Workforce Synthesis by P-graph Method

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8th International PhD & DLA Symposium
University of Pécs, Pollack Mihály Faculty of Engineering and Information Technology
October 29–30, 2012

Outline

- Workforce scheduling
- The synthesis step
- Mathematical programming model

Workforce Scheduling

- Workforce scheduling (staff rostering, staff and labor scheduling) means assigning employees with various competences to shifts, determining working days and rest days, constructing flexible shifts with starting times.
- It is an important, complex and often multistage planning problem that every company or institution must solve.
- Recent focus is on the application areas of nurse rostering, call centers, postal services, transport companies and retail stores.
- Recent methods include various decision support techniques, ant colony optimization, dynamic programming, genetic algorithms, hyperheuristics, metaheuristics, and integer programming.

Ercsey et al, 2012.

Limitations

- There are many commercially available workforce scheduling solutions in the industry.
- Rostering more than 100 employees is an extremely demanding task.
- As the number of employees grows beyond this limit, the computation time needed to find acceptable solutions grows drastically.

Ercsey et al, 2012.

Reasons for the increased interests

- Being one of the most critical resources for the organizations careful planning of human resources can significant lower costs and lead to a more effective productivity.
- Public institutions and private companies no longer want to handle the problem manually.
- Computer power has reached the level to solve real-world problems.
- New specialized algorithms are being developed to support automated processes.
- Good rosters are important from the welfare of the staff point of view: they increase employee satisfaction, reduce sick-leaves. Besides, effective labor scheduling can also improve customer satisfaction.

Ercsey et al, 2012.

Initial data

- There is a list of tasks together with their duration, the number and the competence requirements (qualifications, skills and experience) of staff required to be performed.
- Each day is divided into periods or timeslots, the smallest unit of time.
- A shift is a continuous set of working hours defined by a day and a starting period along with a shift length (the number of timeslots). Shifts can also be grouped in shift types, such as morning, day and night shifts.
- Days are divided into working days (days-on) and rest days (days-off).
- There is a demand for the staff for each time interval during the day or for the whole planning horizon, ie one month.

Ercsey et al, 2012.

To Do

- Give a combination of shifts and days-off assignments that covers the fixed period of time.
- Allocate the specific tasks during the particular shifts to the available staff.
- Determine the number of staff necessary over a period of time. Workload prediction (also known as demand forecasting), is the process of determining the staffing levels, ie the number of employees needed for each timeslot.
- Determine shifts over a period of time. Shift generation is the process of determining the shift structure, tasks to be carried out on particular shifts and the competence needed. Shifts are created anonymously.

Ercsey et al, 2012.

The Roster

- A work schedule for an employee over the planning horizon is called a roster.
- Staff rostering (also known as shift scheduling) deals with the assignment of employees to shifts. It can also specify the starting time and duration of shifts for a given day. In most cases starting time and duration are preassigned.

