THE COMPUTERWORLD HONORS PROGRAM

CASE STUDY

LOCATION:
Lisboa, Portugal

YEAR:
2006

STATUS:
Laureate

CATEGORY:
Transportation

NOMINATING COMPANY:
Deloitte

ORGANIZATION:
SISCOG

PROJECT NAME:
CREWS

Summary

CREWS is a software product for planning and managing the work of rail-staff, that provides solutions to one of the core problems that transportation companies face today – effective management of resources. CREWS addresses, in an integrated way, all phases of the planning and management process.

At any stage of the process, the integration of a very powerful optimizer with the possibility of manual intervention provides un-precedent power and flexibility that are unmatched by any of the systems of the competition.

Introductory Overview

BACKGROUND.
SISCOG is a Portuguese software company that has specialized in the development of rail-staff planning and management systems for the railway industry. Founded in 1986 by two computer scientists that had recently obtained their Ph.D. in the United States, SISCOG quickly recognized a market niche where specialized knowledge and advanced computational techniques could bring dramatic gains for railway companies. Almost since its inception, SISCOG has been devoted to the development of a software product, called CREWS, that can be adapted to different realities and has the capability of handling the complexity of planning and managing on-board staff. CREWS-based systems nowadays plan the daily work of more than 20,000 rail-staff members across Europe that are responsible for transporting several millions of citizens on a daily basis.

CONTEXT.
As transport liberalization grows worldwide, railway companies face increased competitive pressure due to ownership changes, vertical desegregation of traditional structure, and open access to infrastructure. This pressure calls for operational effectiveness and agility, and, as a result, productivity and optimization of resources get un-precedent attention. Railway companies are introducing new management styles to improve the results of the business. In particular, new tools are being searched to improve the use of human and material resources. This trend is simi-

ORGANIZATION:
SISCOG

PROJECT NAME:
CREWS

LOCATION:
Lisboa, Portugal

YEAR:
2006

STATUS:
Laureate

CATEGORY:
Transportation

NOMINATING COMPANY:
Deloitte

lar to what was felt in other areas of transportation where the benefits of IT solutions have been extensively explored.

Planning resources in railways is far more complex than planning resources in other transportation domains, such as airlines and bus companies:

•Many railway companies offer different types of transportation, from regular suburban and intercity passenger operations to regular and irregular freight operations;

•These operations involve different types of rolling stock, such as locomotives, electric multiple units, rail cars, and wagons, which require different types of human resources, such as drivers, guards, inspectors, and catering personnel;

•Unlike other domains, in railways, a train normally involves several equipment units (or rolling stock), such as a set of railcars or one or more locomotives coupled to a number of rail cars or freight wagons. These units may be coupled and uncoupled several times during the day, to create different types of compositions to answer to different capacity requirements set up by customer demand;

•Trains usually have multiple stops, giving rise to many different potential ways of changing rail-staff, in order to improve their productivity;

•Train operations involve a number of resources far greater than other transportation domains, probably due to the fact that most railway companies were state-owned companies with countrywide operations.

For these reasons, rail-staff planning and management in railway companies has not been supported by IT systems until recently. In a large number of companies, this task is still carried out manually by a small number of planners that acquire most of their knowledge through experience. A human planner not only has to deal, within a short period of time, with huge amounts of data to produce plans, but also has to handle changes that pop up constantly, which must be incorporated in the existing schedules without producing much disturbance.

Another aspect that puts a high demand on planners is the increasing complexity of labor rules, required to comply with increasing social benefits given to workers. Scheduling rail-staff is considered by railway companies to be much more difficult than scheduling rolling stock or producing the train timetable. Rail-staff scheduling requires human skills, knowledge, and hard work.

THE PROCESS.

In order to provide services, a railway company needs to manage three types of resources, track, rolling stock (engines and cars), and rail-staff, besides time, the most important resource in planning. First, time and track must be allocated to trains, taking into account track constraints and availability, as well as the type of rolling stock to be used for the train service. Second, rolling stock units must be allocated to trains, taking into account train requirements, track and rolling stock constraints, as well as rolling stock availability. Finally, rail-staff must be allocated to trains, taking in consideration the different tasks to be done both with rolling stock and within stations, the number of resources needed for each task, the skills required, the availability of human resources, as well as many types of constraints, such as operational, labor and social constraints.

