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Title: **WorkForce Management (WFM)**

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Abstract

Cost Reduction of Telecommunication Network Provisioning Operation and Maintenance is today a strategic issue for Telco operators. Workforce Management (WFM) environments and techniques allow a dramatic cost and performance improvement for the "on the field" technicians management. Basic functionalities offered by the WFM environments are: automated task assignment to workers and mobile office techniques.
CSELT has developed a WFM environment to evaluate the cost reduction and performance improvement by using Artificial Intelligence and Operations Research techniques to automatically assign the tasks, Data Transmission techniques based on GSM-SMS (Short Message Service) and Inmarsat-C Satellite communication, geographical localization and representation using GPS (Global Position Satellite) and GIS (Geographical Information System) and Mobile Office techniques.
This paper describes: the CSELT WFM environment with particular emphasis with the Automatic Assignment Algorithm and the results obtained during the extensive field trials in two Telecom Italia Control and Operation Centers.

1. INTRODUCTION

Today Telecom operators must provide, operate and maintain all the TLC network equipment scattered into its competence territory (e.g. Telecom Italia network covers all the national territory). Therefore a great number of technicians (in Italy about 20.000) must be available to allow the intervention to be performed quickly. The objective is clear: to provide, operate and maintain (PO&M) the network into a wide territory, but there can be many different ways to organize technicians that perform the intervention.

Cost analysis have demonstrated that PO&M processes have a great impact on the global costs of a Telco operator. Furthermore, it is important to guarantee a high level of performances to obtain a high level of Customer Satisfaction. For these reasons it is strategic to maximize efficiency and effectiveness by considering a mix of key factors: Organization, Procedures, Technology.

This presentation describes how the Workforce Management (WFM) problem has been faced and which are the solutions proposed to reduce operations costs (i.e. increase number of interventions), to improve service quality (i.e. optimize intervention time and workload performances) and to improve the technician job quality (i.e. make easier the evolution of current enterprises toward flat enterprise). CSELT has set up a WFM environment designed to evaluate: the integration of enabling technologies (i.e. GIS, GPS, mobile computing via GSM and/or satellite communication systems) with advanced algorithm techniques for automatic tasks assignment and possible operation costs savings. Core of the WFM is RAPID (Resource Allocation through Powerforce Intelligent Dispatching), a System designed and developed by CSELT on the basis of Telecom Italia requirements. RAPID is a package-system composed by two different tools: (a) RAPID_Laboratories performs detailed simulation scenarios in the Lab to estimate the correctness of the algorithms in front of Present and Future Mode of Operation (PMO/FMO) and (b) RAPID to be used on the field by the Provisioning, Operation and Maintenance technicians.

In the next pages there is a description of: the processes involved, the CSELT WFM environment, the resource scheduling problem and the ARCO embedded solutions, the results of RAPID Operations on the field.

2. WFM BUSINESS PROCESSES

Network Operation, Assurance and ***Delivery*** have been identified as the main processes for representing the PO&M tasks to be performed by the Workforce available. The Network Assurance (based on alarms and claims) process includes scheduling, performing and tracking tasks for maintenance interventions on the network. It also includes Customer Care tasks, which involve the reception of Customer claims and subsequent contacts with the Customer to solve the problem. The Network Delivery (based on customer requests) process for narrowband services includes scheduling, performing and tracking tasks for activation and transfer of POTS (Plain Old Telephone Service) or STS (Supplementary Telephone Services) lines. Main organizational difference between Assurance/Operation and Delivery is related to the intervention site: for Network Assurance/Operation case, an high percentage of interventions are performed within a Work Center. In the Network Delivery case, nearly the whole number of interventions is performed outdoor (at Customer location, on external network or both).

In spite of these and other differences, the high level description can be the same: in front of an input, there is an assessment phase, whose output is the identification of an intervention to be

made. Then these information are sent to a worker that performs all the actions to fix the trouble or to activate services. A test phase is performed to verify correctness of the intervention.
The figure 1 describes the impact to the processes due to the introduction of the WFM environment by representing a possible FMO (Future Mode of Operation) for Assurance processes. In the figure the greyed squares represent activities supported by automatic procedures through WFM. It is possible to see that the effectiveness gains are obtained by the automatic activities execution. So, for example, the fact that the technician is chosen automatically and just after the Work Request compilation and that the chosen technician receives all the technical information directly, without any intermediate steps, can lead to a meaningful effectiveness improvement.