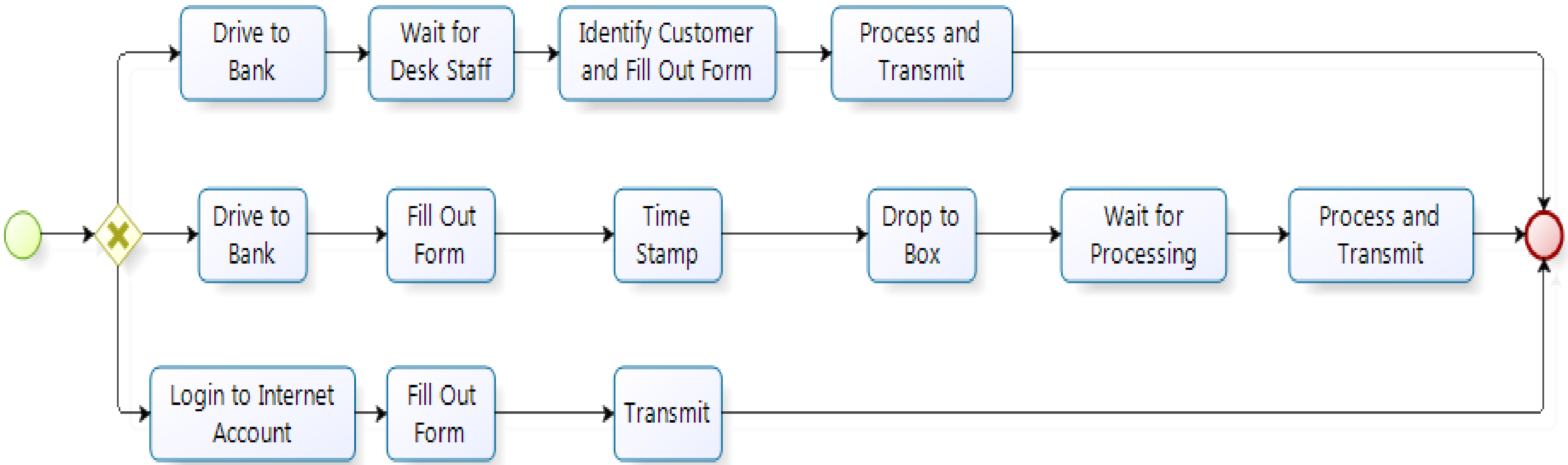
Specialities

- Days-off scheduling deals with the assignment of rest days, vacations and special days, for example training.
- When days-off and shifts are scheduled simultaneously, the process is sometimes called tour scheduling.
- Sometime days-off scheduling and staff rostering is considered over a longer period to enable the employees to plan their free time more conveniently.

Process Network Synthesis

- Optimization methodology well known for production processes. Cornerstones of the P-graph framework are developed and available.
- The analogy between production and business processes was already introduced: the transformation of BPD to P-graph is also available.

Synthesis = Alternatives



Illustrative example: bank transfer

–Personal transfer order presented to the desk staff.

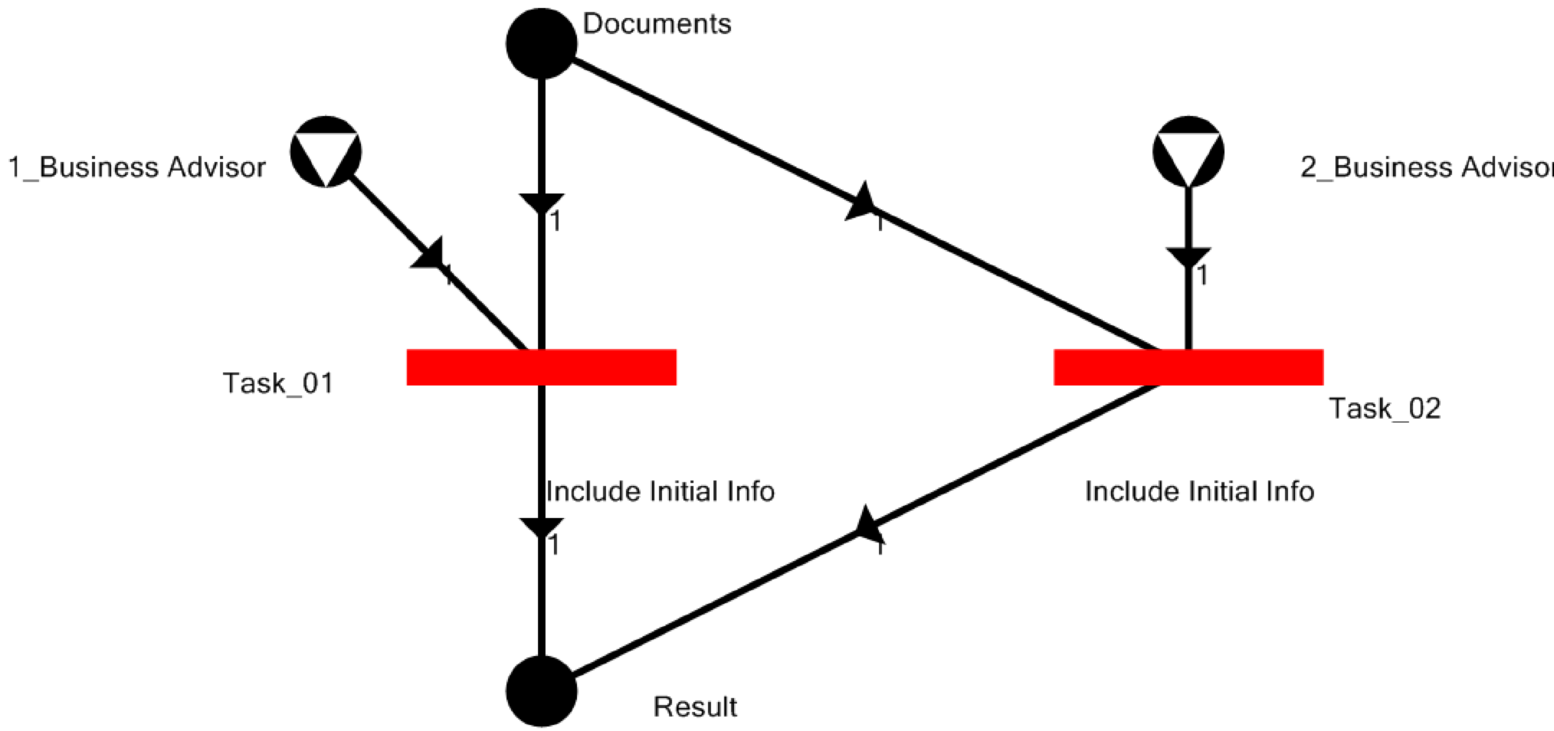
–Personal transfer order dropped at the branch.