Due to its complexity, from a global point of view, this problem is addressed in a sequence of phases, in each of which resources must be planned/managed in sequence.

ORGANIZATION:
SISCOG

PROJECT NAME:
CREWS

LOCATION:
Lisboa, Portugal

YEAR:
2006

STATUS:
Laureate

CATEGORY:
Transportation

NOMINATING COMPANY:
Deloitte

•Long-term planning (Phase 1). Generates a plan without taking into account particular resources or particular dates when the work is being planned. Resources are represented abstractly in terms of their type, skills, and number. Dates are represented abstractly in terms of weekday frequencies. Long-term planning deals with the regularity involved in the operation (there are services that are repeated at regular frequencies, e.g., daily, Monday to Friday, just on Fridays), leaving the exceptions and the irregularities to be handled at the short-term planning phase.

Long-term planning is done in two steps. Planning duties. Produces sequences of tasks to be done by one person in one day – duties. Constraints in this phase include, among many others, maximum duration of a duty, space continuity between adjacent tasks, transfer times between different rolling stock, places and times for meal breaks, compatibility of route and equipment skills. Constraints may be hard (cannot be violated) or soft (may be violated, but violations should be avoided and recorded). Planning rosters. Produces sequences of duties, rest time, and days off – base rosters. Constraints in this phase include, among many others, maximum week working time, rest time between duties, weekly days off, and available skills.

•Staff allocation (Phase 2). Associates persons to the weeks of the base rosters producing an allocated roster. All persons in a roster must have the skills required by the roster. The result of this phase can be seen as a daily plan obtained by instantiating the allocated roster for a certain timetable period.

•Short-term planning (Phase 3). Deals with foreseen irregularities that were not considered during long-term planning, such as services that operate in particular calendar days, rather than being repeated at a certain frequency. It also amends the daily plan for a certain number of days, either because some of the tasks have changed (e.g., a change in the timetable due to track work) or because a person is not available to work in a certain calendar period. Short-term planning works with particular days and with particular persons. The constraints handled in this phase include all the constraints in the long-term planning plus the constraints associated with particular persons, such as maximum working hours per year and holidays. Due to operational reasons, the violation of soft constraints becomes more permissive.

•Dispatching (Phase 4). Deals with the unexpected. It is performed on the day where the operation takes place. It is similar to short-term planning but works in real-time. It takes as input the day plan and real-time events. The changes introduced at this level may be due to delays, breakdowns or unexpected absence of rail-staff.

•Control (Phase 5). Checks the work performed, taking the results of Phase 4, comparing it with the work that was planned in phases 2 and 3, updates personnel records, and feeds the payroll system.

The overall planning and management process evolves along two orthogonal directions, one dealing with the different phases, another dealing with the different types of resources. Managing and controlling this process, where change is the rule and data flow in different directions, is a complex problem by itself, besides the complexity of planning/managing each resource in each of the phases.

APPROACH.
Automatic rail-staff planning is a very complex problem due to the combinatorial explosion of alternative ways in which the entities to be scheduled can be combined in order to produce plans. When CREWS started being developed, around 1986, automatic rail-staff planning had

ORGANIZATION:
SISCOG

PROJECT NAME:
CREWS

LOCATION:
Lisboa, Portugal

YEAR:
2006

STATUS:
Laureate

CATEGORY:
Transportation

NOMINATING COMPANY:
Deloitte

already been approached by traditional programming (supported by Operational Research), but the results obtained with automatic "black-box" optimization algorithms had limited success and have proven to be unsatisfactory in the following aspects: when faced with a full size problem, these solutions tend to need computational resources that by far exceed what is available; they could not provide explanations about the decisions placed in the solution, limiting the capability of being understood by human planners; and solutions could not be manipulated by human planners to adapt them to changing circumstances or to ill-represented constraints.