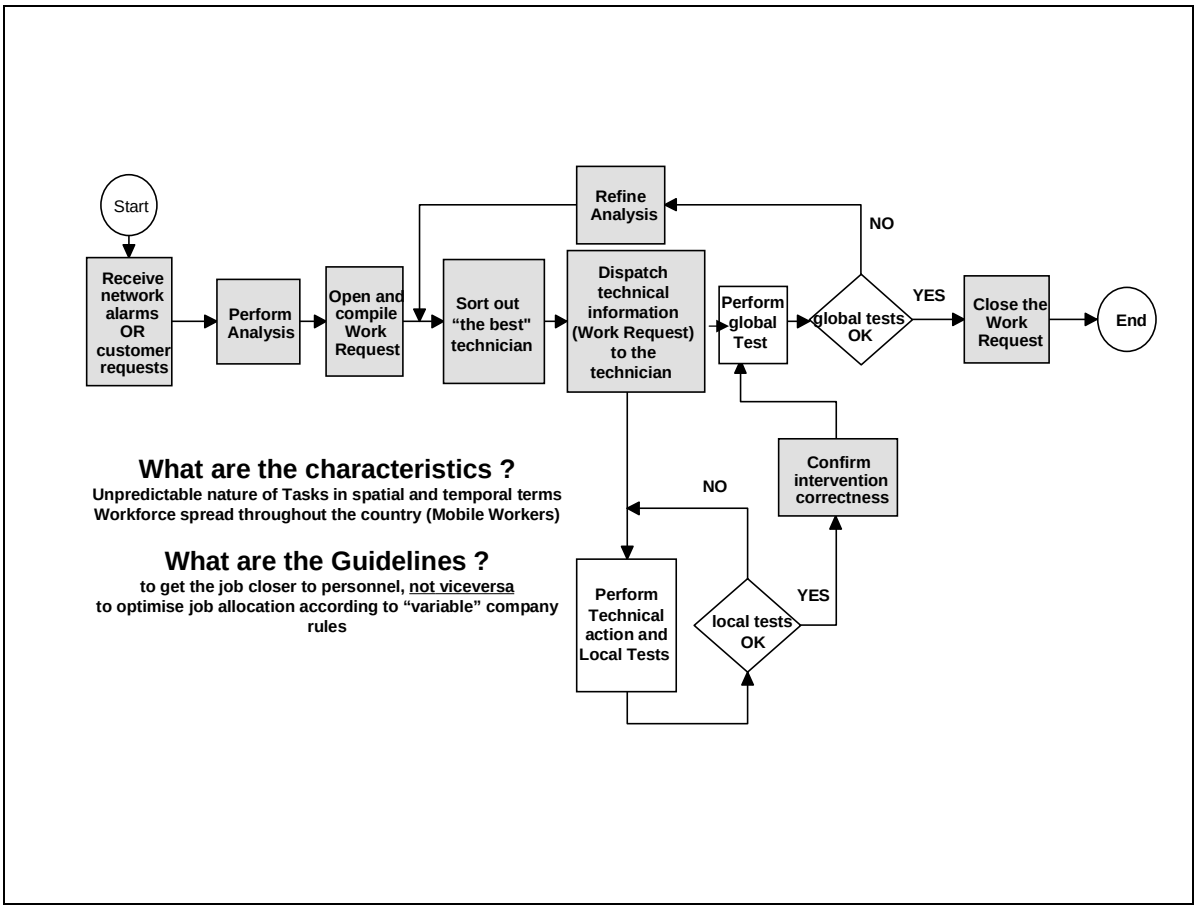

Figure 1: The WFM Assurance Process

3. THE RESOURCES SCHEDULING PROBLEM

One critical aspect in a Workforce Management System is the Resource Allocation module that, in front of the incoming Work Requests, assigns to each of them a starting time, one or more technicians, a vehicle for outdoor tasks, and the spare parts of probable use. In doing this it is necessary to optimize a set of hard and soft constraints (or preference rules) like for example: resources availability, distances to be travelled, tasks priorities, technicians skills and workload balancing, etc. Moreover other aspects must be considered in the assignment:

- Organizational: some people are appointed to a definite geographical sub-area, or to a particular network (or switch) technology, and can be assigned to these tasks only. Different policies can be applied to overtime work depending of the contract of each group of workers.
- Legal: some tasks must be performed by at least two people, for instance when a dangerous task is involved.
- Technical: people have different skills.
- Human: two technicians may have problems when working together, the algorithm should avoid teaming them up.
- Contractual: some faults may involve penalties and should be scheduled with higher priority.

These factors and Constraints unceasingly evolve and different policies may be appropriate to similar allocation problems in different contexts. This means that flexibility and maintainability of the algorithmic solutions are critical. For the same reason, off-the-shelf resource allocation products do not exist. The solution must be tailored onto the target operational process.
A second aspect that needs customization is the definition of what is an optimum for the allocation program, in terms of how many parameters need to be optimized, and how well.

4. THE CSELT WFM ENVIRONMENT

The CSELT WFM (see figure 2) environment is composed by:

- a RAPID Server located in a Control Center;
- RAPID Clients located in remote operations centers;
- a Field Access System to allow the communication of on the field technicians with the Control and Operations centers;
- Radio Communication channels (different channels can be used: satellites and GSM);
- Mobile Office equipment (Palmtop, PDA etc.);
- GPS receivers to locate the geographical position of technicians car;
- GIS functionalities for the geographical representation of the Network Elements and of technicians cars.

