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**TOTAL COST OF OWNERSHIP PURCHASING
OF A SERVICE: THE CASE OF AIRLINE
SELECTION AT ALCATEL BELL**

by

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at Alcatel Bell**

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Abstract

The multiple objective problem of purchasing for business falls into two broad categories: the purchasing of components for manufacturing and the purchasing of services. Several supplier selection models have been suggested in the literature for the purchasing of production-related components. To our knowledge, no supplier selection model for the purchasing of services has been published. In this paper we elaborate on a mathematical programming model that selects suppliers of a multiple item service and simultaneously determines market shares of the suppliers selected. The methodology is based on the collection of Total Cost of Ownership (TCO) information, quantifying all the costs associated with the purchasing process throughout the entire value chain of the firm. We apply this methodology to the real life case study of selecting airlines for 56 destinations at Alcatel Bell and have obtained TCO savings of 19.5%.

OR/MS index:

1. decision support systems: airline selection for business travel
2. transportation: airline selection for business travel

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1. Introduction and Literature Review

The multiple objective problem of purchasing for business falls into two broad categories: the purchasing of components for manufacturing and the purchasing of services. There are three main differences between the purchasing of professional goods and services. Services are intangible and their performance cannot be seen, felt, tasted, inspected or touched in the same manner as goods. Secondly, whereas the production and consumption of goods can be separated, the production and consumption of a service usually occurs simultaneously. Finally, components can be stocked, while services have to be delivered at the moment they are needed. Several supplier selection models have been suggested in the literature for the purchasing of production-related components. For an overview of such models we refer to Weber, Current and Benton (1991) and Degraeve, Labro and Roodhooft (2000). To our knowledge, no supplier selection model for the purchasing of services has been published. However, in today's business environment, a growing proportion of the Gross National Product (GNP) is accounted for by services.

The existing literature on the purchasing of services can be subdivided into three domains: general ideas, surveys on purchasing practices in specific environments and in-depth case studies on purchasing practice.

Firstly, Schonberger (1980) defines a purchasing continuum, from highly tangible goods such as simple production components, e.g. screws, to highly intangible services such as consulting. He suggests that, moving towards intangibility, purchasing contracts can only be based on input and procedural surrogates for quality rather than output standards of quality. Sullivan (1975) and Lebell (1975) discuss how to negotiate contracts for the purchasing of services and they list elements that should be considered. Tinsley and Lewis (1978) suggest evaluating industrial services on performance factors, input factors, output assurance factors and promotion factors, but do not provide any assistance with how to make these assessments. Rosander (1985) discusses quality aspects for several services, including transportation, from the point of view of the service-providing firm which could implement a quality control programme. Parasuraman, Zeithaml and Berry (1988) develop a scale to measure consumer

perceptions of service quality. However, this scale only addresses the quality aspect of the service in a retailing context, rather than in a business-to-business context.

Secondly, three surveys were conducted in different service procurement situations to determine which criteria are used in practice when selecting a supplier for a service. Sarkar and Saleh (1974) find that within the context of selecting a consultant engineer, several “competence” factors – such as knowledge of conditions in the buying organization, experience, quality of previous projects and references from previous clients – have to be supported by “personality” factors, such as capable staff and honest sales personnel. They also find a discrepancy between the buyer’s and the seller’s perception of the relative importance of the selection criteria. For the purchase of warehouse services, Ferguson (1983) comes up with selection criteria such as prompt service, fulfilment of special instructions, accurate record keeping, reputation and previous experience with the supplier. He also sheds some light on how the different members of the buying group interact to select the supplier. Daugherty, Stank and Rogers (1996) identify supplier capabilities for helping out in emergencies, handling change and being flexible as the most important selection criteria for the broad area of logistics services.

Thirdly, two more in-depth case studies about the purchasing of services were also performed. Zemansky (1979) discusses the governmental purchasing of services and devotes special attention to corrupt and illegal activities in this context. West (1997) researches the key purchasing criteria for advertising using in-depth interviews and finds reputation, references, experience, examples of work, current clients, equipment and price to be of prime importance.

We have found only two articles on the purchasing of services that were written within a transportation context. Cavinato (1984) discusses how buyers can negotiate profitable transportation contracts with carriers of goods by paying attention to several criteria. Kleinsorge, Schary and Tanner (1992) elaborate on the use of Data Envelopment Analysis (DEA) for monitoring the relationship with a shipper-carrier over time. However, they do not provide any help with selecting this supplier of a transportation service, but assume the relationship with one carrier to have been established earlier. Both these papers consider the transportation of goods, not of

people. To our knowledge, no scientific papers have been written on the selection of suppliers for business travel.

All of these articles on the purchasing of services are of limited help to the practitioner who has to select a supplier for a particular service, since they either elaborate on quite broad and vague ideas without proposing a practical solution for the problem, or are merely describing current purchasing practice.

In this paper we elaborate on a mathematical programming model that selects suppliers of a multiple item service and simultaneously determines the market shares of the suppliers selected. The methodology is based on the collection of Total Cost of Ownership information, quantifying all the costs associated with the purchasing of airline tickets to business destinations.

The contribution of this paper is fourfold. Firstly, to our knowledge, this is the first model to have been proposed for selecting the suppliers of a service and determining order quantities to be placed with them and to do it for a real life case study, resulting in 19.5% savings on TCO. Purchasing management at Alcatel Bell states that the model is both strategically and operationally valuable. Secondly, due to the diversity of combinations of the various possible discount schemes offered by the airlines, it becomes practically impossible for a human decision-maker to develop even a reasonably good purchasing strategy, exploiting the opportunities offered. In addition, the flexibility of the airline industry that continuously devises new pricing strategies adds to the complexity. We show that the available discount schemes can be considered simultaneously, combined with other TCO elements and optimized from the buyer's viewpoint. Thirdly, the operations research community has researched the airline business extensively from the point of view of the airline itself, from a selling perspective (e.g. Tilanus, 1997; Gang, 1998): scheduling of the flights, pricing strategies, placement of hubs, crew allocation, etc.. To our knowledge, we are the first to present research that looks at the airline business from a customer perspective, making it a novel field of study. Fourthly, we do not adhere to the classical operations research representation of fixed and variable costs in an objective function, but introduce the Activity Based Costing hierarchy from the management accounting literature, where costs become variable at different levels in the organization.

2. The Case of Airline Selection at Alcatel Bell

The service studied at Alcatel Bell, Antwerp, Belgium, is the selection of airlines to cover several destinations. The purchasers in Antwerp decide on all business air travel for all Alcatel personnel in Belgium, a business of approximately BEF 500,000,000 per year (about USD 16,700,000). A choice of 34 different airlines are available, covering 56 different destinations and departing from Brussels. Specifically for this case study, we consider all the data, including the savings, over the decision horizon of one year, because airline pricing policies are fixed for this time period.

In Tables 1, 2 and 3 we present the criteria and costs included in our model using an illustrative example. For confidentiality reasons, we are not allowed to disclose the real-life data. However, the real-life data are used to derive our conclusions, which are presented in sections 4 and 5.

- insert tables 1, 2 & 3 about here -

Purchasing managers are confronted with a complex discounting system, which we describe in this section. First, they are able to negotiate with some airlines on charging lower prices than the IATA (International Air Transport Association) fares for some destinations; these are known as route deals. An example in Table 3 is KLM offering a low price of BEF 15,000 to Zurich. It should be noted that a price on a route deal is not always that attractive, since some other airlines might offer a lower price without calling it a route deal.