Over the last two decades, SISCOG has been engaged in the development of a rail-staff planning and management product, aiming at the optimization of resources alongside with the possibility of a "white-box" interaction in the sense that the planner can perceive what is going on, can interact with the system by proposing alternatives or querying decisions, and can adapt the behavior of the system to changing circumstances. In CREWS, planning can be done in automatic, semi-automatic or manual modes. Along the years, CREWS has evolved to address the several phases of the planning and management cycle, in a modular fashion, namely, long-term planning, short-term planning, real-time dispatching, and control.

The approach has been quite successfully, providing yearly savings of millions of dollars to clients that include the Dutch Railways, Finnish Railways, Norwegian State Railways, Danish State Railways, and the London Underground.

Benefits

The main goal of the development of CREWS has been to increase the planning efficiency of railway companies through the optimized use of human resources. This goal has largely been achieved with the use of automatic planning, but many other benefits, that were not fully apparent when the project started, have surfaced along the years.

As a first point of discussion, one should concentrate on the meaning of "optimization" and its link with the problem at hand. One may think that by an optimized solution is meant a solution with the minimum rail-staff costs or the minimum number of resources. This goal, however, must be carefully considered. One should bear in mind that within one duty, rail-staff typically change the rolling stock units where they perform their service. Although a change of a rolling stock unit is associated with some standard "buffer" time to account for possible delays, it is always associated with the risk of loosing the connection and, thus, introducing operational disruptions. Often it is preferable to sacrifice some optimality for reliability, and rules such as "a driver should be kept in the same unit as much as possible" play an important role for obtaining the right balance between optimization and reliability. Thus, besides the official rules associated with the planning process (such as rules that define the maximum driving time or time to transfer from one rolling stock unit to another in a particular station), CREWS enables the introduction of rules of thumb, or heuristics, that work well in most of the cases. Even with this loss regarding theoretical optimization, CREWS-based systems are able to achieve a 3-5% cost reduction in the use of staff. In companies with several thousand workers, this quickly adds up to savings of several million dollars a year. On the other hand, more reliable and complete statistics contribute to improvement of cost control and pricing of services. Hidden costs become visible and the use of the system contributes to a reorganization of the planning process.

Besides the cost-savings aspect directly obtained by the company, CREWS-based systems take an important burden of repetitive and tedious work that has been placed on the work of plan-

ORGANIZATION:
SISCOG

PROJECT NAME:
CREWS

LOCATION:
Lisboa, Portugal

YEAR:
2006

STATUS:
Laureate

CATEGORY:
Transportation

NOMINATING COMPANY:
Deloitte

ners, enabling them to concentrate on their planning work with a user-friendly help provided by the system.

Another related benefit corresponds to the possibility of generating several alternative solutions. When a non-IT approach is used, the railway company is usually satisfied when a plan is produced to cover the work on all trains. This may seem strange for a casual reader of this case study, but the amount of data involved, the amount of changes propagated along different resources types, the tight deadlines within which rail-staff planning has to be done, usually place a very high burden of work on planners, who produce the plan just in time before a new timetable starts being operational. With CREWS, a more than 10-fold speed increase in the production of plans has been achieved, together with the possibility of having several planners, working in parallel, producing alternative plans. Companies that use CREWS-based systems could, for the first time, start comparing other aspects of the solution, such as social benefits given to workers (other than the aspects that are prescribed in the rules), which enable the balance of costs and social aspects. Thus, gained time is primarily used to make better plans and to create more alternatives for the next and later timetable periods.

CREWS provides a "what-if" simulation mode, where new rules and conditions can be tested by simple changes in parameters. In this way, the company can evaluate the consequences of new rules being discussed with trade unions and the effect of providing new skills to staff located in different personnel bases.

Another important benefit that is not easily quantified corresponds to the preservation of the planning knowledge within the company. In fact, since CREWS corresponds to a knowledge-based system, all the knowledge pertaining the task at hand is stored within the system.

