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Experience in industrial deployment of Constraint Programming technology

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Plan

- **Plan of the talk**
  - **A bit History (CP, ECRC, COSYTEC)**
  - **Applications areas for CP**
  - **Business sectors for CP**
  - **What CP brings / benefits**
  - **Specific requirements in industrial contexts**
  - **Issues in design, development & deployment**
  - **Case Studies**

History / Constraint Programming

- **CP : A powerful computing paradigm**
  - **Appeared in 80's in the LP community (CLP)**
  - **Mixing declarative programming (LP) with "constraints solving"**
  - **Efficiency by combining "constraint reasoning" and "search procedures"**
  - **Integration of different techniques : AI, OR, Discrete Maths**

- **CLP / Pioneers**
  - **Prolog III : Univ. Marseille (F)**
  - **CLP(R) : IBM (USA)**
  - **CHIP : ECRC/Munich (D)**

History / From ECRC to COSYTEC

- **ECRC : Research in CLP (1985->1990)**
  - **CHIP : CLP with "Finite domains", "Rationals", "Booleans"**
  - **Introduction of "symbolic constraints" --> combinatorial problems (cf. Alice)**
  - **Applications of CHIP in different domains (prototypes) :**
    - OR : Project planning, Cutting-stock, Car sequencing, Warehouse location,…
    - Circuit design : Circuit verification, Fault diagnosis, Test generation,…
    - Finance : Portfolio management, Asset & Liability management, …
- **COSYTEC : Industrial deployment of CLP/CP (1990->)**
  - **Introduction of "global constraints"**
  - **Concentration of Business on advanced Planning & Scheduling applications**

What types of problems ?

- **Industrial organizations have combinatorial problems**
  - **Organization of Activities/Operations (e.g. production, transport, logistics)**
  - **Allocation of Resources (e.g. equipments, personnel)**
    - **→ Planning & Scheduling of Activities & Resources (part of « Business Process Optimization »)**

- **Complex Planning & Scheduling problems**
  - **Multiple types of constraints, hard to find a feasible solution, dynamic config,…**
  - **Complementary to standard business packages : ERP, SCE/M, WMS, HRMS,…**
  - **Alternative to other "optimization" techniques : IP/MIP, SA/GA, ad-hoc methods,..**

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Main Application areas for CP (1)

- **Production Scheduling & Supply Chain Management**
  - Assembly-line Design, Planning & Scheduling in Aircraft Manufacturing
  - Maintenance Scheduling in Aircraft Manufacturing
  - Automatic Generation of Process Operations in Metal Industry
  - Real time scheduling of Steel product plant
  - Optimal production scheduling in electronic components industry
  - Planning Transport of Nuclear Fuel Assemblies to the Reprocessing Plant
  - Circuit optimization of the primary logistics supply for multiple refineries
  - Just-in time transportation from farms to factories in Food industry
  - Planning & Scheduling of Resources in a Warehouse
  - …

Main Application areas for CP (2)

- **Workforce (Personnel) Planning & Scheduling**
  - Scheduling on-board TGV trains catering services
  - Crew Planning for Mediterranean Ferries
  - Automatic planning of firefighting personnel schedules & duty sheets
  - Scheduling of Operations for the Personnel Planning in the Cleaning Industry
  - Planning and Scheduling of activities and resources in Broadcasting/TV
  - Planning of technical personnel in Broadcasting Services companies
  - Simulation of work shifts to optimize the organization of the Personnel of prisons
  - Optimal rostering of personnel in Retail
  - Course Time-tabling and automatic assignment of Students to Courses
  - …

Main Application areas for CP (3)

- **Miscellaneous :**

  --> Configuration, Placement, Packing, Assembling, Routing, …

  - Fighter Aircraft reconfiguration
  - Optimal configuration of telecommunications satellites
  - Automatic allocation of stock spaces for Automobile Manufacturing Factory
  - Optimization of the display panels in advertising networks in urban areas
  - Optimization of take-off/landing sequence and runway allocation in Airports
  - Intelligent cabling system for buildings
  - Decision support in Water management
  - …

Main Business sectors for CP

- **Industry :**
  - **Aeronautics/Space, Nuclear Energy, Steel/Petrochemical, Manufacturing,..**
  - **Ex. : Airbus, Dassault, EDF, ArcelorMittal, ERG, Toyota, Alcatel-Lucent,Fujifilm**
- **Public Administration & Transport**
  - **Security/Emergency Services, Rail/Sea/Road/Air Transports**
  - **Ex. : Min. Justice, Fire&Rescue Dept, Ferry(SNCM), Railways(W-Lits), JAXA**
- **Service Sector**
  - **Media & Broadcasting, Retail, New services**
  - **Ex. : Canal+, Arte, RTS, France24, RTL, Ericsson BSF, Castorama,…**