–Online transaction via the Internet.

Alternatives

- Alternatives mean subprocesses which may replace, or may be performed parallel to other subprocesses.
- The alternatives may differ in terms of
  - Tasks,
  - Costs,
  - Resources necessary,
  - Duration,
  - Etc.

Employee Qualifications, Time etc.



Ercsey et al, 2012.

Synthesis Problem

- The alternatives are given.
- Employment questions are considered.
- Based on the above mentioned a maximal structure is generated.

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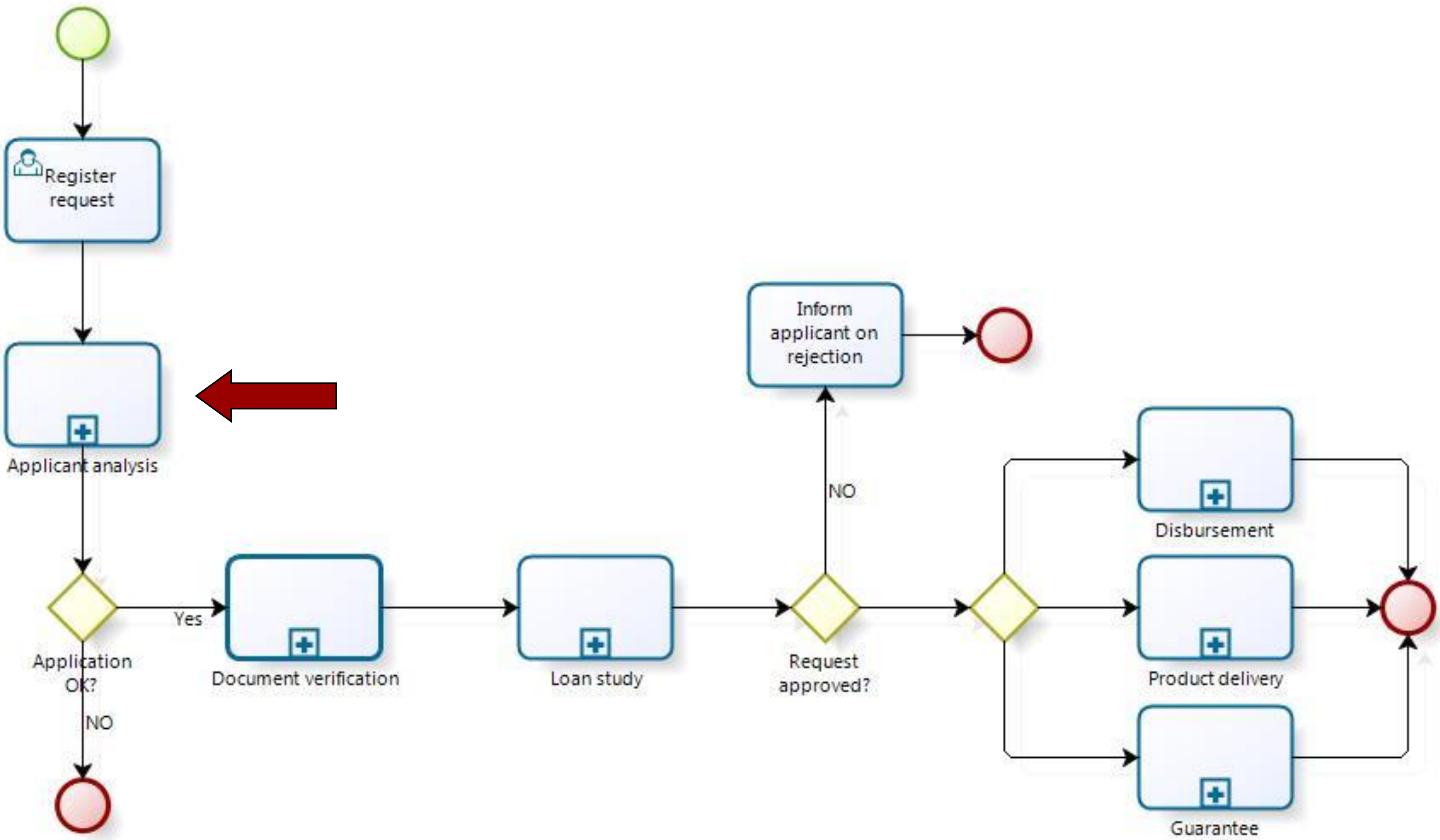
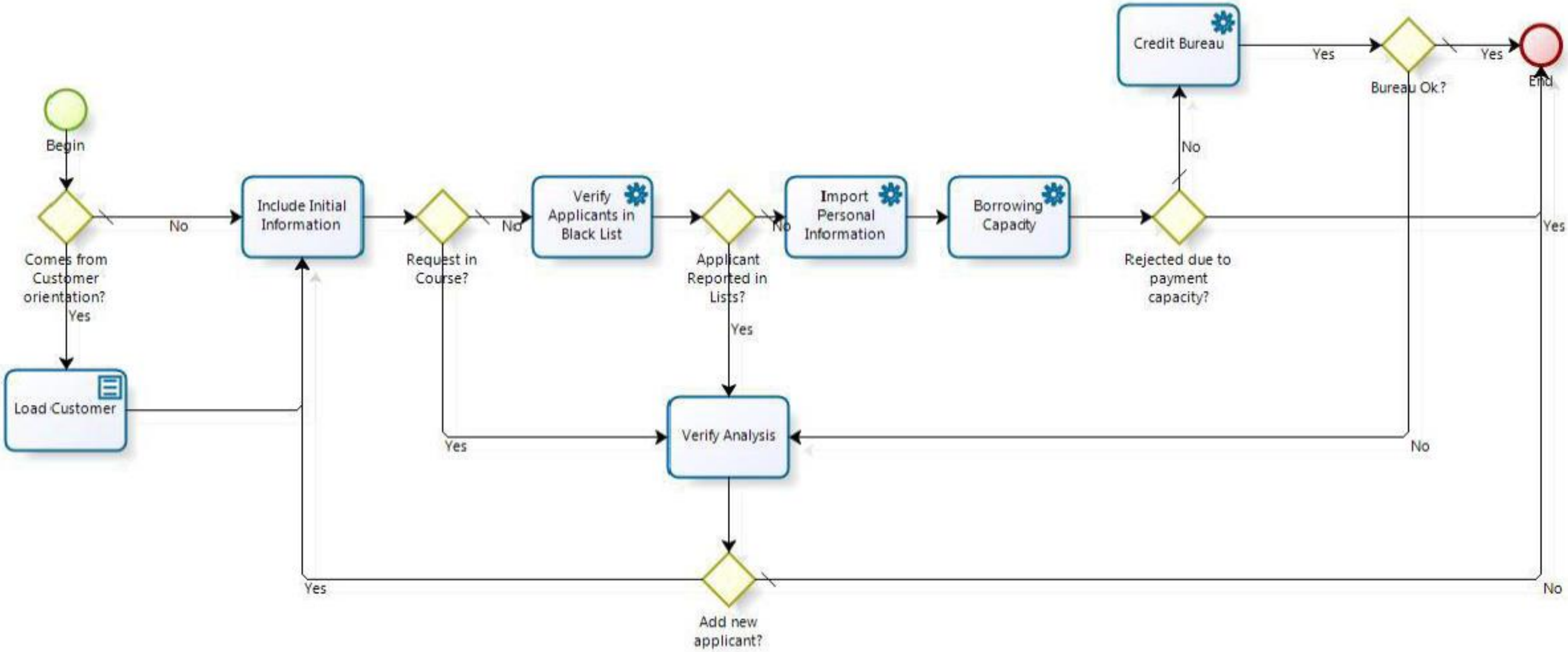
- Selection of the best overall process? The alternatives can be sorted into an order.