Since all labor rules are built into the system, detailed knowledge of all rules is not required of all planners. Differences in rules and regulations for different classes of personnel, seen by most companies almost as dealing with different realities, become insignificant when CREWS is used. As a consequence, planners can perform planning for different personnel groups and the planning units can be integrated.

As a final benefit, it should be stressed that by providing more accurate and robust plans, CREWS minimizes the number of disruptions due to rail-staff-related events, thus providing more reliable service to millions of people that travel on trains on a daily basis.

The Importance of Technology

Artificial Intelligence was the key information technology that led SISCOG to be involved in this project. The reasons were manifold.

First, rail-staff planning in a railway company is a very complex problem, since there are endless different ways in which a planner can combine a set of tasks to produce duties. Complex problems of this kind require powerful optimizers, such as those provided by Artificial Intelligence (AI) or Operational Research (OR) techniques. The first contributions to the problem came from OR but they were not powerful enough to cope with real-world problems. It seemed to SISCOG that this could be a good domain for applying the capability of AI search techniques that look for solutions for problems where there is a potential for a combinatorial explosion of alternatives. Also, since there was no known algorithm to solve the problem, knowledge engineering techniques, developed in AI for constructing Expert Systems, could ease the task of

ORGANIZATION:
SISCOG

PROJECT NAME:
CREWS

LOCATION:
Lisboa, Portugal

YEAR:
2006

STATUS:
Laureate

CATEGORY:
Transportation

NOMINATING COMPANY:
Deloitte

building a system for this complex domain. They could enable the elicitation of knowledge from the human experts that solve the problem without much difficulty, but cannot explain how they do it.

Second, rail-staff planning and managing in a railway company deal with data that are huge, inconsistent and incomplete, preventing IT standard technology to be effectively used. A planning problem may involve thousands of trains, rolling stock units and rail-staff, requiring different abstraction techniques to cope with its complexity. Also, trains, rolling stock, and train staff are planned and managed by different departments, in a sequence of phases that are part of a complex process that does not always run in a synchronized way. For example, whenever a change is introduced in a train timetable, it may force a change in the rolling stock plan and, consequently, in the rail-staff plan, because the rolling stock or rail-staff duties may no longer be valid. When these changes are done by different departments, at different times, the plans become inconsistent or incomplete, at least for sometime. So, a computer application for this domain must be capable of dealing, not only with complex abstraction models, but also with data dependencies across different planning entities and different phases and with inconsistency and incompleteness of data. In other words, it becomes a good candidate for the application of AI techniques, such as abstraction and truth maintenance techniques.

Third, planners tend to reject solutions proposed by computers, either because are afraid to be replaced by them or because there are so many exceptions to deal with in a real life problem that an automatic solution can never be considered an adequate solution. From its inception, CREWS was designed as a product that should allow a high degree of human interaction, not only for enabling the manual change of automatic solutions, but also for enabling users to advance suggestions and hints prior to the development of solutions. CREWS-based systems should be decision support systems, supporting the planners with different levels of automation and following a white-box approach than enables users to interact with the system in ways unseen before. AI always followed the approach that must be the machine to get closer to the needs of the users, rather than forcing users to learn complex computer routines. By using knowledge models that can be understood by users, intuitive graphical interfaces that allow users to interact with the system with concepts that they are familiar with, explanation models that make users understand the reasoning of a computer, and powerful functionality that increase productivity can improve the chances of a system to be accepted by human planners. This kind of support allows human planners to make their job with un-precedent quality and speed, concentrating in the most intelligent and social aspects of the work and leaving the most tedious ones to the computer.

These different aspects of the use of AI in the development of CREWS had a different impact on its success.

The use of an AI-based optimizer had not the success that SISCOG had hoped. Constructive approaches that create a plan from scratch proved to have a very local view of the planning process, producing sub-optimal solutions, except for small problems. Even constraint satisfaction and propagation techniques were not powerful enough to make the system to have a global overview of the planning process and to find better solutions than those produced by the human planners. Lately, reparative approaches that improve an existing plan, created by a constructive approach, proved to be capable of obtaining very good solutions, better than the ones produced by human planners. However, it was by the use of OR techniques that the system obtained the best solutions. These solutions are near optimal even for much larger problems.