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Planning & Scheduling Software for Resource Management and Optimization

What CP brings / Benefits

- **CP : a powerful paradigm for combinatorial problems**
  - **High-level Modeling of Planning and Scheduling problems (cf. global constraints)**
  - **Efficient Constraint Solving, reasoning and propagation techniques**
  - **Flexible combination of Search procedures with Constraint solving**

- **Other important features of CP**
  - **Incremental constraint solving → interactive systems (Decision Support)**
  - **Possibility for relaxation of constraints (hard/soft)**
  - **Adaptability to reconfigurations**
  - **Fast prototype development**

Specific requirements in industrial contexts

- **Requirements for an industrial software :**
  - **Robustness : any use by anyone**
  - **Scalability : up-sizing of operations**
  - **Adaptability : change of configuration**
  - **Connectivity : easy integration**
  - **Portability : into any environment**
  - **Compatibility : with older releases**
  - **…**
  - **Performance of the solution: cost , resp. time, use of comp. resources,…**
  - **Flexibility of the solution : any time / any case, scalable, parametrization,..**
  - **Ergonomy of the solution : easy to use, understandable**

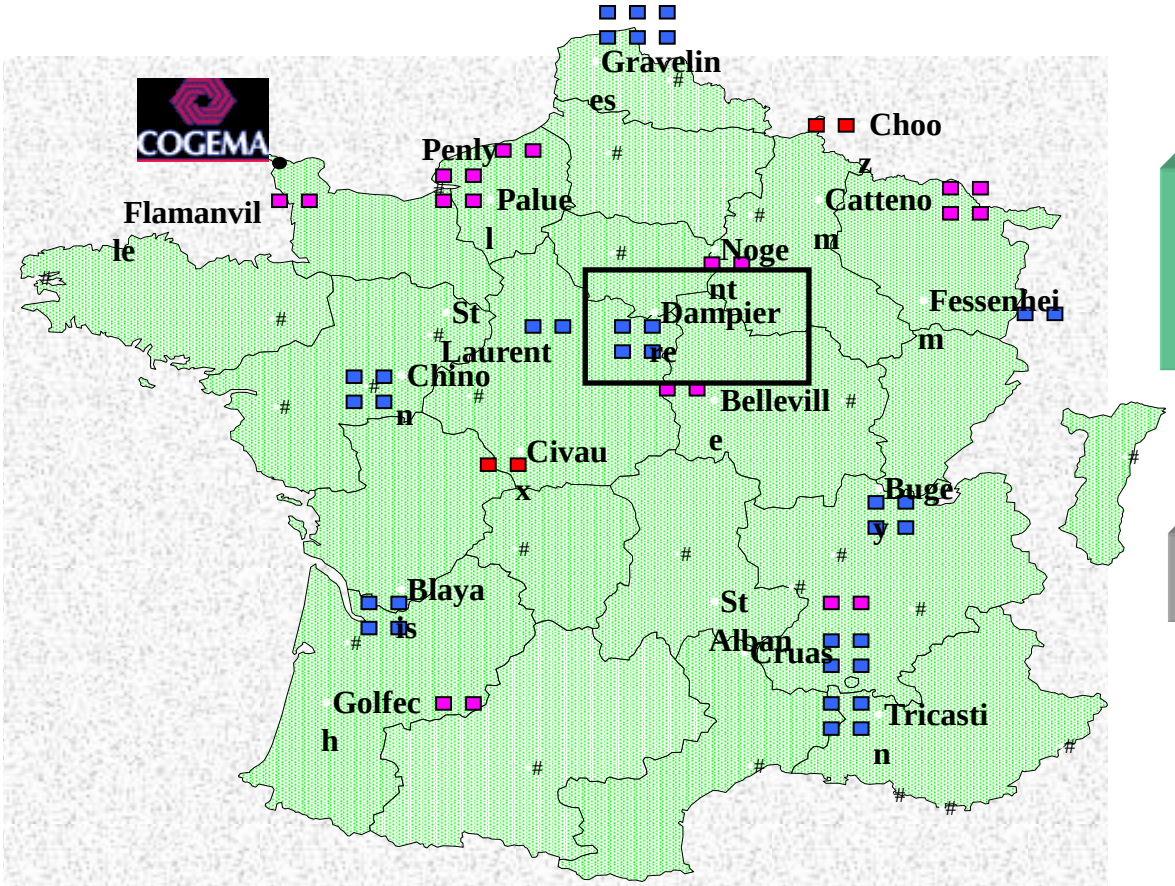
Issues for design, development & deployment

- **Important issues in an industrial context :**
  - **No formal description of the problem !**
  - **Understand the business “needs” (-> cf. “business process”)**
  - **Find the “right” problem to solve ! (-> improve the business process)**
  - **Work in collaboration with the customer for FDS (not obvious !)**
  - **Find the “right” modeling (-> can be solved “reasonably”)**
  - **Look for a “reasonably good” solution : cost, resp. time, quality,…**
  - **Look for a “flexible” solution : any time / any case, scalable, parameterizable**
  - **Look for a “user-friendly” solution : easy to use, ergonomic, understandable**
  - **---**
  - **Acceptance of the software & solution**
  - **Change Management (organizational issue @ Customer)**

Case Studies

- Planning Transport of Nuclear Fuel Assemblies to the Reprocessing Plant
  - **EDF (Electricity of France)**
- Circuit optimization of the primary logistics supply for multiple refineries
  - **SDIS (Fire & Rescue Department of Rhone)**
- Automatic planning of firefighting personnel schedules & duty sheets
  - **ERG Petroli**
- Crew Planning for Mediterranean Ferries
  - **SNCM (Societe Nationale Corse Mediterranee)**
- Optimal rostering of personnel in Retail

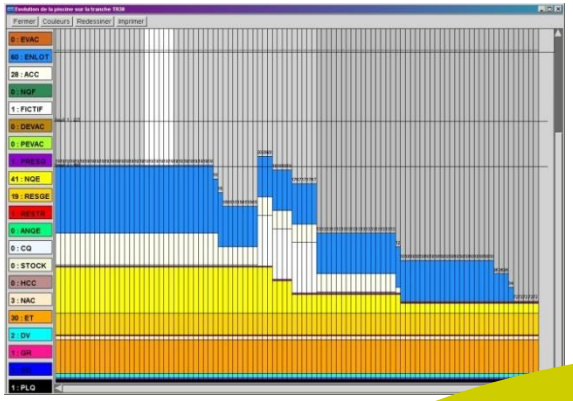
Nuclear Power Plants in France



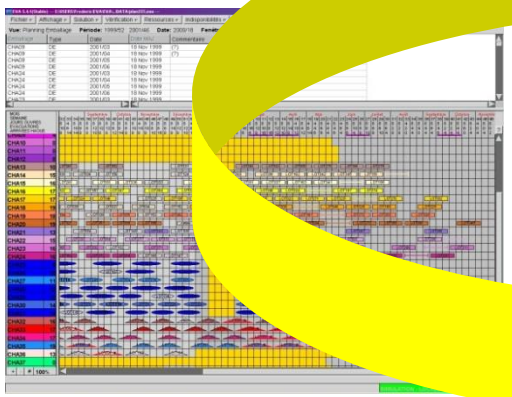
- REP 900 MW
- REP 1300 MW
- REP 1450 MW

LA HAGUE

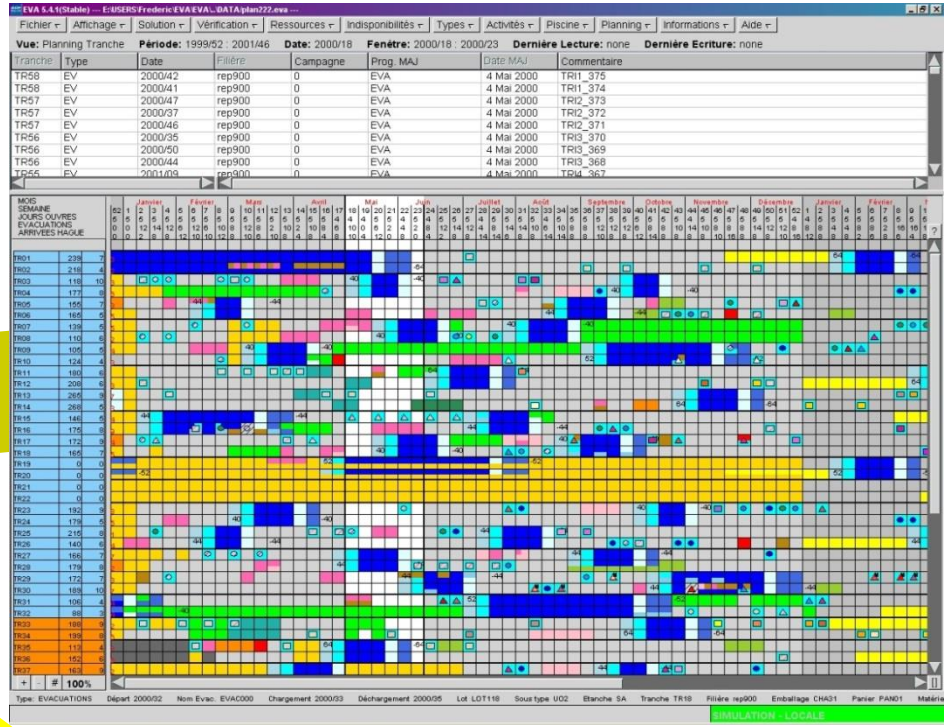
Planning Transport of Nuclear Fuel Assemblies



Evolution of pools level

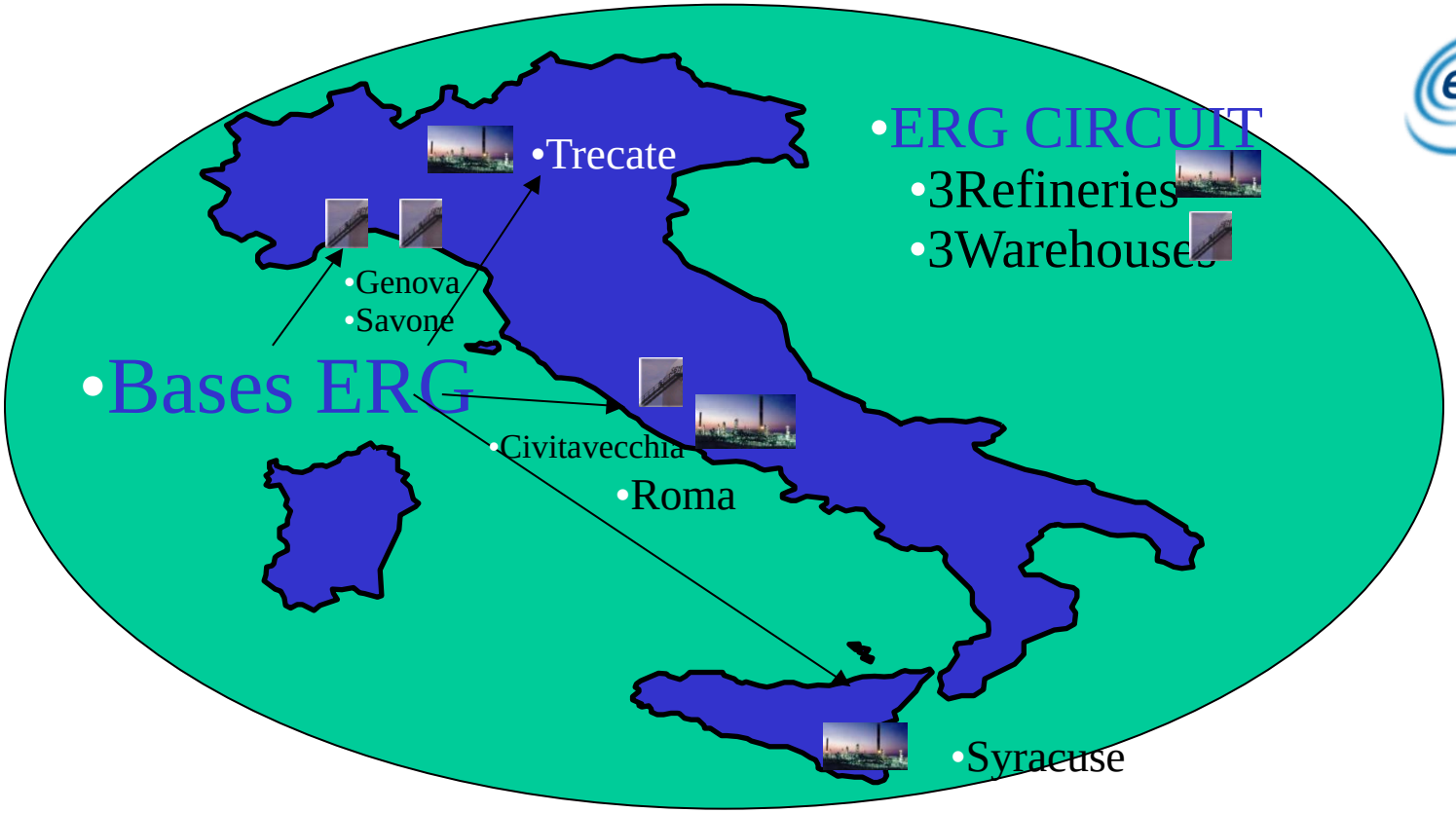


Planning of containers

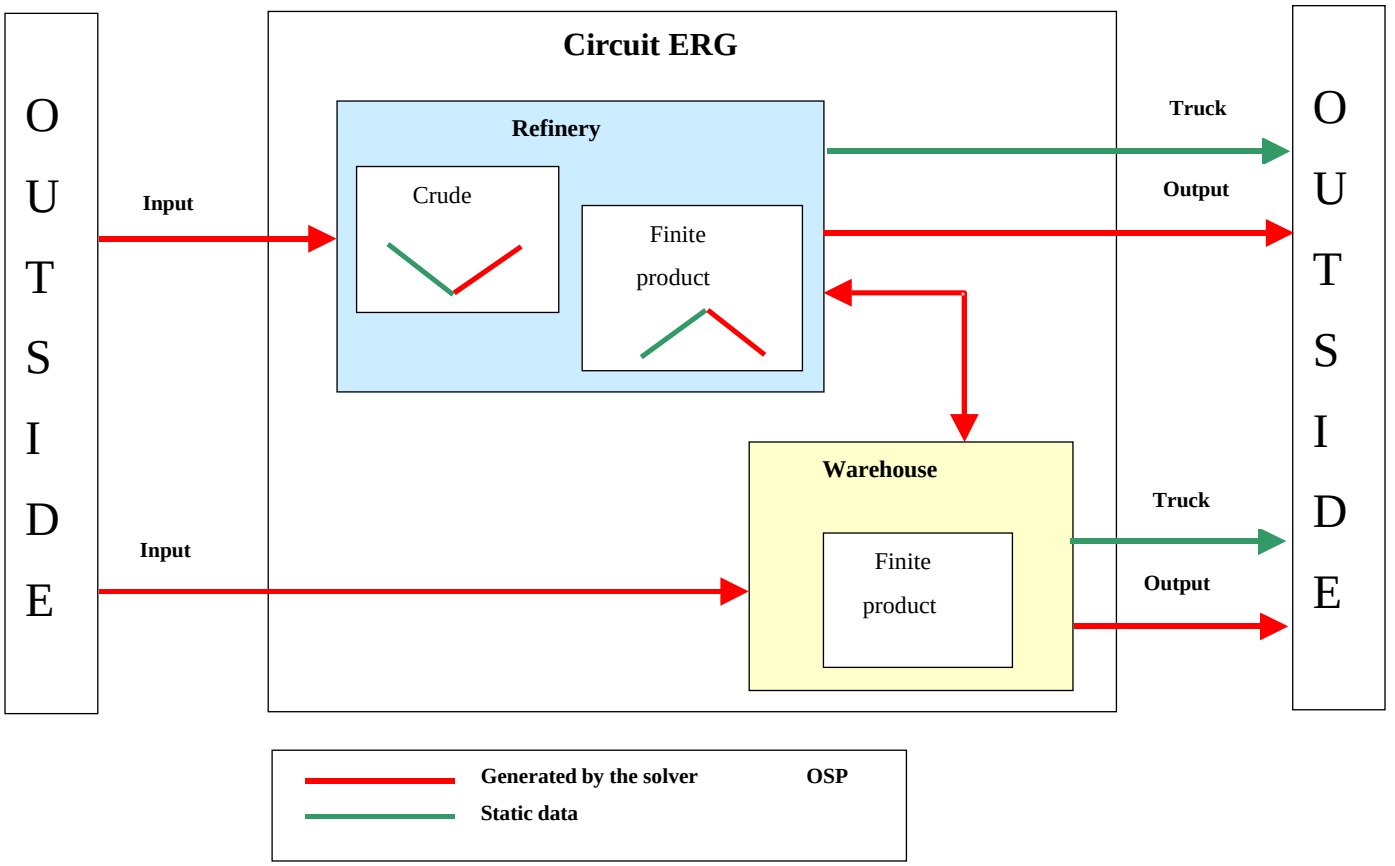


Planning of plants

Logistics for Refineries



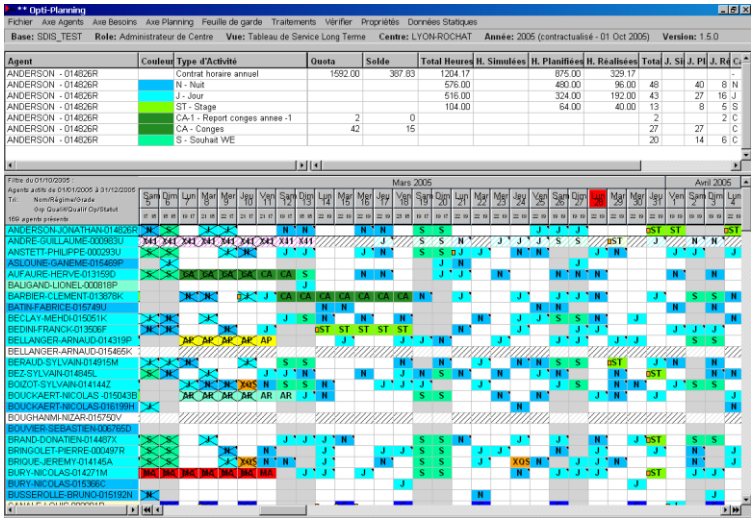
Circuit optimization of logistics for Refineries



Emergency Services

Fire & Rescue Department of Rhône

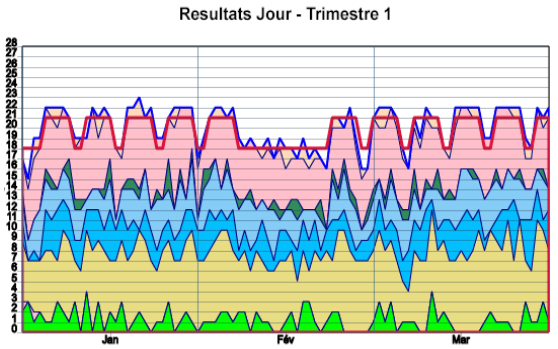
- Volumetry
  - **2000 firefighters**
  - **15 centers**
- Regulatory Constraints (e.g.)
  - **Minimum rest between 2 shifts**
    - 11 hours
  - **Maximum working hours**
    - 48 hours maxi / 7 consecutive days
    - 44 hours maxi / 12 consecutive weeks
  - **Forbidden sequences of shifts**
    - Ex: Night-Day

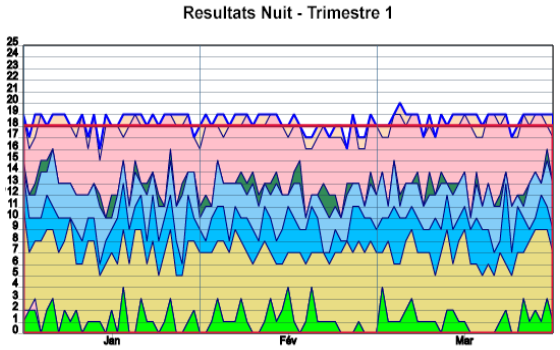


Emergency Services (2)

- **Fire & Rescue Department of Rhône**

  - Optimization
    - **Annualization of 35 Hours**
      - Target: 1596 hours for each agent
      - Annual planning (updating every 3 months)
    - **Coverage of the needs**
      - Balanced coverage throughout the year
      - Uniform distribution of the qualifications
    - **Equal treatment of the agents (fairness)**
      - Number of shifts (Day / Night)
        Week / Week-end / Holidays
      - Wishes of the agents (Rests, Week-end,...)

