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MABS: Spreadsheet-based decision support for precision marketing

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Abstract

In this paper, we describe a decision support system developed for automatically scheduling and optimising broadcasts of advertisements to mobile phones via SMS (Short Message Service) text messaging. The system, MABS or "Mobile Advertising Broadcast Scheduler", is developed in Microsoft Excel with a link to Lingo, a modelling language and IP solver. It was developed for a London-based company specialized in location-sensitive precision marketing via mobile phones. The system significantly reduced the time required to schedule the broadcasts, and resulted both in increased customer response and revenues.

Keywords: Decision support systems; Marketing; Scheduling; Integer programming; Large scale optimisation

1. Introduction

A recent study by the Mintel International Group (2003) estimates that approximately 76% of British adults owns a mobile phone, and 93% of people between 20 and 24. In London, the overall penetration is highest with 82% of the population. Also, SMS (Short Message Service) text messaging is becoming more and more popular, with 16.8 billion messages exchanged in the United Kingdom in 2002, which is set to increase to 20 billion in 2003, or around 55 million per day (Mobile Data Association 2003). Barwise and Strong (2002) report that 68% of mobile-phone owners use text messaging, and up to about 95% of young adults.

The ever-increasing penetration of mobile phones creates a new opportunity for precision marketing. Using this technology, potential customers can be targeted individually using voice, text or picture messages, resulting in dramatically

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higher response rates compared to more traditional advertising media. Advantages of mobile advertising versus traditional advertising media include that advertisements can be sent to potential customers when they are actually shopping instead of at home and that the ads can be tailored to a particular customer. With email-based advertising, ads can also be customized, but they cannot be sent to customers when they are shopping. Text messaging has the additional advantage that is relatively inexpensive.

Barwise and Strong (2002) argue that mobile advertising should be permission-based, where the consumer agrees beforehand to receive advertising via his/her mobile phone. Recent experiments with mobile ads broadcast without permission have resulted in a series of complaints. A recent example was a voice message sent to promote the DVD release of the film "Minority Report" starring Tom Cruise. Twentieth Century Fox Entertainment, who broadcast the ad to approximately 27,000 people, received a multitude of complaints from people who received the ad, and also from the Advertising Standards Authority, despite their claim that the message had been sent only to people who registered their contact details on the company's website and asked for information about film and DVD releases. Nevertheless, Barwise and Strong (2002) report that 24% of mobile-phone users would agree to permission-based advertising.

ZagMe, a London-based company established in 2000, was in the business of location-sensitive permission-based mobile advertising using SMS text messaging. The company started its operations in two shopping centres in London, *Bluewater* and *Lakeside*, in November 2000 and January 2001, respectively. *ZagMe* was specialized in sending advertisements from retailers in the shopping centres to customers that were shopping at the time of the broadcast. The ads were customized to particular customers and were broadcast using mobile-phone and SMS technology. When customers arrived at a shopping centre, they logged on to the system, and during their shopping trip, they received ads from retailers in the shopping centre every hour on the hour, including a welcome and a goodbye ad.

ZagMe had a contract with approximately 150 retail outlets, and initially built a registered customer base of more than 80,000 people. The customers had registered on-line via *ZagMe*'s website and they had specified preferences for the different types of products and services that could be advertised. This information, complemented with age and gender information, was used to construct individual member profiles. The majority of the ads were promotional offers aimed at driving consumers into shops with special offers that expire after a certain period. The customer received the discount by showing the ad on the display of the mobile phone. The ads are location sensitive, meaning they are designed to appeal to people who are close to a retail outlet and like to act on impulse. Early results indicated a great success, with some promotional offers causing a rush into the shop.

In addition to being an important new medium for marketing, mobile advertising also presents an emerging opportunity for operations research. Scheduling the advertisement broadcasts requires identifying which customers to target with which ads at what time, a complex task with a multitude of objectives and constraints. The problem was brought to our attention by the management of *ZagMe* because they were scheduling the advertisement broadcasts manually, which was time consuming, tedious, error-prone and preventing them from operating on a larger scale. Advances in information technology enabled an integration of decision technology, marketing databases and mobile-phone technology, allowing automated and optimised mobile advertising.

In De Reyck and Degraeve (2003), we present a mathematical formulation of the broadcast scheduling problem and give a brief description of the system we developed for *ZagMe*. In this paper, we elaborate on the implementation of the system, the *Mobile Advertising Broadcast Scheduler* or MABS, with details on the system architecture, and how the system links a user interface in Microsoft Excel with Lingo, a modelling language and IP Solver (Schrage, 2000), using Visual Basic for Applications or VBA. The advantage of the system is the combination of the user-friendliness and flexibility of Excel with the computational power of an IP solver. Similar systems can be developed for other applications, which could greatly enhance the penetration of Operations Research models in practice.

In Section 1, we describe the broadcast scheduling problem and the need for an automated system. Section 2 contains a first glimpse of the MABS system, with details on the user interface and the Excel sheets containing the information required by the scheduler. In Section 3, we formulate the problem, and in Section 4 we elaborate on the MABS system architecture, with details on how we linked a user interface in Excel with an IP solver. Section 5 contains a summary of the results, including a comparison of the automated system and the manual scheduling procedure. In Section 6, we highlight some areas for improvement, and in Section 7, we reveal what happened after the adoption of MABS by *ZagMe*. Section 8 contains our conclusions.

2. The problem

Scheduling the broadcasts involves deciding which ads to send out to which active customers at what time. In its first year of operations, the management of *ZagMe* constructed the broadcast schedules manually. Retailers provided *ZagMe* with information concerning upcoming promotions, for which *ZagMe*'s marketing department would then create an appropriate ad. The message of the ad was designed in such a way as to entice a response, while fitting on the phone's display. *ZagMe*'s marketing department also decided when the ad was broadcast, how often and to which customers, based on the retailer's preferences. A dedicated broadcast planning team consisting of people from upper management, marketing and IT met on a weekly basis, typically on Thursdays and Fridays, to construct the broadcast schedule for upcoming week. Each day in the schedule was split into 12 time slots of one hour (10–11 am through 9–10 pm), complemented by an extra activation and deactivation slot. Customers were classified in 12 different segments depending on their age and gender, and one ad was broadcast to each customer segment every hour on the hour. When the broadcast schedule was finalized, it was linked with the customer database, and a specialized system automatically broadcasted SMS text messages to the selected customers at the appropriate time. The retailer then paid for each time the ad was broadcast.