ORGANIZATION:
SISCOG

PROJECT NAME:
CREWS

LOCATION:
Lisboa, Portugal

YEAR:
2006

STATUS:
Laureate

CATEGORY:
Transportation

NOMINATING COMPANY:
Deloitte

Nevertheless, AI reparative approaches are still useful, when a plan must be repaired without disrupting it too much.

The use of a system module, called Data Manager, for detecting data inconsistency and incompleteness and for managing change in the process, proved to be a key factor in the deployment of CREWS-based systems. One of the most important aspects for the success of a system in the real world is its capability to integrate well with existing systems and to support the business processes. On one hand, the module is capable of detecting inconsistencies in input data coming from other systems, thus preventing the system from using data that are not correct and should not be part of the resulting plans. Before the development of this module, users spent more time in detecting inconsistencies and correcting input data than on the planning process itself. On the other hand, the system can proceed immediately with the consistent data and, later on, incorporate in the plans data that were previously inconsistent, thus allowing the process to proceed in spite of some data being incorrect.

The white-box approach, adopted since the inception of the system, enabling the integration of different automation modes, was probably the key feature that allowed CREWS to be accepted by human planners almost from the beginning and for providing time for the improvement of the optimizer. Automation was the driving force for customers to buy CREWS-based systems, but it was the manual mode that provided the flexibility to enable the deployment of these systems and the adjustment to the customer realities. The power and flexibility of CREWS manual mode and the value that brought to customers maintained their interest in CREWS throughout the years and gave time to SISCOG to do research with different technologies for supporting automation. Even when adopting a black-box component, based upon OR, it was the white-box approach, based upon AI, that enabled the integration of that component with the remaining part of the system. This increased planners' understanding of the black-box and the level of interaction with this component, enabling planners to give suggestions to influence its solutions.

Originality

CREWS was the first system to introduce important concepts in the design of rail-staff planning and management systems. Most of these concepts ended up by being adopted by SISCOG's competitors in developing similar systems.

By the late 1980s, in a project for CP, the Portuguese Railways, SISCOG introduced a mechanism for supporting manual, semi-automatic and automatic modes in an integrated way, giving rise to the white-box approach in CREWS. A solution could be constructed in any of these modes of operation or by using any arbitrary combination of them. All modes of operation used the same set of labor rules, which were defined independently from the system and could be changed by the customer to adapt the system to a new reality. The labor rules were validated during the construction of the duties of rail-staff. In order to comply with these rules, the system was capable of creating new tasks to be combined with the tasks to be planned, such as sign-on and sign-off tasks to be placed, at the begin and end of a duty, respectively, meal break tasks to enable rail-staff to have a pause in the middle of their duties in order to take a meal, and positioning trips to place rail-staff where they are needed to perform the tasks. Each mode of operation provided a different level of support to the user, enabling users to choose the one that felt most comfortable with. By then, CREWS was the only commercial rail-staff planning

ORGANIZATION:
SISCOG

PROJECT NAME:
CREWS

LOCATION:
Lisboa, Portugal

YEAR:
2006

STATUS:
Laureate

CATEGORY:
Transportation

NOMINATING COMPANY:
Deloitte

product based on AI techniques.

By the mid 1990s, in a project for NS, the Dutch Railways, several changes were introduced in CREWS that were quite original for rail-staff planning systems:

•A new multi-user architecture was adopted, enabling human planners to work in a competitive and cooperative environment. New functionality was created to distribute and re-distribute the tasks to be planned among users and to lock tasks to a planner preventing other planners from using them.

•The Data Manager was developed with several purposes in mind: to enable the definition of different sets of rules and constraints, in order to enable the system to handle different types of personnel and share common data; to ease the integration of CREWS-based systems with the other customer systems that must interact with, by pointing inconsistency in input data; and to guide the users in the construction of solutions, showing missing input data and inconsistencies in the plans, and thus supporting a process that is normally in constant change.

•All components of CREWS started being developed based on the same principles of adapting to changing circumstances, detecting inconsistency and incompleteness of input data and thus supporting the repair of existing plans.