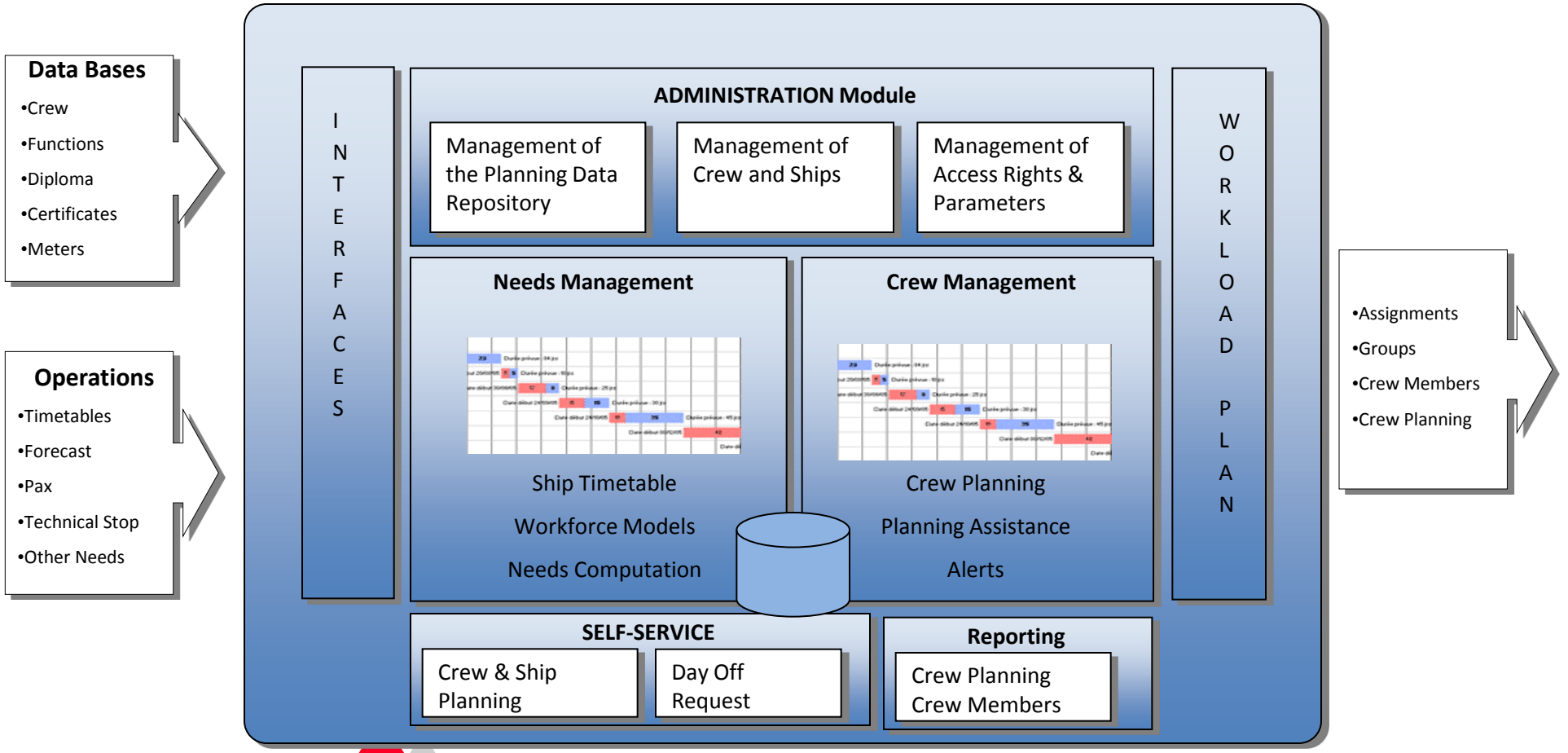




Mediterranean Ferries

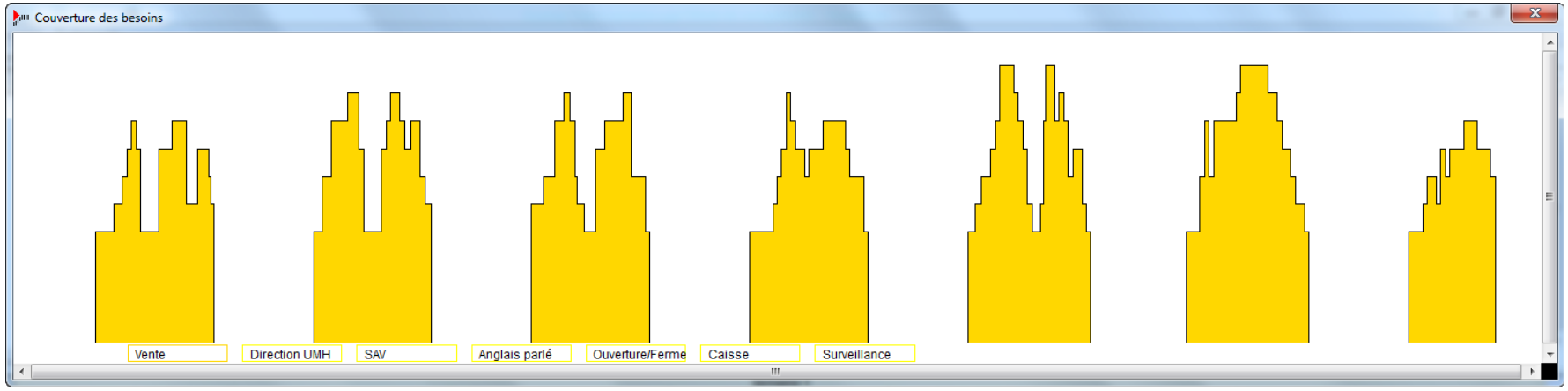
- **SNCM case**
  - **Volumetry**
    - 2000 crews (with 800 CDD)
    - 9 ferries
    - 4 agences portuaires (Marseille, Ajaccio, Bastia, Nice)
    - 1 200 000 passagers / year
  - **Very specific planning rules of « SNCM »**
    - Rights to « rest »
    - Substitutions
  - **Different professions and qualifications**
    - Captain Staff
    - Engine machinery technicians
    - Catering / room services