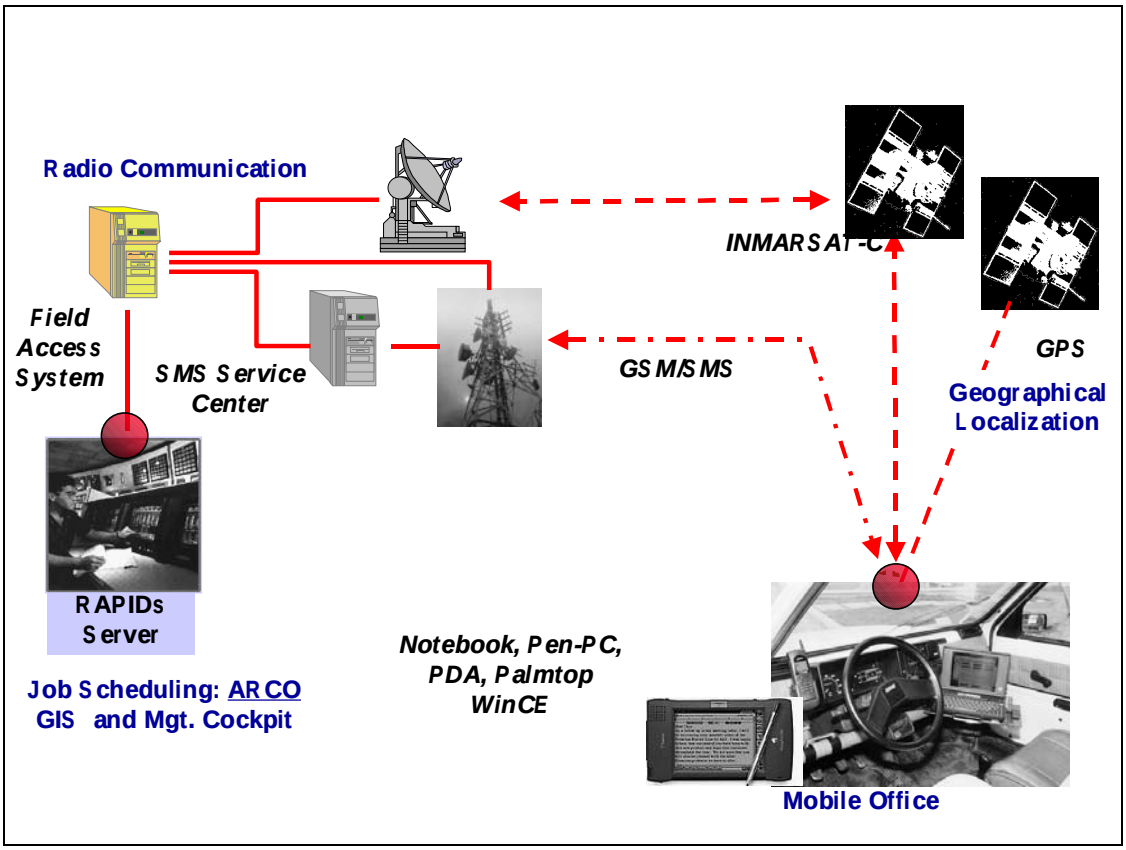

Figure 2: The CSELT - WFM Environment

RAPID is a client-server system that performs workforce monitoring and management. The Core of RAPID is ARCO the resource allocation algorithm. ARCO uses Heuristic search and Constraints Programming for the tasks planning. The WFM architecture is a two tiers Client Server Architecture based on: Unix (Server O.S.), Windows (Client O.S.) and Oracle (RDBMS).
In the WFM environment there are three main functions categories (see figure 3):

- Algorithm functions (developed in C++ language using a Commercial Platform named ILOG and running on the Server);
- GUI, Monitoring and Management functions (developed in Visual Basic , based on ODBC and SQLNET and running on the Client);
- Interfaces and Utilities functions (developed in C and running on the Server).

The main Algorithm functions are:

- Compute Agenda (it calculates a Gantt plan for the tasks to be performed);
- Agenda reshuffling (when an external event happens the Agenda can be reshuffled trying to minimize the changes on the technicians Agenda);
- Assign Single Task;
- Assign Urgent Task (an Urgent task is an unplanned task to be performed as soon as possible, an example of a urgent task is the repairing of a fault);

- Appointment (the algorithm fixes automatically and precisely the appointment to the Customer);
- Delay task (when an task does not end at the estimated time it is necessary to readjust, in real time, the Agendas).

The main GUI, Monitoring and Management functions are used by the technicians managers:

- Planning, GANTT, Allocation, Work Request Management;
- Resource Management (people, cars, spares, equipment);
- Cartography Management;
- Statistics and Indicators;
- Escalation and Warning, Cockpit.

The interfaces functions allows the WFM to interface external Systems and the utilities functions manage specific requirements like: priorities escalation, GPS simulation etc.