The broadcast planning team needed approximately two days for constructing a weekly broadcast schedule for the two shopping centres. *ZagMe*'s CEO recognized that this would cause problems in the near future. First, *ZagMe* was planning a rapid expansion, in the United Kingdom as well as in mainland Europe, and the time required to manually construct broadcast schedules for a large number of shopping centres was excessive. This prompted *ZagMe*'s management to think about automating the broadcast scheduling task. Second, the results obtained with the manual schedules were not satisfactory. *ZagMe*'s CEO envisioned a gradual move to a system where customers would be targeted more and more on an individual basis, by broadcasting ads particularly suited for a specific customer. The manual system did not allow this increase in granularity because of the increased complexity. For instance, when an ad was not deemed to be of interest to a particular customer, no ad was broadcast at all, whereas another ad could have been broadcast instead. Also, mistakes were sometimes made, for instance broadcasting an ad to a wrong customer segment or when a store was closed, which could be prevented using an automated system.

We were first contacted by the CEO of *ZagMe* in early 2001 with a request to develop an automated broadcast planning system which would enable *ZagMe* to grow by making the broadcast scheduling task more efficient, but also to make it more effective by maximizing both the retailers' and the customers' satisfaction. After a series of meetings in which we outlined and designed a conceptual system, we developed several prototypes that were used by *ZagMe*'s scheduling team for evaluation, enabling us to refine our scheduling criteria. A first operational system was completed at the end of March 2001, and was used in a test case in the week of April 2, 2001, showing a dramatic improvement compared to a manually developed schedule.

3. MABS user interface

The system is comprised of a user interface in Microsoft Excel, which interfaces via a VBA (Visual Basic for Applications) program with Lingo, a modelling language and IP Solver (Schrage, 2000) for solving the broadcast scheduling problem. We will first describe the Excel sheets acting as a user interface. The sheets contain information about the retailers and the advertising campaigns, and is completed by *ZagMe* based on communications with the retailers.

3.1. The Advertisement sheet

Fig. 1 shows the *Advertisement* sheet, containing information about the ads:

- No: number of the ad. The system is designed for 100 ads, although this can be increased.
- Advertisements: a description of the ad, typically a retailer name and a number in case of multiple ads.
- Client: not all retailers pay the same fees. In order to maximize revenues, ads from retailers paying the most are given priority. Retailers were classified in four categories, *1 star* to *4 star*, according to the nature of the contract, with *4 star* retailers the most interesting ones.
- Quality: not all ads are equally interesting from the customer's perspective. To maximize customer response and increase the size of the member base, the broadcast schedule should contain interesting offers that attract customer attention and entice an immediate response, while fostering loyalty and lock-in. The attractiveness of an ad is determined by *ZagMe*'s marketing department, and determined using a classification similar to the one introduced for retailers. Attractive *4 star* ads typically con-

No	Advertisements	Client	Quality	Type	Min	Max	Legend	
1	Air Born Kites - 1	2	2	SP	1	4		
2	Air Born Kites - 2	2	2	SP	1	4	**Client**	**Description**
3	All Sports	4	3	SP	4	4	1	*
4	Artworld	2	3	MI	1	4	2	**
5	Baron Jon	2	3	FA	1	4	3	***
6	Base	2	4	FA	1	4	4	****
7	Bears'n'Bunnies	2	2	GI	1	4	P	Pre-booked
8	Big Blue Rock	2	4	SP	1	4		
9	Club Golf	4	2	SP	3	4	**Quality**	**Description**
10	Dome Bar Café - Meal	3	2	RE	3	4	1	Low (generic offer, no call to action)
11	Dome Bar Café - Coffee	3	3	RE	3	4	2	Average
12	GT Recollections - 1	4	2	MI	2	4	3	High (strong offer, call to action)
13	GT Recollections - 2	4	3	MI	2	4	4	Very High (free gift, really special offer)
14	Giant Clothing	3	3	FA	1	4		
15	Hargreaves	3	2	SP	1	4	**Type**	**Description**
16	Into the Void	2	1	MI	1	4	BE	Beauty
17	Just Leathers	2	1	FA	1	4	FA	fashion
18	L'occitane	2	3	BE	1	4	GI	Gifts
19	Letter Box	2	2	MI	1	4	JE	Jewelry
20	Lush - A	3	3	BE	1	4	MI	Miscellaneous
21	Lush - B	3	3	BE	1	4	RE	Restaurant
22	Mikey	3	3	JE	1	4	SP	Sports
23	Mish Mash	1	2	FA	1	4	EN	Entertainment
24	Morgan	3	2	FA	1	4	BO	Books
25	Nando's - 1	p	3	RE	1	4		
26	Nando's - 2	p	4	RE	1	4	**Min**	**Description**
27	Nando's - 3	p	3	RE	1	4	x	Offer to be broadcast at least
28	Nando's - 4	p	3	RE	2	4		x times in every selected segment
29	Pecksniff's - 1	4	4	BE	1	4		
30	Pecksniff's - 2	4	3	BE	1	4	**Max**	**Description**
31	Pilot	3	2	FA	1	4	x	Offer to be broadcast at most
32	Pizza Hut	3	2	RE	1	4		x times in every selected segment

Fig. 1. The *Advertisement* sheet.

tained offers for free gifts or deep discounts on popular products, whereas *1 star* ads were mainly generic brand-building messages.

- Type: indicates the type of product advertised. The products were classified in nine types: beauty, fashion, jewellery, gifts, sports, books, entertainment, restaurants, and miscellaneous.
- Min, max: indicates the minimum and maximum number of times an ad can be broadcast. The minimum limit was used to guarantee a retailer a certain number of broadcasts, the maximum was used to restrict the number of broadcasts of the same ad to prevent repetition and increase the diversity of offers in the schedule.
- Legend: the last two columns describe the meaning of the other columns in the sheet.

3.2. The Customer Segment sheet

Fig. 2 shows part of the *Customer Segment* sheet, detailing which customer segments are to be targeted with each ad. The company used 12 different customer segments based on gender (M/F) and age ($\leqslant$17, 18–24, 25–34, 35–44, 45–54, $\geqslant$55), with most of the customers in age brackets $\leqslant$17, 18–24 and 25–34 and a majority of women. Each retailer could request a broadcast to one or more segments.

3.3. The Timing Preference sheet

Fig. 3 shows part of the *Timing Preference* sheet, with information on the retailers' preferred timing for the broadcast of each ad. Each retailer was asked to provide three sets of time slots indicating a first, second and third choice, as well as a list of other possible time slots in case the three choices were already taken, or to permit additional broadcasts if capacity allowed. Each preference is indicated by a different colour. In Fig. 3, the colour scheme has been altered to black and white; darker squares indicate higher preference, a cross indicates an inappropriate time slot, and an empty cell indicates additional time slots. A preference could be expressed for a contiguous time interval, e.g. Saturday between 2 pm and 8 pm, or for a non-contiguous set of time slots, e.g. every weekday at 11 am, or for a single time slot. If a preference was expressed for multiple time slots, this meant that the retailer was indifferent between the time slots in that set. Also, prebooking was allowed with advance payment and guaranteed broadcasts. Obviously, prebooked slots were more expensive.