Secondly, sometimes Alcatel may receive a back-end volume discount if the market share with an airline for a specific destination exceeds a negotiated percentage. If Alcatel Bell flies with the specific airline on the specific destination for more than this percentage of the turnover on this destination for the year, the company may receive a discount which may reach higher levels for higher market share percentages. Those market share percentages of most companies with the airlines for the various destinations become known as they are collected by IATA under the various Billing and Settlement Plans (BSP) and disclosed to the airlines on a monthly basis. Airlines that offer these discounts depending on market share have contractually agreed with Alcatel Bell that they will provide them with these BSP figures. The main reason for the

existence of these BSPs is, however, to enable the settlement of inter-airline invoices, which is needed when a flight booked with one airline is in fact flown with another airline. The example in Table 3 indicates that, if Alcatel Bell flies to Austin with Alitalia (AZ) for more than 60% of the total number of flights to Austin in that year, the firm will get a 10% back-end discount on the Austin flights from AZ. If they fly more than 70% of the total number of flights to Austin with this airline, they offer a 20% discount. Some airlines give a discount on the volume travelled to a destination irrespective of the market share with this airline for the destination, such as Air France (AF) to Amsterdam.

Thirdly, an additional volume discount on business with a specific airline, irrespective of the destinations travelled, is often offered. Some airlines offer this volume discount on the total volume of Alcatel Bell's business with the airline, while others only offer this additional sales volume discount on destinations that are not subject to front-end route deals, the so-called non-route deal destinations, but do take the sales volume on these route deal destinations into account when determining the relevant discounting percentage. If many destinations are considered route deals and the discount is only offered on non-route deals, a percentage that may at first sight seem high might not generate an enormous amount in monetary terms. Some of the airlines state the levels the total sales volume has to reach in order to be eligible for a certain discount percentage in absolute terms, while others state them in percentages relative to the total sales volume of Alcatel Bell, which again becomes known from the BSP figures collected by IATA. The latter airlines give Alcatel Bell the opportunity of obtaining discounts even if Alcatel's worldwide policy is to cut down the overall level of business travel. Again, the discount percentage offered increases for higher sales volumes. In the remainder of the paper we use the term "absolute volume discount" for the former discount type and "relative volume discount" for the latter type. For example, as can be seen from Table 1, United Airlines (UA) offers an absolute total sales volume discount of 5% if Alcatel Bell purchases tickets from them worth more than BEF 3,000,000 and offers 10% if they buy more than BEF 4,000,000 worth. Lufthansa (LH) calculates the relevant discounting percentage using the total sales volume figure, but applies it only to the non-route deal destinations, in this case Amsterdam, Austin and Rio de Janeiro. Consequently, Tables 1 and 3 show that it offers

an absolute non-route deal sales volume discount of 0.5% on non-route deal turnover when total turnover exceeds BEF 6,000,000. Sabena (SN) states the discount intervals in terms relative to the overall business of Alcatel Bell, offering a relative total sales volume discount. Table 1 illustrates that if more than 50% of the total business is flown with SN, it offers a 6% discount, while if more than 70% is reached, the firm will receive a 7% discount. KLM offers these discounts only on the non-route deals Austin and Bogota, using a relative non-route deal sales volume discount of 10% on the non-route deal turnover when the total turnover reaches 50% or more of the overall business of Alcatel Bell, as indicated in Tables 1 and 3. Observe from these tables that some airlines work with a combination of these different discounting environments, while others stick to a single type of discount.

In our Total Cost of Ownership (TCO) approach, we look not only at price differences between the airlines, but also take into account all the costs that are generated by the airline selection policy in the whole value chain of the purchasing firm. We no longer use the traditional fixed and variable cost objective function, but model a systems approach incorporating several levels of costs in a company-wide objective. These costs can be quantified using an Activity Based Costing method that recognizes a hierarchy among costs that become variable at these different levels. Costs that were previously considered to be fixed can now become variable at a higher level in the hierarchy or in a longer, strategic, time period. Degraeve and Roodhooft (1999) distinguish three hierarchic levels of activities into which the parameters of a purchasing problem can be subdivided: (1) the supplier level, (2) the order level and (3) the unit level. Resources consumed by the activities in the three hierarchic levels together equal the TCO. If fewer activities are performed or fewer resources are consumed by the activities, these resources can be put to an alternative use. In this specific case of purchasing a business travel service, there is no need to recognize order level costs since orders and invoices are not grouped and take place every time a ticket has to be booked. They do not differ between airlines because ordering is done via a travel agency, whose commission is included in the price. To anticipate future changes, we include an alliance level in the model. Most airlines group themselves into alliances in order to be in a better position to respond to competition. Purchasing management expects that from next year onwards some airlines will negotiate at alliance level and also give

discounts based on sales volume with the alliance. As is indicated in the illustrative example in Table 2, purchasing management expects alliances will, as airlines do now, also work with absolute or relative, total or non-route deal sales volume discounts. This is not yet happening for this year's case study but we have prepared the model to deal with this situation and all possible combinations of discounting environments that will probably arise in the very near future. For this specific case, we thus recognize three hierarchic levels: (1) alliance level, (2) airline level, the supplier of the service, and (3) unit level, a return trip to a destination.

Apart from these all unit discounting schemes, the airlines differ on five other criteria. Firstly, the cost of the purchasing manager to manage the relationship with the airline differs substantially. This relationship management includes the preparation of the negotiations, negotiating and follow-up during the year. Negotiations with some airlines take a long time, while others only require a short time investment by the purchasing management. Some airlines require monthly follow-up reports while others only request them on a quarterly basis. For example, as is indicated in Table 1, the purchasing manager spends 8 hours a year managing the relationship with Cathay Pacific (CX), at a wage cost of BEF 2,000 per hour. For this year's case study, the cost of this purchasing manager is recognized at airline level, since none of the airlines yet negotiates at alliance level. However, we expect that from next year onwards, this cost will shift to alliance level for some airlines, as is indicated in Table 2 for alliances All1, All2, Star and Atlantic. Secondly, the duration of the flights to the same destination differs from airline to airline because of other routes, stopovers or non-direct flights. When the flight time is longer than the shortest possible, these "lost" minutes will be weighted by the gross wage per minute of the employees flying for Alcatel Bell and included in the modelling section of the paper in the so-called "additional unit level costs", as opposed to the bare monetary purchasing costs that also apply at unit level. In the example in Table 3, we can see that AZ offers the shortest flight to Rio de Janeiro, whereas if we were to fly with AF to that destination it would take us 40 minutes longer. These figures are weighted with the average gross wages of BEF 33.33 per minute. Thirdly, Alcatel Bell places its business travel orders through one travel agency, whose profit flows entirely back to the firm, as stated in the contract. The revenues of the agency are variable and come from the commissions that are already included in the

quoted airline ticket price and the overrides paid by the airlines to the travel agency as a percentage of the ticket price. Overrides are paid by the airlines to the travel agency and give the latter an incentive to book tickets with them. Usually, these override percentages range from 0 to 9% and are higher for the airlines with which Alcatel Bell has not negotiated discounts or route deals, giving Alcatel Bell an incentive to book tickets with these airlines anyway. This is illustrated in Table 1, where Delta Airlines (DL), with which no route deals or discounts are negotiated, offers a high override of 9%, whereas the overrides of the other airlines range from 0 to 6%. The cost of the agency is fixed in annual negotiations and includes a sum to cover all expenses and a management fee. The figures used in the example are BEF 500,000 and 20,000 respectively. This “open book” management fee relationship with the travel agency was introduced in October 1998, whereas beforehand a profit-sharing system was in operation under which the agency received incentives to buy expensive tickets. Fourthly, airlines have a different number of flights per week to each of the destinations, providing reduced or increased flexibility in choosing the appropriate day and time for the flight. Finally, not every airline flies to all destinations, for example Table 3 shows that UA does not fly to Amsterdam. Criteria two to five are considered at the unit level.

The airlines do not differ on several other criteria. Firstly, the payment delay offered by all airlines is 30 days. Secondly, ordering and invoicing costs are the same since every ticket is booked with the travel agency whenever a trip is necessary, a minimum of three days in advance. The travel agencies do all the ordering and invoicing and therefore incur these costs. The revenues of the travel agency consist of a variable and a fixed part. The variable part is a commission per return ticket, which is already included ex ante in the price data. The grouping of orders would not help Alcatel Bell save on ordering costs, since they still have to pay the same commission per return ticket, irrespective of the number of tickets ordered at the same time. The fixed revenues are a management fee and a sum to cover their costs, which are negotiated ex ante for the whole year. Thirdly, since all airlines invoice in Belgian francs, there is no exchange risk. Fourthly, the quality of meals and other services is considered the same for all airlines when flying under the same level of comfort, i.e. economy vs. business class.

We have not included the differences in punctuality and delays between airlines, although, as will be shown, these are quite easy to model. It is very difficult to obtain

objective data for these delays⁽¹⁾. We have also deliberately chosen not to include the differences in frequent flyer programmes (FFPs) in our model because FFP benefits only accrue to the traveller and not to the company for which he/she is travelling⁽²⁾.

The airline selection model presented in this paper was developed in two phases over the course of an 18-month period. In the first phase, which took about 7 months, a pilot study involving 18 airlines and 34 destinations was modelled and developed. An in-depth comparison of the resulting optimum suggested policy with the purchasing policy currently implemented at Alcatel Bell demonstrated savings of more than 22% on the yearly budget. Based on the pilot study, the purchasing manager for general expenses decided that it was worth the data collection effort and time spent and gave the green light for the extension of the case to 34 airlines and 56 destinations. Also, several extra features were added to the model following discussions with management. The fact that the 19.5% savings, obtained after the second phase of the study, were lower than the savings shown in the pilot study can be attributed to two reasons. Firstly, purchasing management had already started developing a policy for some of the destinations in the pilot case based on the information from the pilot study and in this way had already achieved some of the savings indicated. Secondly, the costs and profits of the relationship with the travel agency were not modelled in the pilot case.

3. The Total Cost of Ownership Model

In this section, we present the mathematical programming decision model that will be used to determine an optimum sourcing strategy for business travel at Alcatel Bell. This model generates a purchasing policy that minimizes the Total Cost of Ownership taking into account different constraints relevant to the problem.

Before stating the model, we provide a summary of the notation for later reference.

For the alliances and the airlines:

- c : symbol referring to the alliances,
- s : symbol referring to the airlines,
- a : symbol indicating absolute discounts,
- r : symbol indicating relative discounts,
- n : index denoting alliances, $n=c$, or airlines, $n=s$,
- p : index denoting absolute, $p=a$, or relative, $p=r$, discounts,

- l : index denoting an alliance of a specific discounting type,
 $T(n,p)$: set of alliances, $n=c$, or airlines, $n=s$, offering total absolute, $p=a$, or relative, $p=r$, sales volume discounts, index i ,
 $N(n,p)$: set of alliances, $n=c$, or airlines, $n=s$, offering non-route deal absolute, $p=a$, or relative, $p=r$, sales volume discounts, index i ,
 A : set of alliances, $A = T(c, p) \cup N(c, p)$, $p=a,r$, index i ,
 S : set of airlines, $S = T(s, p) \cup N(s, p)$, $p=a,r$, index i ,
 $M(n)_i$: set of discount intervals for alliance and airline i , $n=c,s$, $p=a,r$, $\forall i \in T(n, p), \forall i \in N(n, p)$ index k ,
 $ET(c,p)_l$: set of airlines in alliance l offering absolute or relative total sales volume discounts, $p=a,r$, index i ,
 $EN(s,p)_l$: set of airlines in alliance l offering absolute or relative non-route deal sales volume discounts, $p=a,r$, index i .

For the destinations:

- B : set of destinations to be covered, index j ,
 $BN_{EN(c,p)}$: set of non-route deal destinations for the airlines that belong to an alliance offering absolute or relative non-route deal sales volume discounts, $BN_{EN(c,p)} \subseteq B$, $p=a,r$, index j .

The parameters indicate the data required. At the first hierarchic level, the alliance level, the parameters describe costs incurred and conditions imposed whenever the purchasing company actually uses the alliance over the decision horizon.

- mah_i : annual hours of a dedicated purchasing manager for alliance i incurred for the time devoted to managing and negotiating the business travel problem, $\forall i \in A$,
 wp : gross hourly wages of the purchasing manager who manages and negotiates business travel,
 alc : total alliance level costs per year,
 $alcs_i$: alliance level costs for alliance i , $\forall i \in A$,
 ca_i : number of intervals for sales volume discounts, $\forall i \in A$.

At the second hierarchic level, the airline level, the parameters describe costs incurred and conditions imposed whenever the purchasing company actually uses the airline over the decision horizon.

ls	: minimum number of suppliers to be used over the time horizon,
us	: maximum number of suppliers to be used over the time horizon,
we	: average gross hourly wage of employees flying for Alcatel Bell,
nc_j	: number of carriers per destination,
pa	: profit by travel agency,
ra	: revenue of travel agency,
ea	: expenses of travel agency,
mgf	: management fee for travel agency,
slc	: total airline level costs per year,
$slcs_i$: airline level costs for airline i , $\forall i \in S$,
msh_i	: annual hours of a dedicated purchasing manager for airline i incurred for the time devoted to managing and negotiating the business travel problem, $\forall i \in S$,
cj_i	: number of price intervals for total sales volume discounts, $\forall i \in S$,
tu_i	: turnover with airline without discounts taken into account, $\forall i \in S$,
com_i	: commission to travel agency already included in price of airline ticket in percentages, $\forall i \in S$,
o_i	: override to travel agency from airline in percentages, $\forall i \in S$.

At the third hierarchic level, the unit level, the parameters specify costs incurred and conditions imposed with respect to the individual return tickets for a specific destination. At this level, we consider:

p_{ij}	: price offered by airline i for destination j , $\forall i \in S$, $\forall j \in B$,
d_j	: estimated annual demand for destination j in number of return tickets, $\forall j \in B$,
ms_j	: minimum market share for every airline selected to destination j , $\forall j \in B$,
so_{ij}	: extra minutes of trip due to other routes, stopovers or non-direct flights in comparison to shortest trip possible, $\forall i \in S$, $\forall j \in B$,
nf_{ij}	: number of flights available per week, $\forall i \in S$, $\forall j \in B$,
md_{ij}	: mean delay when flying with airline i to destination j , $\forall i \in S$, $\forall j \in B$,
$purc$: total monetary purchase costs per year,

- $aulc$: the additional unit level costs generated per year,
 ulc : total unit level costs per year,
 c_{ij} : number of intervals for destination-specific quantity breaks, $\forall i \in S, \forall j \in B$.

In the next section, we introduce the parameters necessary for modelling the different types of discount.

For the total sales volume discounts with an alliance and airline i , $\forall i \in T(n, p)$, $n = c, s$; $p = a, r$ and for each discount interval k , $\forall k \in M(n)_i$, we consider:

- $lt(n, p)_{ik}$: minimum quantity to be bought in the discount interval k in monetary terms,
 $ut(n, p)_{ik}$: maximum quantity to be bought in the discount interval k in monetary terms,
 $dct(n, p)_{ik}$: price discount as a percentage in discount interval k .

For the non-route deal sales volume discounts with an alliance and airline i , $\forall i \in N(n, p)$, $n = c, s$; $p = a, r$ and for each discount interval k , $\forall k \in M(n)_i$, we consider:

- $ln(n, p)_{ik}$: minimum quantity to be bought buy in the discount interval k in monetary terms,
 $un(n, p)_{ik}$: maximum quantity to be bought in the discount interval k in monetary terms,
 $dcn(n, p)_{ik}$: price discount as a percentage in discount interval k .

For the discount on specific individual destinations with an airline when exceeding a certain market share, we consider $\forall i \in S, \forall j \in B, \forall k \in M(s)_i$:

- lms_{ijk} : minimum market share to be bought in discount interval k in percentages per destination,
 ums_{ijk} : maximum market share to be bought in discount interval k in percentages per destination,
 lb_{ijk} : minimum quantity to be bought in discount interval k in monetary terms per destination,
 ub_{ijk} : maximum quantity to be bought in discount interval k in monetary terms per destination,

dc_{ijk} : price discount as a percentage in discount interval k per destination.

The decision variables can also be subdivided into the same three hierarchic levels. The alliance level decision variable indicates whether or not the alliance will be used by the purchasing company over the planning horizon and is as follows:

$z(c)_i$ = 1, if we select alliance i , 0, otherwise, $\forall i \in A$.

The airline level decision variable indicates whether or not the supplier will be used by the purchasing company over the planning horizon and is as follows:

$z(s)_i$ = 1, if we select airline i , 0, otherwise, $\forall i \in S$.

The unit level decision variables pertain to the number of return tickets for a destination for which a procurement decision has to be made and are defined as follows:

x_{ij} = number of return tickets to destination j bought from airline i , $\forall i \in S$,
 $\forall j \in B$,

y_{ij} = 1, if we fly to destination j with airline i , 0, otherwise, $\forall i \in S$, $\forall j \in B$,

$xm(s)_i$ = total purchases from airline i in monetary terms, taking destination-specific and airline volume discounts into account, $\forall i \in S$,

$xm(c)_i$ = total purchases from alliance i in monetary terms, taking destination-specific, airline volume and alliance volume discounts into account, $\forall i \in A$.

Decision variables for the alliances and airlines offering total sales volume discounts are as follows, $\forall i \in T(n, p), \forall k \in M(n)_i, n = c, s; p = a, r$:

$wt(n, p)_{ik}$ = 1, if we order in total sales volume discount interval k for alliance or airline i , 0, otherwise,

$xt(n, p)_{ik}$ = total amount ordered in total sales volume discount interval k for alliance or airline i in monetary terms.

Decision variables for the alliances and airlines offering non-route deal sales volume discounts are as follows, $\forall i \in N(n, p), \forall k \in M(n)_i, n = c, s; p = a, r$:

$wn(n, p)_{ik}$ = 1, if we order in sales volume discount interval k for alliance or airline i , 0, otherwise,

$xn(n, p)_{ik}$ = total amount ordered in sales volume discount interval k for alliance or airline i in monetary terms,

vn_{ik} = total amount ordered in sales volume discount interval k to the non-route deal destinations for alliance or airline i in monetary terms.

For alliances and airlines offering relative, $p=r$, volume discounts, we also define, $\forall k \in M(n)_i, n=c, s$:

$kr(n,r)_{ik}$ = total sales volume, if $wt_{ik} = 1$, 0, otherwise, $\forall i \in T(n,r)$,

$lr(n,r)_{ik}$ = total sales volume, if $wn_{ik} = 1$, 0, otherwise, $\forall i \in N(n,r)$.

Decision variables for the airlines offering destination-specific discounts are as follows, $\forall i \in S, \forall j \in B, \forall k \in M(s)_i$;

w_{ijk} = 1, if we order in destination j specific discount interval k with airline i ,
0, otherwise,

xd_{ijk} = total amount ordered in destination j specific discount interval k with airline i in monetary terms.

With the notation given above, the mathematical decision model is described below.

Objective : minimize the Total Cost of Ownership over the time horizon;

$$\text{Min } alc + slc + ulc \quad (1)$$

The objective function (1) is a minimization of the Total Cost of Ownership and reflects net prices and resources consumed by the activities in the three hierarchic levels distinguished.

Define the annual alliance level costs;

$$alc = \sum_{i \in A} mah_i z(c)_i wp \quad (2)$$

The alliance level costs are incurred whenever the purchasing company actually uses alliance i over the planning horizon, i.e. $z(c)_i = 1$. The time spent by a dedicated purchasing manager on negotiating, managing and following up the relationship with alliance i can be put to some alternative use if alliance i is not chosen, i.e. $z(c)_i = 0$. In this case, the specific activities of these purchasing managers should not be considered in the purchasing decision. The gross hourly wage of the purchasing manager is multiplied by the number of hours he estimates are consumed in managing the relationship with alliance i . If the negotiations are not at alliance level, mah_i is equal to 0.

Define the annual supplier level costs;

$$slc = \sum_{i \in S} msh_i * wp * z_i \quad (3)$$

The supplier level costs are incurred whenever the purchasing company actually uses airline i over the planning horizon, i.e. $z_i = 1$. Again, the time spent by a dedicated purchasing manager on negotiating, managing and following up the relationship with airline i can be put to some alternative use if supplier i is not chosen, i.e. $z_i = 0$. If the negotiations do not take place at airline level, msh_i is equal to 0.

Define the unit level costs over the time horizon;

$$ulc = purc + aulc - pa \quad (4)$$

Specifically, the unit level costs consist of the annual purchase costs and the annual “additional” unit level costs minus the annual profit of the travel agency that flows back to the purchasing firm.

Define the annual purchasing costs;

$$purc = \sum_{i \in A} xm(c)_i \quad (5)$$

The annual purchasing costs are equal to the sum of all purchases made from the alliances, taking all discounts into account. We will discuss the modelling of these discounts in a subsequent section of the paper.

Define the annual additional unit level costs;

$$aulc = \sum_{i \in S} \sum_{j \in B} (so_{ij} + md_{ij}) \frac{we}{60} x_{ij} \quad (6)$$

Additional unit level costs are incurred when flight time is longer than necessary due to other routes, stopovers and non-direct flights. These “lost” minutes are weighted with the average gross wage per minute of the employees flying for Alcatel Bell. As is indicated in (6), the mathematical formulation of the model can easily include delay figures but, as explained earlier, we decided not to take punctuality problems with the airlines into account because of the subjectivity of the data.

Define the annual profit made by the travel agency that flows back to the firm;

$$pa = ra - ea - mgf \quad (7a)$$

$$ra = \sum_{i \in S} \sum_{j \in B} \left(com_i + \frac{o_i}{1 + com_i} \right) p_{ij} x_{ij} \quad (7b)$$

As explained earlier and indicated in (7b), the revenues of the travel agency are variable and come from commissions com_i already included in the quoted airline ticket price and

overrides o_i paid by the airlines to the agency as a percentage of ticket price. The cost of the travel agency is fixed in annual negotiations and consists of a sum to cover all expenses and a management fee.

This concludes the derivation of the objective function. The constraints relevant to the procurement problem of business travel trips are as follows.

Satisfy the demand;

$$\sum_{i \in S} x_{ij} = d_j \quad \forall j \in B \quad (8)$$

This constraint (8) will determine that the sum of all business trips flown to a certain destination equals the demand for this destination.

Enforce the limits on the number of suppliers used;

$$\sum_{i \in S} z(s)_i \geq ls \quad (9a)$$

$$\sum_{i \in S} z(s)_i \leq us \quad (9b)$$

$$z(s)_i \leq \sum_{j \in B} x_{ij} \quad \forall i \in S \quad (9c)$$

$$x_{ij} \leq d_j z(s)_i \quad \forall i \in S, \forall j \in B \quad (9d)$$

The conditions (9a) and (9b) force the purchasing plan to contain at least the minimum number ls , and at most the maximum number us , of airlines over the time horizon. Using constraint (9c), the decision variable $z(s)_i$ will be equal to 0, if the model chooses not to fly with airline i , while constraint (9d) forces $z(s)_i$ to be equal to 1 if business travellers fly with airline i to any of the destinations.

Impose the minimum number of airlines and their market share per destination;

$$\sum_{i \in S} y_{ij} \geq nc_j \quad \forall j \in B \quad (10a)$$

$$x_{ij} \geq ms_j d_j y_{ij} \quad \forall i \in S, \forall j \in B \quad (10b)$$

$$x_{ij} \leq d_j y_{ij} \quad \forall i \in S, \forall j \in B \quad (10c)$$

Condition (10a) imposes a minimum number of carriers per destination, which can vary across destinations. Conditions (10b) and (10c) impose a minimum market share for each airline flown with to a destination and, at the same time, enforces proper relations between x_{ij} and the binary variable y_{ij} .

Model the proper relations between the binary variables $z(s)_i$ and $z(c)_i$, $p=a,r$;

$$z(c)_i \leq \sum_{i \in ET(c,p)_i} z(s)_i \quad \forall i \in T(c,p) \quad (11a)$$

$$z(c)_i \geq z(s)_i \quad \forall i \in T(c,p), \forall i \in ET(c,p)_i \quad (11b)$$

$$z(c)_i \leq \sum_{i \in EN(c,p)_i} z(s)_i \quad \forall i \in N(c,p) \quad (11c)$$

$$z(c)_i \geq z(s)_i \quad \forall i \in N(c,p), \forall i \in EN(c,p)_i \quad (11d)$$

Conditions (11a) and (11c) force $z(c)_i$ to 0 if nothing is ordered with any of the corresponding alliance members. Conditions (11b) and (11d) imply that $z(c)_i$ will be 1 if any of their airline members is selected by the purchasing firm.

In the following section we model the different types of discounts offered by the airlines. Expressions (12a) to (12d) model the discount an airline offers when Alcatel Bell flies more than a specific market share percentage with that airline on a particular destination.

$$\sum_{k \in M(s)_i} x d_{ijk} = p_{ij} x_{ij} \quad \forall i \in S, \forall j \in B \quad (12a)$$

$$x d_{ijk} \geq lms_{ijk} d_j p_{ij} w_{ijk} \quad \forall i \in S, \forall j \in B, \forall k \in M(s)_i \quad (12b)$$

$$x d_{ijk} \leq ums_{ijk} d_j p_{ij} w_{ijk} \quad \forall i \in S, \forall j \in B, \forall k \in M(s)_i \quad (12c)$$

$$\sum_{k \in M(s)_i} w_{ijk} = z(s)_i \quad \forall i \in S, \forall j \in B \quad (12d)$$

Expression (12a) computes the total amount bought over all discount intervals. Constraints (12b) and (12c) impose the lower and upper limits of the market share discount intervals respectively, ensuring that the binary variable w_{ijk} is equal to 1 in only one discount interval. Constraint (12d) ensures that we cannot obtain discounts on a destination if we do not fly with the airline. Destination-specific discounts offered irrespective of the market share which the airline has for this destination are included here by setting the lower limit of the market share to zero.

Expressions (13a) to (13u) model the discounts offered by the airlines on sales volume. Expressions (13a) and (13b) compute the total purchases per airline taking the destination-specific discounts into account, grouping them per airline discounting type, for $p=a,r$.

$$\sum_{k \in M(s)_i} x t_{ik} = \sum_{j \in B} \sum_{k \in M(s)_i} (1 - dc_{ijk}) x d_{ijk} \quad \forall i \in T(s,p) \quad (13a)$$

$$\sum_{k \in M(s)_i} xn(s, p)_{ik} = \sum_{j \in B} \sum_{k \in M(s)_i} (1 - dc_{ijk}) xd_{ijk} \quad \forall i \in N(s, p) \quad (13b)$$

Compute the total purchases on non-route deal destinations, for $p=a, r$;

$$\sum_{k \in M(s)_i} vn(s, p)_{ik} = \sum_{j \in BN_{EV}(c, p)} \sum_{k \in M(s)_i} (1 - dc_{ijk}) xd_{ijk} \quad \forall i \in N(s, p) \quad (13c)$$

Expression (13c) computes the total purchases on non-route deal destinations for airlines offering absolute and relative non-route deal sales volume discounts.

Set the limits of the absolute, $p=a$, sales discount intervals for airlines, $n=s$;

$$xt(n, a)_{ik} \geq lt(n, a)_{ik} wt(n, a)_{ik} \quad \forall i \in T(n, a), \forall k \in M(n)_i \quad (13d)$$

$$xt(n, a)_{ik} \leq ut(n, a)_{ik} wt(n, a)_{ik} \quad \forall i \in T(n, a), \forall k \in M(n)_i \quad (13e)$$

$$xn(n, a)_{ik} \geq ln(n, a)_{ik} wn(n, a)_{ik} \quad \forall i \in N(n, a), \forall k \in M(n)_i \quad (13f)$$

$$xn(n, a)_{ik} \leq un(n, a)_{ik} wn(n, a)_{ik} \quad \forall i \in N(n, a), \forall k \in M(n)_i \quad (13g)$$

$$vn(n, a)_{ik} \leq un(n, a)_{ik} wn(n, a)_{ik} \quad \forall i \in N(n, a), \forall k \in M(n)_i \quad (13h)$$

Constraints (13d) and (13e) impose lower and upper limits on the absolute total sales volume discounts, whereas (13f) through (13h) do the same for the absolute non-route deal sales volume discounts. Notice in (13d) to (13g) that the total sales volume, including the sales volume on route deal destinations, is taken into account to determine the valid discount interval.

Set the limits of the relative, $p=r$, sales volume discount intervals for airlines, $n=s$;

$$xt(n, r)_{ik} \geq lt(n, r)_{ik} wt(n, r)_{ik} \sum_{i \in S} \sum_{j \in B} \sum_{k \in M(n)_i} xd_{ijk} \quad \forall i \in T(n, r), \forall k \in M(n)_i \quad (A)$$

$$xt(n, r)_{ik} \leq ut(n, r)_{ik} wt(n, r)_{ik} \sum_{i \in S} \sum_{j \in B} \sum_{k \in M(n)_i} xd_{ijk} \quad \forall i \in T(n, r), \forall k \in M(n)_i \quad (B)$$

$$xn(n, r)_{ik} \geq ln(n, r)_{ik} wn(n, r)_{ik} \sum_{i \in S} \sum_{j \in B} \sum_{k \in M(n)_i} xd_{ijk} \quad \forall i \in N(n, r), \forall k \in M(n)_i \quad (C)$$

$$xn(n, r)_{ik} \leq un(n, r)_{ik} wn(n, r)_{ik} \sum_{i \in S} \sum_{j \in B} \sum_{k \in M(n)_i} xd_{ijk} \quad \forall i \in N(n, r), \forall k \in M(n)_i \quad (D)$$

$$vn(n, r)_{ik} \leq un(n, r)_{ik} wn(n, r)_{ik} \sum_{i \in S} \sum_{j \in B} \sum_{k \in M(n)_i} xd_{ijk} \quad \forall i \in N(n, r), \forall k \in M(n)_i \quad (E)$$

Conditions (A) to (E) are non-linear because decision variables directly relating to x_{ijk} are multiplied together. Since we cannot efficiently use constraints (A) to (E) in a linear integer optimization package, we introduce conditions to formulate the bounds of the relative discount intervals in a linear fashion. This is performed as follows. Define

$kr(n, r)_{ik} = wt(n, r)_{ik} \sum_{i \in S} \sum_{j \in B} \sum_{k \in M(n)_i} xd_{ijk}$, then we need constraints that

effectively force $kr(n, r)_{ik} = \sum_{i \in S} \sum_{j \in B} \sum_{k \in M(n)_i} xd_{ijk}$ when $wt(n, r)_{ik} = 1$ and $kr(n, r)_{ik} = 0$ when

$wt(n, r)_{ik} = 0$. This is performed as given below.

Set the limits of the relative, $p=r$, sales volume discount intervals for airlines, $n=s$;

$$xt(n, r)_{ik} \geq lt(n, r)_{ik} kr(n, r)_{ik} \quad \forall i \in T(n, r), \forall k \in M(n)_i \quad (13i)$$

$$xt(n, r)_{ik} \leq ut(n, r)_{ik} kr(n, r)_{ik} \quad \forall i \in T(n, r), \forall k \in M(n)_i \quad (13j)$$

$$xn(n, r)_{ik} \geq ln(n, r)_{ik} lr(n, r)_{ik} \quad \forall i \in N(n, r), \forall k \in M(n)_i \quad (13k)$$

$$xn(n, r)_{ik} \leq un(n, r)_{ik} lr(n, r)_{ik} \quad \forall i \in N(n, r), \forall k \in M(n)_i \quad (13l)$$

$$vn(n, r)_{ik} \leq un(n, r)_{ik} lr(n, r)_{ik} \quad \forall i \in N(n, r), \forall k \in M(n)_i \quad (13m)$$

$$kr(n, r)_{ik} \leq \sum_{i \in S} \sum_{j \in B} \sum_{k \in M(n)_i} xd_{ijk} \quad \forall i \in T(n, r), \forall k \in M(n)_i \quad (13n)$$

$$kr(n, r)_{ik} \leq B wt(n, r)_{ik} \quad \forall i \in T(n, r), \forall k \in M(n)_i \quad (13o)$$

$$kr(n, r)_{ik} \geq \sum_{i \in S} \sum_{j \in B} \sum_{k \in M(n)_i} xd_{ijk} - B + B wt(n, r)_{ik} \quad \forall i \in T(n, r), \forall k \in M(n)_i \quad (13p)$$

$$lr(n, r)_{ik} \leq \sum_{i \in S} \sum_{j \in N} \sum_{k \in M(n)_i} xd_{ijk} \quad \forall i \in N(n, r), \forall k \in M(n)_i \quad (13q)$$

$$lr(n, r)_{ik} \leq B wn(n, r)_{ik} \quad \forall i \in N(n, r), \forall k \in M(n)_i \quad (13r)$$

$$lr(n, r)_{ik} \geq \sum_{i \in S} \sum_{j \in B} \sum_{k \in M(n)_i} xd_{ijk} - B + B wn(n, r)_{ik} \quad \forall i \in N(n, r), \forall k \in M(n)_i \quad (13s)$$

Constraints (13i) and (13j) set the lower and upper limits of the relative total sales discount intervals. Constraints (13k) to (13n) do the same for the relative non-route deal sales discount intervals. If we do not buy in a specific relative total discount interval, i.e. $wt(n, r)_{ik} = 0$, constraints (13r) and (13s) force $kr(n, r)_{ik}$ to be zero as well, where B is a large number. If we buy in a specific relative discount interval, i.e. $wt(n, r)_{ik} = 1$, constraints (13q) and (13s) force $kr(n, r)_{ik}$ to assume the value of the total sales volume. Since the total sales volume is also taken into account in determining the relevant discounting interval constraints for the relative non-route deal discounts, (13q), (13r) and (13s) provide a similar linearization in this discounting environment.

If we fly with the airline, we fly within a given sales volume discount interval, for $n=s$ and $p=a, r$;

$$\sum_{k \in M(n)_i} wt(n, p)_{ik} = z(n)_i \quad \forall i \in T(n, p) \quad (13t)$$

$$\sum_{k \in M(n)_i} wn_{ik} = z(n)_i \quad \forall i \in N(n, p) \quad (13u)$$

In (14a) and (14b) we compute the total purchases per airline, $n=s$, also taking the sales volume discount into account, for $p=a, r$;

$$xm(n, p)_i = \sum_{k \in M(n)_i} (1 - dct(n, p)_{ik}) * xt(n, p)_{ik} \quad \forall i \in T(n, p) \quad (14a)$$

$$xm(n, p)_i = \sum_{k \in M(n)_i} (1 - dcn(n, p)_{ik}) * vn(n, p)_{ik} + (xn(n, p)_{ik} - vn(n, p)_{ik}) \quad \forall i \in N(n, p) \quad (14b)$$

Specifically, expression (14b) only calculates the discounting percentage on the non-route deal destinations for these airlines with a non-route deal sales volume discount scheme.

On top of the destination-specific and sales volume airline discounts, the model is also prepared to accommodate discounts offered by alliances. Alliances are expected to offer absolute or relative, total or non-route deal destination discounts in the very near future. Expressions (15a) to (15e) model these potential alliance discount schemes on sales volume. Expressions (15a) and (15b) compute the total purchases per alliance, grouping them per alliance discounting type, for $p=a, r$.

$$\sum_{k \in M(c)_i} xt(c, p)_{ik} = \sum_{i \in ET(c, p)_i} xm(s, p)_i \quad \forall i \in T(c, p) \quad (15a)$$

$$\sum_{k \in M(c)_i} xn(c, p)_{ik} = \sum_{i \in EN(c, p)_i} xm(s, p)_i \quad \forall i \in N(c, p) \quad (15b)$$

Compute the total purchases to non-route deal destinations, for $p=a, r$;

$$\sum_{k \in M(c)_i} vn(c, p)_{ik} = \sum_{i \in EN(c, p)_i} \sum_{k \in M(s)_i} (1 - dcn(s, p)_{ik}) vn(s, p)_{ik} \quad \forall i \in N(c, p) \quad (15c)$$

Expression (15c) computes the total purchases to non-route deal destinations for alliances offering absolute and relative non-route deal sales volume discounts.

To set the limits of the absolute sales discount intervals for alliances, expressions (13d) to (13h) are repeated for $n=c$ and $p=a, r$.

When setting the limits of the relative sales volume discount intervals for alliances, a non-linear problem similar to that in conditions (A) to (E) is encountered and resolved in the model as previously in conditions (13i) to (13s), this time with $n=c$ and $p=a, r$.

In order to make sure that if we fly with an alliance, we fly in a sales volume discount interval, we repeat expressions (13t) and (13u) for $n=c$ and $p=a,r$.

Subsequently, the total purchases per alliance, also taking the alliance sales volume discount into account, are computed as in (14a) and (14b) but now for $n=c$ and $p=a,r$. The resulting $xm(c,p)_i$ for $p=a,r$ figures are then fitted into expression (5).

In order to conclude the model specification, constraints (16a) to (16i) impose the proper integrity and non-negativity conditions that apply to the decision variables. For all $n=c,s$ and $p=a,r$:

$$z(n)_i \in \{0,1\} \quad \forall i \in A, \forall i \in S \quad (16a)$$

$$y_{ij} \in \{0,1\} \quad \forall i \in S, \forall j \in B \quad (16b)$$

$$xm(n,p)_i \geq 0 \quad \forall i \in T(n,p), \forall i \in N(n,p) \quad (16c)$$

$$x_{ij} \geq 0, xd_{ijk} \geq 0, w_{ijk} \in \{0,1\} \quad \forall i \in S, \forall j \in B, \forall k \in M(s)_i \quad (16d)$$

$$wt(n,p)_{ik} \in \{0,1\}, xt(n,p)_{ik} \geq 0, kr(n,p)_{ik} \geq 0 \quad \forall i \in T(n,p) \quad (16e)$$

$$wn(n,p)_{ik} \in \{0,1\}, xn(n,p)_{ik} \geq 0, vn(n,p)_{ik} \geq 0, kn(n,p)_{ik} \geq 0 \quad \forall i \in N(n,p) \quad (16f)$$

Model (1) - (16f) is a mixed integer linear program that can be solved with specialist optimization software such as LINGO (Cunningham and Schrage, 1995) on any IBM-compatible 486 or higher PC. The current dimensions of the problem are 56 different destinations which can be reached on 34 airlines and a maximum of three times 9 discount intervals, resulting in 10,204 variables, of which 4,084 integers, 16,268 constraints and 44,595 non-users. This model and the scenarios discussed in section 5 are solved in LINGO version 6.0 on a Pentium II 400 MHz machine with 128 RAM in approximately two hours each. The gap between the LP relaxation and the optimal integer solution is slightly less than 3%. An Excel interface with Object Linking and Embedding (OLE) technology allows data input in a user-friendly way. The Excel output sheet gives information on the TCO, divided into alliance level costs, airline level costs and unit level costs. The unit level costs are subdivided into monetary costs, longer trip costs and travel agency profit. For each alliance, airline and total bare turnover without discounts, the discounts - subdivided into alliance volume, airline volume and destination specific discounts - and the actual sum paid are given. A graphical representation of this helps us interpret these figures. For each airline and

volume discount type, it is made clear which discounting interval is attained. An indicative number of tickets to order with the airline on a destination and the market share of the airlines on the destinations are also reported.

4. Results

In Tables 4, 5 and 6 we summarize the results for the optimum policy of the illustrative case to illustrate some general strategies which also arise from the real-life Alcatel Bell case, which we are not allowed to present in such detail for reasons of confidentiality.

- insert tables 4, 5 and 6 about here -

The Total Cost of Ownership of the optimum policy for these imaginary data is BEF 8,623,084 and consists of BEF 120,000 alliance level costs, these being the management costs for the selected alliances All1 and All2, BEF 16,000 airline level costs, these being the management cost for the selected airline CX and BEF 8,487,084 unit level costs. The unit level costs consist of BEF 9,206,350 monetary costs paid to the alliances (Table 6) and airlines, BEF 43,833 longer trip costs and BEF 763,100 profit flowing back from the travel agency to the purchasing firm. As indicated in Table 4, the optimum policy proposes single or dual sourcing for all destinations, making complete use of the available destination-specific discounts. Tables 5 and 6 also illustrate that the ideal strategy is to buy just on or slightly above the lower limit of a sales volume discount interval and then spend the additional BEF on another airline to reach a higher discount interval for that airline as well. BEF 4,000,000 is spent with CX, thus just reaching the lower limit of the discount interval for receiving the 6% total sales volume discount (Table 5). Subtracting the destination-specific discount from the overall turnover with KLM, leaves the purchasing firm with a market share of 50.075% with KLM, slightly above the required 50% to entitle it to a 10% sales volume discount on the non-route deal destinations (Table 5). The amount spend with ALL2 is also slightly above the BEF 5,000,000 cut-off and results in a 2% total sales volume discount (Table 6).

In Table 7 we summarize the results of the optimum policy for the real-life Alcatel Bell case and compare these to the current policy. To preserve confidentiality, we express all figures as percentages of the Total Cost of Ownership of the optimum policy and indicate airlines and destinations with numbers.

-insert table 7 about here-

The optimum airline selection policy narrows down the supplier base from 34 to 9 airlines and proposes single sourcing for most of the destinations. For only one destination is the market share split between two airlines. As we can see from Table 7, the Total Cost of Ownership is dominated by the purchasing costs at unit level in this case. Savings of 19.5% compared to the current purchasing of airline tickets are possible. The optimum policy saves on the supplier's level costs by decreasing the number of airlines, on purchasing costs by optimizing the total discounts and on additional unit level costs by booking shorter flights. It makes optimum use of the different volume discounts offered by always buying just above the lower limit of a discount interval. As a percentage of the bare turnover without taking any discounts into account, the sales volume discounts amount to 2.584% in the optimum case and 2.534% in the current policy. The savings due to the optimum use of the destination specific discounts are remarkable. Whereas in the current policy these amount to slightly less than 1% of the bare turnover due to the scattered purchasing policy, they reach almost 4% in the optimum, mainly single sourcing, case. Alliance level costs are currently non-existent because all negotiations are still done and discounts are still offered at airline level. However, the model is ready to cope with alliance level negotiations and discounts that are expected to be offered over the next year for some alliances.

At present Alcatel Bell does not operate an airline selection policy. Negotiations take place centrally, but tickets are booked on an ad hoc basis by personnel needing them. By working in this way, Alcatel is not able to make full use of the discounts negotiated. Even if bookings were made centrally, it would be impossible to obtain all of the savings using the simple Excel spreadsheets currently available because of the complicated discounting environment. It is remarkable that the optimum policy can even save substantially on additional unit level costs, where one would expect personnel

booking tickets ad hoc to look for the shortest possible trip. Purchasing management at Alcatel Bell is currently implementing the model and formulating an airline selection policy on the basis of its results in order to obtain these savings. In order to be able to set up the use of this model during the year, in stead of at the beginning of a new year, the tickets bought before the installation of the model (xun_{ij}) can be entered and the model can then be optimized so as to find the optimum purchasing policy for the rest of the year, taking the tickets already bought into account (18). This possibility makes the model, as well as being strategically valuable in developing an airline selection policy and an aid to negotiations with the airlines, also operationally usable, since policies can be readjusted during the year in order to accommodate changes in demand, prices or discounts.

$$xun_{ij} \leq x_{ij} \leq d_j \quad \forall i \in S, \forall j \in B \quad (18)$$

5. Decision Support for Policy Development and Negotiations

The model is also able to provide further decision support for the development of the business travel policy and negotiations with the different airlines in several ways, as is illustrated by the results of the scenarios in Table 8. All cost figures are in percentages of the TCO of the optimum solution which is repeated in the second column.

-insert table 8 about here-

Firstly, it is possible to impose a minimum number of carriers per destination to be selected and a market share for each of the chosen airlines, as is already discussed in expressions (9a) and (9b). Alcatel Bell wants a back-up carrier for each of its destinations to ensure reliability of the service, but is not quite sure on which minimum market share percentage to impose on this second carrier. We therefore ran two scenarios requiring at least two airlines for each destination, one with a 10% market share and a second one with a 20% market share as a minimum for each carrier. If we did not impose a minimum market share for the second carrier, the model could easily pick a solution in which only one ticket was ordered with the back-up carrier, but this would hardly ensure the reliability of the service. The results are in columns 3 and 4 of Table 8 respectively. The policy of having a back-up carrier costs Alcatel Bell 2.8% in

TCO when imposing a 10% market share and 5.3% when imposing a 20% market share, compared to the optimum policy that selects a single source for all but one of the destinations. There is an increase in airline level costs because more airlines are selected (22 and 24 respectively, compared to 9 under the optimum policy), as well as in monetary costs and longer trip costs because, for each destination, a second-best carrier is selected for part of the market share.

Secondly, Alcatel Bells wants to choose airlines with at least 14 flights a week to European destinations and 6 flights a week to long-haul destinations, in order to provide flexibility in choosing a time schedule. This increases the TCO by 1.6% compared to the optimum policy and changes the airline selection for 16 of the 56 destinations, as is shown in column 5 of Table 8. The increase in TCO is small, but there is a change in the airlines selected for 29% of the destinations. If we combine the latter two and impose the constraints on the number of flights per week and the second carrier with a 10% market share, the TCO increases by about 6.6%, as is indicated in column 6 of Table 8.

Thirdly, in order to accommodate its business travellers, Alcatel Bell could consider not selecting flights that take over one hour longer than the shortest possible trip. This is done by adding a constraint to the mathematical programming model which excludes choices of x_{ij} where so_{ij} is greater than sixty minutes. The resulting policy, shown in the third column of Table 9, would cost the firm almost 3% extra in TCO and would change the optimum selection of airlines for 17 destinations. A relatively large reduction in additional unit level cost, which includes the cost of extra minutes of flight, is more than compensated by the higher purchasing costs.

-insert table 9 about here-

Fourthly, an airline might be excluded. The reasons for this could be assessment of the negotiation position of this airline or the filing of complaints about its catering. Management considers not using airline 1 any more. As column 4 shows, this policy would cost about 4.5% in TCO. There is a reduction in supplier level cost because airlines for which less negotiation is necessary are selected, but this is more than offset by the higher unit level costs, as is shown in column 4 of Table 9. Since airline 1 was

offering the shortest flights to several destinations, many additional hours will have to be flown in this scenario, as is indicated by the increase in additional unit level costs.

Fifthly, proposals made by airlines during negotiations can be valued instantly. Airline 9 could suggest that it is ready to increase its absolute total sales volume discounts by 1 percent in each interval. Although this may sound quite attractive, it can be shown (column 5 of Table 9) using the mathematical programming model that the suggestion made by this airline is not terribly attractive to Alcatel Bell or to airline 9 itself. The TCO will only decrease by 0.0037% compared to the optimum policy and only for one destination will tickets now be booked with airline 9. Even in the highly unlikely event of airline 9 increasing its sales volume discounting percentages by 6%, it will not attract a substantial amount of additional business from Alcatel Bell. The TCO would still remain essentially the same (column 6 of Table 9).

6. Conclusion

Although Total Cost of Ownership is a widely accepted theoretical concept, our approach is, to the best of our knowledge, the first model that makes this concept operational in a service-purchasing context. The model uses Total Cost of Ownership information in an objective mathematical programming model to simultaneously select vendors and determine market shares for a multiple item service. In this paper, we have modelled the real-life problem of purchasing business air travel within Alcatel Bell. Purchasing managers are faced with a complicated discounting environment. We were able to obtain a saving of about 19.5% on Total cost of Ownership compared to the current ad hoc purchasing policy.