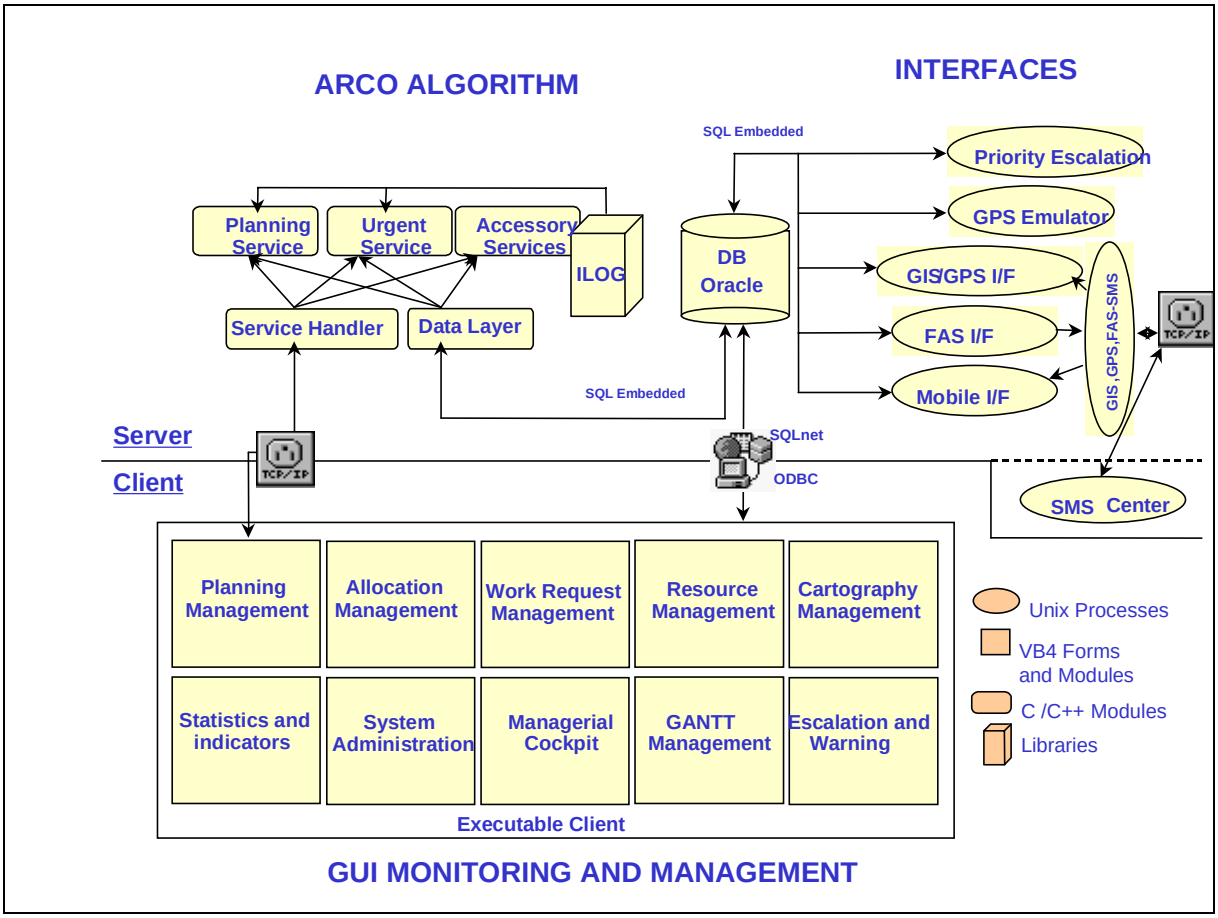

Figure 3: The WFM Functions

5. ALGORITHMIC TECHNIQUES

Existing State of the Art Scheduling Techniques suitable to solve the Resource Scheduling problem can be grouped into two big families:

- The Operational Research (OR) family, which includes classical algorithms such as Linear Programming, Branch-And-Bound and the more recent Tabu Search. OR algorithms are fundamentally numerical methods, very efficient and consolidated if the problem is tractable, but prone to suffer from the combinatorial explosion problem, in worst cases.
- The Artificial Intelligence (AI) family, which includes:
  - symbolic methods (Hill climbing, Simulated annealing, Constraint Satisfaction), where heuristic knowledge play a fundamental, indispensable role in order to effectively and efficiently drive the search for the best solution through the solution space: some of these methods are mainly applied to problems (such as Constraint Satisfaction), where the purpose is to satisfy a set of constraints, while others are used for optimization problems where near-optimal solutions are acceptable (Hill climbing, Simulated annealing). Rule based systems could be applied as well, but with not always satisfactory performances and also problems of maintenance.
  - subsymbolic methods (Genetic Algorithms, Connectionist methods), both used for optimization and constraint-satisfaction problems, but expected to be costly and laborious to apply, especially in domains such as the Telecom one, where custom solutions are looked for.

Constraint satisfaction techniques [Saraswat95] [Marriot98] [Caseau95] are especially useful in domains involving task scheduling and planning, such as the WFM one, where a number of constraints has to be taken into account. Tasks scheduling proves to be a very complex job, involving the combination of three NP-Hard problems [Garey-Johnson79] [Root65]: resource allocation (Knapsack problem), scheduling in the presence of time constraints and the travelling salesman problem. These domains typically involve the use of two kinds of constraints: hard constraints (that MUST be satisfied) and soft constraints (whose satisfaction is preferred but not necessary). Constraint programming offers thus a natural way to express them. Moreover, to keep the problem dimensions tractable and the response time acceptable, heuristic search (i.e.: preference rules specific for the domain) can be used to drive the search over the solution space (i.e. over the solutions potentially provided using constraint programming techniques): the real time performances and the reliability required by WFM systems indicate that a suboptimal solution is often sufficient.