3.4. The Schedule sheet

Fig. 4 shows part of a broadcast schedule. For each time slot and customer segment, except

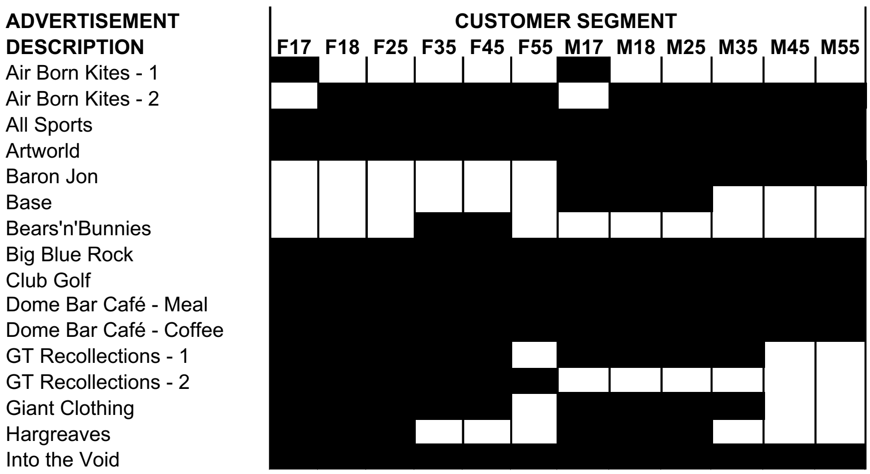

Fig. 2. A part of the *Customer Segment* sheet.

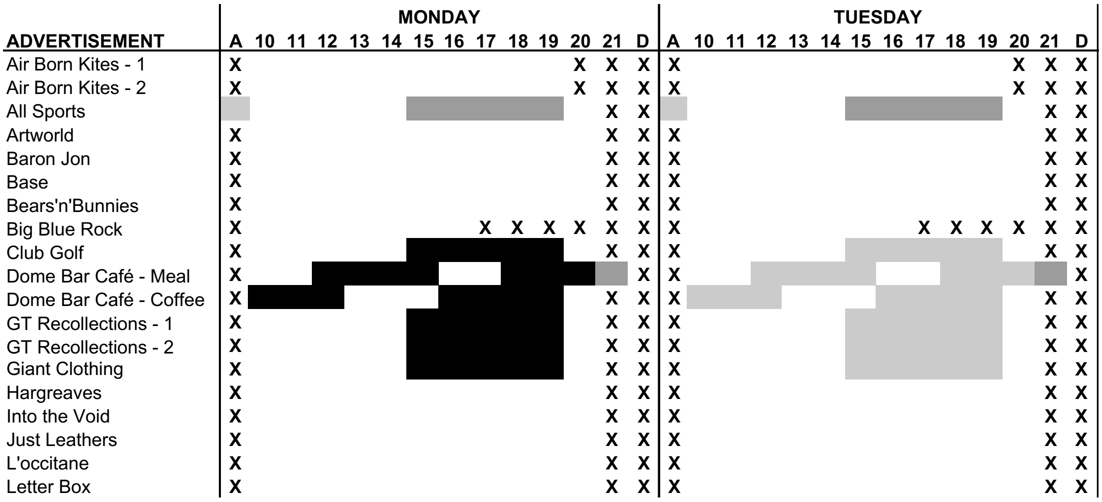

Fig. 3. A part of the *Timing Preference* sheet.

MONDAY

	Female 17 or less	Female 18-24	Female 25-34	Female 35-44	Female 45-54
Activate	**all:sports - SP**	**all:sports - SP** Yo! Sushi 50% day - RE	**all:sports - SP** Yo! Sushi 50% day - RE	**all:sports - SP**	**all:sports - SP**
10.00	**GT Recollections 1 - MI** Pontis - RE Quicksilver 1 - SP	**PizzaExpress 1 - RE** Top Shop - FA The Bonsai House - MI	**Dome Bar Café Coffee - RE** Wallis - FA Quicksilver 6 - SP	**Lush A - BE** Dome Bar Café Coffee - RE Artworld - MI	**Suits You - FA** Artworld - MI Pontis - RE
11.00	**Dome Bar Café Coffee - RE** Top Shop - FA GT Recollections 2 - MI	**Lush A - BE** Dome Bar Café Coffee - RE Quicksilver 5 - SP	**Pilot - FA** Pontis - RE Waterstones Britney - BO	**GT Recollections 1 - MI** Giant Clothing - FA Pontis - RE	**Lush A - BE** Waterstones Travel - BO The Bonsai House - MI
12.00	**Lush A - BE** Dome Bar Café Meal - RE World of Football - SP	**Yo! Sushi 20% - RE** Watch It - JE Warehouse - FA	**Lush A - BE** Top Shop - FA World of Football - SP	**Quicksilver 6 - SP** Mikey - JE L'occitane - BE	**Dome Bar Café Coffee - RE** GT Recollections 2 - MI Club Golf - SP
13.00	**Big Blue Rock - SP** L'occitane - BE Warehouse - FA	**Quicksilver 6 - SP** Giant Clothing - FA Waterstones FPD - BO	**Yo! Sushi 20% - RE** Watch It - JE L'occitane - BE	**Yo! Sushi 20% - RE** Wallis - FA GT Recollections 2 - MI	**Quicksilver 6 - SP** Dome Bar Café Meal - RE Wallis - FA
14.00	**Yo! Sushi 20% - RE** Giant Clothing - FA all:sports - SP	**Pontis - RE** all:sports - SP L'occitane - BE	**Quicksilver 6 - SP** Dome Bar Café Coffee - RE Warehouse - FA	**Mish Mash - FA** Artworld - MI Dome Bar Café Meal - RE	**Yo! Sushi 20% - RE** L'occitane - BE Artworld - MI
15.00	**GT Recollections 2 - MI** Quicksilver 5 - SP Watch It - JE	**Quicksilver 5 - SP** GT Recollections 2 - MI Wallis - FA	**Giant Clothing - FA** Quicksilver 4 - SP The Bonsai House - MI	**The Bonsai House - MI** World of Football - SP Giant Clothing - FA	**Warehouse - FA** Quicksilver 1 - SP Mikey - JE

Fig. 4. An example of part of a Monday broadcast schedule.

for the activation time slot, three ads are scheduled, although only one is actually broadcast. When customers register for the service, they complete a form that indicates the type of products the person is interested in. When the first ad matched the customer's profile, it was broadcast. If not, the second one was broadcast instead. If the second ad was also inappropriate, a third one was broadcast.

