Building and Optimizing Timetables for Airport Employees

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PACTE NOVATION

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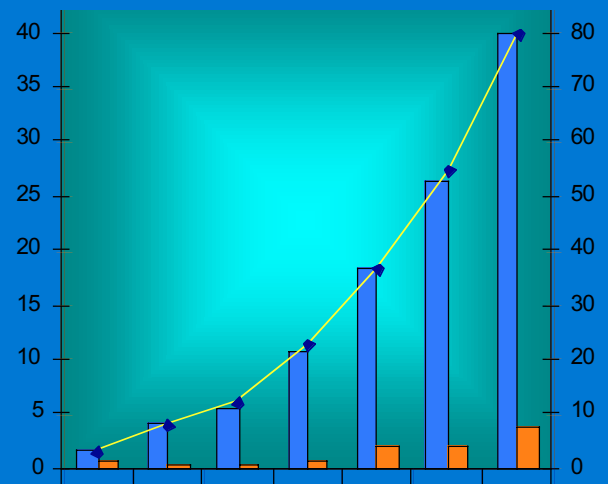
- Start up company
- Created on April 1994
- 70 persons
- Assets: 512 kEuros
- Business strategy:
  - technical expertise.
  - Know-how accumulation.



	94/95	95/96	96/97	97/98	98/99	99/00	00/01
CA (MF)	1,8	4,1	5,8	10,8	18,5	26,5	40
R?sultat net (MF)	0,8	0,41	0,45	0,9	2,3	2,3	4
Effectif Moyen	3	8	12	23	37	55	80

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Main Problem (1)

- Global system : MAXIME (Module d'Aide à l'eXploitation Informatisée des Moyens de l'Escale). Says who does what regarding ADP 2000 on-ground employees.
- Connects to existing ADP databases.
- Interactive Gantt chart.

⇒We focus on the optimization part.

Main problem (2)

- Build a timetable for each group of airport on-ground employees.
- Optimize this timetable regarding various quality criteria.
- Insert incoming tasks on the fly into a timetable.
- Perform the main operation (assignment) in **less than 1 minute.**

Modes

- The MAXIME system may be used in three modes:
  - **Planning** (MAX-P): tasks are assigned to shifts in a row 6 months in advance during one night through a computer background task.
  - **Day-to-day** (MAX-J): tasks may be changed and inserted into an existing timetable, due to unexpected flight events.
  - **Regulation** (MAX-R): daily expert change.

End user

- A **supervisor** of a group of on-ground agents/employees.
- No specific knowledge in computer science.
- S/he defines in real-time and/or in advance who will work on what.
- So far, **one day** to prepare a single timetable.

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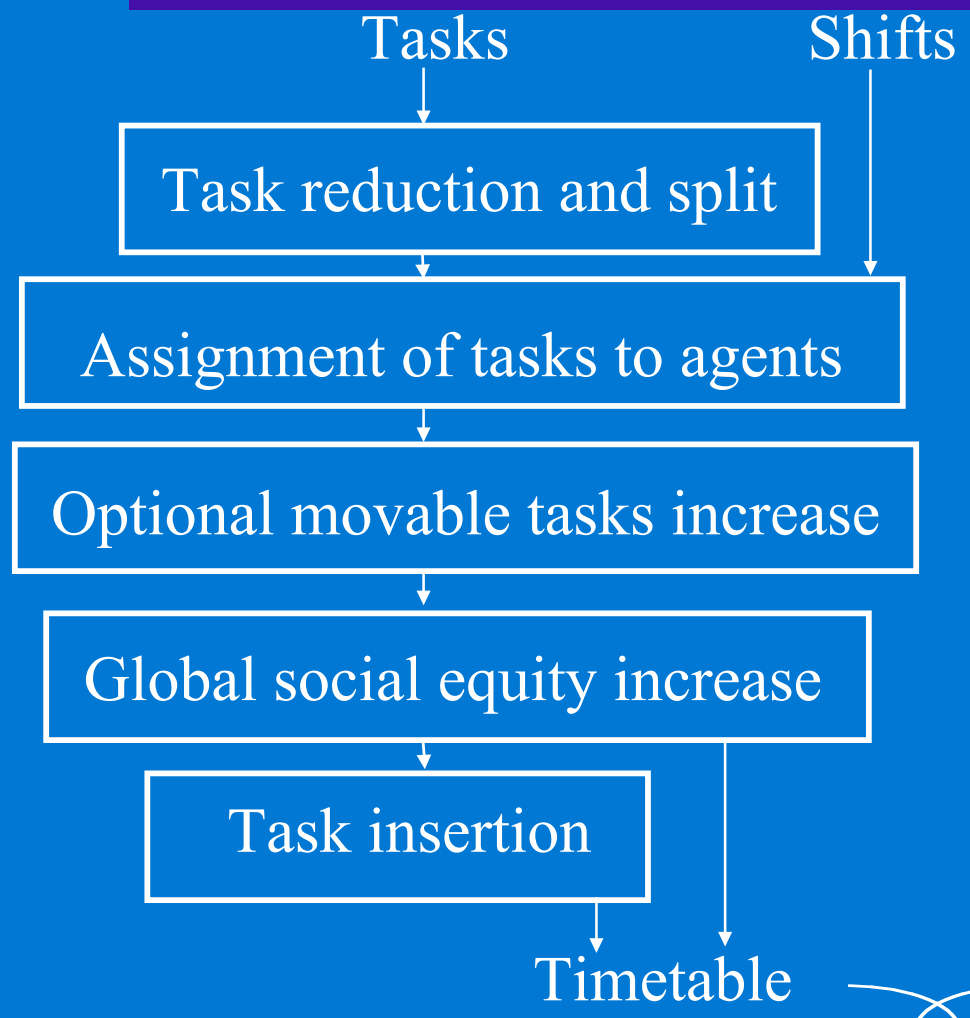
Tasks

- Each task is fixed in time *(regular task)* (e.g., check in).
- Some tasks are attached to a shift, but are movable in time within a range *(movable tasks)* (e.g., medical visit).
- Some movable tasks are optional *(optional movable tasks)* (e.g., lunch/dinner breaks).
- Task must **not** overlap + inter-task time.

5 modules



Deterministic alg.

SOLVER

“Tabu” search alg.

“Tabu” search alg.

A* search alg.

Task reduction and split

- The workload curve reveals main peaks at 11am and 3pm.
- **Counter-productive**, since the supervisor must hire agents the whole shift for a few minutes of actual work.
- Goal: reduce peaks by task reduction and split.

⇒Deterministic sweepline algorithm.

Assignment of tasks to agents (1)

- Goal: assign tasks to shifts while minimizing the number of unassigned tasks and, if possible, maximizing the number of empty shifts.

⇒ Use constraint programming and heuristics for the min/maximization criteria (see "Discussion" part).

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Assignment of tasks to agents (2)

- Primary model: An integer variable is attached to each task: the number of the shift the task is assigned to.
- Dual model: an integer set variable is attached to each shift, each element is a task number.

Assignment of tasks to agents (3)

- The constraints are:
  - Integrity;
  - Adequation;
  - Non overlapping;
  - Movable tasks always present;
  - Minimum number of optional movable tasks.
- Solutions are enumerated, so as to heuristically minimize the number of unassigned tasks.

Assignment of tasks to agents (4)

- Heuristics for choosing a shift for a task are:
  - **Leftmost** (earliest in the shift);
  - **Most filled** (shift);
  - **Least filled**;
  - **Leftmost + most filled**
  - **Regret** (smallest number of tasks which could have taken its place);
  - **Priority** (comparison workload and shift load).

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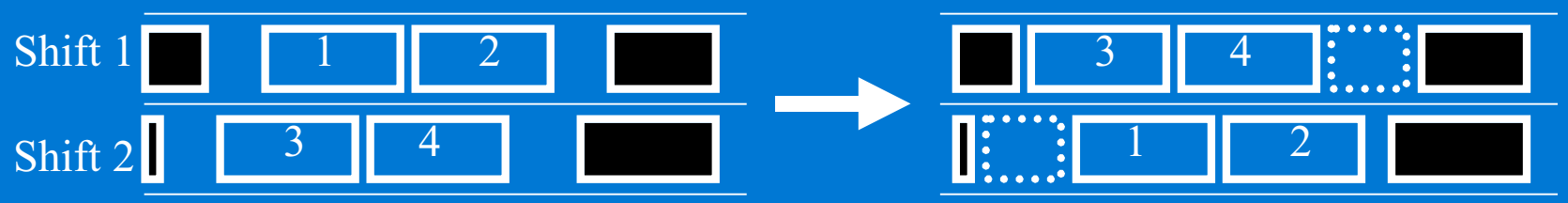
Movable tasks increase (1)

- The previous module has a fixed number of optional movable tasks (e.g., lunch, dinner breaks).
- Goal: increase the number of optional movable tasks.
- A first solution already exists

⇒ **Tabu algorithm** with an escape mechanism (to avoid local minima).

Movable tasks increase (2)

- Tasks are moved or switched among shifts, to increase the number of optional movable tasks.



Global social equity increase

- Goal: no agent should complain because s/he has a clearly worse shift than the others regarding complexity, diversity, mobility, productivity.
- A first solution already exists (i.e., generated by the previous module).

⇒ As before, **tabu algorithm** with an escape mechanism.

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Task Insertion (1)

- New flights may come unexpectedly. They must be serviced as regular ones.
- New incoming tasks must be inserted into an already built timetable, while minimizing the number of changes into this existing timetable.

$\Rightarrow$ **A* algorithm**

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Task insertion (2)

- An A* algorithm is a best-first search in the space of paths.
- **State:** a whole timetable + the task to insert.
- **Successors:** move or switch of tasks.
- **Cost function from the initial state to the current state:** the number of states.
- **Cost function to the expected solution:** zero.

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Task insertion (3)

- Several tasks may be inserted at once: completely solve the first one and then the others.
- Drawback: Computationally explosive.
- Limited in time: At least, it protects the supervisor from obvious changes (distant of less than 7 states in practice in 15 sec.).

Implementation

- The 5 models have been developed on PC machines with C++ and ILOG SOLVER.
- Ported on Bull's RS6000 machine for performance increase.
- Task assignment takes 20 sec. for 600 tasks and 150 shifts. 15 iterations in 15 sec. for each tabu algorithm (17,000 scanned states per performed state).

Discussion

- A second model for task assignment: mixed integer programming (ILOG CPLEX).
- But 2.5 hours for the relaxed solution!!!
- A third model for task assignment: scheduling (ILOG SCHEDULER).
- But 5 movable tasks per shift only and less flexibility regarding dynamic heuristics.

Conclusion

- 5 modules for tasks assignment and quality improvement of timetables.
- Good quality of the built timetables, say expert supervisors => ADP expresses satisfaction.
- Operational for ADP supervisors at Roissy and Orly on a daily basis since June 2000.