6. THE ARCO ALGORITHM

ARCO is embedded in RAPID and fundamentally offers functionalities of planning, scheduling and resource allocation.
It takes into account information relevant:

- to available resources (i.e. technicians of the considered Working Centers, vehicles and spare parts),
- to tasks to be performed, characterized by a set of features, such as priority, average duration, typology, required skills, and so on,

- and to distances among intervention sites,

and produces as output a task plan (agenda) for each technician, from the current time until the end of the scheduling horizon.

Every day, at its start, ARCO prepares, in batch mode, an initial set of agendas to be handed out to the technicians, upon their arrival. However, since the situation is highly dynamic and a variety of events may occur during the working day, such as arrival of new tasks, notifications of delays, changes to the resources availability, illness of a technician and so on, ARCO is able to behave accordingly and change, dynamically and in real time the agendas in the most appropriate way.
In general, it can be said that ARCO behaviour is triggered by a variety of events/requests, that endlessly arrive during the day, and, as a result, agendas are updated accordingly.

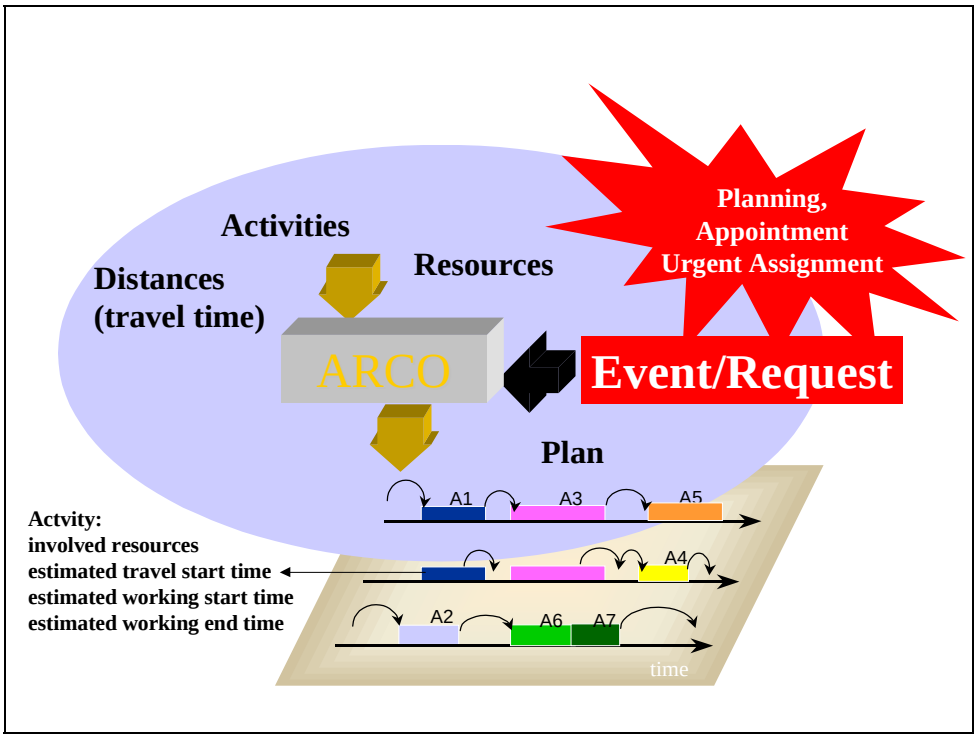

Figure 4: The ARCO Algorithm Logic

7. ALGORITHM ON THE FIELD TUNING

RAPID and ARCO have been used in Telecom Italia Operation and Maintenance Work Centers for a period of one year and for Real Operations and Maintenance tasks.
Each plan generated by ARCO has been proposed for confirmation/rejection to the technicians' Supervisors. After a period (almost 2 months) of macro and fine tuning done by changing (through the GUI) the calibration parameters or the scheduling heuristics we achieved more than 90% acceptance from the Supervisors (see figure 5). A closer look to the non-accepted plans reveals that rejected plans are, most of the time, comparable in efficiency but simply different from the solutions given by the Supervisors. The efficiency of ARCO solution is a very important topic for

the acceptance of the WFM System. During our field trials we noticed (especially at the beginning) a strong opposition from the people. This negative reaction to the introduction of the System is not surprising and it can be interpreted considering the following main points:

- the WFM System is a real threat for the supervisors because it replaces partially their job;
- technicians can see the WFM System as a loss in the flexibility in performing their job;
- technologies used are very advanced and change dramatically the way people operate.