4. The model

When all information concerning the set of ads for the upcoming week is gathered in the *Advertisement*, *Customer Segment* and *Timing Preference* sheets, a scheduling algorithm can be initiated using a set of buttons (Fig. 5). The user can choose to generate all three schedules simultaneously, generate a specific schedule, generate a

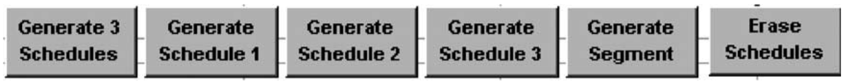

Fig. 5. Scheduling buttons.

schedule for a specific segment or simply erase all schedules. Subsequently, the schedules are generated by solving an Integer Programming (IP) problem.

4.1. Objective

The objective of the system was twofold. On the one hand, the broadcast schedule should be constructed in such a way as to maximize revenues from retailers. This depends on the extent to which preferences specified by the retailers can be met, as this will directly drive revenues because retailers would only pay if their requests were met. These preferences include timing of the ads and the targeted customer segments. On the other hand, future success depends on whether the customer is satisfied with the ads received, as this will drive growth in the member base, response rates and eventually also the retailers' willingness to pay. Customer satisfaction depends on how attractive the ads are, how well they are customized to a particular customer and whether they are broadcast at an appropriate time.

We have developed an objective function based on a set of subjective priorities, determined by *ZagMe*'s marketing department. The priorities indicate which ads should be given priority when allocating a specific broadcast slot based (a) on how much the retailer is paying for the ad, as indicated by the retailer star classification; (b) how interesting the ad is from the customer's perspective, as indicated by the ad star classification; and (c) what preference was given to that time slot by the retailer. These three multiple objectives are combined into a single objective using weights. The weights can be used to model a trade-off between the different objectives, or to define a priority between the objectives, by selecting weights that increase according to a scheme that results in prioritisation instead of trade-offs.

Through discussions with *ZagMe*'s management, we were able to identify the appropriate prioritisation and trade-offs. Neither retailer revenues, nor ad quality, was deemed more important than the other. Instead, their combined effect resulted in a preference of one ad over another. For instance, 4* ads, containing deep discounts or free gifts, were considered to be very interesting and should therefore be given priority, except when the retailer was rated 2* or lower. In that case, a 3* ad of a 4* client was deemed even more interesting. It is important that these trade-offs and priorities are correctly determined, as they significantly influenced the resulting broadcast schedule. We were able to construct the priority list depicted in Table 1, determining which ads should be given priority depending on retailer and offer quality. Naturally, the priority list could be amended at any time.

The time preference expressed by the retailers was handled similarly. Ads were assigned their preferred time slot as much as possible, with the first preference having priority over the second and the third. However, revenues and offer quality had a higher impact on priorities. For example, we would rather assign a second-preference time slot to a 4* client than a first-preference time slot to a 3* client if this would result in the 4* client being assigned a third-preference time slot.

These considerations resulted in a single overall priority for an ad to be scheduled at a particular time to a specific customer segment. Priorities are enforced in the objective function by multiplying the relevant decision variable, i.e. whether or not an ad is scheduled at a particular time for a particular customer segment, with an appropriate coefficient. The coefficients are set in such a manner that a choice with lower priority, if enforced in the schedule, will result in a lower objective value if it forces a choice with a higher priority out of the schedule. Also, the coefficients are increased or decreased in order to prioritise the client's time preference.

Table 1
The ad priority list

Client	4*	3*	4*	2*	3*	2*	1*	4*	3*	1*	2*	4*	3*	2*	1*	1*
Offer	4*	4*	3*	4*	3*	3*	4*	2*	2*	3*	2*	1*	1*	1*	2*	1*

4.2. Constraints

Next to ad quality and timing considerations, other factors also influenced customer satisfaction. These issues were modelled as constraints in the IP. To achieve variety among the ads, the same ad was prevented from being broadcast more than once per day, and two different ads of the same type were prohibited from being sent out in adjacent time slots to prevent repetition or broadcasting competing ads. Also, the same ad could not be broadcast in identical time periods on adjacent days because the company had observed that many customers shop on consecutive days at a similar time, especially on Saturdays and Sundays. Diversity was ensured among the ads broadcast to different customer segments, enabling groups of people shopping together to receive different ads if they belonged to different segments. Finally, the ad in the first schedule was prevented from being reused in the second or third schedule around the same time by imposing a minimum three-hour time gap.

4.3. Model formulation

An important consideration was that the system needed to be able to generate the broadcast schedule relatively fast, as this would allow an interactive use of the system. It should also allow scheduling several shopping centres simultaneously. In order to reduce the computational complexity, we decomposed the problem into 36 separate subproblems, one for each of the three schedules and for each of the 12 customer segments. Therefore, we initially ignored the constraints and objectives linking the different schedules and different customer segments, namely (a) diversity of ads simultaneously broadcast to different customer segments; and (b) prevention of the same ad to be broadcast around the same time (within a three-hour window) for the same customer segment in different schedules.

To prevent the same ad being broadcast around the same time in different schedules, we generate the schedules sequentially with the results of the previously generated schedule(s) acting as a constraint on the solution space of the new one. To account for the diversity of ads simultaneously broadcast to different customer segments, we schedule the customer segments sequentially, and maximize diversity with the customer segments already generated. The customer segments are scheduled starting with $F \leqslant 17$ through $F \geqslant 55$, followed by $M \leqslant 17$ through $M \geqslant 55$. The reason for choosing this sequence is that the teenagers and young adults segments are considered to be the most important segments, as they contain the most members. Also, the female segment is significantly bigger than the male segment. Initial experimentation revealed that the quality of the resulting broadcast schedule is not very sensitive to the actual sequence used. The IP formulation of the problem and details on the solution methodology can be found in De Reyck and Degraeve (2003).

5. MABS system architecture

5.1. Overall system structure

The core of the MABS system consists of an Excel workbook with a number of sheets containing information about the ads (Fig. 1), the targeted customer segments (Fig. 2), the timing preference (Fig. 3), and the generated schedules (Fig. 4). A separate workbook is developed for each shopping centre. Fig. 6 gives an overview of the architecture of the system.

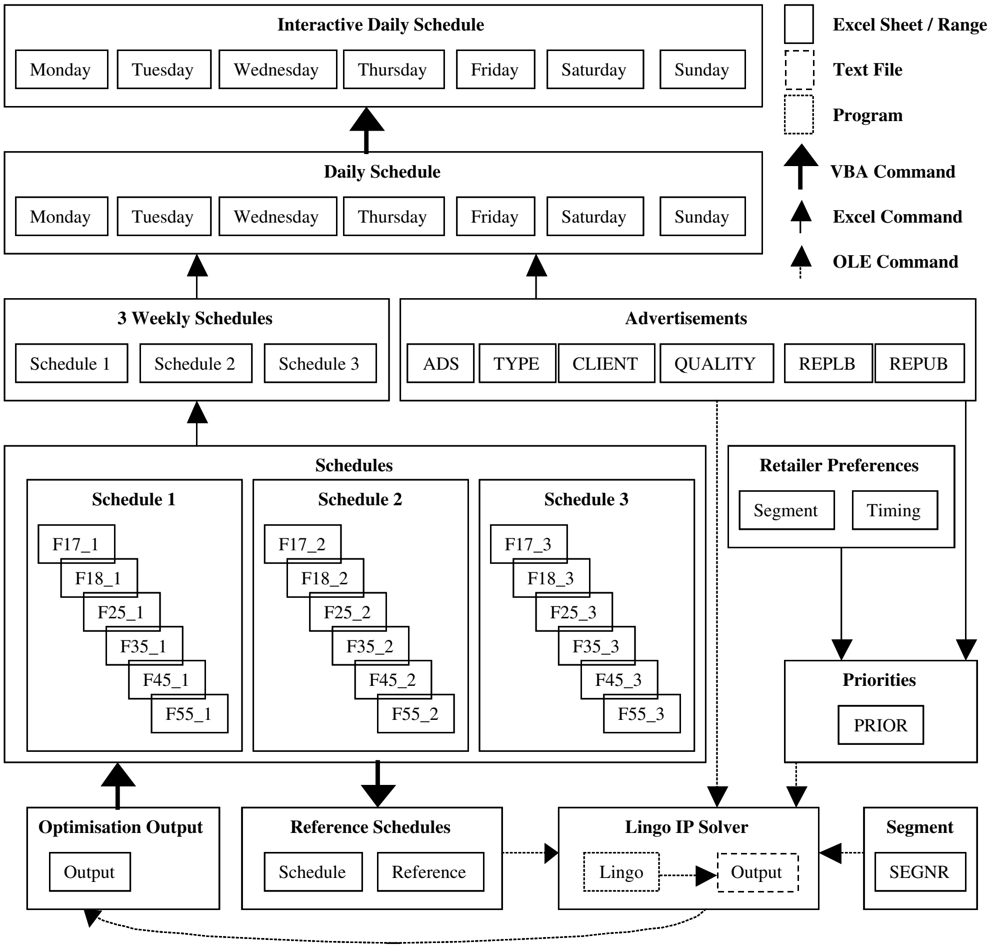

Fig. 6. MABS system architecture.

The *Interactive Daily Schedule* (*IDS*) contains seven sheets with the broadcast schedule for each day of the week. The cells are text inputs so that the user can use all the functionalities of Excel to manually modify the schedule if required, e.g. by moving ads to another customer segment or time slot using drag-and-drop. It is important to allow for manual manipulation of the schedule to allow for idiosyncratic requirements to be taken into account, and to allow the user to rely on his/her experience to improve the schedule. Any changes can then be monitored to be incorporated in the system. The *Daily Schedule* (*DS*) sheets contains the same information as the *IDS* except that the cell values are computed using Excel formulas based on the information contained in the three *Weekly Schedule* (*WS*) sheets and the *Advertisement* sheet. A VBA command is used to copy the computed values in these sheets to the *IDS* sheets for further manipulation.

The *Advertisement* sheet (Fig. 1) contains several named ranges with information about the ads, namely ad names in range *ADS*, ad types in *TYPE*, retailer ratings in *CLIENT*, ad ratings in *QUALITY*, and the minimum and maximum number of repeats in *REPLB* and *REPUB*, respectively. This information will also be required for computing the ad priorities and for solving the IP in Lingo.

A part of a *WS* sheet is given in Fig. 7. It contains information on which ad, represented by a number, is to be broadcast to each customer segment in each time slot, numbered M1 (first time slot on Monday) through S14 (last time slot on Sunday). In this way, the core of the system is decoupled from the ad names and the timing details of each of the time slots, making it more flexible.

An entry in the *DS* sheet can be computed from the *WS* sheets using Excel's LOOKUP formula combining the information in the *WS* and *Advertisement* sheets. In turn, the *WS* sheets are computed, using Excel's MATCH formula, from 18 sheets with a schedule for a particular customer segment and each of the three schedules. A part of the *F17_1* sheet, the first schedule for women under 18, is given in Fig. 8. The sheet contains the schedule information in 0/1 format, which is copied from the optimisation output in the *Output* sheet using a VBA command. A "1" indicates that the ad numbered on the left is scheduled for the time slot shown on top.

The *Output* sheet is copied, using VBA code, from Lingo's *Output* text file, which contains a single column of values of all binary decision variables in the optimal solution. Lingo can read data in named ranges in Excel directly using OLE, object linking and embedding. It reads the information in the ranges ADS, REPLB, and REPUB in the *Advertisement* sheet, a priority for each ad in the *Priorities* sheet, a number indicating the customer segment to be scheduled in the *Segment* sheet and so-called reference schedules.

	F17	F18	F25	F35	F45	F55	M17	M18	M25	M35	M45	M55
M1	0	0	0	0	0	0	0	0	0	0	0	0
M2	32	32	32	32	32	32	63	70	3	65	70	2
M3	34	34	34	34	34	34	34	63	34	34	65	70
M4	76	63	9	65	10	65	3	17	64	9	2	55
M5	63	75	64	17	65	17	9	2	9	10	3	65
M6	73	9	76	2	17	9	17	3	10	55	9	0
M7	9	29	17	29	9	3	10	7	2	17	74	9
M8	29	17	10	9	29	2	1	9	55	3	17	74
M9	17	10	29	3	2	29	74	55	17	0	67	17
M10	1	76	2	73	3	75	70	10	74	2	55	3
M11	75	2	3	10	73	55	72	34	7	66	34	34
M12	3	73	75	55	75	10	51	22	4	74	10	6
M13	10	3	73	75	55	73	7	74	50	6	62	10
M14	0	0	0	0	0	0	0	0	0	0	0	0
T1	0	0	0	0	0	0	0	0	0	0	0	0
T2	75	75	75	75	75	75	31	63	10	65	65	74
T3	59	59	59	59	59	59	63	34	64	10	34	34
T4	63	47	15	47	48	65	9	10	48	47	9	65
T5	47	63	64	65	65	9	10	9	3	9	74	21

Fig. 7. Part of the *Weekly Schedule* (*WS*) Sheet.

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	T1	T2	T3	T4	T5
1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

Fig. 8. Part of the *F17_1* Sheet.

The priority for each ad is computed based on the retailer's preferences in terms of timing and targeted customer segments, which can be found in the *Customer Segment* and *Timing Preference*

```
MODEL:                      ! MABS: MOBILE ADVERTISING BROADCAST SCHEDULER;
                            ! AUTHORS: BERT DE REYCK and ZEGER DEGRAEVE, APRIL 2001;
SETS:
   NUMDAY / 1..7 / : ;      ! NUMBER OF DAYS IN HORIZON;
   PERDAY / 1..14 / : ;     ! NUMBER OF TIME PERIODS IN A DAY;
   PERIOD / 1..98 / : ;     ! THE TIME PERIODS;
   OFFER :                  ! THE ADS;
      TYPE ;                ! TYPE OF AD;
   OTYPE / 1..9 / : ;       ! THE TYPES OF ADS;
   DEMOG / 1..12 / : ;      ! THE DEMOGRAPHICS;
   OXD( OFFER, DEMOG) :
      REPLB,                ! LOWER BOUND ON NUMBER OF REPETITIONS;
      REPUB ;               ! UPPER BOUND ON NUMBER OF REPETITIONS;
   OXP( OFFER, PERIOD) :
      PRIORITY,             ! PRIORITY FOR AD AND TIME PERIOD;
      S,                    ! = 1, IF AD ALREADY AIRS IN PERIOD IN PREVIOUS SCHEDULE, 0, OTHERWISE;
      Y,                    ! = NUMBER OF TIMES AD ALREADY AIRS AT PERIOD IN PREVIOUS SEGMENTS;
      X ;                   ! = 1, IF AD AIRS AT PERIOD, 0, OTHERWISE;
ENDSETS

DATA:
   OFFER    = @OLE( 'ZagMe.xls', 'OFFER');       K     = @OLE( 'ZagMe.xls', 'SEGNR');
   PRIORITY = @OLE( 'ZagMe.xls', 'PRIORITY');    TYPE  = @OLE( 'ZagMe.xls', 'TYPE');
   REPUB    = @OLE( 'ZagMe.xls', 'REPUB');       REPLB = @OLE( 'ZagMe.xls', 'REPLB');
   S        = @OLE( 'ZagMe.xls', 'SCHEDULE');    Y     = @OLE( 'ZagMe.xls', 'REFERENCE');
ENDDATA

!  OBJECTIVE FUNCTION: MAXIMIZE TOTAL PRIORITY;
   MAX = @SUM(OXP( I, J) | REPUB( I, K) #GT# 0:  ( PRIORITY( I, J) – 0.001 * Y( I, J)) * X( I, J));

! 1. ONE OFFER AT MOST IN EACH TIME SLOT;
   @FOR(PERIOD( J):  @SUM( OXP( I, J) | REPUB( I, K) #GT# 0: X( I, J)) < 1 ;);

! 2. EACH OFFER ONCE A DAY;
   @FOR(OFFER( I) | REPUB( I, K) #GT# 0: @FOR( NUMDAY( L1):  @SUM( PERDAY( L2): X( I, 14 * ( L1 - 1) + L2)) < 1 ;););

! 3. EACH OFFER IN ONE SPECIFIC TIME SLOT IN TWO CONSECUTIVE DAYS;
   @FOR( OFFER( I) | REPUB( I, K) #GT# 0: @FOR( PERIOD( J) | PRIORITY( I, J) J #LT# 85: X( I, J) + X( I, J + 14) < 1 ;););

! 4. REPETITION OF OFFERS;
   @FOR( OFFER( I) | REPLB( I, K) #GT# 0: @SUM( OXP( I, J):  X( I, J)) > REPLB( I, K) ;);
   @FOR( OFFER( I) | REPUB( I, K) #GT# 0: @SUM( OXP( I, J): X( I, J)) < REPUB( I, K) ;);

! 5. NO TWO IDENTICAL TYPE OFFERS IN CONSECUTIVE TIME PERIODS;
   @FOR( OTYPE( T): @FOR( PERIOD( J) | J #LT# @SIZE( PERIOD):
         @SUM( OXP( I, J) | TYPE( I) #EQ# T #AND# REPUB( I, K) #GT# 0: X( I, J) + X( I, J + 1)) < 1 ;););

! 6. MAKE OFFER TYPE DIFFERENT FROM PREVIOUSLY GENERATED OFFER TYPES IN THIS TIME PERIOD;
   @FOR( OXP( I, J) | REPUB( I, K) #GT# 0 #AND# S( I, J) #GT# 0:
      @FOR( OFFER( L) | REPUB( L, K) #GT# 0 #AND# TYPE( L) #EQ# TYPE( I): X( L, J) = 0 ;););

! 7. EACH OFFER SPREAD OUT PER DAY ACROSS PREVIOUSLY GENERATED OFFERS IN THIS DAY;
   @FOR( OFFER( I) | REPUB( I, K) #GT# 0: @FOR( NUMDAY( L1):
         @FOR( PERDAY( L2) | S( I, 14 * ( L1 - 1) + L2) #GT# 0:
            @FOR( PERDAY( L3) | L3 #GE# L2 - 3 #AND# L3 #LE# L2 + 3: X( I, 14 * ( L1 - 1) + L3) = 0 ;););););

! 8. ZERO OUT SOME REMAINING UNNECESSARY VARIABLES;
   @FOR( OXP( I, J) | REPUB( I, K) #EQ# 0 #OR# PRIORITY( I, J) #LT# 0: X( I, J) = 0 ;);

! 9. INTEGRALITY;
   @FOR( OXP: @BIN( X) ;);

DATA:
   @TEXT( 'OUTPUT.TXT') = X;
ENDDATA

END
```

Fig. 9. Lingo model.

sheets, and on the retailer's and ad's rating, contained in the CLIENT AND QUALITY ranges in the *Advertisement* sheet.

The reference schedules are used to make sure that (a) the schedule does not contain ads broadcast to the same customer segment around the same time as in previously generated schedules; and (b) that the schedule is as different as possible from schedules previously generated for other customer segments. The former is achieved by prohibiting the scheduling of an ad if in the sheet *Schedule*, which contains the combination of any previously generated schedules (zero, one or two), the same ad is scheduled to be broadcast to the same customer segment in a three-hour window. The latter is achieved by subtracting from the objective function a value that depends on how many times the same ad was broadcast simultaneously to other customer segments. The entries in the reference sheets, which contain a non-zero value of an ad is broadcast to a customer segment at a particular time, are weighted with a coefficient that represents the ''similarity'' of different customer segments. For instance, it is important to make sure that ads broadcast to ''adjacent'' customer segments, or segments with same age profile but different gender, are different. Weights are used to model the ''distance'' between customer segments. The reference schedules are computed using VBA commands based on the *Schedules* sheets.

5.2. The Lingo model

The optimisation subroutine of Lingo is called using VBA code that initiates the Lingo solver and waits until it returns a code indicating it has finished. At that time, Lingo will have written the results in the *Output* text file, which can then be copied using VBA code to the *Output* sheet. Standard features of Excel and VBA do not allow for a smooth coupling with the Lingo optimisation subroutine for highly complex integer programs. Therefore, we had to write our own VBA code.

The Lingo model is given in Fig. 9. In **MODEL** we provide the name of the model. Next, we define the sets. There are 7 days (**NUMDAY**) in the time horizon, and 14 time slots per day (**PERDAY**), with time slot 1 and 14 denoting the activation and de-activation time slots. This gives a total of 98 time periods (**PERIOD**). Each ad or offer (**OFFER**) is one of nine types (**TYPE**). The customer segments (**DEMOG**) are numbered 1 through 12 denoting $F \leqslant 17$, $F18–24, \ldots,$ $F \geqslant 55$, $M \leqslant 17$, $M18–24, \ldots,$ $M \geqslant 55$. The number of repetitions of an advertisement can differ depending on the ad and the customer segment for which it will be aired. This is controlled by a lower bound (**REPLB**) and an upper bound **(REPUB**). There is a specific priority (**PRIORITY**) associated with each advertisement and time slot in which it can be scheduled. A parameter **S** indicates if the ad is already broadcast in the time slot in a previously generated schedule. This parameter will allow us to avoid inter-schedule repetition of identical ads. A second parameter **Y** counts the number of times the ad is already broadcast at the specific time slot in previously scheduled customer segments for the current schedule, weighted by coefficient measuring the ''distance'' between the customer segments. Similar to the parameter **S**, this coefficient will be used to achieve intra-schedule diversity maximization among different customer segments. The coefficient is set a rather low value, which results in the diversification criterion to work as a tie-breaker, to select a solution out of a set of alternative optimal solutions. Based on initial experimental results, we observed that the IP typically resulted in a large number of alternative optima, all of which scored differently on the ''diversity'' scale. The tie-breaker is then used to select one of those alternative solutions that generates the maximum ''diversity score''. Finally, the decision variable **X** will be 1 if the ad airs in the particular time slot and 0 otherwise. The data is read-in via OLE (Object Linking and Embedding) technology from Microsoft Excel.

In our model we only consider variables which have a non-zero upper bound for repetition, **REPUB**. The objective function maximizes total priority which is adjusted for the number of times the ad has already been scheduled in the same time slot for previously generated customer segments within the same schedule. The first constraint limits the number of ads in one time slot to be at most one. In constraint 2, we specify that each ad can be aired at most once per day. The third constraint enforces that an ad cannot be scheduled in the same time slot in two consecutive days. In constraint 4, we set the appropriate lower and upper bounds on the decision variables. To achieve a diversity of offer types, we model in constraint 5 that no two ads of the same type can be broadcast in two consecutive time slots. In the following three statements we zero out decision variables that would give us conflicting decisions with respect to the diversity requirements of the solution. This approach has considerable advantages, in addition to eliminating the need for additional constraints to achieve diversity and therefore complicate the model; zeroing-out decision variables achieves the same result while actually making the models smaller and thus easier to solve. With constraint 6 we achieve that the offers that will be aired at the same time in the three consecutively generated schedules will be of a different type. In constraint 7 we eliminate the decision variables which would allow us to schedule the same ad more than once in a three-hour interval before and after the ad in the three consecutively generated schedules. Decision variables which have a repetition upper bound of zero or a negative priority are eliminated in constraint 8. Finally, we enforce integrality using constraint 9. The results of the optimisation are written to a text file named "Output.txt".

6. Results

MABS is able to generate three weekly schedules for one shopping centre in approximately 15 minutes on a 2 GHz PC. This allows for an interactive use of the system and scheduling multiple shopping centres in parallel.

The quality of the generated schedules was assessed by specialists in the company, and mainly depends on the quality of the offers broadcast and the variety in the schedule as defined above. Overall, our system resulted in more attractive offers being broadcast, more ads matching customer profiles, more ads broadcast at the retailers' preferred time and an increased variety among ads broadcast to different customer segments. Other observed advantages were a guaranteed prevention of intra-day, inter-day and inter-schedule repetition.

To compare the manual schedules with the automatically generated ones, we ran the system in parallel with the manual scheduling procedure. The following improvements were observed for the test case in the week of April 2, 2001. A scanned image of the Monday section of the manual schedule is given in Fig. 10. When comparing the manual schedule with the one generated by MABS, the following improvements could be observed:

- In the manual schedule, 27% of the time slots (out of 1176) were allocated to retailers who had specified that time slot as a preferred time slot, i.e. either as a first, second or third preference. The automated system effectively doubled this to 55%. In the manual schedule, 18%, 5% and 4% of the time slots were allocated to retailers' first, second and third preference, respectively. The automated system increased this to 38%, 9% and 8%.
- In the manual schedule, 121 time slots, i.e. more than 10%, were left unused, due to time constraints or oversight, resulting in unwanted time slots being ignored rather than allocated to retailers as extra slots. This resulted in customers expecting promotional offers but not receiving any. Naturally, the automated system avoids unused broadcast capacity completely.
- In the manual schedule, 17 ads were broadcast to customer segments for which the ad was not appropriate. In total, 26 time slots were affected, i.e. approximately 2.5%. When confronted with this issue, the company's schedulers claimed that due to time constraints, checking these restrictions manually was deemed too difficult and time consuming.
- In the manual schedule, 48 of the ads broadcast, i.e. more than 4.5%, were of the same type as the ad previously broadcast to that customer segment. Also, in the manual schedule, on 11 occasions the same ad was broadcast on consecutive days in identical time slots.