By then, the design of CREWS already included an integrated architecture for supporting the full integration of the several phases of the problem, in terms of data, functionality, and graphical interfaces. The experience gained with the CP and NS projects in duty planning and rostering, as well as with Iberia, the Spanish Airlines, in the real-time dispatching of operations, gave a good insight on the whole planning and managing process. Due to the complexity of the domain, the implementation of the full architecture of CREWS had to wait for the beginning of the 21st century, but the original concept was kept untouched.

CREWS-based systems have won awards and have been featured in many articles. Among other awards described in SISCOG's website, the following are worth of mention:

•A public recognition of SISCOG's competence in the planning domain has been shown through a special invitation to participate in the Conference and Showcase on "The Information Society" that was held in 1995 in Brussels, alongside the G7 Meeting, with the presence of U.S. Vice-President Al Gore, EU Commission President Jacques Santer, and the G7 Ministers. The goal of the Showcase was to show how more and more people around the world are benefiting from new applications of technology, embracing business, health care, leisure, education, transport, and domestic environment. SISCOG was selected to be present, among 130 companies around the world. There were only four companies from non-G7 countries and SISCOG was the only one in the planning domain. SISCOG demonstrated the operation control system developed for Iberia. That system is capable of re-scheduling resources in an airline, when unexpected situations arise.

•SISCOG received the 1997 Innovative Application Award, given by the American Association for Artificial Intelligence, for the rail-staff planning system that it developed for the Dutch Railways addressing long-term planning. In 2003, SISCOG received, for the second time, the Innovative Application Award, for the rail-staff planning and management system developed for the Norwegian State Railways, addressing long- and short-term planning in an integrated way. The American Association for Artificial Intelligence is the largest and most prestigious AI society in the world. Since 1990, it selects the most impressive AI applications of the previous year to

ORGANIZATION: *SISCOG*

PROJECT NAME: *CREWS*

LOCATION: *Lisboa, Portugal*

YEAR: *2006*

STATUS: *Laureate*

CATEGORY: *Transportation*

NOMINATING COMPANY: *Deloitte*

receive the Innovative Application Award. The awarded applications are selected based on their demonstrated business value and their technical innovation. The awarded applications are selected based on clear evidence of the impact and value that AI technology has in today's world.

At the turn of the century, SISCOG signed contracts with several European railway companies, which led to the development of the Staff Allocator, Short-term Scheduler and Real-time Dispatcher modules and to the consolidation of the Long-term modules. During this period, the customization of CREWS to many different customer realities increased the robustness of the system and increased its level of functionality.

Success

After twenty years of hard work, the success of the product is a proved reality. Long-term and Short-term planning modules routinely handle the work of more than 20,000 staff members across Europe contributing to the reliability of the rail systems that is used by millions of people on a daily basis.

The vision that was set up to the development of a integrated product, back in the middle of the 1980s, is still actual and more than never is in demand by the railway industry.

Many modules of the product are fully operational, while some other modules are still under development phases, namely the real-time dispatcher that enables the reaction to unexpected events, and rail-staff communication functions that ease the communication of last minute decisions to staff. During the 20-year development period many new issues have popped up that called for the development of new modules, for example the Data Manager for handling the consistency of data, and new functionality, as required by required by different realities.

The two testimonials bellow, show the savings capability of the product, the good acceptance by its users, and the potential it provides to the companies that use it.

Mr. Erwin J.W. Abbink, one of the responsible persons from the system at the Dutch Railways, NS Reizigers (passenger trains), in a 2004 testimonial gives an idea about the levels of direct savings that can be achieved with the system, "… the end users (planners) really appreciate the system. The number of planners has decreased to 8, while before the implementation of the system we had about 14 planners. Next to that we were able to save millions of Euros by making more efficient schedules. This is not only the result of the system, but without such a system this would not have been possible".

