measurement addresses the problem that only relevant flights should be considered. Therefore, only "space planned" flights are included into the performance analysis.

This is simply defined to be a flight where the total number of bookings exceeds the cabin capacity. Practically speaking, these are all flights with a probability of denied boardings being greater than zero. However, this definition is not useful for the determination of relevant flights.

A strict application of the above definition would mean that flights which experienced slightly more bookings than cabin capacity are also included even though the authorization limit has never been reached. Thus, flights with poor historical show-up rates, never being expected to become critical (because of too few bookings but just enough to exceed the cabin capacity), are subject to the performance analysis. It is questionable whether these flights are important in terms of measuring the overbooking performance. Consider, for example, a flight (cabin capacity: 100 seats) with an authorization level of 125 bookings. Assuming furthermore that, due to low demand, only 101 passengers were booked of which 80 showed up for the flight. The corresponding show-up rate can be determined to be $\approx 80\%$ which means that the authorized overbooking level was perfectly set (125 bookings at a show up rate of 80% leads to 100 show-ups). Nevertheless, this flight would be subject of the performance analysis with a contribution of 20 spoiled seats because the number of bookings exceeded the cabin capacity. Although the number of accepted bookings was not affected by the authorized overbooking level at any time, the flight is considered to be space planned in the sense of the definition as stated above. It is obvious that the application of this definition would falsify the results of any cost comparison between spoilage and oversale costs due to the high spoilage cost contributions of flights with an "non-activated" overbooking authorization. It is therefore more appropriate to consider only flights which were constrained by the authorization level sometimes during the booking process and did not end up with a perfect hit. The issue of what flights should be included in a performance evaluation will be discussed in greater detail in Chapter 3.

Nevertheless, the attempt to exclude non-relevant flights is important because no meaningful ratio can be expressed by system wide ratios which include all flights, i.e. relevant as well as non-relevant flights in the system. The subsequent analysis is also based on the ratio of spoilage per oversale costs. Again, the average costs of spoilage or denied boarding are calculated for a selected sample of flights. For the purpose of the graphical evaluation, the costs of spoilage and denied boarding are expressed per 1000 passenger boarding. Of even more importance is the cumulative value which indicates the total costs of denied boarding and spoilage per 1000 passenger which is direct linked to the airline objective of revenue maximization. As mentioned before, the calculation of overbooking costs automatically starts the discussion about the most significant factor of a cost based evaluations, the assumed costs per spoiled seat and denied boardings itself. It is therefore necessary to make realistic and justifiable assumptions for the estimated costs. Within United's

model the opportunity costs of empty seats are set to the fare of the highest selling nested class prior to departure of the flight. The denied boarding costs are estimated by "the average cost for a particular flight". Although this statement is not further specified, it can be assumed that these are the average costs of a particular flight as characterized by a single flight number over a certain time. Although the stated assumptions appear reasonable, it is difficult to decide without additional data support, if this estimation of overbooking costs is realistic. As discussed before, it is another challenge to determine the costs of oversale and spoilage.

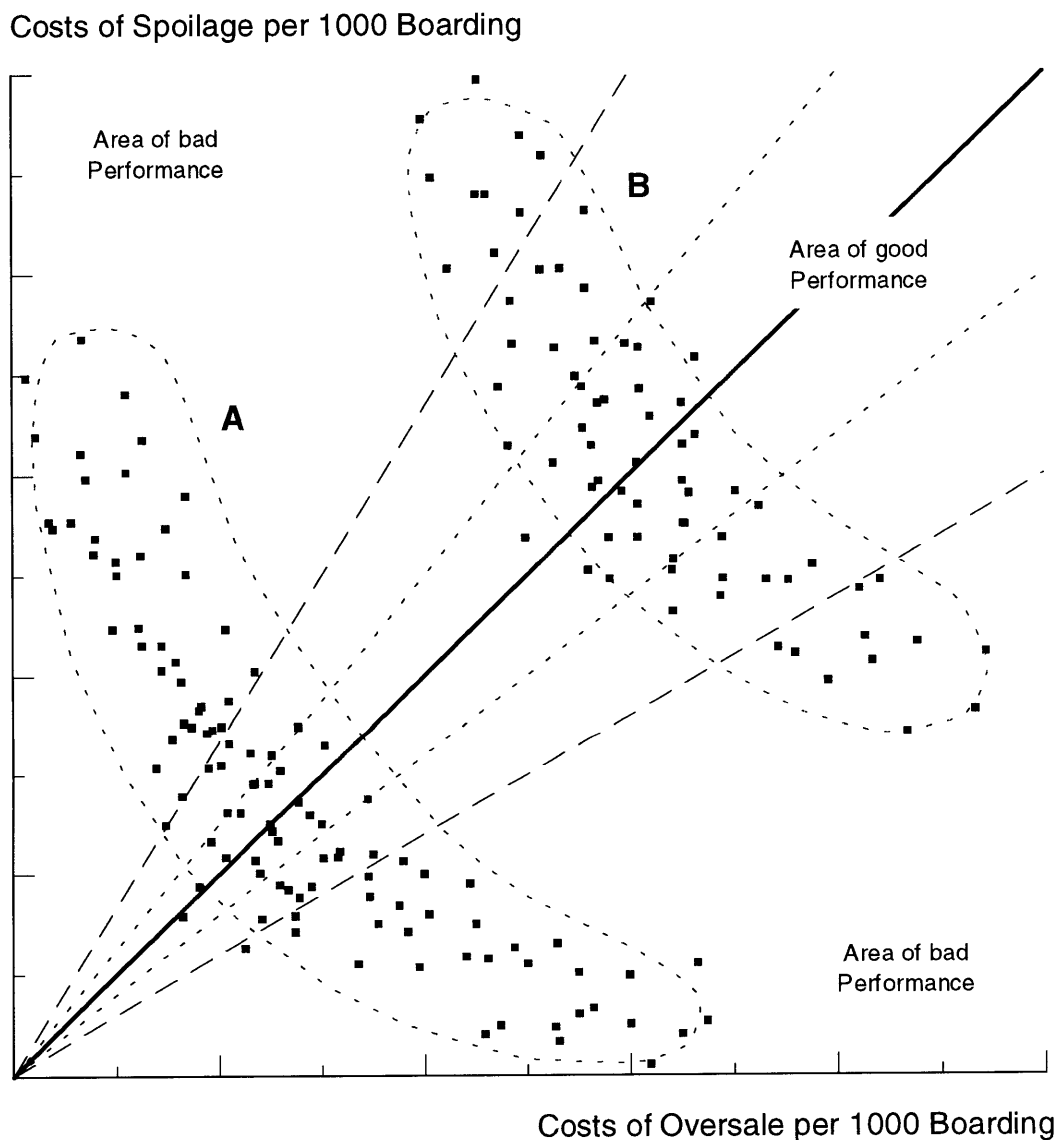


Figure 2.1 Costs of Spoilage/Oversale Relation - "United Airlines Approach"

The most interesting aspect of United's implementation is their way to visualize and further analyze the results and findings. The average costs of spoilage are depicted over the costs of denied boarding as presented in Figure 2.1, showing the performance of two flights A and B. Further, a "line of perfect hits" is defined by the Cartesian co-ordinates where the costs of oversale match exactly the costs of seats light. Since the statistically predicted net revenues are maximized when the average expected costs of denied boardings match the respective spoilage costs, this line represents the ideal case to be achieved. The closer any analyzed sample of flights is to this line, the better is the performance in the sense of matching the two costs of overbooking. Thus, three zones, two regions of bad performance and one area of good performance, are defined. While the area of good performance is obviously the region around the "line of perfect match", the remaining two regions are areas of bad performance which are characterized by an extremely disproportionately relation of spoilage and oversale costs. With the definition of these extreme performance regions it becomes now a matter of judgment and experience which flight is considered to be excellent, good, reasonable or bad.

Another aspect, which is clearly presented, is the fact that flight B in general experiences higher costs of overbooking than flight A. Reasons for this might be a more stable no-show rate or simply lower costs of overbooking (shorter route with lower fares and lower compensation payments for example) in the case of flight A. This highlights the two aspects of overbooking costs which are (1) the cumulative total costs due to spoilage and oversale and (2) the respective relation of these costs. While the latter issue can be directly influenced by altering the inputs of the applied overbooking tools in order to match the average expected costs of spoilage with the average expected costs of oversale, the total costs are characterized by the particular route. The ability to affect the general level of total costs is therefore very limited. It can further be concluded that flight B shows a much better overbooking performance than flight A. The latter one suffers by many incidents where the costs of spoilage and denied boardings are grossly unbalanced which is an indication for poor overbooking performance. Any extreme deviation from the area of good performance should be therefore notified as an alert to trigger a more detailed analysis and eventually corrective actions.

Although the discussed measurement approach accomplishes the requirement to incorporate the economic implications of overbooking and suits therefore the needs of the airlines better than a non-monetary model, there are still some shortcomings which limit the application of this model. Firstly, the determination of oversale and spoilage costs, the crucial part of the model, is difficult and requires further attention. But this is a general and systematic problem of monetary performance measurement methodologies which applies to every monetary model. Secondly, the "success of overbooking" can only be determined for a sufficiently large sample of flights. Even

though the analysis can be performed for a relatively small (compared to a system wide comparison) sample of flights, there is no way to derive a number which shows the overbooking performance for a single flight. Finally, the interpretation of the data is still laborious and requires too much understanding of the model, i.e. is too complex. The approach fails to express the success of overbooking by a meaningful performance indicator such as a percentage number or a comparable measure which is easy to understand and also contemplates the economic relationships.

Nevertheless, the adopted evaluation system reflects the revised overbooking policy of United Airlines to maximize net revenues. The approach is further capable to monitor the criterion as declared by N. B. Ashby [14] also of United Airlines. He mentions three key characteristics which determine a good performance in accordance with the airline objectives. His indicators are (1) high load factors coupled with low denied boardings, (2) costs of empty seats should approximate costs of denied boardings, and (3) total costs should be within the target range. All of these features are easy to review by the proposed evaluation technique.

The by far most interesting contribution towards overbooking performance measurement is the analysis approach and in particular the new way of data presentation. The developed practice helps to support the understanding of the overbooking problems and to identify a selection of flights which need more attention in the future.

2.2.2 Revenue Opportunity Approach (ROA)

Another popular attempt to relate the success or failure of overbooking to monetary terms is the concept of the Revenue Opportunity Approach which has been applied by American Airlines [4], Delta Airlines [18] and British Airways [19]. Rather than assessing overbooking performance on an aggregate flight level, it addresses the problem of evaluating a single flight and can also be used to determine a system wide performance index. The basic philosophy of the Revenue Opportunity Approach is easy to explain. As the name suggests, the ROA tries to relate the actual overbooking result to the maximum achievable revenue potential or revenue opportunity. In order to apply the Revenue Opportunity Approach the following key revenue values are required. These are (1) the actual achieved revenues, (2) the maximum possible revenues which could have been achieved in an ideal situation (perfect control) and (3) the minimum generated revenues if no overbooking measures would have been taken to compensate for no-shows (no control). The difference between the ideal case and the "do nothing" case represents the maximum amount of revenues which could have been generated because of overbooking. Now, the amount by which achieved revenues exceed the revenues in the hypothetical "do nothing" case is related to this revenue opportunity. The result

is a percentage value, a performance indicator, which expresses the level of achievement. Practically speaking, the performance indicator represents the percentage amount of revenues out of the total obtainable revenue opportunity which has materialized because of overbooking.

The resulting percentage value ranges (hopefully) between 0% and 100%. While 0% indicates that the same amount of generated revenues would have been achieved without any overbooking at all, a performance indication of 100% proves that the overbooking activities were successful and all possible revenues were collected. In extreme situations it might happen that a negative percentage value is generated by the Revenue Opportunity Approach. In such a situation, the authorization level was set too high and too many passengers were denied boarding. Thus, the positive effect of overbooking is more than offset by the high costs due to oversales. In this case the generated net revenues are pushed below even the revenue value which would have been obtained if no overbooking would have been done.

This type of measurement can be applied for a single flight, because the basis of comparison is only dependent on the actual flight and is totally autonomous from other flights. An evaluation on a more aggregate flight level or even on a system wide basis is also possible. Such a measure could either be determined by averaging all performance indicators of the considered flight sample or by adding up the single revenue values to three aggregate values (overall revenue opportunity, overall actual generated revenues, etc.) which allow the determination of a single performance indicator.

The principal philosophy of the ROA is shown in figure 2.2. While the actual case is the outcome of the flight, the other two cases define the extreme possible outcomes, the maximum revenue value and minimum revenue value. The worst case (no control) is the theoretical result under the assumptions that no overbooking would have taken place, i.e. the flight was only booked up to cabin capacity. Now the hypothetical number of passengers can be determined by analyzing the booking data for the flight. For example, the really experienced show-up rate could be used to estimate the number of show-ups. Vice versa the ideal authorization level can be obtained which would have lead to the perfect hit - perfect control. Assuming further an average fare per passenger, the calculated passenger numbers translates into revenue values which enfold the total revenue opportunity.

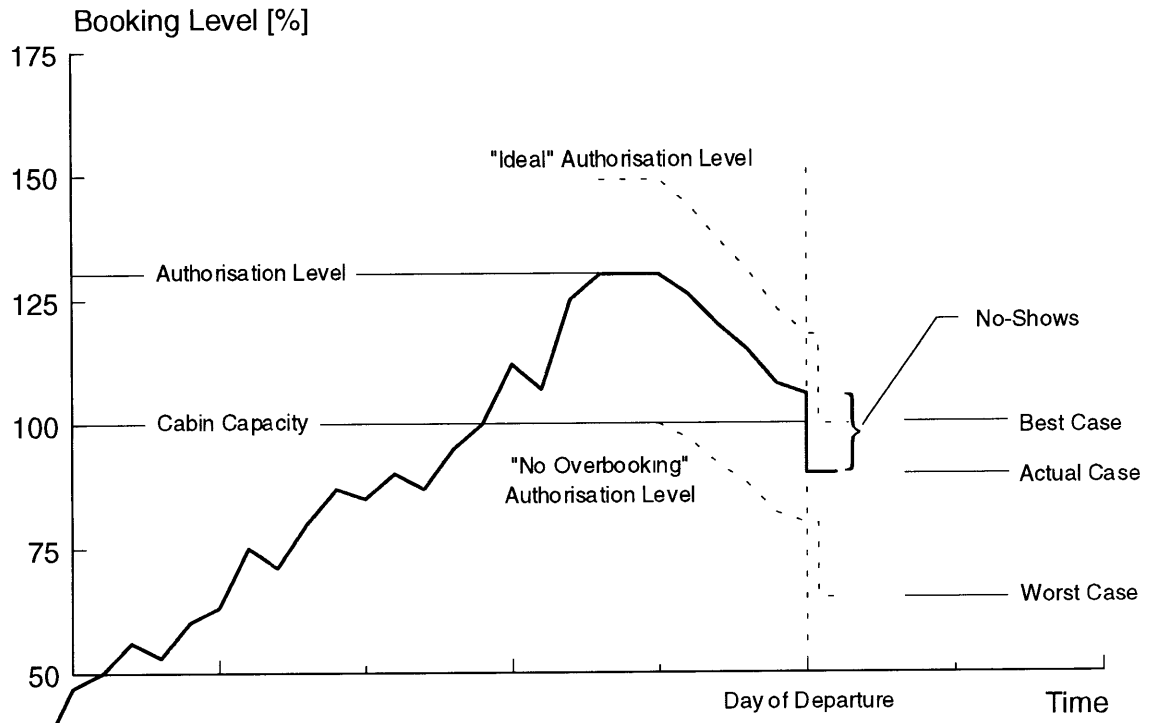


Figure 2.2 Revenue Opportunity Approach

As easy as it can be described, as difficult does it turn out, even with perfect post-departure hindsight, to calculate the required revenue values. Whatever complex methodology is applied, the result does not necessarily reflect the true revenues which would have been generated if either no control or perfect control were employed. In contrast to the "costs of spoilage/oversale relation" as discussed before, not only the revenue value of the perfect hit must be appraised but also the lost revenues of the worst case scenario. This adds extra uncertainty to the ROA.

A refined model of American Airlines [4] addresses the problem of estimating the no control and perfect control case more accurate. Rather than estimating an average fare, the supposedly sold fare classes are obtained by evaluating the recorded booking data of the flight. The no control revenues are derived from the booking process under the assumption that reservations are accepted up to the cabin capacity. Once this limit is reached, an additional booking is only allowed if other reservations are canceled. Now, the generated net revenues are estimated by the sum of the fares of all booked passengers who showed up. The revenues of the perfect control scenario are determined by eliminating spoilage and oversale. In case of denied boardings the total revenue value is calculated by adding up the highest fares out of all show-ups until the cabin capacity is reached (theoretically deny boarding to lowest fare passengers out of all show-ups). If spoilage occurs, the

actual generated revenues are increased by the highest fare reservations which were turned away due to overbooking control for every spoiled seat. While the assumptions for the no control case appear fairly reasonable, it is doubtful if the approach for the perfect control case is realistic. It is difficult to decide which bookings were turned away. Not every request by a travel agent for a particular fare class would automatically result in a reservation even though seats might be available. It is obvious that this, still relatively simple approach, requires further improvement. As mentioned before, the revenue estimation in an "if-then-case" is another challenge.

This raises automatically the question how the ROA performance index must be interpreted. The appraisal suggests that a 100% realization of the achievable revenues is possible. It certainly is feasible on that rare occasions when a perfect hit, i.e. no spoilage and no denied boardings, was accomplished. But even in those cases, when the ROA should be indicated with 100%, the strict application of American's revenue appraisal would lead to indexes below 100%. Remembering their philosophy, it could be argued that requests for high fare reservations were turned away. Thus, the calculated theoretical potential was still not achieved. This, again, underlines the problems with the revenue opportunity estimation. But even without being that picky, the ROA figure is somewhat misleading and implies that the objective must be 100% revenue realization. Due to the probabilistic nature of the show-up process, it is simply impossible to be successful on every flight. This is also reflected in the overbooking models, which success is measured. As outlined before (see chapter 1) today's overbooking models determine the optimum authorization level by matching the average expected costs of oversale with the corresponding costs of spoilage. This automatically implies that every flight is burdened with a cost element of overbooking. Thus, not the ideal case should be the measure of the overbooking performance but the predicted net revenue value.

Another disadvantage which is less obvious at the first glance is the sensitivity of the Revenue Opportunity Approach. This over-sensitivity can be especially experienced on flights with a very small gain-able revenue potential. On those flights, high changes of the ROA performance index are caused by relatively insignificant absolute revenue differences. This is a systematically shortcoming which is a result of the ROA performance index definition. Every additional revenue which were gained beyond the minimum revenue value are related to the overall revenue potential. Since passengers tend to turn up in incremental units, the fare impact of one additional passenger upon the overall economic result is extreme if the difference between minimum and maximum revenue values is equivalent to very few passengers. Table 2.1 shows some examples which shall help to clarify this effect.

Table 2.1 - Revenue Opportunity Approach - Sensitivity Example

Flight	Passengers real	Available Seats	Number of Reservations	Show-Up Rate	Passengers no control	Passengers perf. control	ROM Index
1	60	100	150	40%	40	100	33%
2	80	100	133	60%	60	100	50%
3	95	100	106	90%	90	100	50%
4	98	100	101	97%	97	100	33%

The examples as shown above illustrate the sensitivity of the Revenue Opportunity Approach. It is assumed that all of these flights are relevant for the overbooking evaluation, i.e. the number of bookings was restrained by some kind of overbooking measures. Further, a very simple method was chosen to determine the ROA performance index. Rather than estimating any costs, the calculation is purely based on the number of passenger, i.e. that the revenue loss due to one spoiled or oversold seat is equally weighted as the revenue value of one passenger. Thus, the ideal situation - perfect control - is achieved if the number of passengers matches the seat availability (100 in this example). The no control case is determined by applying the experienced show-up rate on the seat availability, i.e. accept reservations up to seat availability. The overall revenue opportunity is therefore obtained by: $rev. opp. = 100 - 100 \cdot show-up-rate$. The number of passenger which exceeded the no control case is now related to this total revenue potential and the ROA performance index is determined.

The problem of over-sensitivity can now be observed by comparing flight 2 and 3. While the overbooking performance of both flights is indicated to be the same, the load factors differ strongly. The show-up rate of flight 2 was obviously overestimated which lead to a poor load factor of 80% (extremely bad on a sold out flight) and only 50% of the possible revenue opportunity has been collected. As opposed to that, flight 3 achieved a much higher load factor of 95% but is also characterized by a ROA performance index of 50%. Again, only half of the total revenue potential could be collected due to the utilization of overbooking tools but the overall generated net revenues are much higher. Even though the overbooking performance is evaluated and not the overall economic performance, it appears a little bit bizarre that flight 3 is characterized by the same bad performance value as flight 2. But how good were the overbooking tools applied? A closer look at these two flights reveals another interesting aspect. Assuming the same show-up rate for the perfect control case as really experienced, the supposedly ideal

overbooking authorization of flight 2 can be calculated by 167 as opposed to an applied authorization of 133. The same figures for flight 3 are 111 as opposed to really authorized 106. While the authorization level of flight 2 was misjudged by 44, the corresponding number for flight 3 is only five. This huge difference is not expected by analyzing only the ROA performance index. While flight 3 was carefully controlled and the authorization level came very close to the ideal authorization level, flight 2 was extremely poorly controlled which lead to high spoilage and therefore a bad economic result. An even larger discrepancy can be detected if flight 1 and 4 are compared. Once more, both flights show the same, very poor, ROA performance index of 33%. But again, the economic result in terms of gained net revenue differs extremely. A load factor of 60% as opposed to 98% illustrates this. Thus, the ROA is very much dependent on the expected show-up rate and results in misleading figures if applied on flights with high actual show-up rates.

However, the Revenue Opportunity Approach shows also some major advantages over the previous discussed performance evaluation models. It addresses the economic issues of overbooking in a way that comes close to the objectives of the airline and appears furthermore consistent with the applied overbooking models. Beyond that, the ROA performance indicator is relative easy to understand and also reflects the situation more tangible than a spoilage per oversale ratio for example. By far the most important improvement over all anterior discussed approaches, is the ability to evaluate a single flight rather than a sample of flights. Thus the overbooking performance of a single incident can be evaluated independent from system averages or any other flights or historical data.

Chapter 3

Preliminary Considerations, Definitions and Notation

The evaluation of overbooking performance has been neglected for a long time. Only recently have schemes been developed by the airlines which allow a measurement of their overbooking activities. It is therefore not surprising that airlines use different notation to express the relevant overbooking data needed to calculate the overbooking performance. In particular, the different views of the airlines towards spoilage and denied boardings and the inconsistent application of these definitions cause severe problems. It is therefore necessary to clarify and standardize the definitions and notations to be used.

Further, the objectives of overbooking performance measurement must be specified in order to develop a powerful analyzing tool which can be used for a meaningful interpretation of the overbooking data.

3.1 Objectives

What are the objectives of overbooking performance measurement and why does an airline need to do this ? The general idea of any performance measurement is the concept evaluating the impacts of applied policies and tools on the company's objectives. The measurement of overbooking performance is an attempt to quantify the economic impacts due to overbooking of flights. It can also be used as quality control tool as far as passenger service is concerned. Nevertheless, its generic purpose should be the reporting and monitoring of the economic success of overbooking in order to maintain a high level of revenue achievement. It is an essential mechanism to close the loop of the overbooking cycle.

Even though the overall economic objectives are clear (revenue maximization), the universal statement of "good overbooking performance" must be more carefully specified. Furthermore, the detailed level of comparison and performance evaluation must be defined. Rather than focusing

only on a system wide analysis of the overbooking performance, it should be feasible to evaluate single flights as well as selected sample of flights. Then it is possible to compare different routes or different flights (as characterized by a certain flight number). In addition, it is important to analyze the impact of authorization overrides by revenue management analysts. Their intervention, which is supposed to be beneficial, is only advantageous for the airline if the generated net revenues are increased. Thus, the same applies for manual authorization settings as for recommended overbooking levels. Again, it is required to measure the success of these actions in a way that allows a comparison between routes and most important revenue analysts.

3.2 Definitions and Notation

A clear and unambiguous definition of spoilage and denied boardings is required to allow an accurate overbooking performance evaluation. Although most of the terminology appears straight forward and obvious at first, the potential for misinterpretation is very high. An example of this are the "relevant flights" which have to be included in the performance evaluation. Although it is accepted that only flights which experienced some kind of overbooking control should be included in an overbooking evaluation, the opinion as to which flights should be considered as relevant differs from airline to airline (see chapter 2 - United Airlines and Delta Air Lines). It is important to specify the criterion for a "closed flight" in order to avoid a dilution of relevant flights with irrelevant flights in terms of overbooking. This is only one example which highlights the importance of clear definitions and notations. The following section presents a discussion of the specific definitions refined for overbooking evaluation.

Cabin Capacity / Seat Availability

Commonly, the aircraft cabin of scheduled carriers is physical divided in either two or three compartments. These are first (F-class) and coach/economy (Y-class) class on domestic flights or first (F-class), business (C-class) and coach/economy (Y-class) on most international routes. Recently, some airlines replaced the three class concept on international routes by a two class concept with an upgraded business and no first class (e.g. *BusinessFirst* of Continental Airlines). However, the allocated number of seats which is made available for bookings of a particular class can differ from the actual visible number of seats in the corresponding cabin compartment. If, for example, some seats in the first or business class are forecast to be empty, these seats can be made available for coach class (Y-class) passenger. Thus, the following notations are used to distinguish between the visible cabin capacity and the total availability.

CAP: *Cabin Capacity* is the physical or visible number of seats which are allocated to a particular cabin compartment.

AVL: *Seats Available* describes the total number of seats which are designated to the considered cabin compartment and can be utilized for reservation purposes. The availability matches the cabin capacity for a particular class, if no additional seats are allocated.

The Y-class availability for example can be larger than the actual capacity if F/C-class seats, which were predicted to be left empty, are "allocated" to Y-class. Thus, the availability either matches or exceeds the cabin capacity. In some rare cases the availability might be exceeded by the capacity if the number of available seats need to be reduced for performance reasons, for example. This is, however, an exception and it can be assumed that AVL is usually greater or equal than CAP.

Passengers

The different "types" of passenger have to be defined. This does not refer to the purpose of their journey but their reservation status. Thus, a classification is introduced which distinguishes between passengers with and without a valid reservation for the flight. This is an important criterion for the later determination of spoilage and denied boardings.

PAX: *Passengers Boarded* includes all passengers who boarded the flight. This incorporates passengers with reservations as well as passengers without reservations (standbys) [$PAX = PAX_C + PAX_S$].

PAX_C: *Confirmed Passengers* are the total number of boarded passengers who held a reservation for this particular flight.

PAX_S: *Standby Passengers* refers to the total number of passengers who boarded the flight without reservation. These passengers turned up in the hope to get accommodated and were successful.

SU: *Show-Ups* describes the total number of people who were booked and showed-up for the flight. Boarded show-ups become confirmed passenger (PAX_C).

STD: *Standby's* defines the total number of people who turned up without a confirmed reservation in the hope to get accommodated. Boarded standbys become standby passenger (PAX_S).

Table 3.1 - Definition of Spoilage and Denied Boardings - Example

Flight	PAX	PAX _C /PAX _S	SU/STD	CAP/AVL	VSP/VDB	TSP ₁ /TDB ₁	TSP ₂ /TDB ₂
1	100	90/10	90/20	95/100	0/10	5/0	10/0
2	95	90/5	90/20	90/95	0/15	0/0	5/0
3	90	90/0	100/10	85/90	0/20	0/10	0/10
4	90	80/10	80/10	100/110	10/0	20/0	30/0

The table shows the relevant overbooking data and the calculated spoilage and denied boarding values according to the three definitions for an hypothetical sample of flights. The impact of these different definitions is extremely obvious if the provided information for Flight 1 are analyzed. Applying the most simple definition of spoilage and denied boardings, this flight experienced 10 Visible Denied Boardings. When we compensate for the standby's, the overbooking situation changes. Rather than having denied boardings, this flight is characterized by a True Spoilage/1st of 5 seats. Going a step further by applying the definition of TSP₂ and TDB₂, the number of spoiled seats increases and now 10 seats are considered to be spoiled. Depending on the employed interpretation of spoilage and denied boarding, the flight is either oversold or undersold. Flight 2 offers even a third option. Depending on the applied definition, the flight was either oversold, undersold or a "perfect hit" was achieved. These examples show the importance of using a definition which is consistent with the economic objectives of the airline as reflected in the overbooking model.

As discussed before the application of TDB₂/TSP₂ is preferred over TDB₁/TSP₁. From a strict economic point of view, the number of "economic" oversales or spoiled seats is related to the forecast availability rather than a fixed capacity. Therefore, the spoilage and denied boarding figures must be related to the availability rather than the capacity. Nevertheless, if an airline still wants to relate the overbooking data to the capacity (CAP) rather than the availability (AVL), i.e. applies TDB₁ and TSP₁, it should be at least ensured, that this definition is applied consistently throughout the performance analysis. A example of inconsistency is illustrated in Figure 3.3 and Figure 3.4, showing the real and the corrected overbooking data for a sample of flights.

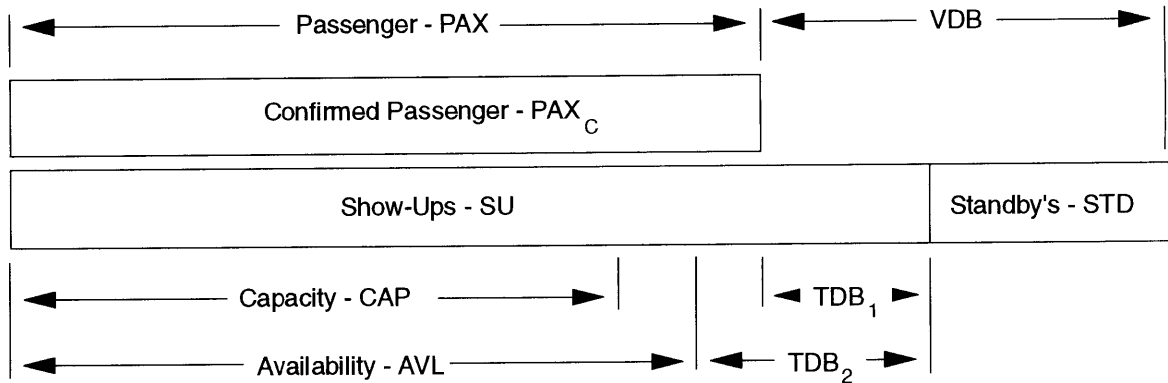


Figure 3.1 Definitions of Denied Boardings

The notation above highlights the different views and understandings of oversales. The number of Visible Denied Boardings (VDB) characterizes the easiest and most naive approach towards counting denied boardings. The figure is simply obtainable by counting the number of people left at gate, as illustrated by Figure 3.1. According to this definition, every standby and go-show who could not be accommodated would contribute to the VDB in the same way as a normal show-up with a confirmed reservation who was denied boarding. Furthermore, passengers who could have been accommodated, because of additional empty seats in F-class for example, are not considered to be oversold although the additional availability was unforeseen. Even though it was a matter of luck that these passengers were not left at the gate, the respective oversale figure does not reflect the underlying overbooking error by the airline. It is evident that this elementary oversale definition is insufficient for detailed measurements of the economic implications of overbooking.

A slightly better way of defining denied boardings is represented by True Denied Boarding/1st (TDB₁). The effect of denied standby's who were included into the VDB is eliminated. While the notation of True Denied Boarding/1st (TDB₁) addresses the problem of oversold standby's, it still does not compensate for the effects of unexpected empty seats in other classes. These effects are included in the most strict definition of True Denied Boarding/2nd (TDB₂). Any passenger who was able to board the airplane due to unexpected empty seats is also considered to be a true denied boarding. Even though this denied boarding was not "visible" and the passenger was not left at the gate, it is treated as an oversale for the purpose of performance evaluation. In a case where the number of boarded passengers (PAX) exceeded the availability (AVL), it was only possible to accommodate the excess passenger due to "lucky circumstances" and not due to careful overbooking control. If these excess passengers are not added to the physical number of show-up denied boardings, the prevention of oversale with its resulting costs would be credited to the

overbooking actions rather than good fortune. The lower denied boarding figure according to TDB_1 would imply a success of overbooking which does not reflect the reality. Thus, it is justifiable to apply TDB_2 as opposed to TDB_1 and employ the increased number of denied boardings (increased by the additional number of passengers who boarded beyond the forecast seat availability) as an input for the subsequent performance analysis.

Spoilage (SPL)

Applying the same philosophy, a similar classification can be established for spoilage. Again, we can distinguish between visible spoilage and two types of true spoilage which involve a stricter interpretation. This enables us to distinguish between performance relevant and irrelevant spoilage.

VSP: *Visible Spoilage* is the number of physical empty seats out of the relevant cabin compartment (CAP). Thus, standby passengers are not considered to occupy "spoiled" seats [$VSP = CAP - PAX$].

TSP_1 : *True Spoilage (first order)* refers to the number of seats out of the cabin capacity (CAP) which were not occupied by show-ups. Here, boarded standbys are considered to occupy "spoiled" seats [$TSP_1 = CAP - PAX_C$].

TSP_2 : *True Spoilage (second order)* relates the definition above to the forecast availability (AVL) rather than capacity (CAP). This means that seats in other compartments which were predicted to be empty and were made available are also considered to be spoiled if left empty [$TSP_2 = AVL - PAX_C$].

Again, the first definition of Visible Spoilage (VSP) is the simplest but also most misleading since it is based on the cabin capacity (CAP) rather than the allocated seat availability (AVL). Neither standby passengers nor empty seats in other parts of the cabin are considered to be spoiled even though the additional space available was predicted and allocated. Although it is still better to carry standbys rather than fly with empty seats, these passengers were, strictly speaking, not eligible for transportation. Despite that they might be revenue passenger who contribute to the overall net revenues, these standbys should be considered to be spoiled for the purpose of overbooking performance evaluation.

This shortcoming is overcome with the next definition of spoilage, the True Spoilage/1st (TSP_1). Here, the standby passengers are not treated as passengers with a confirmed reservation but as spoilage for the purpose of overbooking evaluation as shown in Figure 3.2.

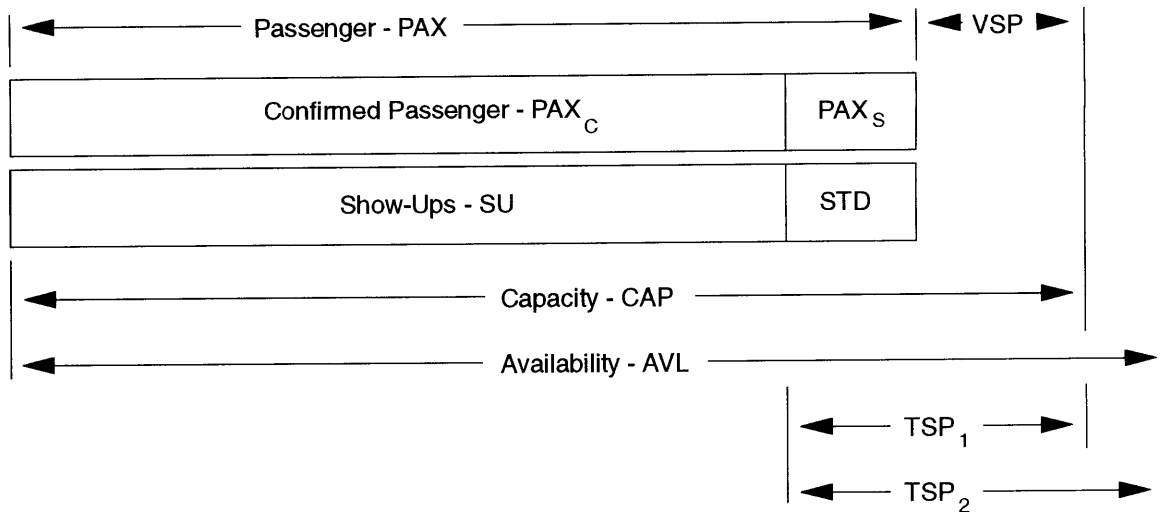


Figure 3.2 Definitions of Spoilage

Nevertheless, the number of empty seats in other compartments is still concealed even though these seats were forecast to be empty and allocated to a particular class. The measure of spoilage is therefore still based on the capacity (CAP) rather than the availability (AVL) which does not correspond with the economic objectives of the airline. The predicted availability and not the capacity (although availability might match capacity) is the basis for the established overbooking level and must therefore be the measure for any performance evaluation. This is the justification of another definition of spoilage, the True Spoilage/2nd (TSP₂), which addresses the anterior discussed problem. As illustrated in Figure 3.2, this definition of spoilage also includes the number of seats which exceed the capacity value and were predicted to be left empty.

Although it is still a matter of airline policy which of the above definitions is applied, it should be kept in mind that the application of TDB₂ and TSP₂ is the most suitable definition which best matches the airline economic objectives of revenue maximization. Depending on the required input data for the overbooking model and its sophistication, either TDB₁ and TSP₁ or TDB₂ and TSP₂ have to be used. If the calculation of the overbooking authorization is based on the capacity (CAP), it is obvious that TDB₁ and TSP₁ should be the measure for any evaluation. Accordingly, TDB₂ and TSP₂ should be used if the authorization level is determined on the basis of availability (AVL). It is obvious that the visible denied boardings and spoilage does not mean very much and should not be considered at all for any overbooking performance evaluation, whatsoever. An example of the impact of these definitions on the spoilage and denied boarding data is shown in Table 3.1.

Table 3.1 - Definition of Spoilage and Denied Boardings - Example

Flight	PAX	PAX _C /PAX _S	SU/STD	CAP/AVL	VSP/VDB	TSP ₁ /TDB ₁	TSP ₂ /TDB ₂
1	100	90/10	90/20	95/100	0/10	5/0	10/0
2	95	90/5	90/20	90/95	0/15	0/0	5/0
3	90	90/0	100/10	85/90	0/20	0/10	0/10
4	90	80/10	80/10	100/110	10/0	20/0	30/0

The table shows the relevant overbooking data and the calculated spoilage and denied boarding values according to the three definitions for an hypothetical sample of flights. The impact of these different definitions is extremely obvious if the provided information for Flight 1 are analyzed. Applying the most simple definition of spoilage and denied boardings, this flight experienced 10 Visible Denied Boardings. When we compensate for the standby's, the overbooking situation changes. Rather than having denied boardings, this flight is characterized by a True Spoilage/1st of 5 seats. Going a step further by applying the definition of TSP₂ and TDB₂, the number of spoiled seats increases and now 10 seats are considered to be spoiled. Depending on the employed interpretation of spoilage and denied boarding, the flight is either oversold or undersold. Flight 2 offers even a third option. Depending on the applied definition, the flight was either oversold, undersold or a "perfect hit" was achieved. These examples show the importance of using a definition which is consistent with the economic objectives of the airline as reflected in the overbooking model.

As discussed before the application of TDB₂/TSP₂ is preferred over TDB₁/TSP₁. From a strict economic point of view, the number of "economic" oversales or spoiled seats is related to the forecast availability rather than a fixed capacity. Therefore, the spoilage and denied boarding figures must be related to the availability rather than the capacity. Nevertheless, if an airline still wants to relate the overbooking data to the capacity (CAP) rather than the availability (AVL), i.e. applies TDB₁ and TSP₁, it should be at least ensured, that this definition is applied consistently throughout the performance analysis. A example of inconsistency is illustrated in Figure 3.3 and Figure 3.4, showing the real and the corrected overbooking data for a sample of flights.

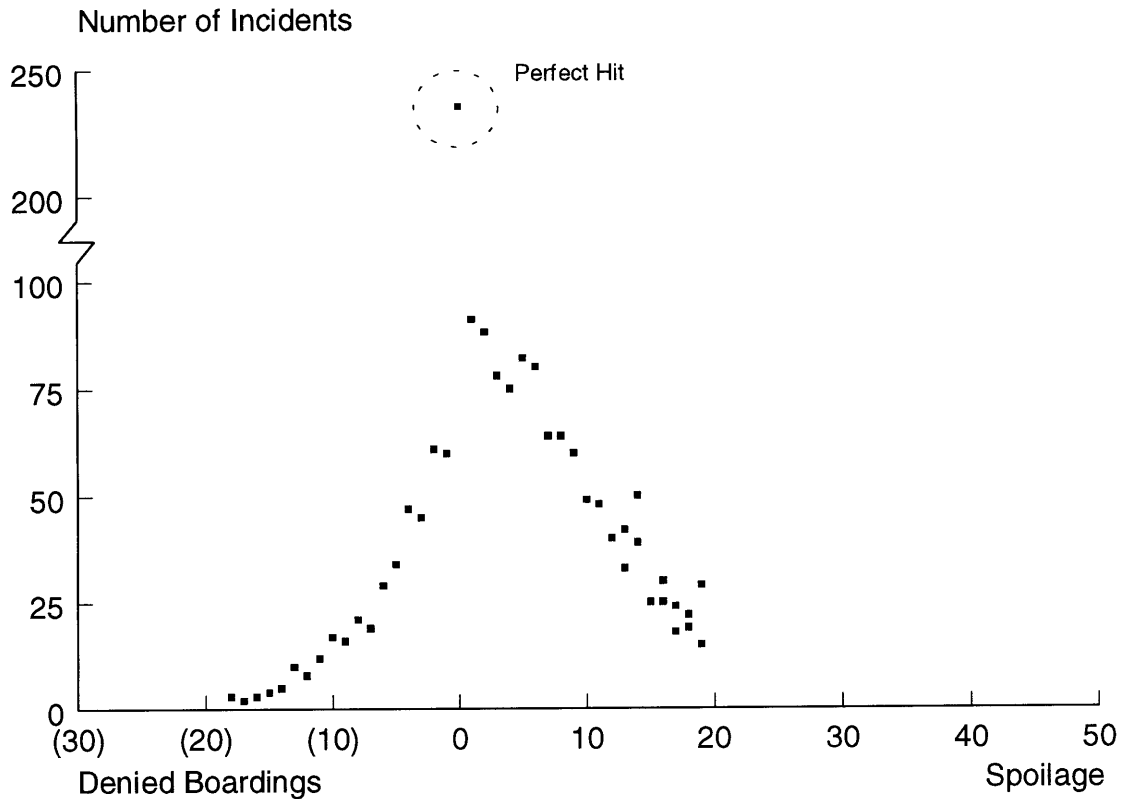


Figure 3.3 Overbooking Data as Reported (Non-Corrected)

Figure 3.3 shows the number of incidents of the respective amount of spoilage and denied boardings for a real sample of about 1750 flights which were subject to overbooking and reached or exceeded the evaluation threshold. The number of incidents appear to follow a distinct distribution with a mean close to the perfect hit, i.e. neither oversale nor spoilage. A very noticeable phenomenon is the extreme high number of incidents in which a perfect hit was achieved (please note the change of scale). While only ≈ 100 incidents were reported with one denied boarding or one spoiled seat, the number of ideal cases, i.e. no spoilage or oversale, exceeds 200 incidents. Why was it possible to obtain so many perfect hits and why were the adjacent incidents of spoilage and denied boardings much less frequently reported? Furthermore, the shape of the distribution appears smoother to the left of the perfect hit (denied boardings) compared to the right range which represents spoilage. The suspicious high number of perfect hits and the asymmetrical shape of the distribution requires a more detailed analysis of the data.

An examination of the applied definitions of spoilage and oversale revealed that inconsistent definitions were applied. While the number of denied boardings was related to the seat availability (AVL) of the flight, the calculation of spoilage was based on the capacity (CAP). Thus, a mixture of TDB_2 and TSP_1 was used to determine the spoilage and denied boarding information. The result is a distortion of the reported overbooking data as shown in Figure 3.3. The application of different definitions for spoilage and denied boardings leads to a "buffer" of seats which were forecast to be empty ($AVL - CAP$). This buffer absorbs excess passengers and does not show up as spoilage. If the number of passengers exceeds the capacity (CAP) but not the availability (AVL), no denied boardings and no spoilage occur according to the definitions of TDB_2 and TSP_1 respectively. Thus, a perfect hit is indicated although allocated seats are still left empty. The calculated spoilage is also misleading if the number of confirmed passenger (PAX_C) is smaller than the capacity. In such a case, the spoilage is $TSP_1 = CAP - PAX_C$ rather than $TSP_2 = AVL - PAX_C$ which is economically more correct. Thus, $AVL - CAP$ seats are ignored and not shown in the spoilage value.

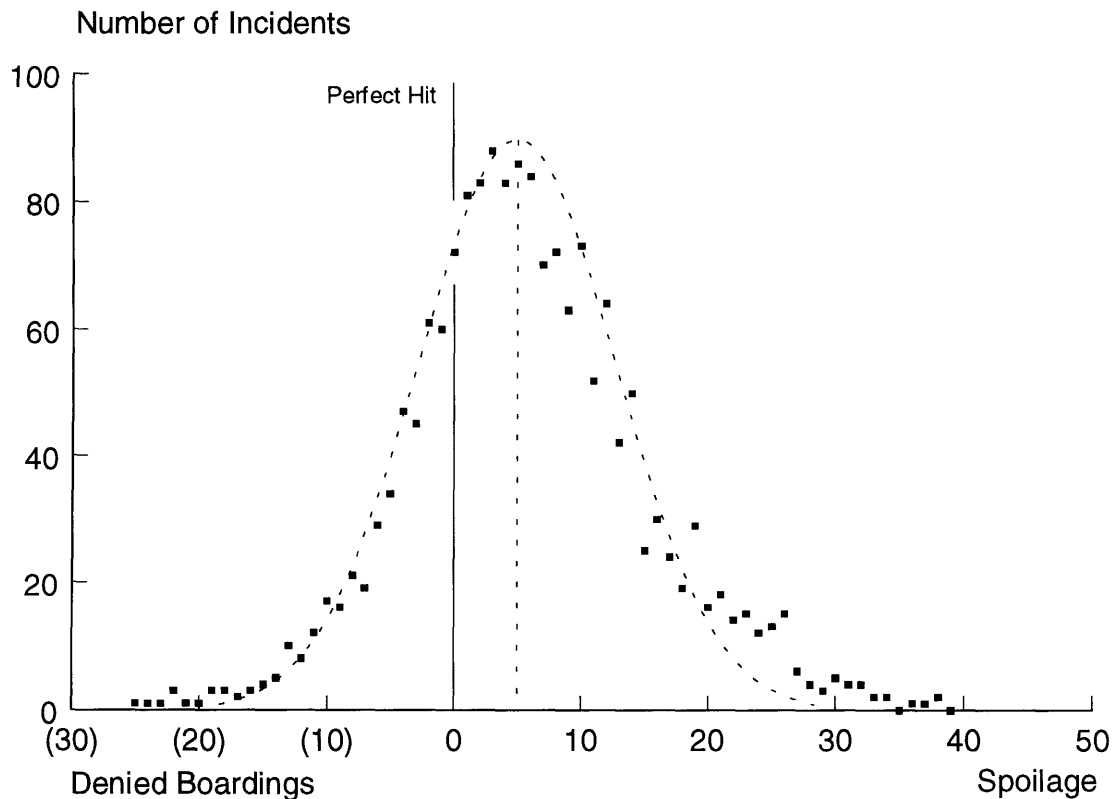


Figure 3.4 Corrected Overbooking Data

The corrected data set is shown in Figure 3.4. The illustrated overbooking information are compensated for the effects described above. While the denied boarding data remain unchanged, the cases in which spoilage and perfect hits were reported have been recalculated by applying $TSP_2 = AVL - PAX_C$. The result is a normal distribution with a mean of ≈ 5 (spoilage). Now the number of perfect hits is also more realistic with 65 incidents compared to 235 incidents as shown in Figure 3.3.

Costs and Revenues

Once the number of denied boardings and spoiled seats is determined, these values should be convertible into costs. As discussed before, the costs per spoiled and oversold seat are difficult to estimate. Whatever cost assumptions are made, the costs should be a function of the number of spoiled seats and oversales as shown below. Furthermore, it should be noted that the terminology of spoilage and denied boardings will be used in the sense of TDB_2 and TSP_2 for the subsequent discussion.

$SPL_{\$}$: *Costs of Spoilage* are the opportunity costs which represents the lost revenue potential of (in an economical sense) empty seats [$SPL_{\$} = \text{cost}(SPL) = \text{cost}(TSP_2)$]

$DB_{\$}$: *Costs of Denied Boarding* includes all costs which occur if show-ups are denied to board the aircraft. This includes the tangible as well as the intangible components of oversale. The costs are a function of the number of denied boardings [$DB_{\$} = \text{cost}(DB) = \text{costs}(TDB_2)$]

Accordingly a revenue function (rev) is defined which determines the monetary value of the generated or possible revenues based on the number of passengers or the availability. Again, it is assumed that the revenue function (rev) is given.

Bookings and Authorization Level

Finally, the notations and terminology of bookings, authorization levels and three frequently used ratios have to be clarified.

BKD : *Bookings* refers to the total number of final reservations for a particular flight.

AU : *Authorization Level* is the applied authorization level. This could either be the recommended (AU_R) or the manually set (AU_M) authorization level.

AU_R: *Recommended Authorization Level* describes the authorization level as recommended by the applied overbooking model.

AU_M: *Manual Authorization Level* indicates the manually set authorization level. This authorization takes place if the recommended authorization level was manually overridden by revenue management analysts.

Show-Up Rate, Booking Rate and Show-Up Factor

sur: *Show-Up Rate* refers to the quotient of booked people who finally showed-up for their flight at the day of departure [sur = SU / BKD].

bkr: *Booking Rate* relates the number of actual bookings (BKD) to the applied authorization level (AU). This addresses the problem that the authorization level does not always perfectly match the number of bookings [bkr = BKD / AU].

suf: *Show-Up Factor* is determined by the quotient of show-ups and availability. It is therefore somewhat similar to the load factor with the difference that the show-up factor can exceed 100% [suf = SU / AVL].

3.3 Relevant Flights

As discussed before, it is essential to distinguish between relevant and irrelevant flights for the purpose of overbooking performance measurement. In order to obtain a meaningful performance indication, it is obvious that irrelevant flights, i.e. flights which were never expected to experience either oversale or spoilage, have to be excluded from the analysis. But how can relevant and irrelevant flights be separated practically ? Certainly every flight which reached the authorized overbooking level at some time during the booking process must be included into the performance evaluation. Such a flight was definitely constrained by some means of overbooking control and must be evaluated concerning its performance. The problem arises when the number of reported bookings did not reach the authorization level (AU) but a level just below the employed AU, i.e. $AVL \ll BKD = AU - \Delta$ at the revision points prior to departure and at the day of departure itself. The reason for that could either be insufficient demand or an undetected reaching of the AU followed by cancellations which lowered the number of bookings below the AU. However, even though a particular flight does not quite reach the AU, there is some likelihood that this flight will end up being oversold (and is actually oversold from time to time). Hence, this flight should "qualify" for the overbooking performance evaluation.

At the first glance, the approach of including a flight with a non zero chance of oversale seems to be the solution for the problem of what flights to include in the performance evaluation. As outlined in section 2.2.1 (United's overbooking performance evaluation), the strict application of this philosophy does not lead to sensible results. Imagining, for example, a flight where the number of bookings (BKD) exceed the availability (AVL) only by a marginal number and do not even come close to the set authorization level, i.e. $AVL + 1 \leq BKD \ll AU$. Although a non zero chance exists that all booked passenger show-up and the flight is oversold, the probability of oversale is very low. This flight would never be expected to be oversold and must not be included in the performance measurement.

As adopted by some airlines, it is therefore more appropriate to use a decision threshold rather than the authorization level itself to distinguish between relevant and irrelevant flights. This threshold is slightly smaller than the authorization level (AU) but much larger than the availability (AVL). If the number of bookings exceed this threshold, the particular flight "qualifies" for the overbooking performance analysis. Usually a fixed allowance x between the authorization level and the decision level is used, i.e. the threshold is defined by the authorization level minus a fixed deduction x irrespective of the aircraft size ($AU - x$).

The related problem is evident. The AU of flights with high authorization levels (large aircraft) would be reduced by the same allowance x as flights with low AU's (small aircraft). An obvious improvement would be the employment of a percentage deduction rather than an absolute allowance between the threshold and the authorization level. An even better approach, however, could use the likelihood of oversale to determine a probability based threshold as illustrated in Figure 3.5. Assuming a particular expected show-up distribution (usually normal distribution), the likelihood of oversale can be determined for every number of actual bookings (BKD). The actual risk of oversale $p(\text{oversale})$, which expresses the probability that one or more passengers are denied boarding, can be obtained by calculating $p(AVL < \text{sur} \cdot BKD)$ with the show-up rate being variable. This relationship is also visualized in Figure 3.5 by the area under the probability density function which exceeds the availability (or perfect hit). In addition, a maximum chance of oversale can be obtained for every flight which occurs when the number of actual bookings reach the authorization level ($BKD = AU$). Since the authorization level is the upper limit of acceptable bookings, the related risk of oversale defines also the upper limit for the oversale probability $p(\text{oversale})_{\text{max}} = p(AVL < \text{sur} \cdot AU)$.

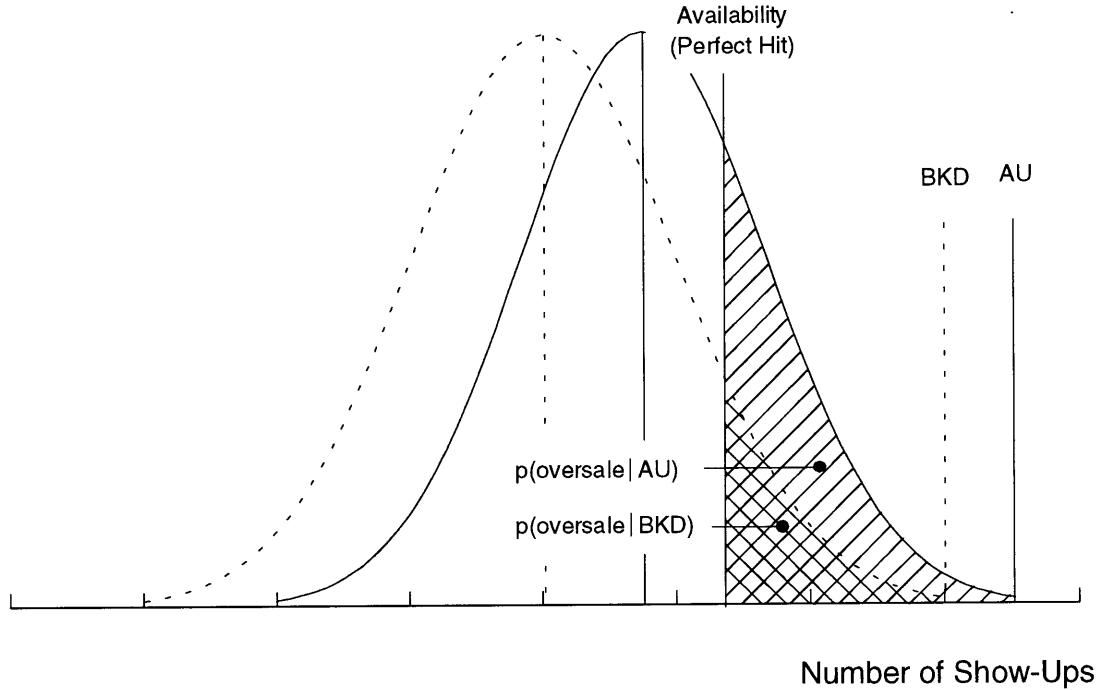


Figure 3.5 Relevant Flights

Now the actual chance of oversale $p(AVL < sur \cdot BKD)$ can be expressed as percentage portion of the maximum oversale likelihood, i.e. $p(oversale | BKD) / p(oversale | BKD = AU)$. This ratio of actual probability of oversale and maximum likelihood of oversale varies obviously between 0 and 1. While zero indicates that there is no risk of oversale, a 1.0 ratio occurs when the actual number of bookings (BKD) matches the authorization level (AU) as shown in Figure 3.5. While the solid line indicates the expected probability density function (assuming a mean show-up rate and standard deviation) for the case that the number of bookings matches the authorization level, the dotted line refers to the respective probability density function of a situation where the number of bookings does not reach the AU. As mentioned before, the areas under these curves and right of the availability represents the risk of oversale. It is evident that the actual risk of oversale is always smaller than the maximum risk of oversale as long as the number of actual bookings do not exceed the authorized limit (AU). If the BKD exceeds the AU, because of malfunctions or overrides of the Computer Reservation System for example, there is no doubt anyway whether the flight is fully booked or not.

Table 3.2 - Relevant and Irrelevant Flights

	AVL	mean sur	std. dev. of sur	AU	max. p(oversale)	threshold ratio	BKD threshold
Flight 1	100	0.85	0.05	115	0.3483	0.50	112.37
Flight 2	100	0.79	0.07	120	0.2682	0.50	117.48

The probability threshold concept can also be visualized by Figure 3.5. As the size of the "risk area" under the dotted curve comes close to the size of the respective maximum "risk area", i.e. the ratio of actual oversale probability and maximum oversale probability is just below one, the flight should be considered to be relevant for the overbooking performance evaluation. It is now a question of definition how this decision ratio is set. A constant application of this defined decision threshold ensures now that only flights are classified to be relevant which exceed the same universal probability threshold. The advantages of this approach are illustrated in Table 3.2.

While both flights have the same availability (AVL), the mean and the standard deviation of the expected show-up rate differ. The stated authorization levels are arbitrarily chosen. Based on this information, the maximum likelihood of oversale, i.e. at least one denied boarding, is determined. The application of a probability threshold ratio of 0.5 results in a booking threshold of 112.37 and 117.48 respectively. By showing two decimals it is evident that neither a fixed number nor a fixed percentage was subtracted from the authorization level. Instead the booking threshold was determined by the number of accepted bookings which result in a oversale probability to be 50 % of the maximum probability. For a practical application, however, these values would obviously be rounded to 112 and 117.

This percentage probability approach appears to be more suitable to be used as a threshold than any other measure mentioned before because it considers the different characteristics (show-up rate, standard deviation of the show-up rate and the authorization level itself) of different flights and decides between fully booked and not fully booked flights on an equal evaluation basis. Relevant flights are specified by their characteristic to exceed the "probability threshold" and not by a fixed or linear deduction of the authorization level. Nevertheless, the percentage decision ratio has to be further specified. Since this matter cannot be more elaborated in this thesis, the approach as described above should be considered for further research work.

3.4 Summary

This chapter established the notation and definitions needed for overbooking performance evaluation. In addition to the description of Passengers (PAX), Confirmed Passengers (PAX_C), and Show-Ups (SU), the terminology of spoilage and oversale has been analyzed. It has been illustrated that it is of great importance to adopt the right view towards spoilage and denied boardings. Only a consistent application of the three proposed definitions leads to sensible results. As highlighted in Section 3.2, any inconsistency in the application of these definitions distorts the overall evaluation basis for a subsequent performance assessment. It is obvious that every overbooking performance measurement model can only be as good as its input data.

Furthermore, it has been shown that the most strict definition of spoilage and oversale, i.e. True Denied Boarding/2nd (TDB₂) and True Spoilage/2nd (TSP₂), are most compatible with the airline objectives of revenue maximization. Other definitions of spoilage and oversale falsify the real economic situation. Even though other definitions could be used to distinguish between oversale and spoilage, it cannot be in the line of interest of the airline to employ such "wrong" definitions intentionally.

Finally, the problem of relevant flights for overbooking evaluations was discussed. Again, it is important to apply an appropriate definition in order to distinguish between relevant and irrelevant flights. Although the problem could not be analyzed in depth, it has been shown that the currently applied approaches are unsophisticated and can be misleading. The outlined philosophy of employing the risk of oversale ratio shows an alternative proposal to determine relevant flights. It addresses the characteristics of such flights better and appears more appropriate for the purpose of determining relevant flights. However, the problem of deciding between relevant and irrelevant flights and the proposed model should be subject of further research work.

Chapter 4

Revenue Achievement Model (RAM) - Single Flight Level

Given the definitions and notation of previous chapters, a new approach towards the measurement of overbooking performance can be proposed. As outlined in the preceding Section 3.1, any overbooking performance measurement approach of a single flight should consider two different situations. First, the flight was overbooked in accordance to the recommended authorization level (AU_R) and second, the calculated authorization level was overridden by revenue management analysts, i.e. the authorization level (AU_M) was manually set. Due to the different nature of the situation, the performance improvements or distortions because of overbooking must be analyzed separately. Therefore, two different approaches have to be developed in order to accomplish the different requirements. The development of these two approaches is outlined in this chapter.

4.1 Overbooking Performance Evaluation of Recommended Authorization Levels

The existing performance measurement models, as discussed in Chapter 2, focus purely on the revenue improvement due to overbooking but do not consider the importance of overbooking on the total amount of generated revenues. Any overbooking activity is only as good as the absolute amount of revenues which has been generated. Thus, the revenue achievement due to overbooking should be also related to the total revenue achievement. The Revenue Opportunity Approach (ROA), the only approach which allows an analysis on a single flight level, does not consider the total revenue generation. As discussed before, the performance value of the ROA is only related to the revenue opportunity available for overbooking and neglects the overall revenue opportunity of the flight. But this overall revenue potential and the respective achievement thereof is the factor which best describes the overall economics of the flight.

The implications of assessing the percentage amount of revenues out of the total overbooking revenue opportunity which could have been generated (Revenue Opportunity Approach), were briefly discussed in section 2.2.2 and are illustrated again in Figure 4.1.

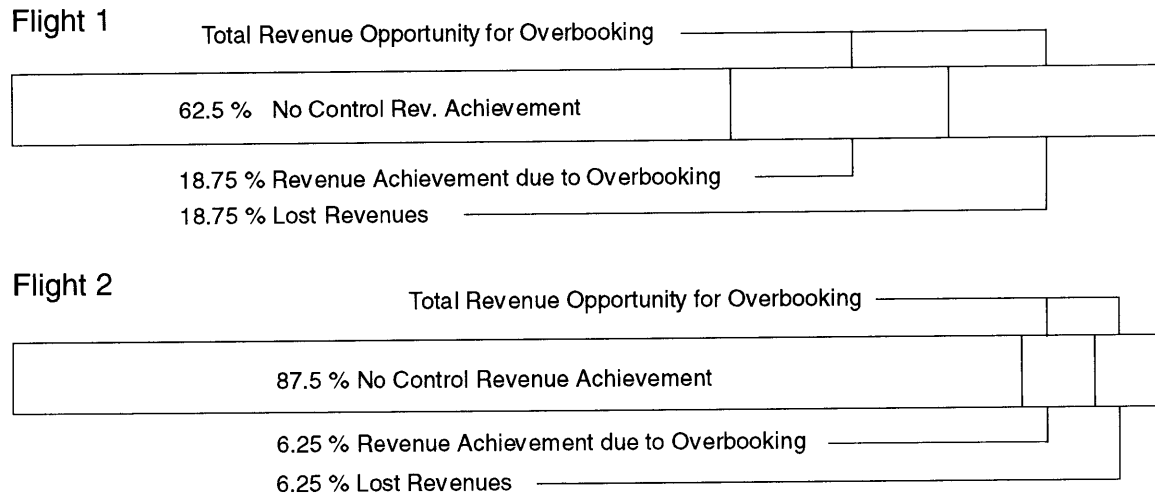


Figure 4.1 Impact of Overbooking on Total Revenues

Figure 4.1 shows the impact by comparing an example of two flights. While Flight 1 was expected to have a show-up rate of about 0.77, Flight 2 was anticipated to experience a much higher show-up rate of about 0.93. Thus, the total revenue opportunity for the purpose of overbooking differs significantly between both flights. Nevertheless, the actual show-up rates of both flights fell below the expectations ($sur_{actual} = 0.62$ and 0.88 respectively) and an equal revenue achievement of 50 % of the maximum possible revenue opportunity was generated in both cases. This number, which expresses the overbooking performance in accordance to the Revenue Opportunity Approach (ROA), does not reflect the fact that 18.75 % of all possible revenues are lost on the first flight while only 6.25 % are lost on the latter. The Revenue Opportunity Approach evaluates the relative gain of revenues but does not consider the absolute revenue improvement. It must not be forgotten that the overall economic objective of the airline is revenue maximization. Since the number of bookings were restricted by some kind of authorization limitation on every closed flight, the overall amount of generated revenues must be maximized. It is obvious that Flight 1 of the example, as shown in Figure 4.1, is certainly less desirable for the airline than the latter flight, even though the same performance indicator of 50 % is generated by the Revenue Opportunity Approach. Extreme cases could even lead to situations where the Revenue Opportunity Approach ranks the performance of a flight over another although the higher rated flight generated less revenues overall. This is even more evident if the limits of the possible spectrum of outcomes is evaluated. Figure 4.2 shows the economic results of a sample of flights if no overbooking control would have been applied. The graph was generated from a sample of about 1750 actual fully booked flights which were subject to overbooking control. It illustrates the revenue achievement per flight over the flights by the order of revenue achievement.

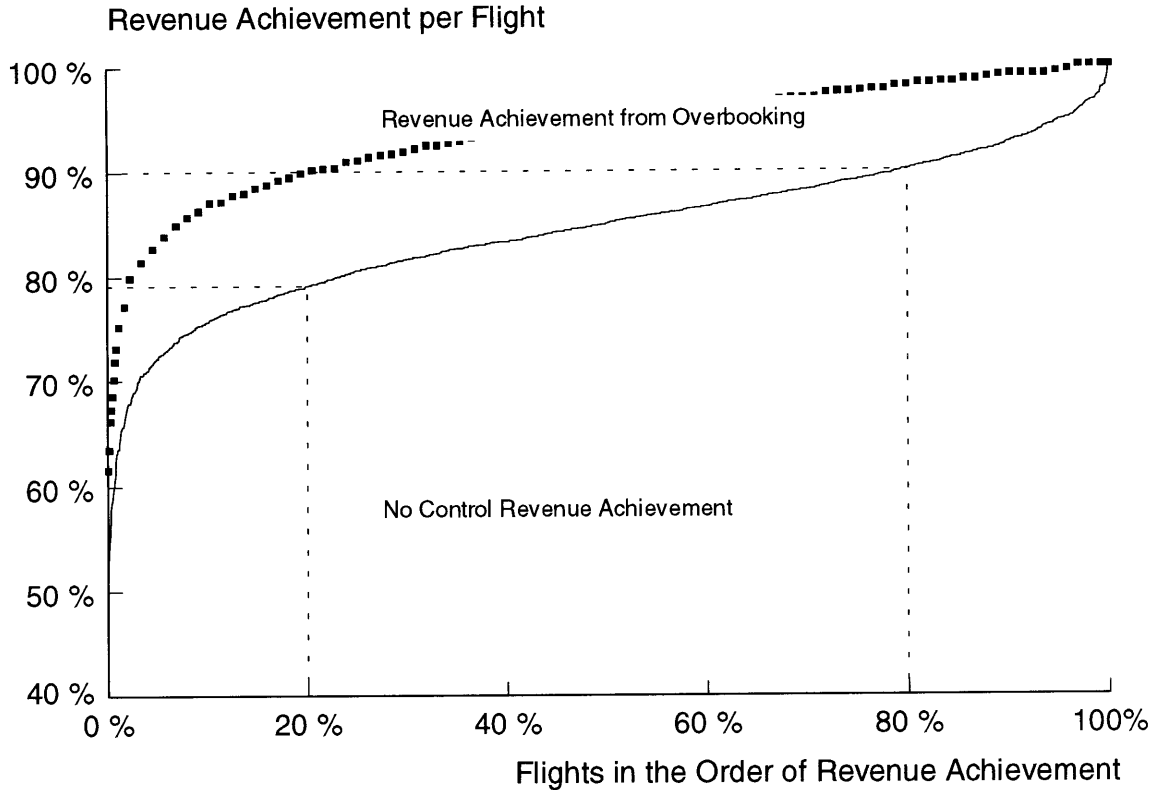


Figure 4.2 Revenue Achievement with and without Overbooking

Figure 4.2 shows two lines which represent the total revenue achievement with and without overbooking. The solid line defines the generated revenues per flight if no overbooking would have been applied. Thus, the area under the solid line, labeled with "No Control Revenue Achievement", represents the total amount of revenues which would have been generated by this sample of flights under "no control" conditions, i.e. if these flights would not have been overbooked at all. Accordingly, the area above the solid line characterizes the potential of revenues which can be gained by overbooking. Now, the dotted line shows the actual generated revenues, i.e. the area between the solid and the dotted line indicates the amount of revenues which were collected because of overbooking. Please note that the flights are shown in the order of revenue achievement. This means that the no control data and the actual data which are shown at the same x-axis position are not necessarily linked to the same flight. It is entirely possible that the actual amount of generated revenues was very high due to overbooking (therefore shown in the right part of the dotted line) while the associated no control achievement would have been lead to a poor result (therefore shown in the left part of the solid line).

Some important findings can be derived from Figure 4.2. First of all, the diagram outlines the general importance of overbooking. As presented, the revenue achievement in cases of no overbooking control varies practically between 50 % and 100 % (theoretically possible would be a variation between 0 % and 100 %). While 80 % of these flights would not have achieved 90 % of the maximum possible revenue, 20 % of these flights fall even below an achievement of 80 %. Thus, it is important for the economics of the airline to overbook. The introduction of overbooking leads to an improvement of the generated revenues, but a significant amount of revenue potential is still not collected, as characterized by the area above the dotted line.

Since the number of accepted bookings of every of these flights exceeded a certain threshold and assuming that there was sufficient demand to fill up the empty seats, the airline could have gained 100 % of the total revenue potential but collected only a portion of it. The economic objective, however, is to gather the maximum possible amount of revenue. In the end it is not important to the airline what portion of the revenue opportunity materialized because of overbooking but the total amount of revenues which has been generated by the flight. There is no point to get excited about a flight where, say 75 % of the overbooking revenue opportunity was generated, leading to a total revenue achievement of 90 % while another flight achieved 95 % of the maximum possible revenues with only, say 50 % contribution from the overbooking potential (the no control revenue achievement would have been 90 % in this case).

The importance of this issue is illustrated in Figure 4.3. Employing the same sample of flights as utilized for Figure 4.2, the "no control" revenue achievement per flight is shown. In addition, hypothetical "iso-ROA-lines" are indicated. These are lines which outline an equal overbooking performance according to the Revenue Opportunity Approach. They represent a situation in which 25 %, 50 % or 75 % respectively, of the possible revenue potential for overbooking has been collected. Now it is evident that a performance expression in percent ROA does not mean very much. Considering, for instance, a performance indication of 50 % ROA. A flight with this performance indication could have achieved between about 77 % and nearly 100 % of its maximum possible revenue opportunity. Once again it must be stressed that the overall economic result is not equal even though the ROA indicates the same overbooking performance.

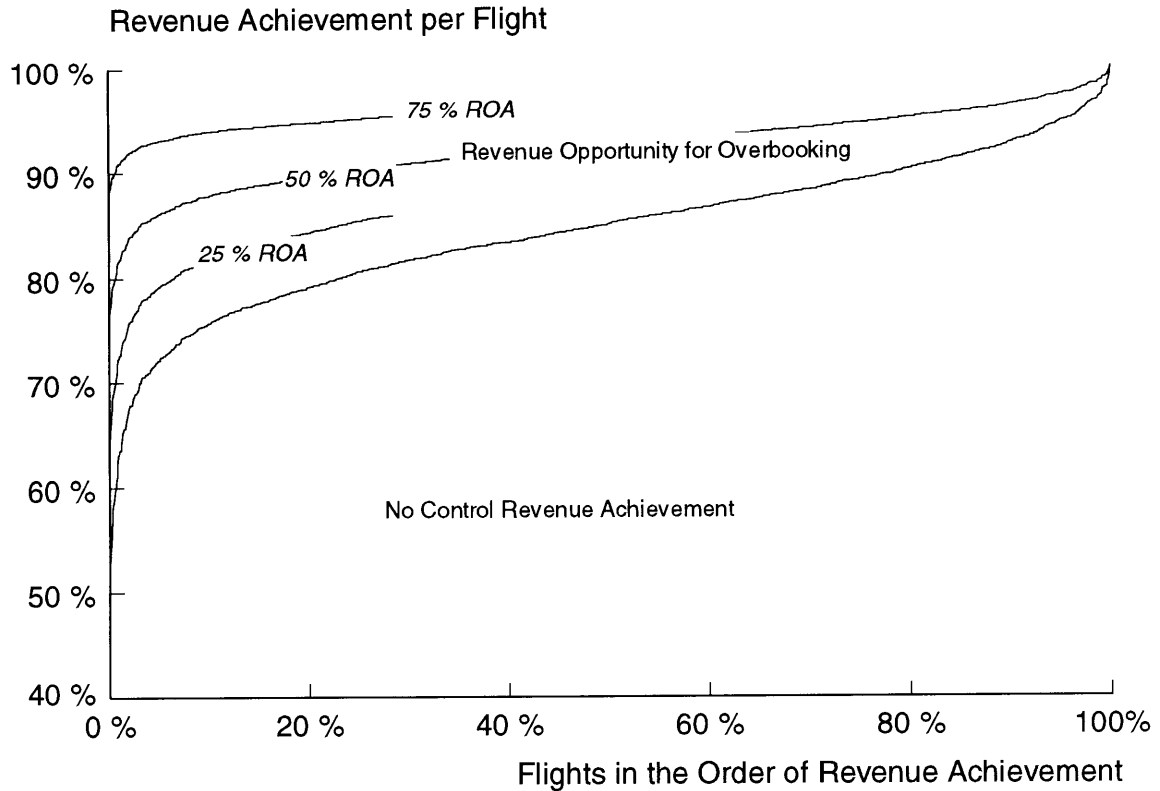


Figure 4.3 Overall Revenue Achievement versus Relative Revenue Achievement

The inconsistency between the actual revenue achievement and the performance indication of the Revenue Opportunity Approach is inherent with the model. Since the ROA-performance is related to the absolute revenue opportunity, the percentage performance measure varies with the expected show-up rate ($sur_{expected}$). While a low show-up rate translates into a large revenue opportunity being available for overbooking, the opposite is true for high show-up rates. Thus, the percentage performance value as determined by the Revenue Opportunity Approach is of little value to assess the significance of the additional revenue achievement on the overall economics of the flight. While the relationship between show-up rate and revenue achievement is linear (at least in a simplified environment, assuming constant costs for spoilage and oversales), the ROA performance indication is non linear even with the simplifying cost assumptions as described before. This leads to extreme difficulties in comparing flights with different show up rates. A ranking of flights by performance is therefore impossible if the ROA is employed. This issue of comparing the performance of flights will be further discussed in Chapter 5, following the introduction of the *Revenue Achievement Model (RAM)*.

The implication of above findings are that the Revenue Opportunity Approach itself is not sufficient to assess the overbooking performance with respect to the economic objectives of the airline. While the ROA is a good tool to express the relative revenue achievement due to overbooking, it does not consider the absolute impact on the total amount of generated revenues. With regard to the economic goals of the airline, the objective of overbooking performance measurement must be defined "from scratch". It is more appropriate to analyze the overall revenue achievement of a flight with respect to the absolute revenue improvement due to overbooking. This ensures that not only the relative performance is assessed, but also the absolute performance of the flight. Even though the revenue gain due to overbooking is not obvious at the first glance, it is "hidden" in the absolute revenue achievement. An evaluation of the relative revenue gain of overbooking as expressed by the ROA can then be used as supplementary analysis tool to an absolute revenue achievement measure in order to understand the particular importance of overbooking on the flight.

However, the performance measurement itself must only rely on the absolute revenue achievement of the flight. It is therefore necessary to develop a model which expresses the overall revenue achievement in order to replace the Revenue Opportunity Approach for the generic performance indication. As outlined before, the ROA can be utilized parallel to the new model to further describe and analyze the performance index. Again, this leads to the terminology of "revenue opportunity" which has to be re-defined in order to distinguish between the *Revenue Opportunity for Overbooking* and the *Total Revenue Opportunity*. While the Revenue Opportunity for Overbooking coincides with the definition as applied by the Revenue Opportunity Approach, the Total Revenue Opportunity relates to the overall revenue potential of a particular flight. Accordingly it must be distinguished between *Total Revenue Achievement* and *Revenue Achievement by Overbooking* in order to obtain meaningful ratios for the subsequent performance measurement. While the Total Revenue Achievement indicates the overall revenue materialization (including the effects of overbooking), the Revenue Achievement by Overbooking expresses the revenue improvement due to overbooking. The specific definitions and notation of the used terminology are shown below (please refer also to the definitions in section 3.2).

RO_{Total} : *Total Revenue Opportunity* is the overall amount of revenues which could have been generated by the number of available seats [$RO_{Total,\$} = rev(AVL)$].

RA_{NC} : *No Control Revenue Achievement* describes the basic amount of revenues which would have been generated if the flight would not have been overbooked [$RA_{NC,\$} = rev(bkr \cdot sur \cdot AVL)$].

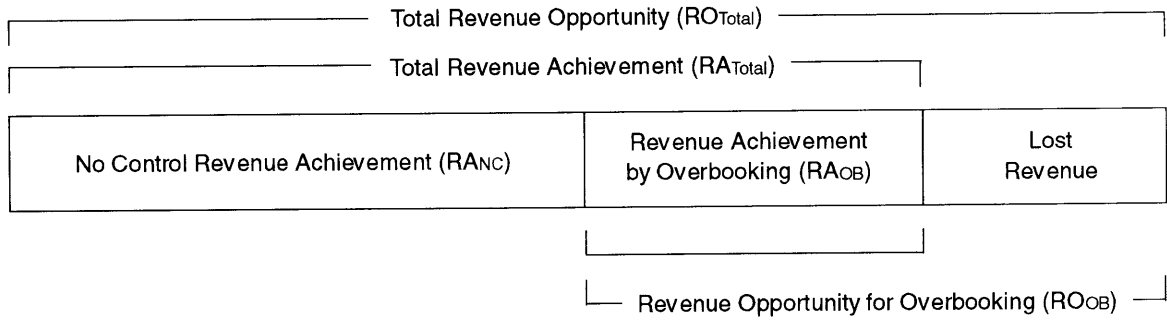


Figure 4.4 Total Revenue Opportunity and Revenue Opportunity for Overbooking

RA_{Total}: *Total Revenue Achievement* refers to the actual revenues of a particular flight. The Total Revenue Achievement includes the No Control Revenue Achievement (RA_{NC}) and the revenue achievement due to overbooking (RA_{OB}).

RO_{OB}: *Revenue Opportunity for Overbooking* defines the overall revenue potential which can be gained by overbooking [RO_{OB} = RO_{Total} - RA_{NC}].

RA_{OB}: *Revenue Achievement by Overbooking* is the amount of revenues which have been generated because of overbooking [RA_{OB} = RA_{Total} - RA_{NC}]

Any of the above values can either be expressed as absolute monetary number or as percentage figures in relation to the monetary Total Revenue Opportunity (RO_{Total,\$}). The percentage Total Revenue Opportunity figure (RO_{Total,%}) equals 100 % by definition. Thus, the RA_{NC,%} and the RA_{OB,%} express the absolute revenue materialization as a percentage portion of the RO_{Total,\$} [RA_{NC,%} + RA_{OB,%} + Lost Revenues_% = 100 %]. However, once the achievement values are related to the respective opportunity figures, the distinction between monetary and percentage figures is irrelevant. Thus, no distinction will be made for the subsequent discussion. The notation as defined above are illustrated in Figure 4.4.

Further, the monetary value of the Total Revenue Achievement (RA_{Total,\$}) is linked to the Total Revenue Opportunity (RO_{Total,\$}) via the costs of spoilage (SPL_{\$}) and denied boarding (DB_{\$}). Any lost revenues are either opportunity costs due to spoilage or compensation payments for denied boardings. Thus, the following relationship applies:

$$RA_{Total,\$} = RO_{Total,\$} - SPL_{\$} - DB_{\$} = RO_{Total,\$} - \text{cost}(TSP_2) - \text{cost}(TDB_2)$$

As discussed before, it is difficult to determine the Total Revenue Opportunity and the costs of spoilage and denied boarding. However, this is an inherent problem which automatically arises if an economic evaluation of the overbooking performance is pursued. Since the overbooking performance measurement model should be in line with the airline objectives, there is no other choice other than an economic approach which includes the costs of spoilage and oversales. Sensible cost and revenue assumptions have to be made anyway in order to feed the overbooking model. Further, any cost and revenue assumptions should be standardized, leading to uniform assumptions for comparable flights. Depending on the flight, a fixed cost value is assumed for every denied boarding and oversale. The monetary figure could be derived from historic data and should coincide with the respective values as employed by the overbooking model. This ensures the compatibility of overbooking model and overbooking performance evaluation.

For the further discussion we will assume that the appropriate cost and revenue information are provided, which allow us to calculate the two revenue opportunity and revenue achievement values.

Once the different revenue opportunities and revenue achievements are determined, a percentage figure can be obtained which relates the above defined achievements to the respective opportunities. Hence, the Revenue Achievement Model (RAM) is defined by the *relative Total Revenue Achievement* which expresses the Total Revenue Achievement (RA_{Total}) as a percentage figure of the Total Revenue Opportunity (RO_{Total}). On the other hand the *relative Revenue Achievement by Overbooking* indicates the Revenue Achievement by Overbooking (RA_{OB}) in relation to the Revenue Opportunity for Overbooking (RO_{OB}). Thus, the relative Revenue Achievement by Overbooking is nothing else than the performance index as generated by the Revenue Opportunity Approach. Therefore, the subsequent defined relative revenue achievements define the overbooking performance indices and are also referred to as *Performance Index RAM* and *ROA* (PI_{RAM} and PI_{ROA}). The notation and precise definition of these two ratios are shown below.

rRA_{Total} : *relative Total Revenue Achievement* relates the overall revenue achievement (RA_{Total}) to the total revenue opportunity (RO_{Total}) and shows therefore the overall economic result of the flight [$rRA_{Total} = RA_{Total} / RO_{Total} = PI_{RAM}$].

rRA_{OB} : *relative Revenue Achievement by Overbooking* expresses the absolute revenue achievement due to overbooking (RA_{OB}) as percentage figure in relation to the revenue opportunity for overbooking (RO_{OB}). Thus, the calculation of the rRA_{OB} is identical to the Revenue Opportunity Approach [$rRA_{OB} = RA_{OB} / RO_{OB} = PI_{ROA}$].

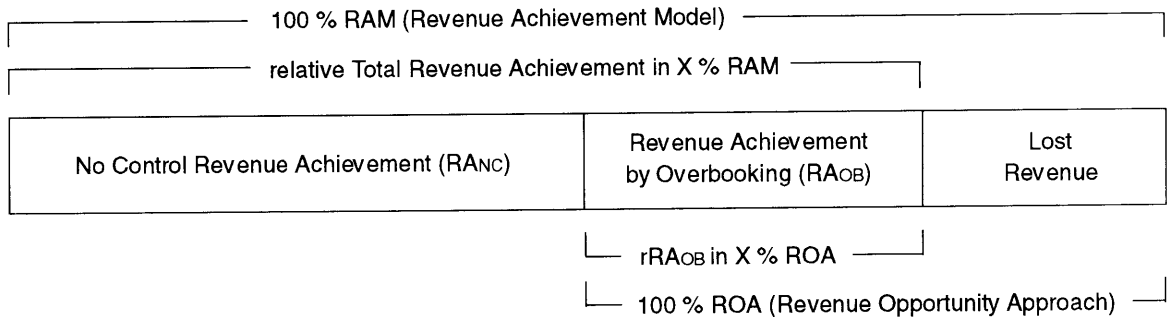


Figure 4.5 Revenue Achievement Model (RAM)

The above defined notations are illustrated in Figure 4.5. In order to distinguish between both percentage values, the rRA_{OB} (or PI_{ROA}) is referred to as $x\%$ ROA (Revenue Opportunity Approach) and the rRA_{Total} (or PI_{RAM}) is shown as $x\%$ RAM (Revenue Achievement Model). Now it is possible to describe the actual outcome of a flight exactly with these two performance indices. While the rRA_{OB} coincides with the "old" Revenue Opportunity Approach, the Revenue Achievement Model (RAM) defined here is the simple and straight expression of revenue achievement of a flight. It indicates the percentage revenue materialization of the maximum possible revenue potential and is somewhat a "monetary load factor". The optimal performance is therefore achieved if 100 % RAM is indicated. Obviously, this represents a full revenue materialization. Every performance indication below 100 % RAM testify that potential revenues were lost.

Thus, the Revenue Achievement Model evaluates the overall economics of the flight. This includes the basic revenue achievement (RA_{NC}) as well as the revenue improvement due to overbooking. It ensures, that not only the relative revenue improvement by overbooking but also the absolute revenue achievement is assessed which is of particular importance for the airline. Remembering the airline objectives (high revenue generation), not the relative revenue gain but the absolute revenue achievement is of concern of the airline. The Revenue Achievement Model addresses exactly this objective and is therefore more suitable to measure the overbooking performance than the Revenue Opportunity Approach.

A performance of 90 % RAM, for example, allows the immediate conclusion that 90 % of the maximum possible revenues have been generated which is equally good or bad independent of other characteristics of the flight. Opposed to this, the performance value of the Revenue Opportunity Approach cannot be interpreted as easily. An index of 65 % ROA, for instance, indicates that 65 %

of the Revenue Opportunity for Overbooking (RO_{OB}) have been gained. Since the RO_{OB} is dependent on the actual experienced show-up rate, a performance index of 65 % ROA indicates a different performance depending on the characteristics of the flights. Thus, the ROA performance index (PI_{ROA}) does not represent an universal and system wide standard as the RAM index (PI_{RAM}) does. It can now be argued that the Revenue Achievement Model generates "unfair" indices because it does not only assess the revenue improvement due to overbooking but the overall revenue achievement which includes two components. First, the revenues which would have been achieved even without overbooking (RA_{NC}) and second, a component of revenue improvement due to overbooking (RA_{OB}). Thus, it might be possible that a relatively high RAM performance index (PI_{RAM}) is generated even though no revenues were gained or revenues were even lost because of overbooking. The ROA on the other hand would consider the bad materialization of the RO_{OB} and would generate a very bad, even negative performance index (PI_{ROA}) which does not consider at all the still good overall revenue achievement. Nevertheless, such a flight is certainly more desirable to the airline than a flight were some portion of the Revenue Opportunity for Overbooking has been gained but the overall revenue achievement was bad.

A more detailed comparison of the RAM and the ROA is outlined in Chapter 5. In particular, the capability to compare flights and the impact of the overbooking measure on the authorization level are discussed.

4.2 Performance Evaluation of Revenue Management Analyst Interventions

While there is no doubt about the requirement to overbook in general, there are cases where it must be discussed if automated algorithms or human judgment and experience should be employed to determine the overbooking authorization. As previously outlined, it is common practice in the airline industry that an automated overbooking model is used which recommends authorization levels (AU_R). Revenue management analysts review these automatically set overbooking levels regularly and can intervene by setting a manual authorization (AU_M) if the automated recommendations appear too high or too low. While the AU_R is based on the optimization algorithm of the overbooking model as described in Chapter 2, the overrides by revenue management analysts AU_M are purely based on their experience and common sense. The regular checks of the set authorization level by revenue management analysts are necessary to feed additional information which were unknown to the system at the time of the AU_R calculation, e.g. special sport events, disasters etc. They are also supposed to ensure that obvious "malfunctions" of the overbooking model (unjustifiable high or low authorization levels) are corrected and unexpected passenger behavior is anticipated (e.g. fewer cancellations than expected).

However, once the revenue management analysts intervene and set the authorization level manually, the question of performance measurement arises. It must be evaluated if the system overrides are advantageous to the airline, i.e. improve the overall revenue achievement. Further, the overall efficiency of AU adjustments must be analyzed in order to justify or reject the general airline policy towards interventions by revenue management analyst. In particular the latter issue is extremely important because of the additional labor costs of revenue management analysts. It is obvious that the revenue gains due to those system overrides must at least offset the additional costs of the revenue management analysts (salaries etc.). It appears therefore also essential to focus on the absolute revenue achievement rather than the relative improvement by revenue management analysts. This would also ensure that the efforts to gain higher revenues are directed towards flights with a higher revenue potential. Since the expense in terms of workload is nearly independent from the size of the revenue opportunity which can be gained, it is evident that the efforts of revenue management analysts must concentrate on the most promising flights. However, before defining a model which evaluates the performance of human overrides, it is necessary to examine the impact of revenue management analyst interventions in greater detail, using the same sample of about 1750 fully booked flight as employed in the previous discussion. Of major interest is here the apparent importance in terms of number of interventions per 1000 flights as well as the absolute revenue impact which is finally the significant measure for success or failure.

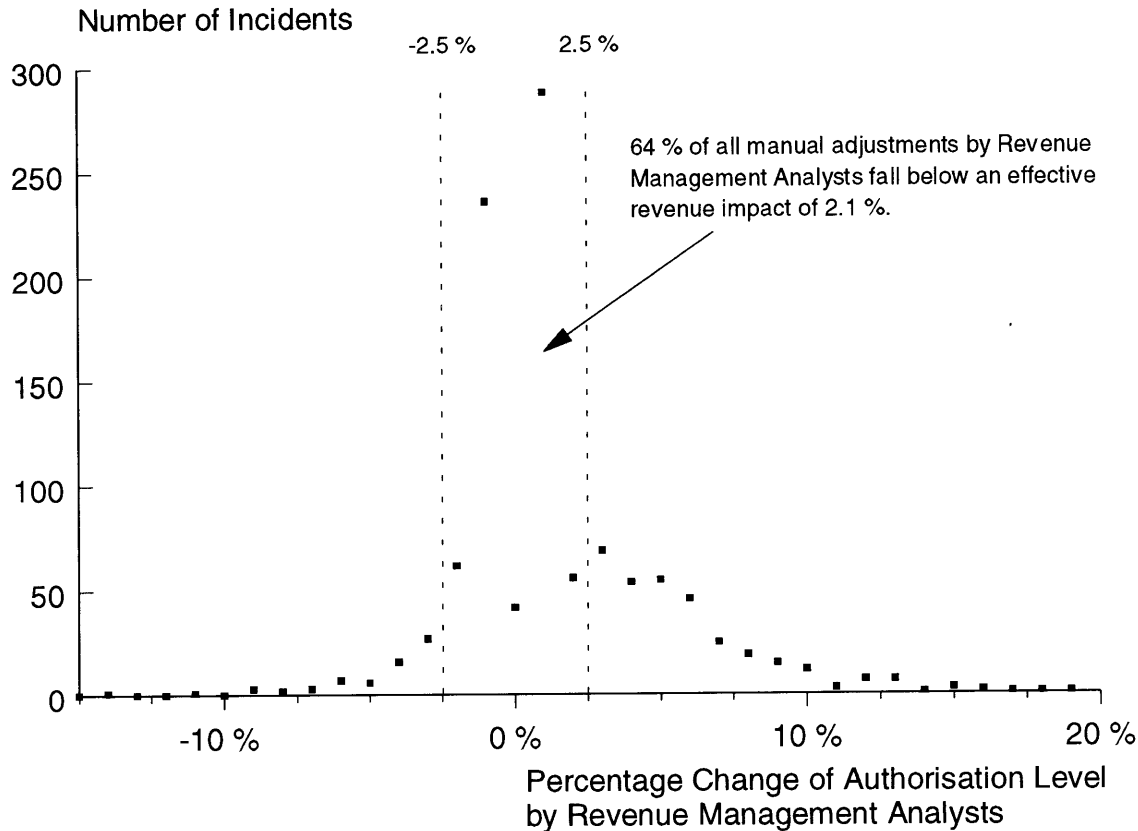


Figure 4.6 Percentage Change of Authorization Level by Revenue Management Analysts

At first glance, the importance of revenue management analyst interventions appears to be tremendous. About 70 % of all relevant flights, i.e. flights which were constrained in our sample by some means of overbooking control, were subject to authorization level adjustments by revenue management analysts. This is, however, only one half of the story and distorts the impression of the significance of manual adjustments.

Thus, it is required to analyze the system overrides in greater depth, as illustrated in Figure 4.6. It shows the percentage deviation of the manually set authorization level (AU_M) from the automated level as recommended by the overbooking model (AU_R). Now it is obvious that only very few of these flights experienced large adjustments of the authorization level. In fact, the manual adjustments of the authorization level was smaller than plus or minus 2.5 % for 64 % of these flights (a noticeable number of flights was adjusted by only -0.5 % to 0.5 %). With an average show-up rate of 0.85, this results in an effective adjustment of 2.1 % or less in terms of availability. Considering an average seat availability (AVL) of 142 seats (derived from the

discussed sample of flights), this translates into an absolute effective change of -3 to +3 seats. It reveals that the majority of revenue management analyst interventions are minor changes. Remembering the purpose of allowing system overrides (prevention of unrealistic recommendations from the overbooking model), it is evident that this objective is only partly met. While most of the AU changes are rather a fine tuning than a major adjustment of the authorization level, it is even more important to bear the overall profitability of these minor modifications in mind.

Employing the prior discussed sample of flights, the economic impacts of revenue management interventions have been analyzed on an aggregate flight level and the results are illustrated in Figure 4.7. In order to highlight the impact of human overrides, four percentage revenue values are shown (determined via the respective absolute monetary revenue values and subsequently related to the Total Revenue Opportunity). Firstly, the revenue achievement without revenue analyst interventions, i.e. applying only the recommended authorization level (AU_R) rather than the manual one (AU_M), is indicated. Secondly, the absolute revenue gain due to system overrides is displayed. These are the sum of all revenue improvements due to manual set authorization levels in the considered sample of flights. Accordingly, the revenue losses are revealed. Again, this number illustrates the sum of all revenue deterioration because of authorization level adjustments. Finally, the actual outcome, i.e. the actually generated revenues are shown.

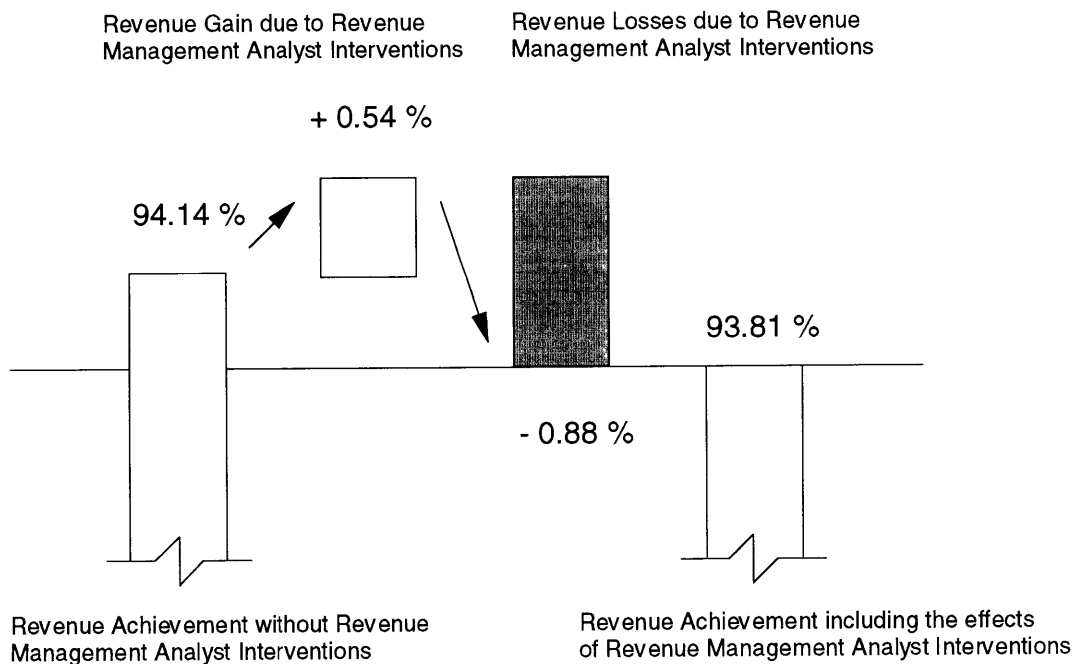


Figure 4.7 Absolute Revenue Contribution due to Revenue Management Analyst Interventions

Now it is evident that, at least in this sample of fully booked flights, the authorization level adjustments by revenue management analysts caused more "harm" than benefit for the overall economics of the airline. The implications of the above findings for a performance evaluation are significant. First of all, the employment of manual set authorization levels must be reconsidered in general. It has been shown that, at least in the analyzed sample of flights, the airline effectively loses money when revenue management analysts override the calculated authorization levels. This raises automatically the question of efficiency of the current practice to allow revenue management analysts to override the automated authorization levels. This issue is even more important when the high number of analyst interventions is considered. Although 70 % of the sample flights were adjusted, the absolute change of the AU was relatively small as outlined before. Thus, revenue management analysts spent evidently too much effort and time on "playing" around with flights which recommended authorization levels were reasonable from the outset and did not require any changes at all. Considering now the effective loss of revenues, it is evident that the system overrides must be constrained to flights which authorization levels do not appear sensible.

However, once revenue management analysts adjust the authorization level, the performance of their activities must be evaluated. The Revenue Achievement Model is now a major part of this measurement. While the RAM should be applied for the overall overbooking performance evaluation, independent if an AU_R or AU_M is used, the purpose of measuring the particular impact of human overrides is to assess the actual revenue improvement by setting an AU_M rather than the AU_R . While there is no "choice" to overbook or not, there is a choice if the recommended authorization level is applied or if a manual setting is employed. It is therefore important to extract the potential benefit of overriding the overbooking model, i.e. comparing the actual revenue achievement with the revenue achievement which would have been achieved if the recommended authorization level had been used. This evaluation of human overrides is therefore an additional component of the overbooking measurement which takes place when the employed authorization level was adjusted.

The incremental revenue improvement can either be expressed as the difference between the two performance measures $PI_{RAM}(AU_R)$ and $PI_{RAM}(AU_M)$ or as an absolute revenue value in \$. Both measures are related via the Total Revenue Opportunity (RO_{Total}). The Revenue Achievement Model relates the Total Revenue Achievement (RA_{Total}) to the respective opportunity (RO_{Total}). Thus, the difference between the $PI_{RAM}(AU_R)$ and $PI_{RAM}(AU_M)$ is nothing else than the incremental revenue change due to analyst interventions in relation to the Total Revenue Opportunity (RO_{Total}).

However, the incremental gains due to revenue management analyst interventions are expected to be relatively small (about 1 ... 3 % as illustrated before) and the effort per adjusted flight is independent from the availability (AVL) and therefore also from the Total Revenue Opportunity (RO_{Total}). Hence, it is more appropriate to focus on absolute figures rather than relative figures. Any attempt to measure the performance should target at absolute revenue improvements or losses rather than relative expressions which are related to the Total Revenue Opportunity (RO_{Total}). As mentioned before, this is justifiable because of the relatively small changes of the revenue value and the relative high efforts and costs to achieve this. An additional passenger on a commuter flight with 19 seats is certainly less "desirable" in absolute revenue terms for the airline than an additional passenger on a transcontinental flight with 300+ seats. Even though the relative revenue gain would favor the small commuter flight, it is evident that it is more important to concentrate on the latter flight. This consideration is even more important when the efforts required to obtain the additional passengers are nearly identical in absolute terms. Thus, the subsequent performance evaluation of revenue management interventions will focus on absolute rather than relative revenue terms.

Recalling the previous used notation and definitions, a new notation has to be introduced. Besides the Total Revenue Achievement (RA_{Total}), the No Control Revenue Achievement (RA_{NC}) and the Revenue Achievement by Overbooking (RA_{OB}), the additional element of *Revenue Achievement by Revenue Management Analysts* (RA_{RMA}) must be considered. As the performance evaluation focuses on the absolute monetary figures rather than relative numbers, only the monetary values of above factors are employed as expressed by the $RA_{Total,\$}$, $RA_{OB,\$}$ etc. Hence, the following equation applies.

$$RO_{Total,\$} = RA_{Total,\$} + \text{Lost Revenues}_{\$} = RA_{NC,\$} + RA_{OB,\$} + RA_{RMA,\$} + \text{Lost Revenues}_{\$}$$

The Revenue Achievement by Revenue Management Analysts is the difference between the actual revenue achievement and the amount of revenues which would have been generated if the recommended authorization level (AU_R) would have been applied. Thus, the $RA_{RMA,\$}$ can be calculated as:

$$RA_{RMA,\$} = \text{actual revenues}_{\$} - \text{rev}(\text{sur} \cdot \text{bkr} \cdot AU_R) = \text{rev}(\text{sur} \cdot \text{bkr} \cdot AU_M) - \text{rev}(\text{sur} \cdot \text{bkr} \cdot AU_R)$$

It is evident that the Revenue Achievement by Revenue Management Analysts is a function of the change of the authorization level $\Delta AU = AU_R - AU_M$. Considering the show-up rate (sur) and the booking rate (bkr) the effective change of the number of passengers is obtained as $\text{sur} \cdot \text{bkr} \cdot \Delta AU$

(remember that the booking rate addresses the fact that the number of bookings do not necessarily match the set authorization level). Now the absolute effective change in passengers determines the absolute gain or loss in revenues due to system overrides as established by the revenue function under consideration of the availability (AVL) and the revenue achievement without revenue management analyst intervention $RA_{RMA,\$} = \text{rev}(\text{sur} \cdot \text{bkr} \cdot \Delta AU \mid \text{AVL and sur} \cdot \text{bkr} \cdot AU_R)$.

If the calculation of the revenue gain or loss is based on the effective change in passengers ($\text{sur} \cdot \text{bkr} \cdot \Delta AU$) it is essential to think about the other key values as described above. It is easily possible that revenue management analyst adjustments raise the authorization level from a "spoilage level" above the ideal level which would have lead to a perfect hit to an "oversale level", i.e. the flight would have experienced spoilage without human overrides and experiences now oversale. Then the revenue management intervention caused a revenue gain (additional revenues which would otherwise have been spoiled) but also a revenue loss due to the occurring oversales. It is important to keep in mind the "limitation" as defined by the availability (AVL). Therefore, it is safer for a practically implementation to determine the $RA_{RMA,\$}$ as the difference of actual revenue achievement and the theoretical revenue generation without revenue management analyst intervention rather than as the effective change of passengers.

The $RA_{RMA,\$}$ indicates the absolute revenue gain or loss and can now easily compared with the costs of revenue management analyst interventions. Furthermore, flights can be ranked by the revenue improvement by human overrides in order to express the importance of revenue management interventions on that particular flight. The advantage of the Revenue Achievement Model over the Revenue Opportunity Approach is the same as discussed in the previous section. Any comparison of a theoretical ROA performance (PI_{ROA}) which would have been achieved by applying the recommended authorization level (AU_R) with the actual ROA performance index (resulting from the manual setting of AU_M) is meaningless because the Revenue Opportunity for Overbooking (RO_{OB}) varies with the show-up rate. Since the impact of revenue management analysts is very small, it is even more important to focus on absolute revenue achievements rather than a performance measure which is based on a varying reference quantity.

Thus, the actual measurement of the overbooking performance should be designed as a two stage procedure. While every relevant flight is assessed with respect to its overall revenue achievement, only some flights are analyzed concerning their Revenue Achievement by Revenue Management Analysts (RA_{RMA}). Thus, the RAM performance index is calculated for all flights and expresses the overall revenue achievement which is the overall comparison tool irrespective whether the recommended (AU_R) or manual authorization level (AU_M) was used to limit the number of

bookings. Once a revenue management analyst adjusts the authorization level, he takes responsibility for the entire flight. His actions could either improve the revenue situation or lead to a loss. Such flights which were adjusted by revenue management analysts are additionally analyzed in terms of their beneficial impact on revenues by the comparison of the RAM performance indices for the AU_R and AU_M or the absolute revenue gain.

4.3 Summary

This chapter proposed a new overbooking performance measurement approach, the Revenue Achievement Model (RAM). It has been shown that its philosophy is purely oriented at the airline objectives of revenue maximization. As the absolute revenue achievement is employed to measure the overbooking performance, the RAM is highly compatible with the economic based overbooking models discussed in Chapter 2. The "monetary load factor", generated by the RAM indicates the overall economics of the flight independent of the expected or actual show-up rate. This ensures a consistent evaluation basis throughout any sample of flights as opposed to the Revenue Opportunity Approach (ROA) which is strongly dependent on the flights' show-up rates.

Furthermore, the Revenue Achievement Model can be used in a performance index (PI_{RAM}) which is easy to understand without additional information. A performance of x % RAM can be translated directly into the finding that x % of the Total Revenue Opportunity materialized. As outlined, such an indication illustrates the performance better than the Revenue Opportunity Approach. In the end, only the overall revenue contribution by a flight is important and not the relative achievement of the Revenue Opportunity for Overbooking (RO_{OB}). Finally, the application of the Revenue Achievement Model for revenue management analyst interventions has been discussed. As the revenue gains and losses due to system overrides are small, it is even more important to focus on absolute monetary values rather than relative expressions which are related to the variable Revenue Opportunity for Overbooking.

The following chapter discusses the capability to compare the overbooking performance of several flights as well as the impact of the two performance measurement approaches on the revenue management analyst "behavior" and therefore on the authorization level. Then, the application of the new Revenue Achievement Model on an aggregate flight level is outlined in Chapter 6

Chapter 5

Model Testing and Comparison - Single Flight Level

In order to highlight the importance of applying the Revenue Achievement Model rather than the Revenue Opportunity Approach, the two models are evaluated with respect to their capability to compare the performance of two or more flights and, even more important, their impact on the set overbooking level. While the first aspect was mentioned before, it might be not obvious that the performance measurement model influences the overbooking level. As claimed, the overbooking process should be considered as a closed control loop where the performance evaluation feeds back into the assumptions and inputs of the overbooking model. It must be assumed that the application of performance measures triggers actions by revenue management analysts which will move towards a maximization of the employed performance measure. Thus, the overbooking performance measurement affects indirectly the set authorization levels. The maximization of any wrong or inadequate performance measure would then lead to sub-optimal authorization levels.

This chapter addresses therefore the issues of comparability of flights and feedback on the authorization level. For the purpose of this analysis, the assumed costs of oversale and spoilage are simplified. A linear relationship between the number of oversales and spoiled seats and the associated costs is used for the subsequent calculation of the RAM and the ROA performance indices (PI_{RAM} and PI_{ROA}). Hence every spoiled seat causes the same costs irrespective of the total amount of spoilage ($SPL_{\$}/TSP_2 = \text{const.}$). The same is true for oversale ($DB_{\$/TDB_2} = \text{const.}$). Even though a constant cost factor is assumed for spoilage and oversales, these cost factors are usually not equal. Therefore, a cost ratio $DB_{\$/SPL_{\$}}$ is used to express the relative values of these costs to each other. Higher costs of spoilage, for instance, can now be expressed by the cost ratio being smaller than one ($DB_{\$/SPL_{\$}} < 1$). Although this is a very simplified economic environment, the findings of the subsequent comparison will not be affected in their validity. Since the assumptions are applied consistently throughout the analysis, the general findings are still the same.

5.1 Performance Comparability of Flights

It has been highlighted before that the Revenue Opportunity Approach does not allow an adequate ranking of flights in accordance to their absolute performance. This is caused by the relativity of the evaluation basis which changes from flight to flight. This comparability requirement is important if the overbooking performance of flights is measured on a single flight level. It is not very sensible to generate a performance index for a flight which cannot be compared with the respective index of another flight. Such a performance index is not meaningful and has no practical use.

Under the assumption of particular costs for oversale and spoilage as well as an average revenue generation per passenger, the overbooking performance indices can be obtained in accordance with the Revenue Achievement Model (RAM) and the Revenue Opportunity Approach (ROA). For the calculation of the performance indices (PI_{RAM} and PI_{ROA}), as illustrated in Figure 5.1, a cost ratio of $DB_S/SPL_S = 1$ and an expected show-up rate of 0.85 was employed. Furthermore, the costs per spoiled seat are estimated to match the average revenue generation per passenger.

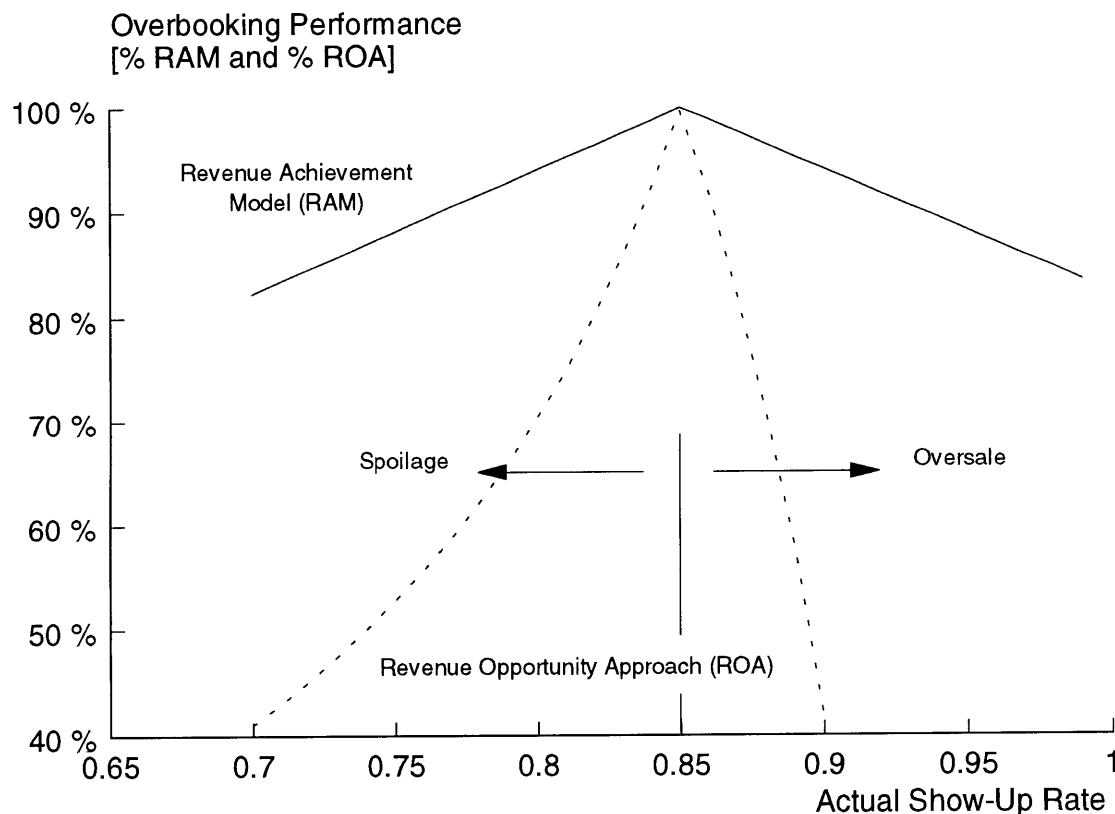


Figure 5.1 Comparability between Flights - RAM vs. ROA (1)

Figure 5.1 shows the overbooking performance in % RAM and % ROA over the actual show-up rate. Now the linear relationship between the RAM and the actual show-up rate is obvious as well as a non-linear dependence of the ROA on the actual show-up rate. Thus, the performance rating of the Revenue Opportunity Approach changes disproportionately with the show-up rate as opposed to the Revenue Achievement Model. The slope of the RAM ($\Delta \text{sur} / \Delta \% \text{ RAM}$) is constant over the show-up rate for spoilage and oversale respectively. Thus, any "performance penalties" are proportional to the deviation of the actual show-up rate from the expected one. This is true for spoilage as well as oversale incidents. The Revenue Opportunity Approach, on the other hand, penalizes small deviations of the actual show-up rate from the expected show-up rate disproportionately higher than large deviations as long as the actual show up rate is smaller than the expected show-up rate (spoilage). This characteristic inverts for the opposite overbooking situation (oversale), i.e. the actual show-up rate being greater than the expected show-up rate. In such a case, larger deviations from the expected show-up rate are penalized disproportionately higher compared to small deviations. This feature is in no way related to any progressive cost estimation for oversale or spoilage (remember the constant cost assumptions for this analysis) but caused by the general philosophy of the Revenue Opportunity Approach. The above discussed characteristic of the ROA, however, is not only crucial for the ability to compare the overbooking performance of two or more flights as subsequently outlined, but also for the set authorization level. Figure 5.1 shows that the ROA penalizes potential oversales situations higher than comparable spoilage incidents. This implies that the ROA is in favor of spoilage which will directly reflect on the authorization level as discussed in greater detail in section 5.2 of this chapter.

The above discussed properties of the Revenue Opportunity Approach lead to difficulties in comparing the overbooking performance of flights with different expected show-up rates. Figure 5.2 illustrates the possible overbooking performance outcomes for two example flights. Again, the same assumptions apply as employed for the calculation of the curves as shown in Figure 1. While Flight 1 was expected to have a show-up rate of 0.75, Flight 2 was predicted to experience a show-up rate of 0.95, i.e. the authorization levels were set in a way that an actual show-up rate of 0.75 and 0.95 respectively would have lead to a perfect hit. The actual show-up rate, however, was lower than expected in both cases, as rates of approximately 0.72 and 0.93 were experienced, as indicated by the vertical lines in Figure 5.2. Further, the respective performance indices for the Revenue Achievement Model and the Revenue Opportunity Approach are marked by the thick solid circles. A comparison of the two flights reveals now the inconsistencies between the RAM and the ROA. It is obvious that Flight 2 achieved a higher performance rating than Flight 1 if the Revenue Opportunity Approach is applied. This means that a larger percentage portion of the Revenue Opportunity for Overbooking (RO_{OB}) was realized by Flight 1 compared to Flight 2.

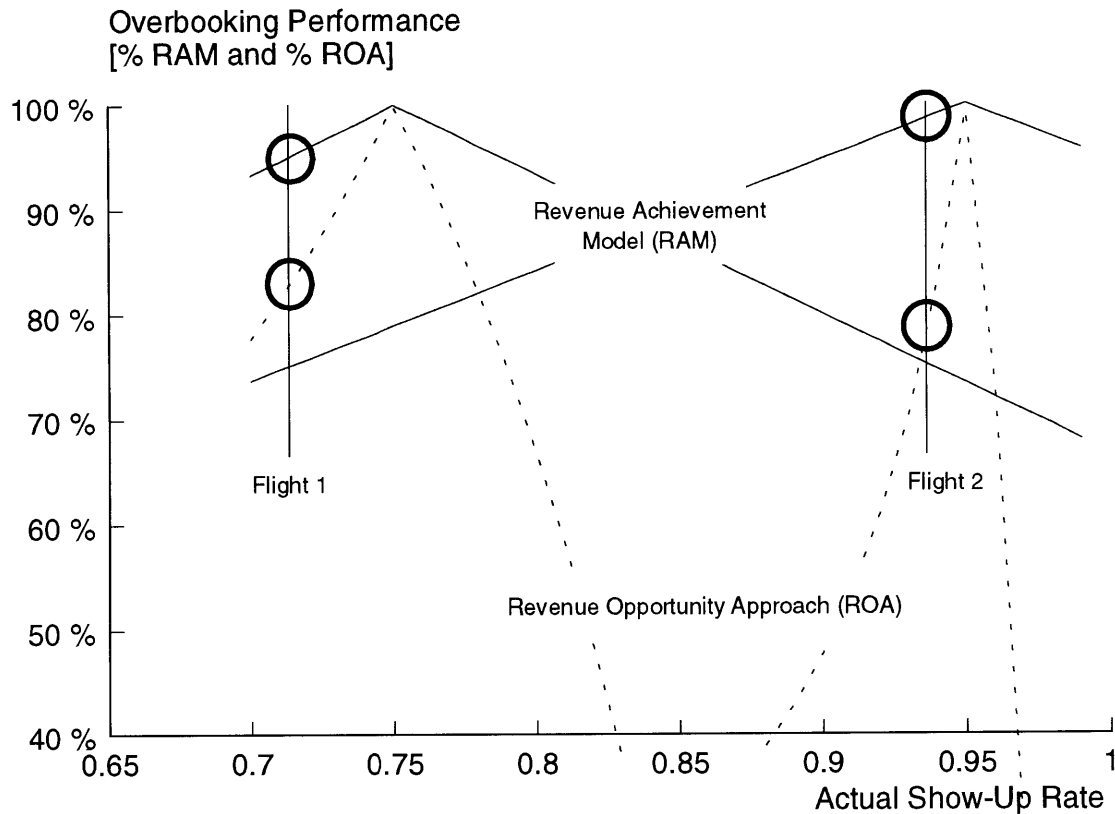


Figure 5.2 Comparability between Flights - RAM vs. ROA (2)

Nevertheless, the overall revenue achievement of Flight 2 was better than Flight 1, as measured by the Revenue Achievement Model. This means that Flight 2 achieved a higher "monetary load factor", i.e. the relative revenue achievement is higher. Therefore, Flight 2 is still more desirable to the airline than Flight 1 even though the ROA indicates the opposite.

Since Flight 2 is more desirable than Flight 1, because the airline objective of revenue maximization is better met, the Revenue Achievement Model (RAM) shows a clear advantage over the Revenue Opportunity Approach (ROA) for the purpose of flight comparison. As outlined in previous chapters, it is not of great interest for the airline which portion of the Revenue Opportunity for Overbooking (RO_{OB}) is generated but the relative overall revenue achievement as expressed by the Revenue Achievement Model. Because of the dependence of the show-up rate and the Revenue Opportunity for Overbooking (RO_{OB}) the basis for the overbooking performance measurement varies from flight to flight. Therefore, it is impossible to compare the overbooking performance of a sample of flights with varying show-up rates on the basis of the Revenue Opportunity Approach.

Further, the Revenue Opportunity Approach pursues an unbalanced evaluation of oversales and spoilage which is not caused by cost differences but by the variability of the RO_{OB} (the smaller the actual show-up rate, the larger is the $RO_{OB} = RO_{Total} - RA_{NC} = rev(AVL) - rev(sur \cdot AVL)$). As illustrated in Figure 5.1 and 5.2, the shape of the ROA curve depends on the overbooking situation (spoilage or oversale). In cases of spoilage, a convex shape of the ROA performance curve is given which turns into a concave shape for oversale incidents. This characteristic results in different performance indices for events of oversale and spoilage even though the same amounts of revenues were lost. While the % ROA values for spoilage cannot drop below zero, the performance indices of oversale situations can drop well below zero (in cases when the lost revenues due to overbooking are greater than the Revenue Opportunity for Overbooking). These extremely low performance values are particular likely if high actual show-up rates are experienced. When the Revenue Opportunity for Overbooking (RO_{OB}) diminishes, it is very easy to lose more money by overselling the flight too much than what could have been potentially gained by achieving a perfect hit. This effect can be observed at the "upper end" of the show-up distribution. When the RO_{OB} is determined by the revenue potential of only a few seats, the ROA performance index is very likely to be negative. In the same situation, the Revenue Achievement Model (RAM) still generates a relatively high performance index (PI_{RAM}) because a high percentage of the overall revenue opportunity realized, i.e. the monetary load factor was very high.

Table 5.1 summarizes the findings, as established before and illustrates the impact on the comparability depending on the deviation of the actual from the expected show-up rate. In order to find a general pattern showing this relationship, a wider range of show-up rates is employed. Both performance indices, for the Revenue Achievement Model as well as the Revenue Opportunity Approach are illustrated for an actual show-up rate ranging from 0.60 to 0.99 and an expected show-up rate ranging from 0.70 to 0.99. The term "expected show-up rate" is, again, used in the sense that a perfect hit is achieved when the actual show-up rate matches the expected show-up rate. Thus, every authorization level can be translated into an expected show-up rate by relating the authorization level (AU) to the availability (AVL). This means that $sur_{expected} = AVL / AU$.

Table 5.1 - Comparability between Flights - RAM vs. ROA

% RAM % ROA	actual sur											
	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	0.97	0.98	0.99	
e x p e c t e d s u r	0.70	85.7 % 64.3 %	92.9 % 79.6 %	100 % 100 %	92.9 % 71.4 %	85.7 % 28.6 %	78.6 % -42.9 %	71.4 % -185.7 %	64.3 % -614.3 %	61.4 % -1185.7 %	60.0 % -1900.0 %	58.6 % -4042.9 %
	0.75	80.0 % 50.0 %	86.7 % 61.9 %	93.3 % 77.8 %	100 % 100 %	93.3 % 66.7 %	86.7 % 11.1 %	80.0 % -100.0 %	73.3 % -433.3 %	70.7 % -877.8 %	69.3 % -1433.3 %	68.0 % -3100.0 %
	0.80	75.0 % 37.5 %	81.3 % 46.4 %	87.5 % 58.3 %	93.8 % 75.0 %	100 % 100 %	93.8 % 58.3 %	87.5 % -25.0 %	81.3 % -275.0 %	78.8 % -608.3 %	77.5 % -1025.0 %	76.3 % -2275.0 %
	0.85	70.6 % 26.5 %	76.5 % 32.8 %	82.4 % 41.2 %	88.2 % 52.9 %	94.1 % 70.6 %	100 % 100 %	94.1 % 41.2 %	88.2 % -135.3 %	85.9 % -370.6 %	84.7 % -664.7 %	83.5 % -1547.1 %
	0.90	66.7 % 16.7 %	72.2 % 20.6 %	77.8 % 25.9 %	83.3 % 33.3 %	88.9 % 44.4 %	94.4 % 63.0 %	100 % 100 %	94.4 % -11.1 %	92.2 % -159.3 %	91.1 % -344.4 %	90.0 % -900.0 %
	0.95	63.2 % 7.9 %	68.4 % 9.8 %	73.7 % 12.3 %	78.9 % 15.8 %	84.2 % 21.1 %	89.5 % 29.8 %	94.7 % 47.4 %	100 % 100 %	97.9 % 29.8 %	96.8 % -57.9 %	95.8 % -321.1 %
	0.97	61.9 % 4.6 %	67.0 % 5.7 %	72.2 % 7.2 %	77.3 % 9.3 %	82.5 % 12.4 %	87.6 % 17.5 %	92.8 % 27.8 %	97.9 % 58.8 %	100 % 100 %	99.0 % 48.5 %	97.9 % -106.2 %
	0.98	61.2 % 3.1 %	66.3 % 3.8 %	71.4 % 4.8 %	76.5 % 6.1 %	81.6 % 8.2 %	86.7 % 11.6 %	91.8 % 18.4 %	96.9 % 38.8 %	99.0 % 66.0 %	100 % 100 %	99.0 % -2.0 %
	0.99	60.6 % 1.5 %	65.7 % 1.9 %	70.7 % 2.4 %	75.8 % 3.0 %	80.8 % 4.0 %	85.9 % 5.7 %	90.9 % 9.1 %	96.0 % 19.2 %	98.0 % 32.7 %	99.0 % 49.5 %	100 % 100 %

The described comparability problem is obvious when flights are compared which have the same properties in terms of difference between the actual show-up rate and the expected show-up rate. Considering, for instance, the following two flights:

Flight 1	$sur_{\text{expected}} = 0.85$	$sur_{\text{actual}} = 0.70$
Flight 2	$sur_{\text{expected}} = 0.80$	$sur_{\text{actual}} = 0.65$

Both flights experienced a smaller show-up rate than it was anticipated. Applying the Revenue Achievement Model and the Revenue Opportunity Model, two overbooking performance measures are generated which allow a ranking by performance. For the above discussed example of flights, the performance measures are (again, a cost ratio of $DB_{\$}/SPL_{\$} = 1$ was employed):

Flight 1	82.4 % RAM	41.2 % ROA
Flight 2	81.3 % RAM	46.4 % ROA

While Flight 2 is rated higher than Flight 1 if the Revenue Opportunity Approach is taken, the opposite is true for the Revenue Achievement Model. These disparities of ranking by the RAM and ROA are not only obvious for the above example but also for all combinations where the flights are positioned relative to each other on the matrix as indicated by the arrow in Table 5.1. This highlights that the ROA does not only distort the performance evaluation because of its distinct characteristic but generates incorrect results if the ROA is employed to compare the performance of flights. Furthermore, the extremely bad performance indices can be observed which are generated by the ROA when the actual show-up rate exceeds the expected show-up rate significantly. Then the flight was overbooked so much that the revenue loss due to oversales exceeds the revenue potential which could have been generated by overbooking (RO_{OB}). However, a performance ratio of -4042.9 % ROA (for $sur_{\text{actual}} = 0.99$ and $sur_{\text{expected}} = 0.70$) for instance does certainly not reflect a meaningful performance index. This confirms again, the "danger" being involved to overbook too aggressively if the ROA is employed which is a clear incentive to lower the authorization level.

Finally, it must be emphasized again that the overall revenue achievement is the important aspect of revenue optimization. Since every overbooking model attempts to maximize the generated revenues exactly this objective must be controlled by the evaluation model. Therefore, the Revenue Achievement Model is more appropriate to apply to any performance evaluation rather than the Revenue Opportunity Approach.

5.2 Impact of the Performance Measure on Authorization Level

As outlined above, there is a link between the performance measurement and the authorization level (AU). It has been emphasized that every revenue management process, including overbooking, must be evaluated towards its achievements. Further, with a strict application of revenue management as a closed control loop any deviation from the ideal situation is supposed to trigger a compensation action. Thus, the outcomes of any overbooking performance measure affect indirectly the inputs of the overbooking model and the authorization level itself. Once an overbooking performance measurement model is introduced, the objective of revenue management analysts would be the achievement of a maximum performance indication. Then, any measure they take would be taken to maximize the performance indicator (PI_{RAM} and PI_{ROA}) over the long term.

Since the set authorization level is affected (either by changing the overbooking model input data or by system overrides) by this drive to maximize the performance index, a sub-optimal situation can occur which does not necessarily meet the economic objectives of the airline. It is therefore extremely important to analyze the effect of performance measurement approaches on the authorization level and the economic objectives of the airline. Considering the different characteristics of the RAM and the ROA as discussed in the previous section 5.1, it must be assumed that the two models affect the authorization level (AU) differently. It has been established that the overbooking performance, as expressed by the ROA, is not proportional to the difference between the expected and the actual show-up rate (in the assumed constant cost environment). Further, the ROA performance index (PI_{ROA}) decreases disproportionately with an increasing number of denied boardings while the opposite is true for spoilage. In cases of spoiled seats, the ROA index decreases less than proportionately with additional spoiled seats, which leads to the concave shape observed in Figure 5.1. Thus oversales are penalized excessively higher than spoilage (even negative performance indices are possible as shown in Table 5.1). Because of this characteristic of the Revenue Opportunity Approach it must be presumed that measures are taken, by revenue management analysts for example, to avoid such extreme performance indices. Even without a detailed analysis it can be anticipated that these actions do not necessarily coincide with the airline objective of revenue maximization.

Since the risk of obtaining a bad performance index appears to be potentially higher for oversale than for spoilage, there is a certain incentive to set a lower authorization level in order to be on the "safe side". It is therefore logical to assume a direct relationship between the applied overbooking performance measurement model and the impact on set authorization levels. As mentioned before,

the natural result would be a maximization of average performance index (PI_{RAM} and PI_{ROA}) which, again, underlines the importance of compatibility between the overbooking model and the overbooking performance measurement approach. Only when the penalty for non-optimal overbooking performance is proportional to the lost revenues, as realized by the Revenue Achievement Model (RAM), does the maximization of the overbooking performance correspond with the airline objective of revenue maximization. In order to gain a better understanding of the impact of the Revenue Achievement Model and the Revenue Opportunity Approach on the authorization level, the two models are analyzed in greater detail to reveal potential differences.

Given an availability (AVL) it is obvious that the Total Revenue Achievement (RA_{Total}) of a single flight is dependent on the set authorization level (AU), the actual experienced show-up rate (sur) and the cost ratio $DB_{\$/SPL_{\$}}$. Since the Total Revenue Opportunity (RO_{Total}) for a particular flight is fixed, a function exists which describes the relative Total Revenue Achievement (rRA_{Total}) and therefore also the RAM Performance Index (PI_{RAM}) dependent on the variables mentioned above. The same is also true for the relative Revenue Achievement by Overbooking (rRA_{OB}) and the ROA Performance Index (PI_{ROA}).

$$PI_{RAM} = \frac{RA_{Total}}{RO_{Total}} = f(AU, sur, DB_{\$/SPL_{\$}}) \quad \text{and} \quad PI_{ROA} = \frac{RA_{OB}}{RO_{OB}} = f(AU, sur, DB_{\$/SPL_{\$}})$$

Considering the likelihood of all possible outcomes of the show-up rate, an average *expected Performance Index RAM and ROA* (exp. PI_{RAM} and exp. PI_{ROA}) can be determined for the PI_{RAM} and the PI_{ROA} . Practically speaking, this expected Performance Index is the sum of all probability weighted revenue achievement ratios, which eliminates the impact of the show-up rate (sur). For a given authorization level (AU) and a given cost ratio $DB_{\$/SPL_{\$}}$, the expected Performance Indices can be obtained as shown in equations (1). While exp. PI_{RAM} represents the expected Performance Index RAM, $p(z)$ describes the probability density function which is presumed for the show-up process. Assuming a normal distribution, equation (2) can be derived. The notations of (2) are self-explanatory.

$$(1) \quad \text{exp. } PI_{RAM} = \int PI_{RAM}(z) \cdot p(z) dz$$

$$(2) \quad \text{exp. } PI_{RAM} = \frac{1}{\sqrt{2\pi} \cdot RO_{Total}} \cdot \int RA_{Total}(sur) \cdot e^{-z(sur)^2/2} dsur \quad \text{with: } z(sur) = \frac{sur - \overline{sur}}{\sigma}$$

The above equations show only the expected Performance Index RAM (exp. PI_{RAM}). The respective figure for the Revenue Achievement by Overbooking (RA_{OB}) can be calculated accordingly. Hence, the expected Performance Indices (exp. PI_{RAM} as well as exp. PI_{ROA}) are now only dependent on the authorization level (AU) and the cost ratio ($DB_{\$/SPL_{\$}}$):

$$\text{exp. } PI_{RAM} = f(\text{AU}, DB_{\$/SPL_{\$}}) \quad \text{and} \quad \text{exp. } PI_{ROA} = f(\text{AU}, DB_{\$/SPL_{\$}})$$

Based on these functions, the on average expected Performance Indices (exp. PI_{RAM} and exp. PI_{ROA} respectively) can be determined for any given combination of cost ratio ($DB_{\$/SPL_{\$}}$) and authorization level (AU). Vice versa the "ideal" authorization level can be found for any given costs ratio $DB_{\$/SPL_{\$}}$. This "ideal" authorization level is the optimum number of bookings to be accepted which maximizes the expected Performance Index (exp. PI_{RAM} or exp. PI_{ROA}). In order to solve the problem of max.(exp. PI_{RAM}) and max.(exp. PI_{ROA}) respectively, a simplified version of equation (2) is employed. Rather than using the accurate equation as shown above, the exp. PI_{RAM} is approximated by the sum as subsequently shown (3). Again, only the exp. PI_{RAM} is illustrated. The exp. PI_{ROA} can be approximated accordingly. For the practical solution of the problem, the range of considered show-up rates was constrained between 0.70 and 1.00 as indicated in equation (4).

$$(3) \quad \text{exp. } PI_{RAM} = \sum_{i=70}^{100} PI_{RAM} \left(\text{sur} = \frac{i}{100} \right) \cdot p \left(\frac{i}{100} - 0.5 < \text{sur} < \frac{i}{100} + 0.5 \right)$$

$$(4) \quad \text{exp. } PI_{RAM} = \frac{1}{RO_{\text{Total}}} \cdot \sum_{i=70}^{100} RA_{\text{Total}} \left(\text{sur} = \frac{i}{100} \right) \cdot \left(p \left(\text{sur} < \frac{i}{100} + 0.5 \right) - p \left(\text{sur} < \frac{i}{100} - 0.5 \right) \right)$$

This allows us to develop a spreadsheet table to determine the exp. PI_{RAM} depending on the authorization level (AU) and the cost ratio ($DB_{\$/SPL_{\$}}$). Now, an iterative optimization algorithm can be used to find the maximum performance index (PI_{RAM}) for any given cost ratio. This enables us to establish a relation between the ideal authorization level and the assumed cost ratio (please note that the phrase "ideal authorization level" is used in the sense that this is the optimal authorization level which will maximize the expected relative Revenue Achievements). The result is a function which expresses the ideal authorization level over the cost ratio. Again, this function is determined for the Revenue Achievement Model as well as the Revenue Opportunity Approach.

$$AU_{\text{ideal, RAM}} = f_{RAM}(DB_{\$/SPL_{\$}}) \quad \text{and} \quad AU_{\text{ideal, ROA}} = f_{ROA}(DB_{\$/SPL_{\$}})$$

For the example calculation, a show-up rate (sur) of 0.85 and a standard deviation of 0.05 were assumed. As mentioned before, the upper bound of the sum was limited by $b = 100$ and the lower bound by $a = 70$. This means that actual show-up rates between 0.70 and 1.00 are considered which is quite sufficient for the applied mean show-up rate and standard deviation ($0.70 = -3 \cdot \sigma$ and $1.00 = +3 \cdot \sigma$). Furthermore, the costs for spoilage and oversales were simplified. While the different costs per oversale and spoiled seat are addressed by the cost ratio $DB_{\$/SPL_{\$/}$, the two cost components are assumed to be linear. This means that every oversale is penalized with the same cost independent from the total number of oversales. The same applies for the costs of spoilage respectively. Even though this is a simplifying assumption, this simplification will not affect the general finding.

The curves of the determined "ideal" authorization level in relative terms are plotted against the cost ratio $DB_{\$/SPL_{\$/}$ in Figure 5.3 for the Revenue Achievement Model and the Revenue Opportunity Approach. The authorization levels are expressed as percentage of the availability (AVL).

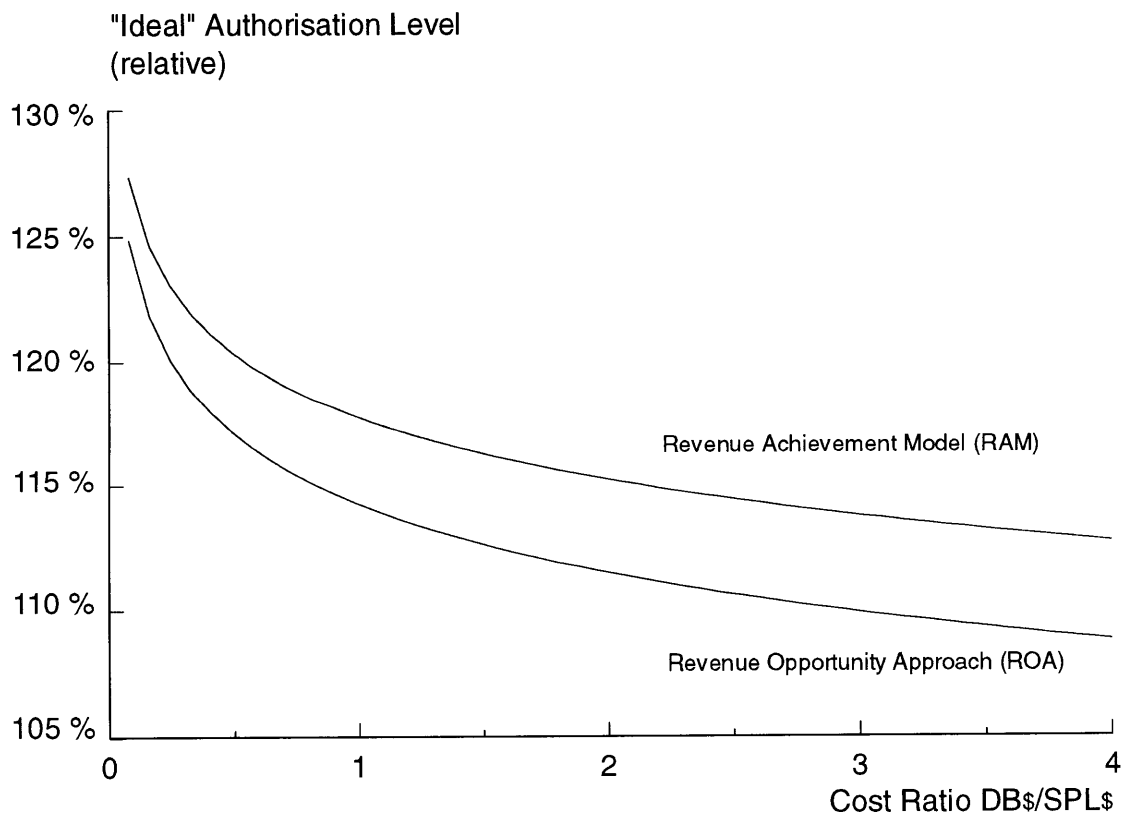


Figure 5.3 "Ideal" Authorization Level - Non-Integer

Although the shape of the two curves is similar, it is now evident that the "ideal" authorization level (AU) of the Revenue Opportunity Approach is lower than the comparable level of the Revenue Achievement Model. This means that the average overbooking performance is maximized at different AU's. Therefore, the two overbooking performance measurement models affect the authorization level as expected. The ideal authorization level to achieve a maximum overbooking performance rating differs by 3 to 4 % depending on the cost ratio $DB_{\$}/SPL_{\$}$. It proves that there is an incentive to reduce the authorization level if the Revenue Opportunity Approach is applied rather than the Revenue Achievement Model. With the presumed show-up rate of 0.85 this translates in an average effective loss of 2.55 to 3.40 % of potential passengers on every fully booked flight (in terms of availability).

As outlined before, the Revenue Opportunity Approach penalizes oversale incidents disproportionately high compared to spoilage situations. This means that a loss of revenues due to denied boardings is assessed worse than the same loss of revenues because of seats light. In order to avoid a higher risk of a bad performance evaluation it is therefore safer for revenue management analysts to lower the authorization level. The Revenue Achievement Model on the other hand assesses the overbooking performance solely on the amount of revenues which has been lost in relation to the overall revenue opportunity. Hereby it does not make any difference if say \$ 1000 were lost because of spoilage or oversale. Only the absolute revenue generation is important and it does not matter at all what caused the non-optimal economic outcome of the flight. Therefore, the RAM does not favor any overbooking situation as opposed to the ROA which is in favor of spoilage.

Because only integer numbers of passengers can be expected, the calculated ideal authorization level is not very useful on a relative basis. Thus, the ideal authorization levels were also calculated for an example flight with an availability of 100 seats. The results, as shown in Figure 5.4, illustrate exactly the same findings as established before. Here the ideal authorization levels for the RAM and the ROA differ by three or four accepted bookings, depending on the cost ratio $DB_{\$}/SPL_{\$}$. Thus, three or four fewer bookings are accepted over the long run if the Revenue Opportunity Approach rather than the Revenue Achievement Model is applied. This translates again in an average effective loss of 2.55 to 3.40 passengers on every fully booked flight with the presumed show-up rate of 0.85. The economic significance of this is obvious. Since airlines operate with very small or even no profit margins it is evident that every passenger counts. Passengers must not be turned away because the wrong overbooking performance measurement model is applied.

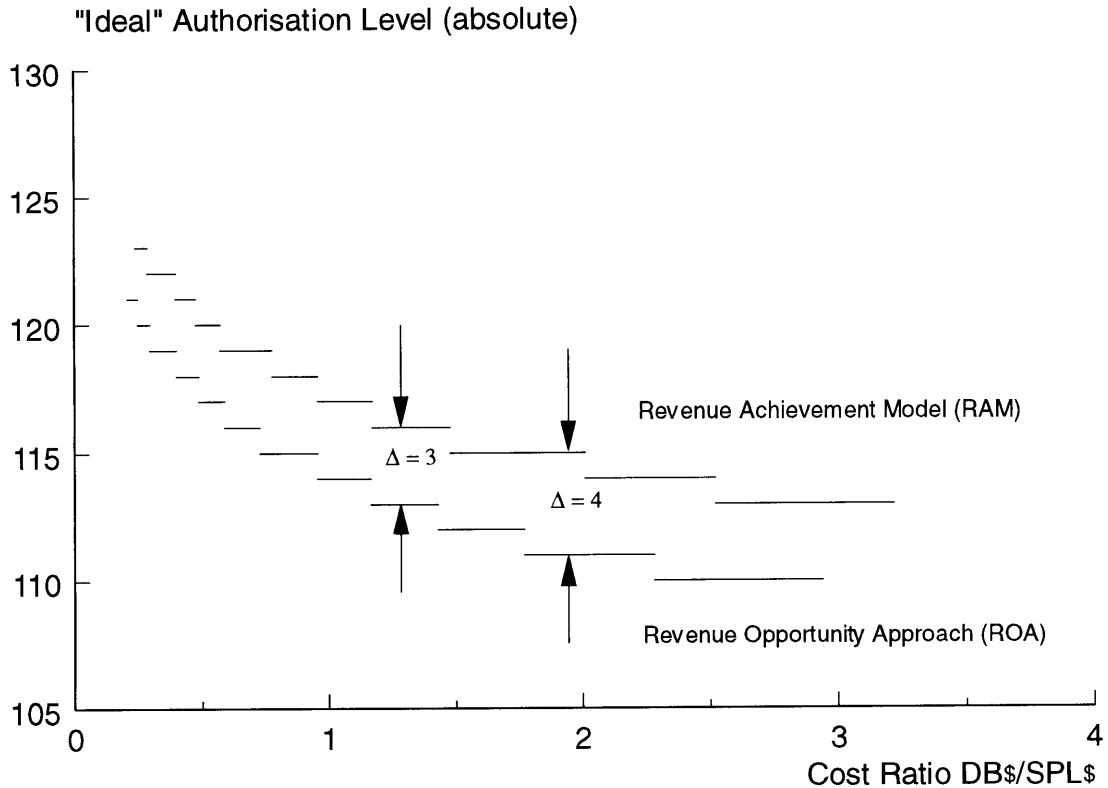


Figure 5.4 "Ideal" Authorization Level - Integer

Furthermore, the previous calculation of the expected RAM Performance Index (exp. PI_{RAM}) and the subsequent optimization of the authorization level shows the direct link between the Revenue Achievement Model and the Overbooking Model. Since the RAM expresses the total revenue achievement as a "monetary load factor" the maximization of this term matches by definition the economic objective of the airline. Thus, the above calculation is nothing else than a simple overbooking model which generates an ideal authorization level for any given cost ratio ($DB_{\$}/SPL_{\$}$), mean show-up rate (μ_{sur}) and standard deviation of the show-up rate (σ_{sur}). The maximization of the RAM Performance Index coincides with the economic goal of total revenue maximization. The ROA on the other hand is an "artificial" measure which is not compatible with the economic objectives. Its maximization does not result in an optimization of the overall revenue generation. Therefore, the required compatibility between the overbooking model and the overbooking performance measurement approach is ensured by the RAM, as opposed to the ROA.

5.3 Summary

This chapter evaluated the Revenue Achievement Model against the Revenue Opportunity Approach with respect to their capabilities to compare the performance on a single flight level and their impact on the authorization level. It has been shown that the overbooking performance comparison of two or more flights, by utilizing the ROA, can be unreliable and can lead to unjustifiable performance rankings. In addition, it has been illustrated that the Revenue Opportunity Approach can affect the authorization level in a way such that the overall revenue generation diminishes. As the ROA is expected to achieve its maximum performance at a sub-optimal (lower) authorization level, it causes an incentive for revenue management analysts to lower the authorization level than increase it.

As discussed, the above summarized shortcomings of the ROA are overcome by the RAM. Furthermore, the Revenue Achievement Model is more compatible with the currently employed overbooking models.

Chapter 6

Revenue Achievement Model (RAM) - Aggregate Flight Level

While the new performance measurement model was introduced for overbooking performance evaluation on a single flight level, it is further necessary to discuss the application of the RAM on an aggregate flight level. Given the probabilistic nature of the overbooking process, the evaluation on an aggregate flight level is even more important for the fine tuning of the overbooking model. While the outcome of a single flight cannot be subject to great uncertainty, the expected overall revenue achievement of a large sample of flights can be estimated with more confidence. Thus, the analysis of large samples of actual flights is essential to feed the entire revenue management process. Furthermore, the intention of an aggregate evaluation is that a better understanding of the economic achievements is gained for a large sample of flights. This sample can be defined by a time criterion as well as geographic criterion. Thus, an aggregate analysis can be performed on a weekly, monthly or quarterly basis for a selected route, particular region or system wide. Again, we distinguish between the general overbooking performance evaluation and the assessment of authorization level adjustments by revenue management analysts.

6.1 Overbooking Performance Evaluation of Recommended Authorization Levels

The approach as established for an overbooking performance measurement on a single flight level can easily be transferred to an aggregate flight level basis. Rather than relating the Total Revenue Achievement (RA_{Total}) to the Total Revenue Opportunity (RO_{Total}) on a single flight level, the respective cumulative values of n flights can be used in order to obtain an *aggregate Performance Index* ($agg. PI_{RAM}$). Thus, the sum of all considered Total Revenue Achievements is related to the sum of all considered Total Revenue Opportunities (RO_{Total}). Here it must be stressed that not the average of all single performance ratios (PI_{RAM}) is employed for the aggregate analysis but the percentage ratio of the cumulative Total Revenue Achievement to the cumulative Total Revenue Opportunity. The difference between these values might not be evident at the first glance but will be clarified in the subsequent discussion.

Employing the average of all single overbooking performance indices would lead to a distortion of the resulting aggregate performance index. Every flight would be equally weighted, independent of its revenue contribution. Hence, flights with small Total Revenue Opportunities would have an unjustifiable large impact while flights with large Total Revenue Opportunities would be underrepresented. Furthermore, calculating simply the average of all RAM performance indices (PI_{RAM}) is somewhat "against the rules" of the Revenue Achievement Model (RAM) because it does not comply with its philosophy to relate overall revenue achievements to overall revenue opportunities.

According to the philosophy of the RAM, a single aggregate revenue achievement must be related to the respective single aggregate revenue opportunity which expresses then the aggregate overbooking performance index (agg. PI_{RAM}). In order to comply with this approach, an equivalent to the Total Revenue Achievement (RA_{Total}) and Opportunity (RO_{Total}) must be defined for a sample of flights. Such a cumulative revenue opportunity as well as a cumulative revenue achievement can be simply obtained by summing up the single achievement and opportunity values. The result is an *Aggregate Total Revenue Achievement* (agg. RA_{Total}) and an *Aggregate Total Revenue Opportunity* (agg. RO_{Total}) respectively as summation over all sample flights i (please note that the absolute monetary numbers are employed as indicated by the \$ sign).

$$\text{agg. } RA_{Total,\$} = \sum_{i=1}^n RA_{Total,\$,i} \quad \text{and} \quad \text{agg. } RO_{Total,\$} = \sum_{i=1}^n RO_{Total,\$,i}$$

Since the Total Revenue Achievement (RA_{Total}) and the Total Revenue Opportunity (RO_{Total}) will have been determined anyway for every single flight (for the overbooking performance measurement on a single flights level), it does not require much effort to calculate the cumulative achievement and opportunity values as shown above. The aggregate RAM Performance Index (agg. PI_{RAM}) is now determined by dividing both cumulative values as illustrated in equation (1).

$$(1) \quad \text{agg. } PI_{RAM} = \frac{\text{agg. } RA_{Total,\$}}{\text{agg. } RO_{Total,\$}} = \frac{\sum_{i=1}^n RA_{Total,\$,i}}{\sum_{i=1}^n RO_{Total,\$,i}}$$

In the extreme unlikely event that only flights with the same Total Revenue Opportunity (RO_{Total}) are considered for an aggregate overbooking performance evaluation, a simplified version of

equation (1) can be used as shown in equation (2). It can be applied when, for instance, a flight is assessed over a certain time span without any change of the availability, the cost and revenue structure or the passenger mix, i.e. the Total Revenue Opportunity (RO_{Total}) is constant for every flight of the considered sample.

$$(2) \quad \text{agg. PI}_{RAM} = \frac{\sum_{i=1}^n RA_{Total,\$,i}}{n \cdot RO_{Total,\$}} = \frac{1}{n} \cdot \sum_{i=1}^n PI_{RAM,i} \quad \text{for } RO_{Total,\$,i} = \text{const.}$$

However, any generated aggregate performance index is of little value if it cannot be compared with a target index which allows a proper interpretation whether the economic objectives are met or not. While the performance indices for single flights cannot be evaluated against a target performance, exactly this is necessary for aggregate performance indices. As shown in previous chapters, the practically achieved performance of a single flight ranges between 60 % RAM and 100 % RAM. Even though a perfect hit is the most desirable outcome, it is evident that, due to the stochastic nature of the show-up process, it cannot be achieved on every single flight. Thus, no target performance index can be defined for a performance evaluation on a single flight level and the single performance indices can only be compared against each other in order to determine better and worse flights.

Accordingly, any aggregate overbooking performance index cannot be expected to reach a performance rating of 100 % or even come close to 100 %. Further it is not feasible to compare the indices of several flight samples against each other purely on the basis of the aggregate Performance Index (agg. PI_{RAM}). Since every flight included in the performance evaluation on an aggregate level is required to have similar characteristics which qualifies it for this particular cross section of the system (this constraint can be loosened as we will see later), every sample of flights is somewhat unique. Thus, it cannot be expected that two or more considered sample of flights are supposed to achieve similar aggregate performance indices. While an agg. PI_{RAM} of say 90 % might be good for one particular sample it does not automatically mean that the same rating qualifies another sample of flights to be good. It is very well possible that the latter sample could have achieved and also was expected to achieve a much higher agg. PI_{RAM} .

As outlined before, the average revenue achievement for a flight is mainly dependent on its mean and standard deviation of the show-up rate (μ_{sur} and σ_{sur}) and the costs for oversale and spoilage ($DB_{\$}$ and $SPL_{\$}$). If a flight is characterized by a high variability of the actual show-up rate, the prediction of denied boardings and spoilage will be less accurate and more revenues will be lost on

average compared to a flight with a very small standard deviation of the show-up rate. The impact of the costs of spoilage and oversale is similar. It might be, for example, the case that the costs of denied boardings are extremely high (compared to the average fare level) on particular routes where passengers are less willing to volunteer for getting bumped. Hence, different samples of flights are characterized by different average revenue losses. Thus, a target performance has to be defined which enables us to distinguish between "good" and "bad" flight samples. Such a target performance must be independent from the actual outcome of the considered flight sample and should be as "unique" as the sample itself by considering the special flight characteristics of the particular sample.

It is therefore essential to develop an *aggregate Target Performance Index* ($\text{agg. PI}_{\text{Target}}$) which is compatible with the economic objectives of the airline but independent from the actual outcome of a particular sample to be evaluated, i.e. the $\text{agg. PI}_{\text{Target}}$ must be derived from the presumed show-up rate characteristics of the sample. Once such a comparison performance is obtained, every aggregate sample of flights can be assessed on an equal reference basis. The aggregate overbooking performance of a sample of flights is considered to be good if the actual achieved aggregate Performance Index ($\text{agg. PI}_{\text{RAM}}$) is close to the aggregate Target Performance Index ($\text{agg. PI}_{\text{Target}}$). Not the absolute value of the indices is important but their deviation from their particular target value.

The basic framework of such an aggregate Target Performance Index can be directly deducted from the considerations of Chapter 5. As there exist an actual Total Revenue Achievement (RA_{Total}) and Total Revenue Opportunity (RO_{Total}) for every flight, it is also possible to obtain an *expected Total Revenue Achievement* ($\text{exp. RA}_{\text{Total}}$) for every single flight which can be easily derived from the expected RAM Performance Index ($\text{exp. PI}_{\text{RAM}}$) and the actual Total Revenue Opportunity (RO_{Total}). Then the expected Total Revenue Achievement ($\text{exp. RA}_{\text{Total}}$) for a particular flight is calculated by:

$$\text{exp. RA}_{\text{Total}} = \text{exp. PI}_{\text{RAM}} \cdot \text{RO}_{\text{Total}} \quad (\text{for every single flight})$$

This expected Total Revenue Achievement ($\text{exp. RA}_{\text{Total}}$) represents the average revenue generation per flight which is expected over a large sample of flights with identical show-up properties. Based on this the expected Total Revenue Achievement ($\text{exp. RA}_{\text{Total}}$), the aggregate Target Performance Index can be obtained in the same way as the aggregate Performance Index ($\text{agg. PI}_{\text{RAM}}$) is determined. Rather than using the cumulative Total Revenue Achievement (RA_{Total}), the sum of all expected Total Revenue Achievements ($\text{exp. RA}_{\text{Total}}$) is related to the

sum of all respective Total Revenue Opportunities (RO_{Total}). The calculation of the aggregate Target Performance Index ($agg. PI_{Target}$) is illustrated in equations (3) and (4).

$$(3) \quad agg. PI_{Target} = \frac{\sum_{i=1}^n exp. RA_{Total,\$,i}}{\sum_{i=1}^n RO_{Total,\$,i}}$$

$$(4) \quad agg. PI_{Target} = \frac{\sum_{i=1}^n \int RA_{Total,\$,i}(sur) \cdot e^{-z(sur)^2/2} dsur}{\sqrt{2\pi} \cdot \sum_{i=1}^n RO_{Total,i}} \quad \text{with: } z(sur) = \frac{sur - \overline{sur}}{\sigma}$$

Again, this approach of calculating a target value to be achieved over the long run, reflects directly the characteristics of currently employed overbooking models. Since the optimization algorithm of most overbooking models burdens every flight with some average costs of overbooking, it is logical that these average costs must be considered somewhere in the overbooking performance evaluation on an aggregate flight level.

Figure 6.1 shows again the general philosophy of overbooking models to maximize the generated net revenues by minimizing the costs of overbooking. The inevitable result is some average loss of revenues due to spoilage and oversales. It is therefore clear that a large sample of flights cannot be expected to generate 100 % of all possible revenues but only a portion of it. Hence, the average expected costs of overbooking for a particular flight can be employed to determine the expected Total Revenue Achievement ($exp. RA_{Total}$). Since the Total Revenue Opportunity (RO_{Total}) is known, the expected Total Revenue Achievement is simply determined as difference between the Total Revenue Opportunity and the average expected costs of overbooking.

$$exp. RA_{Total} = RO_{Total} - aver. exp. costs of overbooking = exp. PI_{RAM} \cdot RO_{Total}$$

This relationship illustrates the close link between the basic features of the overbooking model and the performance evaluation by the Revenue Achievement Model. It therefore proves again that the evaluation philosophy of the RAM is highly compatible with the previous discussed overbooking models. It underlines therefore that the RAM is more appropriate to measure the overbooking performance than other evaluation tools.

Costs of Overbooking

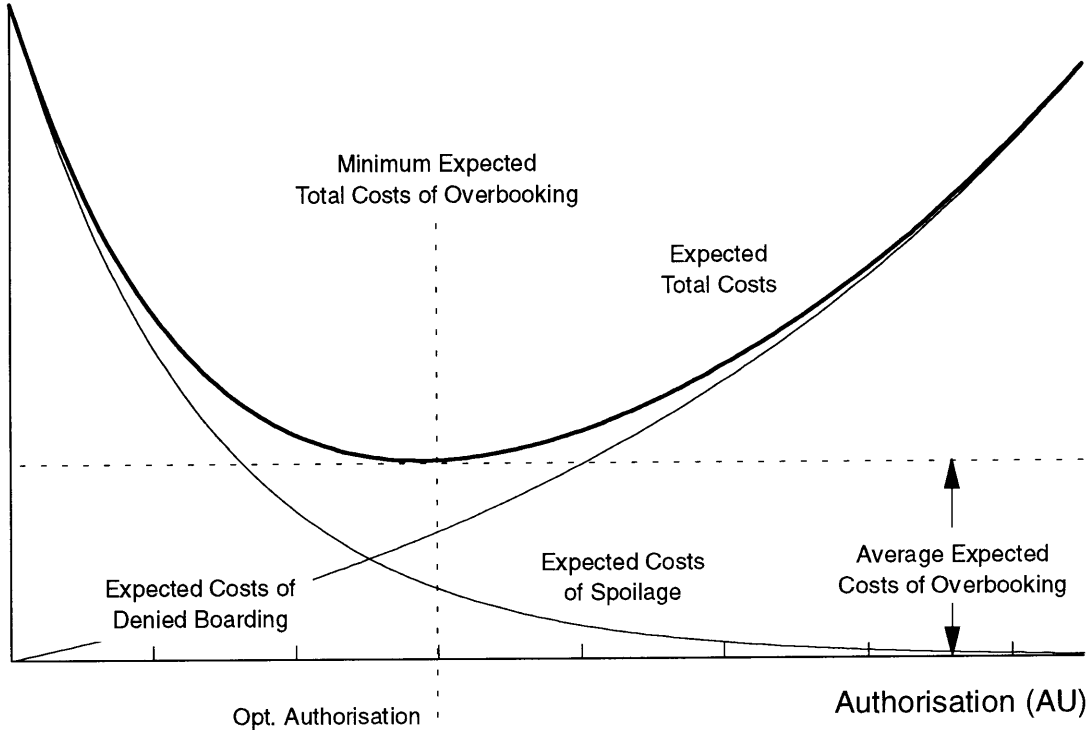


Figure 6.1 Average Expected Costs of Overbooking

Once the aggregate Target Performance Index is calculated, the actual aggregate Performance Index ($\text{agg. PI}_{\text{RAM}}$) can be compared with its target value. Now it is possible to distinguish between good and bad flight samples simply based on their ratio of the actual achieved aggregate Performance Index and the desired Target Performance Index. When the aggregate Performance Index lags behind the aggregate Target Performance Index ($\text{agg. PI}_{\text{RAM}} < \text{agg. PI}_{\text{Target}}$) it is evident that the overbooking performance was not optimal. Vice versa, when the aggregate Performance Index exceeds the aggregate Target Performance Index ($\text{agg. PI}_{\text{RAM}} > \text{agg. PI}_{\text{Target}}$), it must be concluded that the actual revenue generation due to overbooking was better than expected. Hence, the aggregate performance of a particular sample of flights can be assessed autonomously from other samples simply by comparing the actual performance with the target value. This ensures that every sample is related to the "same" basis. Even though this individual determined basis is unique and therefore different for every sample of flights, it defines the appropriate target evaluation base.

Table 6.1 - Aggregate Target Performance Index Sensitivity

Sample	AVL	$\mu_{\text{exp. sur}}$	$\sigma_{\text{exp. sur}}$	ideal AU*	agg. PI_{Target} *
1	100	0.88	0.04	116	97.2 %
2	100	0.85	0.05	120	96.5 %
3	100	0.82	0.06	125	94.2 %
4	100	0.79	0.07	129	87.4 %

* assumed cost ratio $DB_{\xi}/SPL_{\xi} = 0.5$ and only integer AU's are permitted

Nevertheless, the long-term objective must be a match of the actual aggregate performance index with its target value ($\text{agg. } PI_{\text{RAM}} = \text{agg. } PI_{\text{Target}}$). Large deviations in either direction over a longer period of time indicate that the target performance is either predicted too high or too low and requires adjustment. It is very well possible that, for whatever reasons, the characteristics of a sample of flights change over the time. If, for example, the standard deviation of the show-up rate increases, i.e. the number of show-ups vary even more, the average expected costs of overbooking increase and the aggregate Target Performance Index diminishes. If this decrease of the $\text{agg. } PI_{\text{Target}}$ is not adjusted, the actual achieved aggregate Performance Index ($\text{agg. } PI_{\text{RAM}}$) is "programmed" to fall short of its target value as shown in Table 6.1. If, for instance, a mean of 0.85 and a standard deviation of 0.05 is assumed for the show-up rate (sample 2) but the show-up process is became less stable with time and the actual values are 0.79 and 0.07 respectively (sample 4), the falsely predicted targets can never be achieved.

Apart from this particular problem, Table 6.1 shows the general importance to compare the actual aggregate Performance Index with its target value. As outlined before, the obtained target performance index depends strongly on the mean and standard deviation of the expected show-up rate. Thus, it is essential to calculate the aggregate Target Performance Index for every sample of flights individually in order to analyze the actual achieved performance appropriately. While, for instance, sample 1 is very "stable" as far as the show-up rate is concerned, the flights of sample 4 are faced with a very high variability of the show-up rate. Accordingly, the aggregate Target Performance Index of the latter sample is calculated to be much lower. Now its is obvious that every $\text{agg. } PI_{\text{RAM}}$ has to be compared with its own unique target performance and not with the aggregate performance indices of other samples. It would not make any sense to compare a sample of flights with a high variability of the show-up rate (similar characteristics as sample 3 or 4) with the target values of flights with a much more steady show-up process.

Based on this finding the previous stated requirement to compile only flight samples with similar characteristics of their show-up process can be loosened. As long as the aggregate Target Performance Index is calculated anew for every sample of flights, every flight contributes in the same way towards the actual aggregate performance index as it contributes to the respective target value. Hence, the probabilistic differences of the flights are considered in the actual PI_{RAM} as well as in the basis of the comparison. Practically speaking, every combination of flights can form a sample irrespective whether they have similar characteristics or not.

In particular, this feature of the Revenue Achievement Model and its philosophy to employ a target value as basis of comparison is a clear advantage over the previously discussed approaches, namely the Revenue Opportunity Approach and the "oversale versus spoilage cost plot" as applied by United Airlines [13]. As stated in section 2.2.1, it is essential that the flights which qualify for the evaluation as proposed by United are required to have identical characteristics in terms of show-up process and overbooking costs. This shortcoming is overcome with the above proposed procedure to analyze aggregate sample of flights. Further, the United approach requires much larger samples in order to allow a statistically significant assessment of the overbooking performance. Furthermore, the model here defined is much easier to understand and the performance rating can be simply expressed by two numbers, the actual achieved agg. PI_{RAM} and the respective agg. PI_{Target} rather than by the relatively complex "costs of oversale over costs of spoilage" positioning map. On the other hand, the United approach allows a more detailed analysis which cannot be provided by the two performance indices. Such a detailed analysis, however, can also be performed based on the data set which is required to generate the respective aggregate Performance Index.

This leads to the comparison of the Revenue Opportunity Approach versus the Revenue Achievement Model concerning their capability to evaluate the overbooking performance on an aggregate flight level. In order to do so, it is necessary to clarify the aggregate modeling of the ROA itself. For the same reasons as stated above, it is not sensible to calculate an aggregate ROA performance index (agg. PI_{ROA}) simply by averaging the single ROA performance indices. Thus, the approach as used by American Airlines [4] to perform an aggregate overbooking performance analysis based on the mean of all considered single PI_{ROA} 's is certainly not the right way to assess the success or failure of overbooking. Again, every flight would be equally weighted, independent of its evaluated revenue potential, the Revenue Opportunity for Overbooking (RO_{OB}). As the Revenue Opportunity for Overbooking depends strongly on the actual show-up rate, the impact of every flight on the aggregate ROA performance index varies with the show-up rate and cannot be predicted.

Hence, the aggregate ROA performance index (agg. PI_{ROA}) must be determined via the cumulative revenue achievement due to overbooking and the cumulative revenue opportunity for overbooking. This ensures that an aggregate performance expression is obtained which is appropriately weighted in accordance to the relative revenue gain by overbooking of every single flight. Thus, an aggregate ROA performance index (agg. PI_{ROA}) must be calculated as shown below. As illustrated, the sum of all Revenue Achievements by Overbooking (RA_{OB}) is related to the respective sum of all Revenue Opportunities for Overbooking (RO_{OB}).

$$\text{agg. } PI_{ROA} = \frac{\sum_{i=1}^n RA_{OB,\$,i}}{\sum_{i=1}^n RO_{OB,\$,i}} = \frac{\sum_{i=1}^n (RA_{Total,\$,i} - RA_{NC,\$,i})}{\sum_{i=1}^n RO_{OB,\$,i}}$$

Once the aggregate ROA performance index is determined the question arises to what basis this value should be compared. Clearly, the agg. PI_{ROA} 's of different samples cannot be compared against each other because of the same problems as discussed before. Thus, it would be logical to develop an aggregate Target Performance Index for the Revenue Opportunity Approach, similar to the previous outlined methodology for the Revenue Achievement Model, which can be employed to evaluate every sample of flights on an equal basis. The detailed derivation of the ROA target performance is analogous to the previous discussed RAM target performance and will not be outlined. Only the implications are subsequently analyzed.

Even though the clear advantage of the RAM over the ROA has been established in Chapter 5 for the single flight level, it is worth to re-stating the findings for an aggregate flight level. At first glance, both models, the RAM and the ROA, appear to be similar. The same principle of calculating the actual aggregate performance index and the subsequent comparison with its target performance value is proposed. Nevertheless, the performance by the RAM is more "tangible" and expresses the airline objectives better than the "artificial" ROA value. An overbooking performance of x % RAM allows immediately the conclusion that x % of the maximum achievable revenues have been gained. The Revenue Opportunity Approach on the other hand does not reflect the revenue situation as clearly.

Table 6.2 - Comparison aggregate Performance Index RAM vs. ROA

Sample	AVL	$\mu_{\text{exp. sur}}$	$\sigma_{\text{exp. sur}}$	- RAM -		- ROA -		
				ideal AU*	agg. $PI_{\text{Target,RAM}}^*$	ideal AU*	agg. $PI_{\text{Target,ROA}}^*$	agg. PI_{RAM}
1	100	0.88	0.04	116	97.2 %	114	73.2 %	97.1 %
2	100	0.85	0.05	120	96.5 %	117	72.0 %	96.1 %
3	100	0.82	0.06	125	94.2 %	121	70.1 %	93.7 %
4	100	0.79	0.07	129	87.4 %	127	65.4 %	87.1 %

* assumed cost ratio $DB_{\xi}/SPL_{\xi} = 0.5$ and only integer AU's are permitted

Even more important, however, is the difference in the target performance indices themselves. It has already been outlined in Chapter 5 that the expected RAM and the expected ROA performance indices are maximized at different authorization levels. This finding reflects also on the aggregate performance evaluation and even though the effects have been discussed in great detail concurrently with the performance evaluation of single flights, the effects are now illustrated within the context of the aggregate performance assessment.

Table 6.2 summarizes the information needed to compare both models concerning their target performance indices. Employing the same samples of flights as used in Table 6.1, the ideal authorization level (AU) and aggregate Target Performance Index (agg. PI_{Target}) for the Revenue Opportunity Approach are added to the respective numbers of the Revenue Achievement Model. Applying the ROA means now that the actual aggregate overbooking performance index is assessed by the shown target value, i.e. the objective is to come close to the ROA target performance. Adjacent to these ROA target performances the associated aggregate RAM Performance Indices (agg. PI_{RAM}) are shown which indicates the actual overall revenue achievement. It is now evident that under the ideal authorization of the ROA the respective RAM performance indices are consistently smaller than the target values as predicted by the Revenue Achievement Model. Thus, the target performance as generated by the ROA does not coincide with the target performance of the RAM. Since the agg. PI_{RAM} expresses the overall revenue achievement, it is clear that the target performance of the Revenue Opportunity Approach is sub-optimal. In fact, between 0.1 % and 0.5 % of the possible revenues are lost if the ROA performance matches its target value.

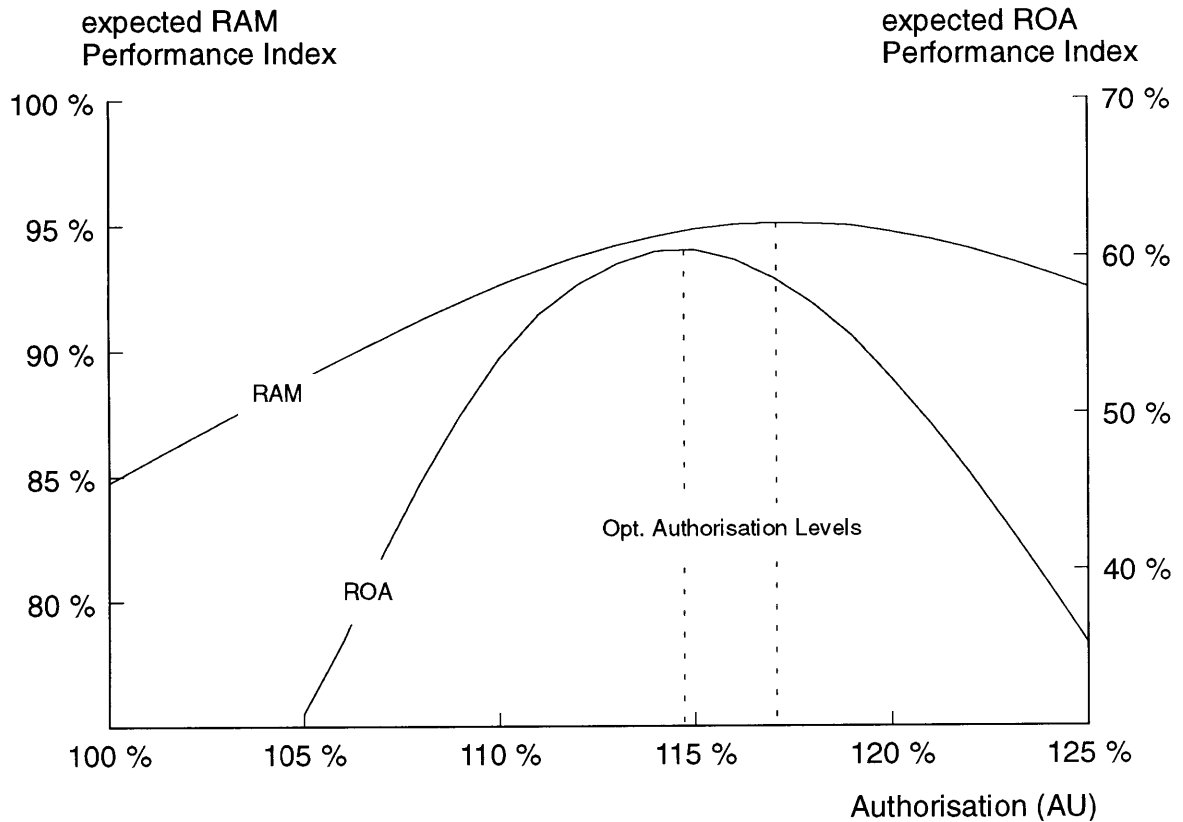


Figure 6.2 RAM and ROA Performance Indices dependent on the Authorization Level

This is also illustrated in Figure 6.2 which shows the expected performance indices according to the RAM and ROA over the authorization level (with $DB_{\S}/SPL_{\S} = 1$, $\mu_{sur} = 0.85$ and $\sigma_{sur} = 0.05$). It visualizes very clearly that the maxima of both performance indices do not fall together. The expected total revenue achievement, as expressed by the Revenue Achievement Model, is obtained at a higher authorization level than determined by the maximum of the Revenue Opportunity Approach (Even though different scales are used for both models, not the absolute numbers are important but the location of the maxima). Hence, it has been shown again that the Revenue Achievement Model expresses the overbooking performance better than the ROA.

The application of the Revenue Opportunity Approach has the danger to lead to lower, sub-optimal, overall authorization levels compared to the Revenue Achievement Model. Not surprisingly it can further be concluded from the example shown in Table 6.2 that also the mean and standard deviation of the show-up rate affect the authorization level and not only the cost ratio DB_{\S}/SPL_{\S} as discussed in section 5.2.

Once again, it is even more important to focus exclusively on the absolute revenue achievements (RAM) rather than the more "artificially" constructed ROA. The following section will outline the aggregate application of the Revenue Achievement Model with respect to the Revenue Achievement by Revenue Management Analysts.

6.2 Performance Evaluation of Revenue Management Analyst Interventions

The performance evaluation of revenue management analyst interventions for the single flight level, as discussed in Chapter 4, can also be translated into an aggregate measurement similar to the methodology as outlined in the previous section. Again, the evaluation of revenue management analyst interventions must be seen as an additional evaluation stage in the overall overbooking performance assessment. While the general performance of every "fully booked" flight is analyzed irrespective whether the recommended (AU_R) or a manual authorization (AU_M) level was applied, only some flights need to be further examined concerning the impact of manual AU adjustments.

The absolute revenue achievement value is now simply obtained by summing up all the single Revenue Achievements by Revenue Management Analysts (RA_{RMA}). As shown below, the agg. $RA_{RMA,\$}$ expresses the absolute monetary difference between the revenue achievement with (AU_M) and without (AU_R) system overrides.

$$\text{agg. } RA_{RMA,\$} = \sum_{i=1}^n RA_{RMA,\$,i} = \sum_{i=1}^n \text{rev}_i(\text{sur} \cdot \text{bkr} \cdot AU_M) - \sum_{i=1}^n \text{rev}_i(\text{sur} \cdot \text{bkr} \cdot AU_R)$$

Whether this value is indicated as an absolute monetary value or a relative number (related to the cumulated Total Revenue Opportunity) is irrelevant in the end. While a target performance can be derived for the automated authorization process based on the stochastic characteristics of the show-up process, this is not feasible for the authorization level adjustments by revenue management analysts. A potential revenue improvement cannot be foreseen as it relies on human judgment and experience (otherwise it would be included into the automated recommendation process).

Since no target value can be calculated which could be used to compare the actual with the predicted performance of revenue management analyst overrides, the simple principle "the larger, the better" applies also in the case of an aggregate performance measurement as it did for the single flight performance evaluation. Once again, it must be stated that only the absolute revenue gain is important.

The evaluation of the revenue management analyst performance on an aggregate flight level is straight forward and easy to perform. As the required flight data were determined for the single flight level evaluation anyway, it is no challenge to compile the RA_{RMA} information for every sample of flights and obtain an overall revenue achievement which indicates now whether the system overrides were beneficial for the airline or not. However, it might be of interest to develop an enhanced strategy for the future which allows the airline to establish a pattern of what type of flights offer the highest "chance" of revenue improvements due to revenue management overrides. Thus, it appears appropriate to determine not only the total revenue gain due to system overrides but also the theoretically revenue achievement which would have been generated if no system overrides would have taken place.

$$\text{agg. } RA_{\text{Total},\$}(AU_R) = \sum_{i=1}^n RA_{\text{Total},\$,i}(AU_R) = \sum_{i=1}^n \text{rev}_i(\text{sur} \cdot \text{bkr} \cdot AU_R)$$

Further it might be of interest to compile the total revenue gain as well as the total revenue loss caused by revenue management analysts, i.e. to separate all flights with revenue improvements from the flights with revenue deterioration.

$$RA_{RMA,\$}^+ = \sum_{i=1}^n RA_{RMA,\$,i}^+ = \sum_{i=1}^n \text{rev}_i(\text{sur} \cdot \text{bkr} \cdot AU_M) - \sum_{i=1}^n \text{rev}_i(\text{sur} \cdot \text{bkr} \cdot AU_R) > 0$$

$$RA_{RMA,\$}^- = \sum_{j=1}^m RA_{RMA,\$,j}^- = \sum_{j=1}^m \text{rev}_j(\text{sur} \cdot \text{bkr} \cdot AU_M) - \sum_{j=1}^m \text{rev}_j(\text{sur} \cdot \text{bkr} \cdot AU_R) < 0$$

Apart from the absolute revenue gain or loss due to system overrides the above calculated values give an indication how much revenue potential was "in the game", i.e. how much could have been won if every intervention resulted in a gain and none resulted in a negative impact. Since the RA_{RMA} values were also determined for the single flight evaluation it is again easy to obtain the cumulative numbers as illustrated above. Now it might be possible to establish a pattern which shows a clear characteristic which flights were less likely and which flights are more likely to require any authorization level adjustment.

6.3 Summary

This chapter outlined the application of the Revenue Achievement Model on an aggregate flight level. It has been shown that the philosophy of the RAM as introduced for a single flight level overbooking performance measurement is consistent with its results on an aggregate flight level. Furthermore, the superior features of the RAM over the previously discussed models has been confirmed for the overbooking performance measurement on an aggregate flight level.

Another important aspect of the proposed model is the comparison of the actual aggregate Performance Index (agg. PI_{RAM}) with a particular target performance. Hence, a reasonable goal to be achieved can be defined for every sample of flights. Now the target can be quantified and it is very well possible to control the success or failure of achieving the set performance objectives. Statements like "high load factors coupled with low denied boardings" [14] can be replaced by more "tangible" standards of overbooking performance.

In addition, the Revenue Achievement Model allows an analysis of flight samples which are composed of flights with totally different characteristics concerning their show-up features. Since every sample is compared with its individual and therefore unique target performance, it is feasible to derive reasonable results for every thinkable combination of flights without the constraint of bundling only flights with similar show-up characteristics.

Chapter 7

Conclusions and Recommendations

This thesis has outlined the general importance of overbooking and in particular of the need to evaluate overbooking activities. As part of every revenue management process, overbooking must be subject to permanent evaluation by overbooking performance measurement with subsequent feedback into the overbooking model itself. The overbooking actions should be viewed as a closed control loop within steering and fine tuning is based on the knowledge gained from the performance measurement. Even though airlines have made great efforts to optimize and improve their reservation control systems, overbooking performance measurement has largely been disregarded in previous decades. Only recently have they realized the importance of reviewing the outcomes of their overbooking activities and to developed different performance measurement models as illustrated in previous chapters.

It has been established that monetary performance measurement approaches must be preferred over non-monetary models. Only monetary approaches allow the required flexibility to incorporate most of the economic effects of overbooking in detail. As long as the positive and the negative consequences of overbooking can be translated into monetary terms it is feasible to comprise all effects on an equal basis. The costs as well as the benefits are then expressed as a number which is easy to understand and more tangible than any other measures like spoilage or denied boarding ratios. Non-monetary measures do not directly consider the economic effects of overbooking. Furthermore, it is extremely difficult to incorporate the non linear costs of overbooking by using non-monetary performance measurement models. As most overbooking models maximize revenues by minimizing the costs of overbooking, the applied performance evaluation should be aligned with this concept in order to compatible with the overbooking model.

The inherent problem with monetary evaluation approaches, however, is the estimation of the costs of spoilage and oversale. Even with perfect post departure hindsight it is difficult to determine the

lost revenue potential of seats which were left empty upon departure and which could have been sold (opportunity costs). As passenger goodwill is hard to quantify accurately, the total costs of involuntary denied boardings cannot be determined either. Both values are required to calculate the overall revenue potential which can be gained from the flight. Hence, the Total Revenue Opportunity as well as the Revenue Opportunity for Overbooking can only be established as accurately as the costs of overbooking are estimated. Chapter 2 outlined how methodologies to obtain the required cost information range from simple average fare approaches to complex evaluations of the booking process information as provided by the computer reservation system. All of these approaches rely on certain assumptions about the booking process which do not necessarily reflect reality that accurately and therefore introduce an element of uncertainty which affects the entire performance evaluation.

Nevertheless, the above described problem is inherent in any monetary overbooking performance assessment. As soon as costs and revenues rather than absolute numbers of denied boardings and spoiled seats are included, sensible cost assumptions have to be made in order to obtain reasonable results. Since the costs of overbooking are required not only for overbooking performance measurement but also to feed the overbooking model itself, it is even more important to determine the opportunity costs of spoilage and the tangible and intangible costs of oversale as accurately as possible. Whatever assumptions are made, it is essential that the same cost estimations be employed for the overbooking model as its performance measurement. This requirement to estimate the costs opens a wide area of research possibilities which require further attention. In particular, the value of passenger goodwill and the opportunity costs of spoilage are factors which appear to be most difficult to assess. These issues should be therefore covered in future studies.

As discussed in Chapter 3, another problem is the determination of the "true" number of spoiled seats and "true" denied boardings itself. Even though this problem appeared to be trivial at the first glance, we have seen that some airlines deal with inconsistent overbooking data. While failures in the computer reservation system or false data inputs by gate agents can never be precluded, some airlines are obviously faced with systematic errors. Sources for these systematic errors are, first, the adopted definitions of spoilage and oversale itself and, second, the inconsistent application of these definitions. Several definitions of spoilage and oversales were discussed which represent different "levels" of economic perspectives. As the airline objectives of revenue maximization are considered it becomes clear that only the most precise theoretical definitions, True Spoilage/2nd and True Denied Boarding/2nd, accomplish the requirement to express spoilage and denied boardings in the economically correct sense.

Since some airlines do not adopt an uncompromising economic attitude towards overbooking performance evaluation, it must be stressed again that it is essential to apply the definitions at least consistently throughout the data gathering and subsequent evaluation process. The sample of fully booked flights analyzed in Section 3.2 showed that inconsistencies in the definition of spoilage and oversale can distort the overall "picture" severely and will mislead the overbooking performance assessment. Even though the definitions of spoilage and denied boardings presented in this thesis might be perceived to be too aggressive at first glance, it has been made clear and is stated again that only strict economic attitude towards overbooking will lead to reasonable results which are in line with the economic objectives of the airline.

With the establishment of the proper definitions of spoilage and oversales arises also the question what of flights should be included in the performance evaluation. While the determination of the number of spoiled seats and denied boardings depends on the definitions and accurate data recording and reporting, the task to distinguish between relevant and irrelevant flights (as defined in Chapter 3) for the purpose of overbooking performance measurement is more difficult. While there is no doubt that a flight which experienced denied boardings should be included in the evaluation, the problems arise when seats are spoiled. Since it is expected that spoilage cannot occur when a flight was not fully booked, it does not appear correct to include such flights in the overbooking performance appraisal. On the other hand, there is a non zero risk of oversale for every flight where the number of bookings exceeded the availability even though the authorization level has not been reached ($AVL < BKD < AU$). While flights which reached (or even exceeded) the authorized number of bookings must be included in every performance evaluation the question is now whether also flights should be included which exceeded the availability but did not quite reach the authorization level. The methodology illustrated in Chapter 3 to draw a line between relevant and irrelevant flights is certainly unsophisticated and requires further attention. A new approach which tackles the problem more logically has been briefly outlined and should be considered in future research work. As the above described problem it is of central concern for any overbooking performance evaluation, it is recommended that new methodologies be developed which help to distinguish between relevant and irrelevant flights.

However, the main purpose of this thesis was the modeling of a new overbooking performance measurement approach. The Revenue Achievement Model (RAM) proposed in Chapter 4 reflects the "economic spirit" of airline overbooking. It is highly compatible with the most commonly applied overbooking models and hence the airline objectives of revenue maximization. The RAM introduces a new approach to overbooking performance measurement. Rather than focusing on a particular portion of the total revenue potential of a flight (e.g. the Revenue Opportunity for

Overbooking and the Revenue Achievement by Overbooking) the entire revenue achievement of the flight should be kept in mind. This is accomplished by the Revenue Achievement Model, which relies only on the overall revenue generation as indicated as a "monetary load factor", i.e. the actual achieved revenues in relation to the overall revenue potential. Rather than focusing only on a more or less arbitrary chosen portion of the overall revenue potential, the entire revenue potential is subject to the evaluation of the RAM.

The importance of doing so was illustrated in the comparison with the commonly used Revenue Opportunity Approach (ROA). As the Revenue Opportunity for Overbooking is dependent on the actual show-up rate of a flight, the reference basis for every performance assessment is therefore a function of the flight's show-up rate. The associated problems of this dependence on show-up rate have been outlined in Chapter 4 and 5. The ROA performance comparison of two or more flights is unreliable and leads to unjustifiable performance rankings. This is a major shortcoming of the ROA which is overcome by the RAM.

Even more important is the danger that the Revenue Opportunity Approach can affect the set authorization levels in a negative way. Considering the conservative attitude of revenue management analysts who are rather reluctant to increase the authorization level, it is "dangerous" to use the ROA as a performance measurement tool to set objectives. Since the Revenue Opportunity Approach achieves its maximum performance expectations at a sub-optimal (lower) authorization level, it causes an even larger incentive to reduce the authorization level rather than increase it. Hence, the total amount of generated airline revenues can be diminished by the ROA.

Nevertheless, the performance evaluation by the RAM cannot replace the overbooking model itself. The Revenue Achievement Model is intended to measure the overbooking performance and to develop target indices in order to fine tune the inputs of the overbooking model. A proper application of the RAM within the overbooking process is therefore able to prevent sub-optimal outcomes, i.e. revenue achievements which diverge from the maximum possible. Since the target performance index and hence the maximum achievable revenues are dependent on the probabilistic characteristics of the show-up process, the Revenue Achievement Model cannot increase the revenue generation beyond the target value. It is only able to avoid an unnecessary loss of revenues due to inaccurate input data of the overbooking model. The application of the RAM helps to direct all overbooking activities in the "right" direction.

The conception of the Revenue Achievement Model outlined in Chapter 6 opens new opportunities to assess the overbooking performance on an aggregate flight level. As a target performance can be

established for every sample of flights, the actual outcome of every sample can be measured against this target value. This philosophy of a target performance indication has a clear advantage over every other outlined model as it allows airlines to quantify more explicitly the overbooking performance objectives. Since this target performance index is exclusively based on the expected characteristics of all flights of the sample, it is now possible to compare aggregate samples of flights with dissimilar show-up characteristics. Since the mean and standard deviation of the show-up rate vary from flight to flight it might not be possible to compile, subject to other constraints (e.g. flights in a particular region or at a certain time), a sufficiently large sample which is statistically significant. Even worse, it could easily happen that a chosen cross section of the system is not compatible at all (in terms of the show-up features of every single flight) and cannot be aggregated to a sample. Then it would not be feasible to perform an aggregate overbooking performance measurement. Furthermore, it is not clear where to draw the line between flights with equal, similar and dissimilar characteristics. Hence, the here suggested fundamental principle to compare every actual performance index with its calculated target value represents a clear improvement over the models illustrated in Chapter 2.

Nevertheless, this philosophy of comparing the actual performance with a target value results in a limitation of the RAM which is necessary to mention. As the target performance calculation is based on the estimated mean and standard deviation of the show-up rate (μ_{sur} and σ_{sur}), it is required to monitor the actual show-up rates of the considered aggregate sample and adjust the assumed values if deviations between the actual and the expected show-up characteristics occur. As illustrated in Chapter 6, a disregard of the need to correct the target values from time to time, can lead to a comparison of actual and target performance which might result in a permanent over- or under-achievement. In the long-run the objective must be match of the actual aggregate Performance Index with its aggregate Target Performance Index. This is, however, only critical for the aggregate performance evaluation. As there exists no target performance for a overbooking performance measurement on a single flight level, any uncertainty in the estimation of the show-up characteristics of a particular flight does not affect the performance evaluation of single flights.

Finally, the Revenue Achievement Model supports the assessment of revenue management analyst interventions better than previously discussed models by utilizing the absolute gain or loss in revenues. In particular, when system overrides are considered, the absolute change in revenues becomes the best way to express the success of revenue management analysts actions. Since no target value can be determined for these authorization level adjustments by analysts, the fundamental principle of "the more the better" applies. Hence, it is required to have a tool available which expresses the absolute changes in the revenue generation. Therefore, the RAM is an

approach for the evaluation of system overrides. As the absolute revenue gain or loss can be easily obtained by the change in the "monetary load factor", it is relatively simple to determine good and bad authorization level adjustments.

The characteristics of the Revenue Achievement Model underlined the need to replace the current applied models of overbooking performance measurement (if any are applied) by the proposed philosophy to concentrate only on absolute revenue achievements. The RAM directly reflects the airline objectives of revenue maximization. Furthermore, it is highly compatible with the economic based overbooking models which are most commonly employed in the airline industry. As airlines take every action in order to gain more revenues, these improvements cannot be jeopardized by inappropriate overbooking performance measurement approaches.

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