So the WFM System introduction process shall carefully consider and manage the cultural change problems induced. To be successful in managing these cultural change problems and obtain WFM System acceptance it is mandatory to have an algorithm able to assign more efficiently than Human beings do. So that's why the ARCO efficiency is a Key Factor for the entire WFM Project success.

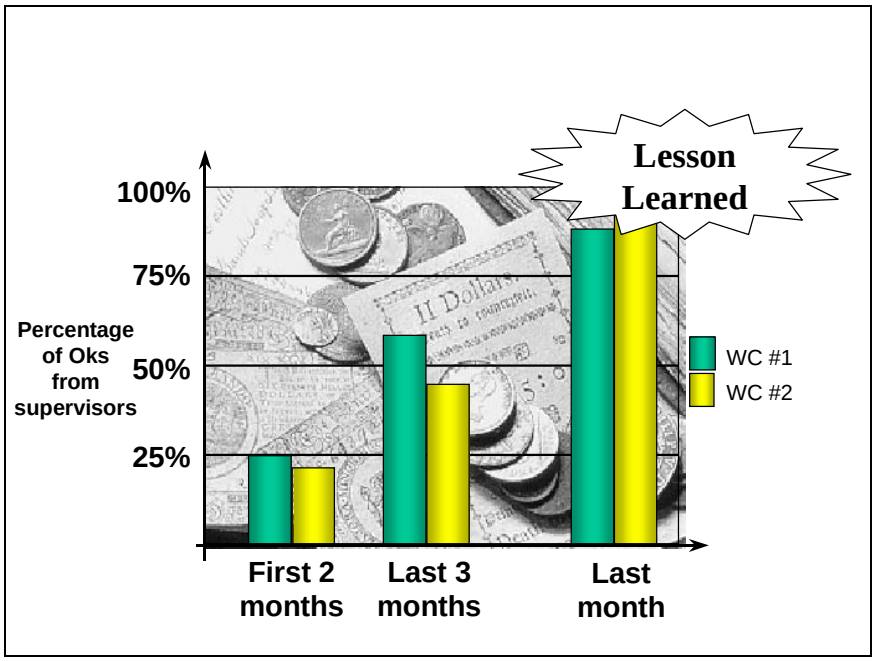

Figure 5: The Results from the field

8. ALGORITHM MANAGEMENT EFFICIENCY

From theoretic analysis and observation on the field it is possible to make a qualitative comparison between human efficiency and algorithm efficiency in finding the solutions. The assumption made by the comparison is that the Human being is experienced and knows the territory, the technicians available, the priorities and so on. It is possible to see that for a small team of technicians the solution given by the experienced Supervisor can be 100% efficient, while the heuristic search done by the algorithm cannot reach the 100% efficiency. When the number of technicians increases, the Supervisor is no longer able to manage the team and very soon the situation will get chaotic. On the other hands the algorithm, in theory and if well designed and calibrated is able to maintain the solution efficiency stable in the average (see figure 6). Therefore the algorithm is a leverage toward a flat organization because while today a Supervisor cannot

manage more than 10-12 technicians, with the WFM support he will be able to manage group of 50-60 technicians. Moreover it is no longer necessary to have Supervisor with the exact knowledge of the territory characteristics (equipment, geographical characteristics) and technicians characteristics (skills and so on). If properly applied this can reduce the number of organizational levels.
Moreover the Algorithm Management efficiency strongly depends on the Tuning. The Tuning is performed on the basis of human rules and experience. Normally it depends on the territory characteristics (City, Country, seasonal dependency etc.). So it is important to define clusters of rules to be applied on a specific territory.

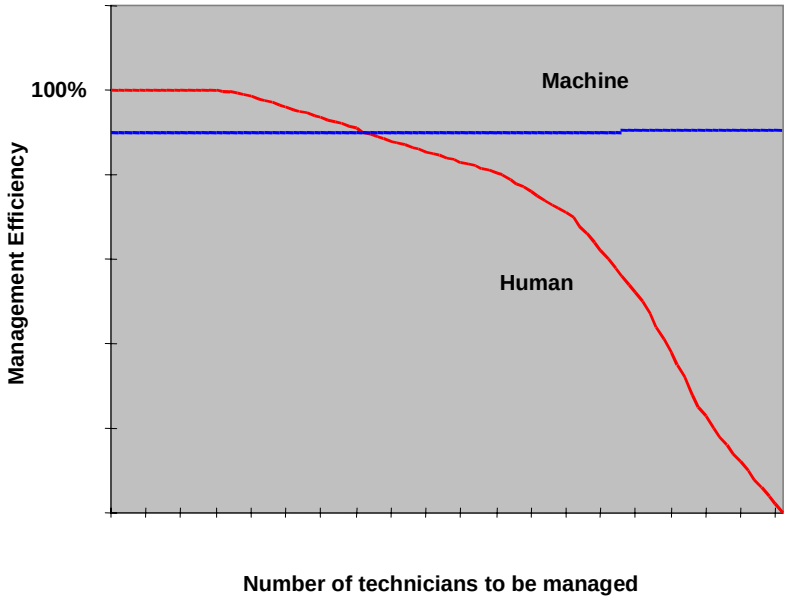

Figure 6: The Algorithm efficiency

9. WFM EFFICIENCY IMPROVEMENT

By considering everyday operation it has been possible to identify the Key Factors for the WFM efficiency improvement (i.e. Cost Savings). Considering the Supervisor it is possible to measure efficiency improvement due to the fact that many manual tasks done today by them can be done automatically by the WFM Systems. The main improvements are however given by technicians tasks. The efficiency improvement can be obtained both on the travelling times to go and come back to the intervention site and execution times to perform the intervention on site.
The travelling times can be reduced by:

- the Algorithmic optimization of the travelling distances and the tour performed by the technicians;
- the Mobile Office techniques that allows a technician to work from outplant without the necessity of coming back to the Operation Center after each intervention.

The execution times can be reduced by:

- the optimization of Spare Management (done by the algorithm);
- the availability, in real time, on a computer screen of all necessary Data to perform tasks (this means a reduction of the time for a technician to understand what he has to do);
- the complexity management performed by the algorithm in finding the “best” technician to perform a task (considering above all the skills, the tasks duration and the tasks priorities).

From CSELT measures and estimations the WFM can lead to 15% efficiency improvement for the technicians (with a travel time reduction of 35%) and 40% efficiency improvement for Managers (Supervisors).

10. CONCLUSIONS

The WFM System is a strategic System for Cost reductions. The investments necessary are very high in case of a big Operator like Telecom Italia (with more than 20000 technicians involved and 16000000 of Work Request per year).
Today main Telco Operators are all moving toward an automated solution for the WFM. This because the revenues are very high and the Payback can be in the range between two and three years. Moreover the competitiveness of the operator can increase dramatically thanks to the cost reduction and the quality improvement. In fact a WFM System besides the cost reduction shall lead to Quality and Customer Satisfaction improvement. The WFM System can be used both for big Telco Operators and for small Telco operators. So the WFM System should be scalable: from a technical point of view (the architecture should be scalable) and from a Cost point of view. Another important topic to be pointed out is that the WFM is not only a System; it is a Programme in which it is important to consider the WFM System impact on the Territory. That’s why the Communication and the Change Management are strategic for the WFM Programme success.
Telco Operators from Latin American (Telecom Argentina and Entel Chile) have already analysed the CSELT -WFM solutions and are very interested in using it. The main differences from Telecom Italia context are:

- the territory to be considered is wider than Italy so the WFM travel optimization is a very important topic;
- the number of technicians and of Work Request is less than for Italy so the WFM System architecture and Costs should be scaled on the basis of the number of technicians.

In particular the revenues expected can be higher than for Italy due to the fact that the territory is very wide.

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