



# Call Center Scheduling

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## **Situation**

These days, consumers have a difficult time escaping the ubiquity of phone services. Whatever we do, whether it's dialing a toll-free number, making a plane or travel reservation, calling the bank, cable company or customer hotline service we have to deal with a phone call center which processes our solicitation through a phone operator.

The traditional walk-up bank teller windows have mostly disappeared in favor of "relocated centers". These centers are supposed to streamline the activity of maintenance and follow up calls of customers in order to improve its quality (in terms of answering delay and open hours), and at lower cost for the provider. The size of these centers may range from ten to as many as several thousands of agents. Two thousands of agents are needed for a mobile phone operator like Bouygues Telecom, third largest French mobile operator with over three million customers, whose customer service is performed exclusively through the telephone.

In order to organize a call center, it is necessary to consider a work load (known or projected) to be matched with a sufficient number of employees. All businesses constitute a human resource that must be coordinated and planned in order to maintain the service quality required with the lowest costs conceivable. To this day, about one hundred thousand of such tele-workers are concerned in France (a million of them are expected in Europe in the coming years), and advocate the development of planning software taking into account the specific constraints of this particular staff scheduling problems.

The aim of the following is to illustrate the complexity of this task through the software development which was made for Bouygues Telecom call centers.

## **Constraints and costs**

In order to simplify our presentation, we will consider that the number of calls to be handled is accurately known. Such a simplification may prove hazardous at times. For example, a flood of incoming calls were ushered in by the massive purchase of cell phones before the holiday season or around Christmas Eve. By the same token, toll-free numbers of humanitarian organizations can generate thousands or even hundreds of thousands of calls after a particularly powerful television campaign. However on a regular basis, the behavior of callers (with the famous end of morning-beginning of afternoon peaks) is relatively determined and can usually be predicated from the past. Moreover, the size of the call centers has a tendency to smoothen irregularities.

We can roughly divide the activities of the employees working for call centers into different specific groups:

- The processing of the calls itself (this can require different skills for the Customer Service Representative - CSR in the following - e.g., a subscription or a cancellation is a less specialized task than settling a disagreement).
- The post-processing part, where usually the CSR captures the data from the call and starts the appropriate procedure
- The follow up calls: these can be done on calm periods
- The back-office work: a necessary task that should not involve the customers
- Inactivity: in case the calling center is overstaffed or in momentary down times
- And of course planning: the activities of the supervisors must be planned along with everyone else



- In the coming months a new service will be offered; "email processing" induces an activity which one can see as a semi front-office task since it can be more or less delayed within the day.

The planning period never reaches beyond a trimester and is mostly determined monthly, depending on legislation or custom. One can distinguish two different planning prospects : planning of vacation days (and thus working days), and planning of the hours of the workday. Accurate planning of any activity depends on the type of service and on the scale of expectations of the work load, but fifteen and/or thirty minutes seem to be the average time grain of most activities. It has to be pointed out that breaks, paid or not, are only a few minutes long and are included into the decision variables.

The data of the daily scheduling problem of a call center could typically be summarized as follows:

- A block of load curves, sampled every 15 minutes for each group of activity (generally less than the average of twenty activities per call center) with corresponding service level asked;
- The work contract for each CSR, his/her minimal and maximal daily, weekly and monthly amount of work, the payment rate, the length of service, history of previous planning as well as his/her competence in regards to the site's different activities.

Additionally, each contract specifies a group of "standard day" or "standard week", rotations that a CSR is required to work. The contract also specifies the number of holiday days-off, as well as the frequency of evenings that the CSR has to work at set times or at flexible hours, and the number of weekends per month (e.g., Saturdays only; Saturday & Sunday; Sunday & Monday, etc.).

As the present computer age is geared towards the everyday needs of the consumer, it would be a mistake to ignore employee wishes such as:

- Their preferences: favorite arrival and departure times, favorite standard day schedule, the relative times for lunch breaks (absolute or related to the arrival time)
- Their contract exceptions: isolated unavailability (dentist appointment planned in two weeks at 10'clock p.m.), or weekly unavailability like a training internship on Mondays, - same thing for the days off -.

To make things more complicated, we must altogether: i) consider the global objective (accomplish the tasks by type of activity); ii) take into consideration the restraints of the CSRs contract; iii) take into consideration the center's restraints; and iv) take into consideration the collective agreement or the current legislation.

Let us also not omit the fact that there should be a minimal "recovery" time between two consecutive days of work, or the necessity of having "difficult" days followed or preceded by a day off. Those notions are today represented with a set of generic constraints offered to the end-user: distance between given shifts, minimum or maximum occurrence of events within a period, .... Moreover, it seems that in Latin countries there is a notion of crew, where people work as an entity and need to be at work on the same days or to have the same weekends off. Members of a crew must work together (have lunch together, particularly in France) and reduce the distance between their arrival and departure time. Couples may wish to have synchronized days off. Finally the site is after all a physical entity and may have equipment restraints (for specialized activities) and/or may have a limited number of seats available.

In case of an employee shortage (which is often the case for at least certain types of activities), the number of calls on hold needs to be minimized. Generally speaking, each type of call is associated with a profit (or a penalty in case the CSR has to put the customer on hold). Also the CSRs receive an hourly rate depending on their seniority, preferences and skills.

As combinatorial as it looks, this issue of load coverage under constraints, the considered stakes do not allow demobilization. The wage bill that constitute the CSRs represents, for an operator like Bouygues Telecom, a substantiate percentage of its expenses. The figure of one hundred million euros is a safe lower bound. Overhiring by even 5% of the required number of CSRs would hurt margins and eventually cause an increase in phone rates. The quality of optimization has to be below that figure.



## **Complexity**

A mathematical decomposition of the scheduling problem offers a few leads to analyze its computational complexity. The days off assignment phase combined with the choice of daily patterns (e.g. opening hours, midday shifts) has something to do with time tabling problems enriched with additional team synchronization constraints. Yet, contrary to the classic rostering problems of the 70s, one has to take into consideration how much the CSR population is heterogeneous : full time workers and part time employees offer the same kind of service, the latter, say students, might prefer to work in the evening or during weekends. The workload too, appears to be pretty much unbalanced throughout the day or the week, which implies intrinsically unsymmetrical rotations.

As far as daily scheduling is concerned, Generalized Assignment Problems comes to mind. The fine grain of the service to be scheduled, which consists in performing a task within a window of less than 15 minutes, together with the various kinds of activities that might be performed within a day, make the problem very much different, in its typology, from the crew scheduling problems addressed in transport companies.

Finally note that if one focuses this time on the seats capacity of the site (or any resource constraint in pieces of equipment per activity) a distinct flavor of multidimensional bin packing occurs.

Hence, the computation of a feasible planning, 5% close to optimality, for every quarter of hour, of every CSR within 10 weeks is a NP-delicate task.

## **Development**

Bouygues' New Technologies Department (DTN) missions mostly consist in modeling, prototyping and development of optimization applications for the various subsidiaries of Bouygues company. In 1997, DTN<sup>1</sup> co-developed and now maintains and enriches an optimization library for the call centers of Bouygues Telecom, scheduling today about one thousand employees on 5 different sites in Paris, Nantes (western France) and Tours in the next future.

Without entering too far into details, the software incorporates three main families of algorithms :

1. Constraint Programming. Within a truncated Branch and Bound scheme, each time a variable is fixed (e.g. a weekend off) the information is instantly propagated to the associated constraints with possible consequences on the other variables involved (e.g. a maximum number of weekends off per month forces then all other weekends to be worked, hence, if Sunday is not worked in general, all remaining Saturdays will be worked). Shifts are assigned in the same manner within the same exploration tree.
2. Insertion based Heuristics. The analogy with classic insertion procedures used for Vehicle Routing Problems (VRP or VRPTW) is the following: Instead of a truck of the fleet, visiting a set of clients/cities, a CSR aims at visiting/answering a set of (allowed) activities so that the length of the tour/shift induced is compatible with the minimum and maximum quantity of work in the day. We refer the reader to the corresponding academic work of Y. Caseau and F. Laburthe for VRP or TSP.
3. Matching and flow algorithms. In particular, one can easily model the skill assignment part of the problem, once all schedules are fixed, as a capacitated flow of maximum cost.

The language used for development is called CLAIRE, and has been developed by Yves Caseau at Ecole Normale Supérieure a couple of years ago. It combines respective advantages of usual paradigms such as:

- object oriented programming : abstract data types, inheritance, genericity
- interpreted functional aspects within a strictly typed context

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<sup>1</sup> Yves Caseau, Tibor Kökény, Arnaud Linz, François Laburthe, and the author have participated in the development of the planning tool.



- hypothetical reasoning : recursive context saving helps to backtrack implicitly along the search
- set iterators : for instance, one can randomly iterate an all CSR, full time employees, working on opening hours and apply a specific algorithm on them. It offers a high level environment for discrete algorithms coding and heuristics comparisons
- garbage collector : to get rid of memory management

Coding and debugging (memory leaks do not account for all bugs) are done in interpreted mode whilst a compilation into C++ provides an efficient running time for the application. It is embedded into the final software as a DLL (Dynamic Linked Library), with access to databases and human interfaces. Globally a one month scheduling for 300 CSR takes about 5 minutes for the planner on a classic 200 MHz PC.

## ***Here and whereabouts***

The ACDC software ("Agenda des Conseillers De Clientele") - Call Center Scheduling - has been operational for over one year on many Bouygues Telecom sites. The external audits that have been made (and the comparisons with the estimations and other commercial tools) have validated the chosen approach towards the management.

A happy consequence was the appearance of new international clients through a young Californian company created on the sector of calling centers, which integrates a more generic version of our optimization engine in a complete application of call estimate and scheduling called Workforce Management.

Because this tool was developed for a French application, (meaning that we had to deal with a particularly restricting social legislation), it offers a decisive advantage: it easily considers the customs and the collective agreements which govern the customer service representatives all around the world. Today, our product is distributed to more than twenty different clients (including Australia, France, Italy, the Netherlands, Swede, and the United States), and plans the schedules of several thousands of agents. This software needs to evolve and anticipate the new needs of its clientele which are:

- Multi-site planning
- In France, simulation and validation of how to deal with the 35 weekly working hours new regulation
- The physical management of the available seats (proximity of crews)
- Finer integration with the stochastic aspects of the queues. Unfortunately the multiskill characteristic of the system does not allow the use of classic Erlang formulas
- Recruitment policies in order to dimension the queues according to the expected demand
- In order to propose a (rough) sensitivity analysis, lower bounding procedures are now being studied. They are based on Lagrange relaxations, richer than the above mentioned linear assignment model.

From the CSRs point of view, surveys conducted at Bouygues Telecom show that the tool has been well accepted. Though, because the CSRs know that their schedule is processed by a computer (i.e., automatically processed), they rightfully ask to have the unrewarding tasks equally distributed (e.g., evening hours or granting of days off). An agent once complained that he had to work late on Christmas Eve two years in a row, an incident which made us consider the history for more than one year of scheduling.

The choice of an adhoc Constraint Programming approach allows a strong reactivity regarding the addition of constraints without debasing the answering time and the quality of optimization.

In conclusion we can say that the necessity for a team of *Discrete Optimizers* to adapt its algorithms and to redefine the heuristics depending on a growing number of clients is a particularly stimulating challenge. Online combinatorics has such an advantage. In our opinion, the field is doing well and finds its mark in the wake of new telecommunication technologies in the general sense. Beyond what the big houses of "prêt-à-optimiser" have to say, the custom designers of algorithms still have beautiful days to come.