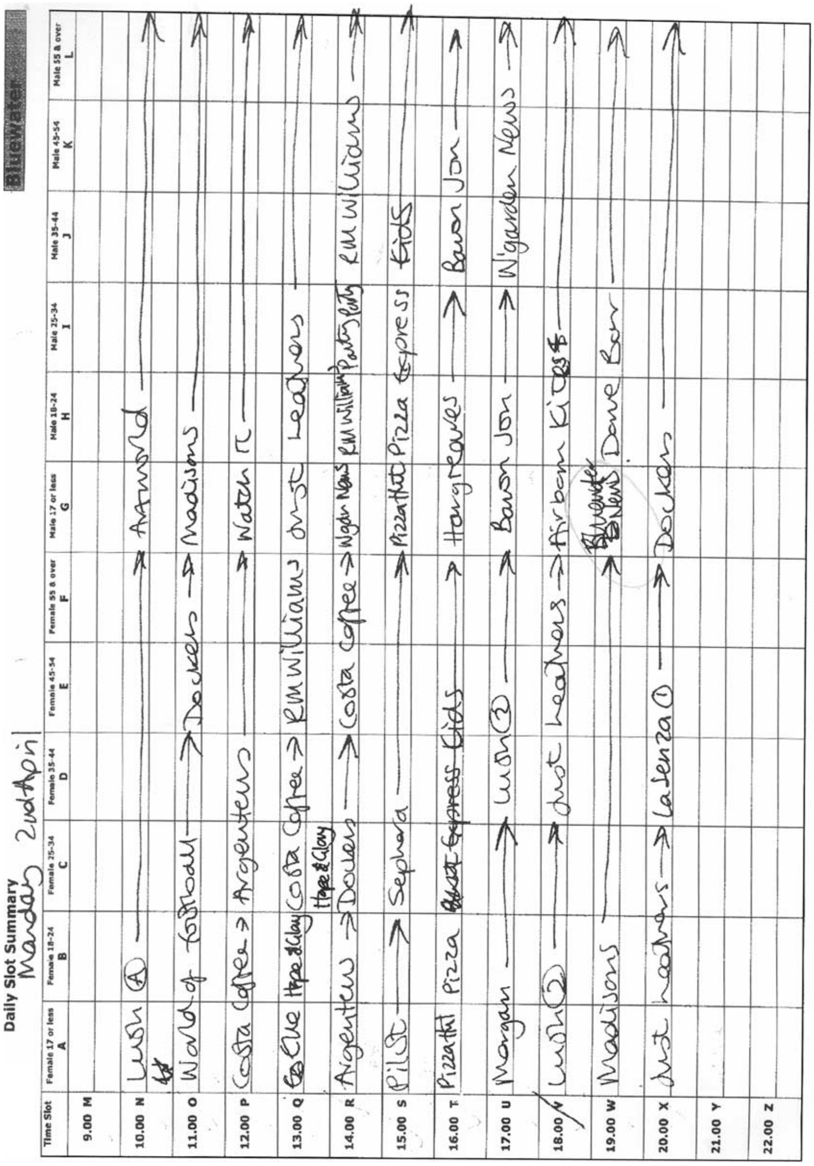

Fig. 10. The manually developed broadcast schedule for Monday 2 April 2001.

- In the manual schedule, diversity among the ads broadcast to different customer segments simultaneously was largely ignored due to the complexity of the scheduling task. Typically, ads were scheduled at the same time for all appropriate customer segments. Only in isolated cases was diversity taken into account.
- Manually, no backup schedules were constructed except for a very basic one and that was essentially constructed by shifting the first schedule forward in time. As a result, customers would regularly not receive any ad when they had opted out of one or more product/service types.

CAMPAIGN DESCRIPTION	CUSTOMER SEGMENT											
	F17	F18	F25	F35	F45	F55	M17	M18	M25	M35	M45	M55
Air Born Kites - 1							1					
Air Born Kites - 2		1	1	1	1	1		1	1	1	1	1
All Sports		4	4	4	4	4	4	4	4	4	4	4
Artworld		1	1	1	1	1	2	1	1	1	4	4
Baron Jon							2	1	1	1	4	4
Base							4	4	3			
Bears'n'Bunnies				1	1							
Big Blue Rock		1	1	1	1	2	4	2	2	4	4	4
Club Golf		3	3	3	3	3	3	3	3	3	3	3
Dome Bar Café - Meal		3	3	3	3	3	3	3	3	3	3	3
Dome Bar Café - Coffee		3	3	3	4	4	4	4	4	4	4	4
GT Recollections - 1		2	2	3	4		4	4	4	4		
GT Recollections - 2		1	1	1	2	3						
Giant Clothing		2	2	2	2		2	2	2	2		
Hargreaves		1	1				1	1	1			
Into the Void		1	1	1	1	1	1	1	1	1	1	1
Just Leathers		1	1	1	1	1	1	1	1	1	1	1
L'occitane		1	1	1	1	1	1	1	1	2	4	4
Letter Box		1	1	1	1	1	1	1	1	1	1	1

Fig. 11. Diagnostic tool showing the number of times an ad is broadcast per week.

Based on these initial tests, several diagnostic tools were included in MABS to be able to quickly evaluate the quality of the generated schedules. These tools include a sheet registering the number of times an ad was scheduled to be broadcast to each customer segment over a week (Fig. 11). This information could be used to re-calibrate the parameters in the system such as the minimum and maximum number of broadcasts, allowing a reduction of the broadcasts of extremely popular ads and giving ads not previously scheduled a "chance" by imposing a minimum number of broadcasts.

7. Directions for improvement

Advances in technology could allow a number of improvements to be made to MABS. First, the system could be modified to enable dynamic real-time scheduling instead of weekly (or daily) static scheduling, where broadcast decisions are made dynamically depending on which customers are active and their current preferences. Second, one could also consider taking advantage of new upcoming technology in mobile telephony that allows tracking of the exact position of a customer to within a few meters, thereby creating opportunities to broadcast ads depending on the exact location of the customer. Naturally, this will work only in a permission-based approach. This would allow the system to be used outside the realm of shopping centres by sending an ad to a customer if he or she approaches a specific store. This transforms advertising from a push-based system to a pull system where individual customers trigger ads to be broadcast to them depending on their location. More details about these possible improvements can be found in De Reyck and Degraeve (2003).

8. Epilogue

Between April and September 2001, *ZagMe* used the automated broadcast scheduling system while initially also developing schedules manually in order to be able to compare the results. In September 2001, *ZagMe* struck a deal with Channel 5, the leading commercial television channel in the United Kingdom, to set up a joint venture featuring interactive TV ads with the possibility of text message responses, allowing advertisers to form personal relationships with viewers who respond, offering discount vouchers or product information via their mobile phones. This would be the first step towards national expansion. Unfortunately, in the wake of the events of September 11, 2001 and the economic downturn, *ZagMe* started to experience financial distress, and started looking for a merger or a takeover (as a target). As a consequence, the operations of the company were scaled back to a very low level to minimize expenditures. This resulted in a drastic reduction of the client base, and several key people, including some in the scheduling team, started to leave the company. This finally resulted in the bankruptcy of *ZagMe* on October 24, 2001.

9. Conclusions

The Mobile Advertising Broadcast Planner presented in this paper illustrates the new opportunities created for the operations research community by the emergence of new advertising approaches in precision marketing. The complexity of precision marketing requires decision support systems that allow taking full advantage of the potential benefits created by targeting individual customers based on detailed customer profiles. Recent advances in information technology in terms of linking decision support systems with marketing databases and mobile technology, now allow the development of sophisticated decision tools, allowing the full potential of emerging marketing opportunities to be realized.

The system, MABS, developed for *ZagMe*, the pioneer in location-sensitive mobile advertising, creates a broadcast schedule with information on which ads are to be broadcast to which customers at what time. The system was crucial to the further development and growth of *ZagMe*, which was hampered by the lack of efficiency and effectiveness of the manual scheduling methods used. We have described the system in detail, including the system's architecture, the user interface in Microsoft Excel and how it is linked with Lingo, an IP solver. The model forming the core of the system optimises retailer and customer satisfaction, by broadcasting interesting offers, personalised to match the customer's preferences, at an appropriate time, with maximum variety among ads. The results show that MABS significantly reduces the time required to construct the schedules, and also improves the quality of the generated schedules, which should lead to increased retailer and customer satisfaction, increased customer response rates and a growing member base.

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