Table 1: Airline data for illustrative example.

	com- mission %	over- ride %	managin g hours	airline sales volume discounts			
				total		only on non-route deal destinations	
				absolute	relative	absolute	relative
LH	9	1.49	0			$\geq 6,000,000 \Rightarrow 0.5\%$	
KLM	7	3	0				$\geq 50\% \Rightarrow 10\%$
AZ	6	2	0				$\geq 35\% \Rightarrow 3\%$
UA	8	1	0	$\geq 3,000,000 \Rightarrow 5\%$ $\geq 4,000,000 \Rightarrow 10\%$			
AF	7	0	0		$\geq 30\% \Rightarrow 0.5\%$		
SN	7	1	0		$\geq 50\% \Rightarrow 6\%$ $\geq 70\% \Rightarrow 7\%$		
OS	7	1	0		$\geq 28\% \Rightarrow 3\%$		
DL	7	9	0	0%			
CX	9	6	8	$\geq 4,000,000 \Rightarrow 6\%$			

Table 2: Alliance data for illustrative example.

	members	managing hours	alliance sales volume discounts			
			total		only on non-route deal destinations	
			absolute	relative	absolute	relative
ALL1	AF, DL	20				$\geq 40\% \Rightarrow 3\%$
ALL2	KLM, AZ	40	$\geq 5,000,000 \Rightarrow 2\%$			
STAR	LH, UA	30			$\geq 5,000,000 \Rightarrow 3\%$	
ATLANTIC	SN, OS	20		$\geq 50\% \Rightarrow 1\%$		
CXA	CX	0	0%			

Table 3: Airline and destination data for illustrative example.

	Amsterdam		Austin		Bogota		London		Rio de Janeiro		Zurich	
demand (tickets)	50		40		30		60		15		20	
	price route deal	extra flight mins.	price	extra flight mins.	price route deal	extra flight mins.	price route deal	extra flight mins.	price route deal	extra flight mins.	price route deal	extra flight mins.
	limit interval	discount	limit interval	discount			limit interval	discount				
LH	20,000	0	280,000	55	150,000 R	30	6,000 R	0	100,000	10	20,000 R	5
KLM	15,000 R	0	150,000	0	90,000	0	5,000 R	10	120,000 R	110	15,000 R	0
			≥70%	20%								
AZ	13,000 R	15	260,000	0	110,000	20	7,500 R	15	110,000 R	0	17,000 R	10
			≥60%	10%								
			≥70%	20%								
UA	/	/	278,000	32	132,000	0	8,000	20	95,000	20	16,000	20
AF	9,000	10	200,000	50	178,000	0	4,500	20	90,000	40	22,000	0
	≥0%	3%										
SN	11,000	10	180,000	15	150,000	30	5,500	0	100,000	30	21,000	13
							≥90%	5%				
OS	12,000	5	170,000	15	/	/	6,500	20	110,000	20	19,000	14
DL	13,000	15	130,000	15	120,000	50	8,000	10	100,000	10	18,000	15
CX	20,000	0	180,000	10	90,000	0	8,000	20	100,000	15	17,000	0

R = route deal

Table 4: Optimum policy for illustrative example: tickets and market shares.

	Amsterdam		Austin		Bogota		London		Rio de Janeiro		Zurich	
	number of tickets	% market share	number of tickets	% market share	number of tickets	% market share	number of tickets	% market share	number of tickets	% market share	number of tickets	% market share
LH	0	0	0	0	0	0	0	0	0	0	0	0
KLM	1	2	40	100	6	20	60	100	0	0	0	0
AZ	0	0	0	0	0	0	0	0	0	0	0	0
UA	0	0	0	0	0	0	0	0	0	0	0	0
AF	49	98	0	0	0	0	0	0	0	0	0	0
SN	0	0	0	0	0	0	0	0	0	0	0	0
OS	0	0	0	0	0	0	0	0	0	0	0	0
DL	0	0	0	0	0	0	0	0	0	0	0	0
CX	0	0	0	0	24	80	0	0	15	100	20	100
demand	50	100	40	100	30	100	60	100	15	100	20	100

Table 5: Optimum policy for illustrative example: turnover and discounts with airlines

airlines	total	LH	KLM	AZ	UA	AF	SN	OS	DL	CX
turnover without discounts	11,296,000	0	6,855,000	0	0	441,000	0	0	0	4,000,000
destination-specific discounts	1,213,230	0	1,200,000	0	0	13,230	0	0	0	0
sales volume discounts	774,000	0	534,000	0	0	0	0	0	0	240,000
paid	9,308,770	0	5,121,000	0	0	427,770	0	0	0	3,760,000

Table 6: Optimum policy for illustrative example: turnover and discounts with alliances

alliances	total	CXA	ALL2	ATLANTIC	ALL1	STAR
turnover with airline discounts	9,308,770	3,760,000	5,121,000	0	427,770	0
alliance volume discounts	102,420	0	102,420	0	0	0
paid	9,206,350	3,760,000	5,018,580	0	427,770	0

Table 7: Results for Optimum and Current Policy.

	Optimum Policy	Current Policy
suppliers selected	1,7,8,12,14,15,16,19,22	1,2,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34
TCO (as % of TCO optimum policy)	100	124,1348
alliance level costs (as % of TCO optimum policy)	0	0
supplier level costs (as % of TCO optimum policy)	0.1790	0.2542
unit level costs (as % of TCO optimum policy) of which:	99.8210	123.8842
monetary costs	99.6323	122.9142
longer trip costs	2.5841	5.2577
travel agency profit	-2.3954	-4.2877

Table 8: Alcatel Bell Decision Support Scenarios.

	Optimum	Back-up carrier with min. 10% market share	Back-up carrier with min. 20% market share	Flexibility in timing	Flexibility & back-up carrier with min. 20% market share
TCO	100	102.8210	105.2632	101.5717	106.6027
supplier level cost	0.1790	0.2219	0.2276	0.1921	0.2158
unit level cost of which:	99.8210	102.5901	105.0356	101.3795	106.3869
purchasing cost	99.6323	101.7701	105.2045	101.6859	105.5420
additional unit level cost	2.5841	3.4644	3.4468	2.3333	3.8853
agency profit	-2.3954	-2.6444	-3.6157	-2.6397	-3.0404
number of destinations with changing airline selection out of 56	N/A	55	55	16	55

Table 9: Other Decision Support Scenarios.

	Optimum	Constraint on extra flight time	Exclude airline 1	1% higher discount proposal by airline 9	6% higher discount proposal by airline 9
TCO	100	102.8609	104.4863	99.9963	99.9724
supplier level cost	0.1790	0.1982	0.1774	0.1642	0.1642
unit level cost of which:	99.8210	102.6627	104.3089	99.8321	99.8082
purchasing cost	99.6323	105.6150	101.8701	99.7842	99.7603
additional unit level cost	2.5841	0.3703	6.3451	2.4517	2.4517
agency profit	-2.3954	-3.3226	-3.9063	-2.4038	-2.4038
number of destinations with changing airline selection out of 56	N/A	17	33	3	3

7. Notes

(1) Several institutions have an incentive to manage the reported punctuality figures because their performances are partially measured on these figures by managers and/or clients, i.e. airlines, airports and air traffic controllers. Depending on which institution is collecting the data, these will differ substantially. For example, a station manager who is responsible for the punctuality of an airline, but also for the insertion of the delay data in the computer system, will try to blame air traffic control and the airport as much as possible for the delays. In so doing, the station manager is not losing “points” on his punctuality record. As a result of this problem with subjective data, we choose not to include delay figures in the model.

(2) Airlines are extremely reluctant to indicate a company as the beneficiary of these FFPs. If we were to introduce FFPs into the model, we also have to consider the cost implication because of travellers selecting non-TCO-optimum airlines for specific destinations to accrue personal benefits on their FFP cards. However, these costs are hard to quantify.

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