Mr. Chris Deal, project manager of West Anglia Great Northern Railway (UK), in a 2000 testimonial stated "with the assistance of CREWS we have been able to plan extra trains without any increase in Driver establishment. … We have achieved a great improvement in the accuracy of data and therefore the outputs. The project has given a far greater understanding of the diagramming rules and therefore the possibilities for change that we may achieve in future discussions with trade unions. It has enabled us to fully document all the rules and constraints previously stored only in people's memories and lost when they leave. CREWS is giving us better statistical information so that we may answer questions like how productive are our drivers".

In the last two years, a new optimizer was developed for the long-term planning modules, using OR techniques. Although the use of these techniques is not original, the resulting optimizers are extremely powerful, producing almost optimal solutions. The optimizers of the remaining sys-

ORGANIZATION:
SISCOG

PROJECT NAME:
CREWS

LOCATION:
Lisboa, Portugal

YEAR:
2006

STATUS:
Laureate

CATEGORY:
Transportation

NOMINATING COMPANY:
Deloitte

tem modules still use AI techniques, since the work they support has more to do with repairing plans than creating new plans from scratch. Comparisons made with systems of the competition have shown that CREWS has the most complete and efficient offer in planning automation. Moreover, the integration of a very powerful optimizer with the possibility of manual intervention, at any stage of the planning process, provides un-precedent power and flexibility that are unmatched by any of the systems of the competition.

Difficulty

There were several obstacles that had to be overcome in order for CREWS to be successful. These obstacles were of several kinds, timing and place of the original proposal, organizational and technical problems, and problems faced by customers.

TIMING AND PLACE OF THE ORIGINAL PROPOSAL.
When SISCOG started developing CREWS and proposing CREWS-based systems, in 1986, most railway companies were not prepared to adopt this kind of systems. The market was not mature enough and most IT applications developed at the time did not have the sophistication envisaged by CREWS. Most deployed applications only addressed administrative functions faced by companies, had limited functionality with almost no automation for complex problems, and no graphical interfaces. They were mostly based on old programming languages and on data base systems.

On the other hand, the technology SISCOG was proposing – Artificial Intelligence – had not been fully tested in the real world and there was resistance to adopt it. AI was by itself somewhat threatening and unknown to most customers. Another resistance came from the use of non-standard tools. At the time, CREWS was first implemented on a special-purpose hardware/software platform designed for AI applications, using LISP (a special-purpose language for AI), and KEE (Knowledge Engineering Environment), a special-purpose software platform for developing Expert Systems. The fact that LISP and KEE were non-standard languages and the hardware itself was non-standard raised many concerns regarding the use of CREWS.

Another obstacle came from the place where the proposal was made – Portugal. Although since its inception, SISCOG selected the world as its market, it was important to build a customer-base in Portugal before trying to conquer the international market. Portugal was still under-developed in what concerns IT, several years behind the rest of Europe and the United States. For this reason, Portuguese customers were not ready to adopt the technology and serve as test-beds for SISCOG to develop applications that could be demonstrated to international customers. Moreover, the Portuguese image abroad was quite poor in what respects IT, raising suspicions about the quality of the solution proposed by SISCOG.

In spite of these problems, SISCOG was able to convince CP, the Portuguese Railways, to finance the development of a prototype that lead to SISCOG's first important contract in 1989 for the development of a full system. In the meantime, CREWS was ported to a more traditional hardware/software platform. The resulting long-term planning system was used to convince the Dutch Railway, to sign a similar contract with SISCOG in 1993. This important event in SISCOG's history, achieved after two years of multiple contacts and difficult negotiations, finally opened the international market to CREWS. This was the first Portuguese IT export and the first IT outsourcing contract signed by NS. It was quite an achievement for a small company, with just 6 employees, and with severe limitations from its economic environment.

ORGANIZATION:
SISCOG

PROJECT NAME:
CREWS

LOCATION:
Lisboa, Portugal

YEAR:
2006

STATUS:
Laureate

CATEGORY:
Transportation

NOMINATING COMPANY:
Deloitte

ORGANIZATIONAL PROBLEMS.
The market demands and the associated increase of contracts at the end of the 1990s brought some organizational problems to SISCOG that forced the company to adapt and to evolve. The company created a new organizational structure that could cope with the problems brought up by an increased number of human resources and by the interaction of product development and customer project development. This lead SISCOG to be organized under three main productive departments, Products, Projects, and Innovation. The Department of Products is responsible for developing and maintaining the company products, namely CREWS. It is further organized in terms of specialized teams. The Department of Projects is responsible for developing and maintaining the customer systems based on products. The members of this department have horizontal skills, knowing how to use all the functionalities of the product in order to develop systems for customers. The Innovation Department is responsible for the introduction of innovation in the company products, in particular in the automation modes.

TECHNICAL PROBLEMS.
Several technical problems were strong obstacles to a faster development of the product. The first obstacle had to do with the size and quality of data that CREWS must deal with. The system must input large volumes of data that must be analyzed before being used. Data is often incomplete and inconsistent. To handle this problem, the Data Manager component was developed and incorporated in CREWS.

A second obstacle had to do with the complexity of the functionality required for solving the problem. Planning staff in any domain is a very complex task due to the combinatorial explosion resulting from trying different alternatives of combining tasks into duties or duties in plans. Planning staff in railways is even more complex, due to the larger number of entities to be scheduled and the complex interrelationship between them. The following are just two examples of entities that CREWS must deal with in order to illustrate the kind of the extra complexity involved in planning rail-staff:

•Positioning trips. The system must be capable of generating positioning trips for the rail-staff, in order to place them where they are needed to carry out some work. This requires a search mechanism that computes the most efficient way to make a trip between two places, using the company trains as well as other means of transportation, such as buses, taxis or just walking. This trip constitutes a task like any another that must comply with the labor constraints. The generation of such a trip must be done almost instantaneously, since these trips are being generated all the time, during validation of the labor rules.

•Rolling stock tasks. Since rail-staff operate the rolling stock units, they must do tasks related with these units, within stations. These tasks include, among others, the preparation and disposal of units, their mobilization or immobilization, their attendance. CREWS is capable of generating these tasks automatically from the rolling stock plans and following specific generation rules of the company. Scheduling these tasks is a complex problem by itself. Since these tasks are done locally, within a station, they can be slid in time within certain limits and split in more than one task in order to make a better use of the rail-staff.

Finally, there is the rail-staff-planning problem by itself! This obstacle was the one most difficult to overcome. Several different techniques were tried along the years, originating from AI and OR, including heuristic search techniques, abstraction techniques to define special-purpose search strategies, constraint satisfaction and propagation, reparative local strategies and integer

ORGANIZATION:
SISCOG

PROJECT NAME:
CREWS

LOCATION:
Lisboa, Portugal

YEAR:
2006

STATUS:
Laureate

CATEGORY:
Transportation

NOMINATING COMPANY:
Deloitte

programming. Only the last approaches, developed quite recently, had a strong success in overcoming this obstacle.

PROBLEMS FACED BY CUSTOMERS.
Customers, themselves, face several obstacles that slow down the full customization of a system. The first problem that usually occurs is the difficulty of the railway company to fully envisage the amount of organizational changes that a system of this sort introduces in the company. Although a need for new working methods and optimization techniques are felt, no single company can foresee the deep changes that are coming. SISCOG has overcome this obstacle with the organization of workshops, at the start of the project, that discuss working methods and the changes that are introduced by CREWS.

Another aspect that usually places a heavy stress on the development of a project is the low availability of expert planners. The best human planners are usually called to be part of the project team, since they are the best persons to convey the planning knowledge and techniques that are used by their company. However, these persons that are extremely valuable to the company cannot be assigned full time to the project, they must also provide help in the planning task. This generates a high load and demand on planners that is sometimes a bottleneck in the development.

The last difficulty that is faced by the company is the deployment of the system. The project team, involving the highest skilled planners, is fully ready to start working with the new working methods once the development is concluded. However, it is important to prepare and convince other people about the advantages of the system. This is usually a time consuming work that has to convince people that their job is not threatened and that they should change their life-long working methods. In all projects so far, this is a rewarding change for planners who end up embracing the new project with much enthusiasm.