Example: Personal Loan Request

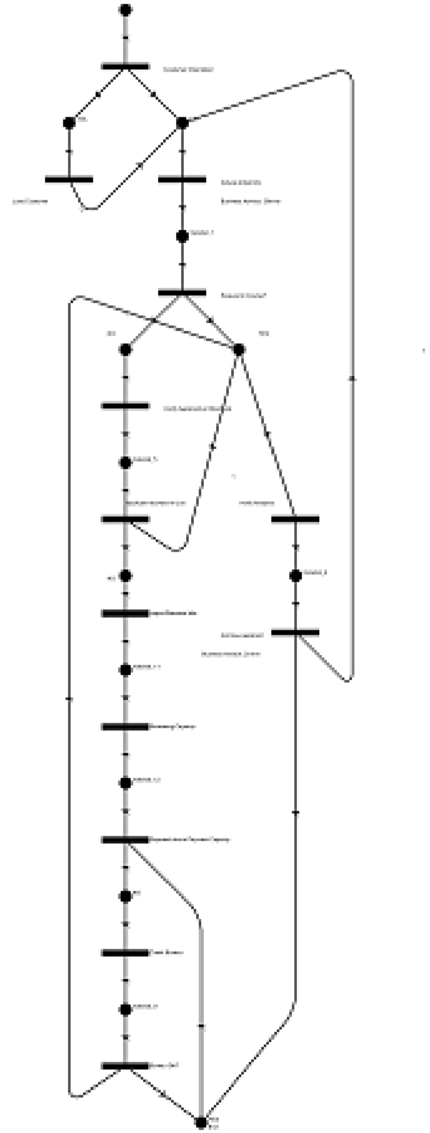


Ercsey et al, 2012.

Applicants Analysis



Applicant Analysis



Ercsey et al, 2012.

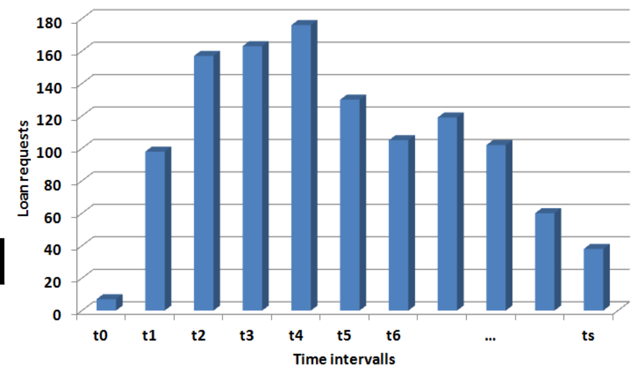
Preparation of the Mathematical Model

Preparation of the P-graph model:

- Disjoint sets of
  - Resources (R),
  - Requests (L),
  - Tasks (T),
  - Intermediate events (E).
- Indexes to the elements of the sets:
  $N = \{1,2,\ldots,n\} = R \cup L \cup T \cup E$
- G(N,A) bipartite directed graph, where
  $A \subseteq (N \times N)$

Specialities

- Let S = {1,2,…,s} be discrete time intervals.
The interval is equal to the smallest duartion regarding the tasks. For example: 8 working hours are divided into 24 time intervals of 20 minutes.
- For every $i \in L$ it is given $(l_i^1, l_i^2, \ldots, l_i^s)$ ie
time intervals: s for the i-th loan request there are so many loan requests recorded



- Example: In the office there is a maximum number of employee to be at a time interval. (0,0,…,0, 25,25,25, 0, …,0)

From the i-th type of employee cannot work more than 25 between 10:00 and 11:00.