Crew Planning for Ferries



Personnel Planning in Retail

Profile of Needs / Salesmen



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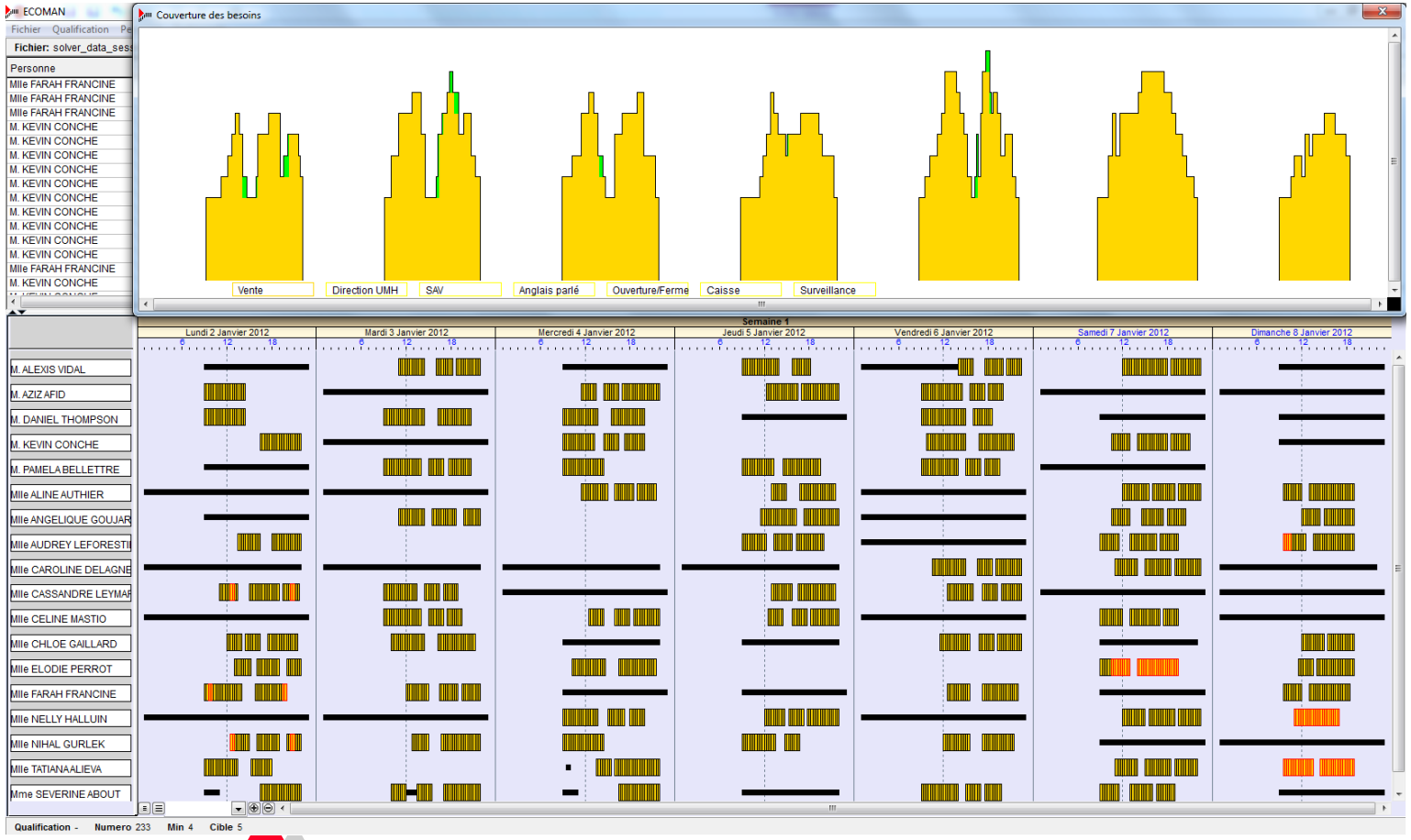
Optimal covering of Needs



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New market / customer