Abstract

Campaign management enables companies to address customers in the best possible way with suitable campaigns according to given marketing objectives. Currently three approaches of campaign management have evolved in practice, differing in the way of selecting customers for competing campaigns. These three generations of campaign management still show clear improvement potential, so a new beginning is introduced in this contribution. This paper shows a new approach for campaign management based on improvement potential of the preceding generations.

The major aspect of our approach is a simultaneous selection of customers and campaigns. The expected utility for all customers and campaigns is maximized taking into account the whole planning horizon and all resource limitations. For the implementation of this new approach optimisation models and specific heuristics are introduced. They can be used separately or in combination depending on the complexity of the problem. It is shown that this simultaneous planning of the fourth generation is superior to present approaches.

1. Campaign Management in Practice

1.1. Characteristics of Campaign Management

Most large enterprises nowadays apply the principles of Customer Relationship Management (CRM). One of its fundamental issues is an all-encompassing, integrated, and synchronised execution and coordination of customer-related marketing, distribution, and service processes [1].

In the field of marketing, Campaign Management plays a key role as it represents the main aspects of operative marketing activities.

The challenge of Campaign Management is to present the right choice of information and offers to the right customer through the right channel using the right communication style [2][3].

Given limited resources, the objective is to maximise the profit generated of each customer or the customer basis as a whole. Currently, three generations of Campaign Management can be distinguished in practice, each of them achieving the above-mentioned goal to a different degree. They will be outlined in brief in the following.

1.2. Approaches to Campaign Management

Generation 1 of Campaign Management can be described as a campaign-specific management of target groups that lies in the hands of several campaign managers. In many companies one or several product groups are assigned to a single campaign manager, who takes full responsibility. Campaign managers select campaigns and preferable target groups independently from each other according to their product-specific goals [4].

Failure to coordinate these target groups results in an excessive advertising impact on 'auspicious' prospects that are regarded as particularly promising by several campaign managers. 'Regular' customers are ignored because of their less favourable characteristics and their below-average buying activity. As an effect, considerable potential is neglected.

In order to avoid these problems Collision Management was installed (Generation 2). By establishing time lags between campaigns the pressure exerted on the individual customer can be explicitly limited, indirectly paying more attention to 'regular' customers [5]. Nevertheless, due to uncoordinated planning of campaigns it still occurs that a customer will be assigned to a campaign even though a different, more beneficiary campaign is running at the same time.

Considering this issue Generation 3 of Campaign Management has evolved, shifting focus from assigning customers to assigning campaigns. A transformation of perspective takes place, the campaign-centric view is replaced by a customer-centric view. Campaign managers of Generation 1, responsible for assigning customers to campaigns,
become customer managers. With each sales activity they aim to offer ‘their’ customers only the most attractive and suitable campaigns out a portfolio of current campaigns. Specific heuristics of allocation (Next Best Activity concept [6]) were developed, allowing to take all campaigns into consideration when choosing the one that is most beneficial to the customer (and the company). The choice of campaigns is restricted to those available at the time of application.

1.3. Discussion of the different approaches

The above-mentioned approaches to Campaign Management differ not only in their relation to time but also in their primary criterion of selection.

Generations 1 and 2 are exclusively oriented towards the past. The selection of customers is based solely on historical data, customer’s reactions in response to actions taken by the company. Generation 3 of Campaign Management, though, shifts the focus to the present. Only those campaigns that yield the highest utility at that point of time are selected for each customer [4].

All three approaches uniformly do not extend their horizon of selection into the future. Once customers are assigned to current campaigns participation in further activities is prohibited for a certain amount of time. In case a more beneficial campaign becomes available during that time it cannot be selected.

By concentrating on a primary criterion of selection all three Generations of Campaign Management employ a one-dimensional perspective. One the one hand, Generations 1 and 2 choose the most suitable customers for a fixed campaign. On the other hand, Generation 3 selects the most suitable campaigns for the individual customer. The restricted point of view and the existence of constraints may prevent customer-campaign combinations of which superior benefit could be expected. If, for example, large numbers of customers are assigned to a campaign it will quickly reach its capacity limits. This campaign will become unavailable even though it might be the most beneficial and therefore most preferable one to be offered to other customers. This issue can only be resolved by simultaneously considering both criteria of selection (customer and campaign).

As a result of this one-dimensional perspective regarding the primary criterion of selection and the rather retrospective relation to time the potential of Campaign Management hasn’t been used to its full avail yet. Based on these considerations Campaign Management of the Fourth Generation, which fully exploits the potential of optimisation, was developed. It will be introduced in the following. Each customer contact is used in a way that maximises the expected impact on all customers and all campaigns within the planning horizon and in consideration of all constraints on resources (e. g. availability of customers, campaign capacity, campaign budget).

2. Campaign Management of the Fourth Generation

2.1. Model structure

In the course of this article we will show the implementation of the Fourth Generation of Campaign Management through integer programming and a number of highly problem-specific heuristics. They can be combined or used separately depending on the complexity of the problem to be solved.

In order to make the problem accessible to integer optimisation and heuristic the problem’s setting has to be formalized. The subsequent considerations use the following notation:

<table>
<thead>
<tr>
<th>Table 1. Model structure</th>
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<tbody>
<tr>
<td>$i = 1 \ldots I$</td>
</tr>
<tr>
<td>$t = 1 \ldots T$</td>
</tr>
<tr>
<td>$j = 1 \ldots J$</td>
</tr>
<tr>
<td>$g = 1 \ldots G$</td>
</tr>
<tr>
<td>$e_{ij}$</td>
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<tr>
<td>$x_{ijt}$</td>
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<td>$A_j$</td>
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<td>$K_i$</td>
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<td>$B$</td>
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<td>$c_j$</td>
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<tr>
<td>$S_{0i}$</td>
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<tr>
<td>$S_{ig}$</td>
</tr>
<tr>
<td>$s_{jt}^0$</td>
</tr>
</tbody>
</table>
Each element of the model structure will be explained in detail in the following chapter in context of its use in the optimisation model.

### 2.2. Optimisation model

The next step of each linear optimisation model is the definition of the **objective function** (see formula 1).

1. \( \max E = \sum_i \sum_j \sum_t e_{ijt} \cdot x_{ijt} \)

The objective function is supposed to maximise the expected utility for all customers and campaigns within the planning horizon.

When using the measure of utility \( e_{ijt} \) it is assumed that \( e_{ijt} \) is constant over time. In the simplest case \( e_{ij} \) represents the probability of response to a contact. The measure of utility can be refined to represent expected turnover, contribution to profit, growth of Customer Lifetime Value, or strategic parameters.

In the following essential **constraints** of the optimisation model are explained:

2. \( \sum_j x_{ijt} \leq A_j \quad \forall j \)

Formula 2 shows the restraint given by each campaign's capacity. The number of customers that can be assigned to a campaign is limited by its capacity \( A_j \).

3. \( \sum_i x_{ijt} \leq K_i \quad \forall i \)

The number of contacts allowed during the planning period is limited for each individual customer. A given customer \( i \) can only be assigned to further campaigns if \( K_i \) has not yet been reached in the observed period [7].

4. \( \sum_j \sum_t c_{ijt} \cdot x_{ijt} \leq B \)

Each contact with customer \( i \) in campaign \( j \) at the point of time \( t \) causes campaign specific costs \( c_{ijt} \). The sum of resulting costs may not exceed the budget restriction for Campaign Management \( B \).

5. \( \sum_i x_{ijt} \leq 1 \quad \forall i, j \)

Each customer \( i \) may only be assigned to one campaign of type \( j \) during the entire planning period \( T \). Repeated contacts are therefore excluded.

6. \( x_{ijt} \leq \min \left(s^0_{ij}, s^\prime_{ij}\right) \)

The variable sets \( s^0_{ij} \) and \( s^\prime_{ij} \) are initialized ahead of the planning period, i.e. ahead of solving the optimisation.

In case customer \( i \')s last contact took place towards the very end of the previous planning horizon the resulting blocking period will be carried over into the following planning horizon. Customer availability based on the previous period's blockings is represented by \( s^\prime_{ij} \).

The availability of a campaign (e.g. from \( t = 3 \) through \( t = 9 \)) is described by \( s^0_{ij} \). In this way, the period of availability of a campaign is represented.

Formula 6 therefore takes into account that the assignment of a certain customer to a certain campaign at any point of time is possible only if the campaign \( (s^\prime_{ij} = 1) \) and the customer \( (s^0_{ij} = 1) \) are available.

7. \( \sum_{j \in J_g} \sum_{t_{\max}(1, t - S_g)} x_{ijt} \leq 1 \quad \forall i, g, t \)

Variable \( S_g \) determines the length of the blocking period between two contacts with customer \( i \) in campaigns of type \( g \). The underlying assumption is that certain customer groups' perception of annoyance depends on the channel of communication. Some channels (e-mail) may cause less annoyance than others (door-to-door sales). This is also true concerning product groups. Customers welcome information and sales activities regarding their preferred product groups while not showing interest in others. The bottom line is that the length of blocking periods varies among the defined campaign groups.

The second sigma sign of formula 7 is of special interest. With increasing \( t \) a timeframe of \( S_g + 1 \) builds up. It encompasses all possible customer-campaign combinations within each period and warrants compliance with campaign- and customer-specific blocking periods. As a result of this constraint no campaigns will be assigned if the customer is still blocked because of previous contacts.
8. \[ \sum_{t} x_{ijt} = 0 \quad \forall (i, j) \in M^- \]

Prior to running optimisation customers can be excluded from specific campaigns. For example, a customer that has participated in a particular campaign during the previous period should be excluded from participation in the exact same activity in the observed period. This is done by adding the customer-campaign combination to set \( M^- \) which prevents it from becoming part of the model's solution.

9. \[ \sum_{t} x_{ijt} = 1 \quad \forall (i, j) \in M^+ \]

In opposition to \( M^- \) all indispensable combinations are added to set \( M^+ \). That includes necessary callbacks or simply birthday congratulations.

10. \( x_{ijt} \in \{0, 1\} \)

Formula 10 restricts the co-domain of decision variable \( x_{ijt} \) to a binary value.

3. Algorithms to solve problems of any dimension

3.1. Test design

After the main features of the optimisation model for Campaign Management of the Fourth Generation had been developed it had to be tested for performance and the results had to be compared with those of earlier-generation models. A close to reality database was generated and filled with simulated data in order to realistically portray the customer database at the disposal of an actual company in the banking sector (see appendix 1).

The database that all analyses are based on was filled as follows:

A total of \( I = 100,000 \) customers and \( J = 30 \) different campaigns were generated. In order to capture actual activities in a bank's Campaign Management realistically campaigns' specifications were based on a mixture of campaigns of short (1-3 days) and intermediate (4-15 days) duration and of continuous availability. Additionally, the campaigns were categorised (e.g. retirement provisions, construction loans, investment) and matched with distribution channels, forming distinct campaign groups \( J_p \).

For each campaign a maximum number of contacts \( A_j \), variable costs of a contact \( c_j \), and a campaign duration \( s^0_{ij} \) for \( T = 90 \) were set. Eventually, the total budget \( B \) was set in consideration of variable costs and maximum campaign capacity. A customer history \( (s'_{ij}) \) was generated from previous optimisation runs to prevent cold start effects.

The test database was filled with normally distributed random values for the measure of utility \( e_{ij} \), each customer's individual blocking period \( S_{ij0} \), each campaign's blocking period \( S_{ix} \) and the allowed total number of contacts per customer \( K_i \). The means and variances for the measure of utility were determined by practical expertise.

The sequence of normally distributed random values was generated by means of the Box-Muller-Transform [8] using two uniformly distributed pseudo-random variables.

In reality customers tend to show similar levels of interest in campaigns that are much alike [9]. Because of that more or less strong correlations in estimates of utility can be observed. These correlations between similar campaigns were integrated into the database subsequently. Random customers were chosen from each campaign and their utility of a similar campaign was determined. A normally distributed deviation for this value was then generated using a random number generator. This deviation was transcribed into the database replacing the original value.

Further research required clusters which were generated using k-means clustering [10]. A total of 1,000 clusters were created. The measure of utility \( e_{ij} \), the allowed number of contacts per customer \( K_i \), the customer's blocking time \( S_{ij0} \), and the periods blocked because of previous campaigns \( s'_{ij} \) were used as variables for cluster analysis.

3.2. First tests and model complexity

Based upon the test database several optimisation runs were performed and their results were compared regarding the customers' average utility. At this point it must be mentioned that Generation 1 of Campaign Management eludes scientific scrutiny. Firstly, results would simply be random. Secondly, the possibility of assigning promising customers almost arbitrarily to a great number of campaigns allows for extreme results because the model disregards the negative effects resulting from the enormous (and unrealistic) pressure of advertising. Due to that fact the comparison of the different approaches' results examines only Generations 2 through 4.

For Generations 2 and 3 program routines have been developed according to the description in section 1.2. and the constraints explained in section 2.2. For all available campaign-customer-combinations the planning decisions are evaluated for each period along
the timeline. To simulate the uncoordinated planning of campaigns in Generation 2, a randomized order of the campaigns per period considered has been implemented. As result of this, simulation can vary for every run; an average result has been used for the following comparison.

Figure 1 supplies evidence that the results consistently improve from generation to generation. The enormous improvement of more then 50% at the transition from Generation 2 to 4 and close to 33% from Generation 3 to 4 is particularly striking. The approach of simultaneous planning by integer programming is obviously by far superior to the Campaign Management currently applied in practice.

![Figure 1. Comparison of the results of the three relevant generations of Campaign Management](image)

The significant improvement of results demands a much higher computation effort, though. Based upon the test database with a relatively small customer base of \( I = 100,000 \), only \( J = 30 \) available campaigns and a planning horizon of \( T = 90 \) days the number of highly interdependent decision variables amounts to \( I \cdot J \cdot T = 270,000,000 \).

In consequence of the combinatory explosion a well-equipped desktop shows the runtime behaviour depicted in figure 2 (computations were performed using ILOG OPL Development Studio 5.1). It is evident that even with a manageable number of customers and the resulting possibilities of combination computation time increases exponentially (see figure 2).

This leads to the conclusion that Generation 4 by far exceeds all other approaches in terms of effectivity. Yet that gain of effectivity is accompanied by a considerable efficiency disadvantage which restrains its useability to problems of very small dimensions.

In order to sidestep this drawback and to fully utilise the demonstrably great potential of Campaign Management of the Fourth Generation efficiency was sustainably increased by decomposing the problem and applying heuristics.

![Figure 2. Runtime of an overall simultaneous optimisation of 4G](image)

### 3.3. Problem decomposition and numerical results

Being convinced that questions of practical relevance cannot be resolved using overall optimisation within Campaign Management of the Fourth Generation due to limited computation capacities the problem was hierarchically decomposed. Problem decomposition leads to the following (see appendix 2):

Instead of calculating the optimum for all customers, campaigns and points of time simultaneously, as intended in overall optimisation, only 1,000 customer clusters were considered on the first level of decomposition (see chapter 3.1.). The most suitable campaigns were assigned to them according to their average characteristics.

As a second step the campaigns assigned to a cluster were reassigned on the level of single customers. That was done by selecting campaigns for single customers within each cluster depending on their individual \( e_{ij} \) value. Not until the last step the campaigns were scheduled individually for each customer.

As shown in appendix 3 increasing decomposition diminishes the result's quality. This fact is not really remarkable because problem decomposition often leads to a loss of information.

The approach of problem decomposition finally makes the application of integer programming possible...
throughout the basic concept developed in the context of Campaign Management of the Fourth Generation.

3.4. Simplified heuristics

The aim of the development of simplified heuristics is to further reduce complexity and computation effort and at the same time imitate the results of the optimisation models as faithfully as possible.

In addition to an overall heuristic to solve the entire optimisation problem a series of heuristics for application on different levels of problem decomposition were developed. All those have in common a relatively simple framework of rules which was implemented with the aid of scripting languages provided by the database systems used.

The following explanations (see figure 3) will concentrate on the overall heuristic as it encompasses most aspects of all heuristics developed and has shown superior results to most combinations of optimisation models and heuristics.

In step 1 of the overall heuristic all available customer-campaign-combinations are assembled and arranged by utility $e_{ij}$ in descending order. Available means, that combinations are only taken into account if the customer has been selected for this campaign beforehand. In step 2 a selected combination is tested for period independent constraints. These are e. g. maximum contacts with customer $K_i$, maximum number of contacts in campaign $A_j$ and budget $B$.

This test passed, a selected campaign is tested in all periods of availability (step 3) for period dependent constraints for scheduling at specific periods (step 4). These tests take into account the availability $s_{ijt}$ of the individual customer which is limited by blocking periods through previously planed or executed campaigns.

If all tests have been passed successfully, the campaign $j$ is planned for customer $i$ at the first valid period $t$, i. e. $x_{ijt}$ is set to 1. The period-loop is interrupted. The outer loop continues with the next best customer-campaign-combination.

3.5. Results of simplified heuristics

As shown in appendix 3, the heuristics return slightly inferior results compared to the mathematical optimisation. Although, the loss of quality of the results can be regarded as marginal. It is furthermore countervailed by the heuristics' almost proportional runtime behaviour when computing these results, which enables them to solve even the overall problem within a reasonable amount of time (see figure 4).

4. Further Research

During the discussion of this optimisation model and the developed heuristics several aspects for further research appeared:

- As our tests have been conducted on a simulated data set, the results can be influenced by the test design used. A comparison of results with real world data in an enterprise environment is necessary to confirm our study outcome.
- To implement the developed heuristics into CRM-systems in practise possible adjustments and the influences on organizational processes in Campaign Management have to be evaluated.
- In the overall heuristic all customer-campaign-combinations are arranged by utility in descending order. First sensitivity analysis showed that esp. costs for contacts in campaigns can have a considerable influence on the results if the
variance of costs between campaigns is very high. Further research has to been conducted to optimise the heuristic in this aspect.

- Some constraints described in section 2.1. are related to each other, e.g. the number of contacts in campaigns and the costs of a contact are linked to the budget. Thus the coordinated setting of these constraints has a great influence on the results of an optimisation. Future research has to be conducted on this aspect.

- As multi-step campaigns gain more relevance in practice an integration of these campaigns with several customer contacts is not covered by the models and heuristics developed yet.

5. Conclusion

The model of simultaneous planning described here has proven superior to all conventional approaches to Campaign Management. Because of the model's complexity and the inherent combinatorial explosion overall optimisation by means of integer programming can only be applied to small problems. Decomposition of the problem, however, allows solutions to problems of nearly any dimension while suffering only marginal losses of quality of results. Much the same thing is true concerning the heuristics developed. Only little effort of implementation comes along with very reliable results. Taking all these circumstances into account, application of the overall heuristic is sustainably advisable.


Appendix 1: Data Model
Appendix 2: Tree decomposition

Customer clusters

Single customers

Time periods

Overall optimisation

Optimisation of campaign contacts based on customer clusters

Heuristic for contacts based on customer clusters to single customers

Optimisation of contacts based on clusters to single customers

Optimisation of contacts for single customers to time periods

Heuristic of contacts for single customers to time periods

Appendix 3: Results

<table>
<thead>
<tr>
<th>Campaign contacts based on clusters of customers</th>
<th>Contacts based on customer clusters to single customers</th>
<th>Contacts based on single customers to time periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Overall Optimisation</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Optimisation</td>
<td>Heuristic</td>
</tr>
<tr>
<td>3</td>
<td>Optimisation</td>
<td>Optimisation</td>
</tr>
<tr>
<td>4</td>
<td>Optimisation</td>
<td>Heuristic</td>
</tr>
<tr>
<td>5</td>
<td>Optimisation</td>
<td>Optimisation</td>
</tr>
<tr>
<td>6</td>
<td>Optimisation</td>
<td>Heuristic</td>
</tr>
<tr>
<td>7</td>
<td>Optimisation</td>
<td>Optimisation</td>
</tr>
<tr>
<td>8</td>
<td>Optimisation</td>
<td>Heuristic</td>
</tr>
</tbody>
</table>

Utility per Customer proportional to 2G

Next Best Activity (3G)

Collision Management (2G)