Tasks

For every $i \in T$

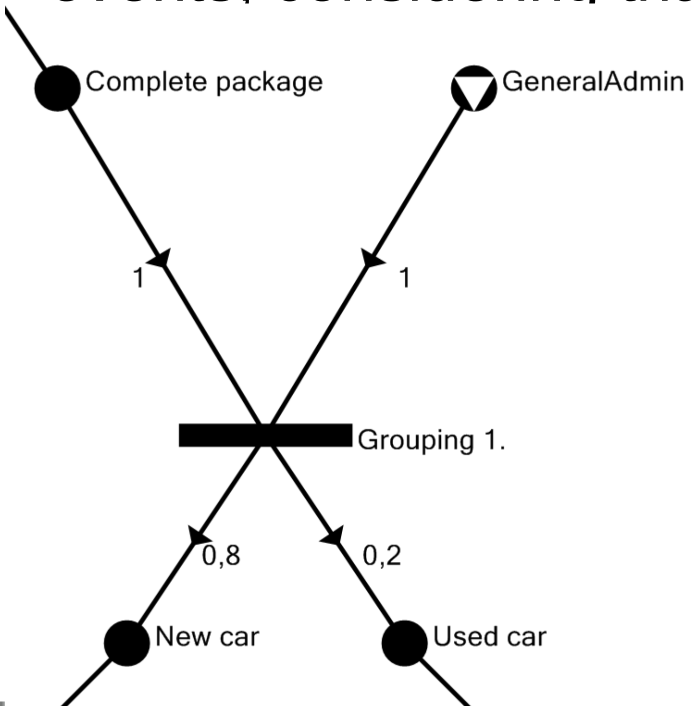
$(x_i^1, x_i^2, \ldots, x_i^s)$

ie

- # time intervals: s
- x_i^2 = i-th task during the 2nd time interval is performed so many times. Remark: it may be that more resources will perform the i-th task.
- Additionally:
  Let us assume that z_i is the processing time of i-th Task.
  For example the processing time of the decision task takes 3 time intervals for a lower quailified employee and only 1 time interval for an employee with a higher qualification.

Ratios

- For every (i,j) $\in$ A let us denote $p_{i,j}$ the ratio that refers to the consumption of the resources of intermediate events; considering that the task is performed once.



For example: when the Grouping 1 task is performed,
1 General Administrator together with
1 Complete Package is necessary and
80% of the cases are in the category of the New Cars and 20% are in the Used Cars.

Mathematical Programing Model

$$\sum_{k\in S}\sum_{\{j:j\in R\ and\ (j,i)\in A\}} c_j x_j^k \rightarrow \min$$ The cost of the resources subject to

$$\sum_{j\in T} x_j^k \le K \qquad \forall k\in S$$ The #employee at a time interval is maximum K.

$$\sum_{\{j:(i,j)\in A\}} (x_j^k + x_j^{k-1} + \cdots + x_j^{k-z_j})\, p_{ij} \le r_i^k \qquad \forall i\in R\ and\ \forall k\in S$$

$$where \quad x_j^{k-u} = 0 \quad u\in\{1,2,\ldots,z_j\} \quad if \quad k-u\le 0$$

The resource consumption is maximized.

$$\sum_{\{j:(i,j)\in A\}} x_j^k p_{ij} \ge l_i^k \qquad \forall i\in L\ and\ \forall k\in S$$

Every loan request has to be processed.

$$\sum_{\{j:(j,i)\in A\}} (x_j^k + x_j^{k-1} + \cdots + x_j^{k-z_j})\, p_{ji} - \sum_{\{j:(i,j)\in A\}} (x_j^k + x_j^{k-1} + \cdots + x_j^{k-z_j})\, p_{ij} = 0 \quad \forall i\in E\ and\ \forall k\in S$$

$$where \quad x_j^{k-u} = 0 \quad u\in\{1,2,\ldots,z_j\} \quad if \quad k-u\le 0$$

The intermediate events also have to be considered.

Acknowledgement

This presentation is supported by the European Union and co-funded by the European Social Fund.
Project title: "Broadening the knowledge base and supporting the long term professional sustainability of the Research University Centre of Excellence at the University of Szeged by ensuring the rising generation of excellent scientists."
Project number: TÁMOP-4.2.2/B-10/1-2010-0012

TÁMOP-4.2.2/B-10/1-2010-0012 projekt

MAGYARORSZÁG MEGÚJUL

A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg.