Logistics of extra-curricular activities for children

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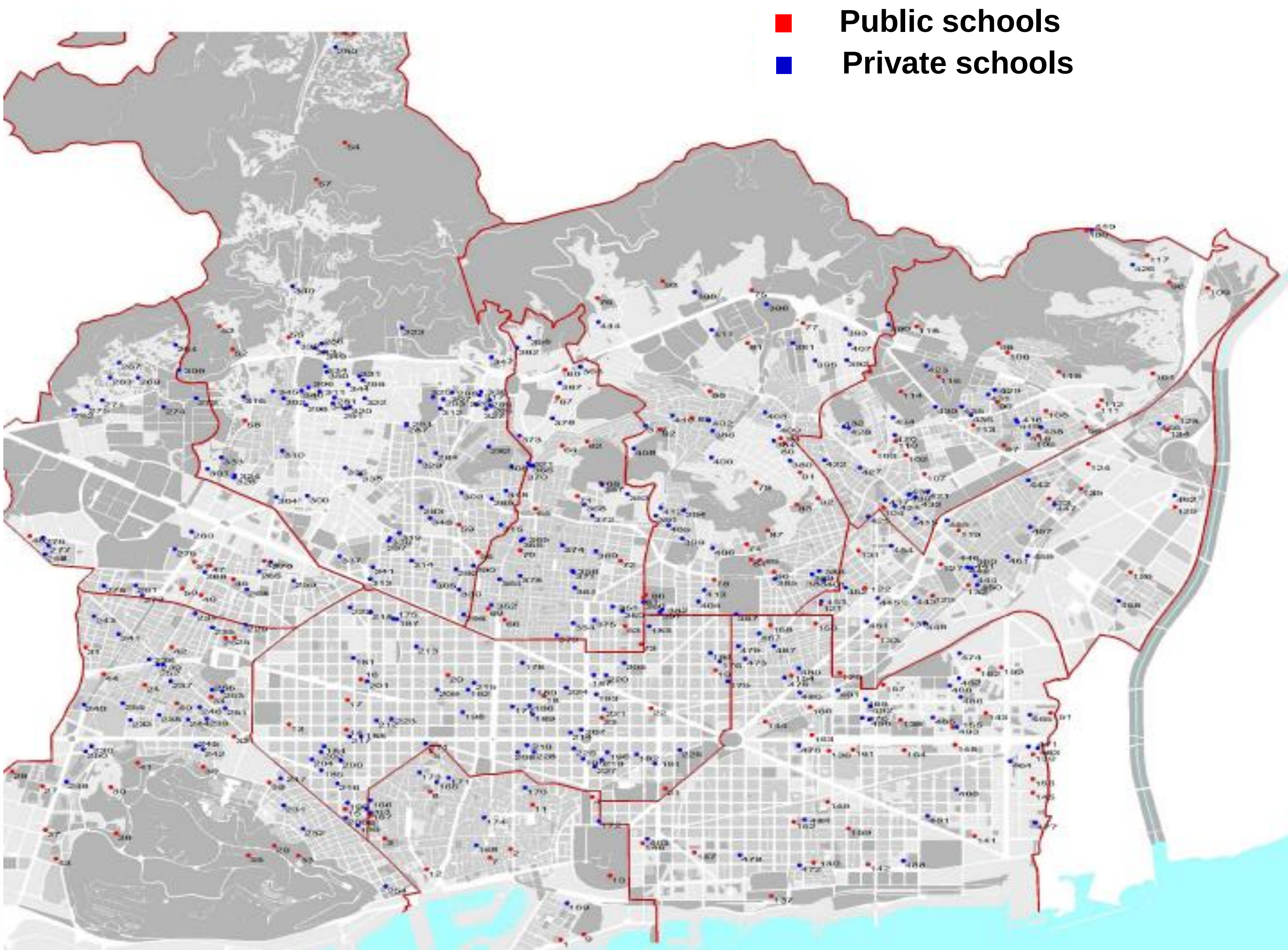
Summary

- Introduction. 2 examples.
- State of the art: the School Bus Routing Problem
- Problem 1. Model and proposed procedure
  - First decision: Clustering
  - Second decision: Activity Assignment
  - Third decision: Transport
- Problem 2. Model and proposed procedure
  - First decision: Group and activity assignment
  - Second decision: Scheduling
  - Third decision: Routing
- Some results on the case studies
- Conclusions

Example 1: Barcelona



Example 1. Introduction

- Most of the children engage in extracurricular activities after school.
- The demand of extracurricular activities, in a single school, is often insufficient to cover the expenses of the trainer.
- Only certain activities are offered in each school.
- The range of activities may be enlarged by considering other schools, thus forming a network of associations.
- This clustering leads to a higher offer and demand.
- The transport of children between schools must be provided.
- The routes for the transport of children between the facilities of each activity must be determined.

Example 2: in the Pyrenees

Example 2. Introduction

- Some children spent the weekend days learning ski in the stations during the light hours.
- Activities in the evening (from 5 pm) could complement this learning.
- In the main city in the surroundings of the ski stations, a set of activities are offered.
- The children must be organized in groups, according to their ages.
- The availability of facilities is limited, but enough for a selection of activities at each age.
- The transport of children between stations and these activities is not considered, but the one after the activities must be provided.
- The routes for the transport of children between the facilities of activities and their home must be determined.

State of the art

- Park and Kim (2010) reviewed research on the School Bus Routing Problem (SBRP).

Example 1

- Problem different to the Vehicle Routing Problem (VRP).
- We can define it as a Set Covering Problem (SCP). Given the set *T* of all schools, school clusters are created such that each student in the cluster gets access to the selected activity.
- Let us solve the case in which each one of the *m* clusters created are disjoint sets: $S=\{S_1, ..., S_m\}$ such that $S_1 \cup ... \cup S_m = T$.

Example 2

- Problem closer to the Vehicle Routing Problem (VRP), with a limited time.
- It must be solved twice if not all the children finish simultaneously.

Model of the problem 1. Notation

- *p* activities (k=1,…,p)
- *m* schools (i=1,…,m)
- *n* potential facilities in schools for activity *k* (j=1,…,n)
- *q* levels in the primary school (t=1,…,q)

- $d_{i,k,t}$: demand in the school *i* of activity *k* for children in age *t*.
- $a_{j,k}$: availability of the facility *j* to carry out activity *k* (we will consider for children in any age *t)*.
- $t_{i,j}$: time (in minutes) of the travel from school *i* to facility *j*.
- t_{max} (waiting time): estimated maximum time a child can wait in a school to be picked up by a bus (to take him or her to another facility). $t_{max}=15$

A graph will be drawn, where only arcs between nodes *i* and *j* such that $t_{i,j} \leq t_{max}$ (i,j=1,...,m)

Proposed procedure for problem 1

Clustering: divide the set of schools into clusters in order to group the closest points.

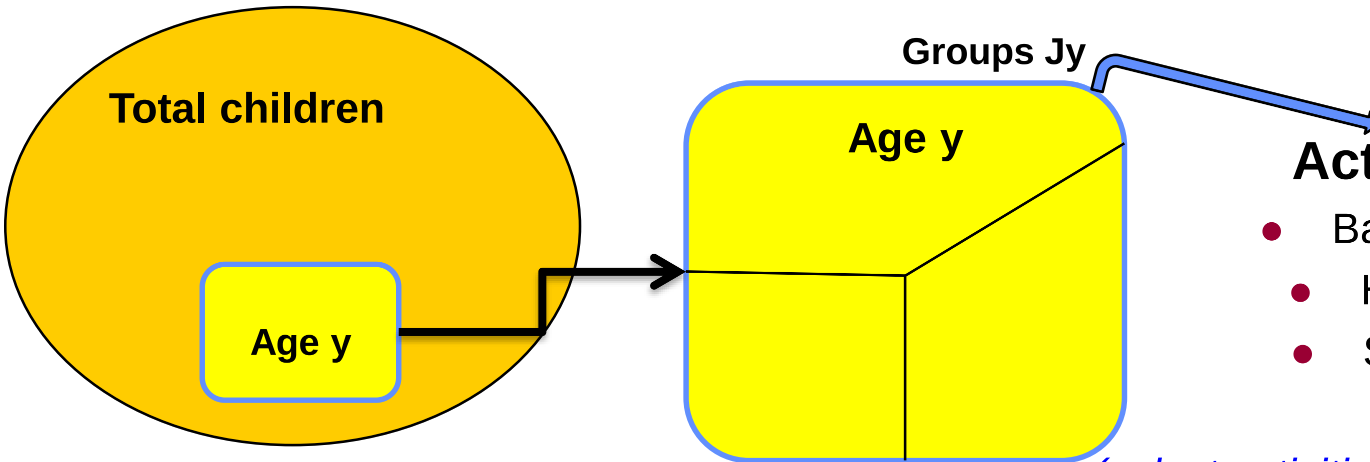
↓ Single or double bus per cluster

Assignment: select one of the school candidates to develop an activity, if possible (for each activity and each cluster).

↓ Children’s destination in a cluster

Transport: determine movement of children, as well as the number of buses per cluster.

Description of problem 2



Activities

- Basketball
- Handball
- Spinning

…

(select activities/group)

Groups

	7A	9A	11A
Time 1	X	X	
Time 2	X	X	X
Time 3	X	X	X
Time 4	X	X	X
Time 5			X

scheduling + routing

Model of the problem 2. Notation

- *m* children (i=1,…,m)
- *n* groups (j=1,…,n)
- *p* activities (k=1,…,p)
- *q* potential facilities (l=1,…,q)
- *s* different ages to create groups (y=1,…,s)

The children are divided according to their ages (s=5).

- I1: set of children with ages of 7-8 years.
- I2: for ages of 9-10 years, and so on up to I5.

The set of *n* groups depends on the number of children per age.

- J1: set of groups (for 7-8 years).
- J2: for groups (for 9-10 years) and so on up to J5

$|J1| = \lceil |I1|/15 \rceil$ (maximum number of children/group is 15)

Model of the problem 2. Notation (II)

Given the set of m children (i=1,...,m).

For each child *i* there is the following information:

- a_i: age of the child *i* (between 7 and 16 years)
- l_i: home location of the child *i*
- $e_{i,k}$: evaluation of activity *k* given by the child *i*
- $d_{i,r} \in \{0,1\}$: indicate if route *r* is the one from the activity facility to child *i* home (destination), or not
- p_i: binary variable to indicate if child *i* leaves permanently there (this children use the activities all the days; visiting children use the activities only Saturdays, but not Fridays)

Proposed procedure for problem 2

Group and activity assignment: divide the set of children into groups according to their ages and select the activities to develop for each group.

↓ Activities for each children group

Scheduling: determine the time for each activity and the correspondent facility.

↓ Ending time for activities of each group

Transport: determine the routes to children's houses and the necessary means of transport.

Level 1: Group and activity assignment

Data

- $\mathrm{I}y$: set of children with ages $y_{min} \leq a_i \leq y_{max}$
- $\mathrm{J}y$: set of groups of age *y*, given the a_i (age of child *i*)
- $\mathrm{K}y$: set of activities for children with age *y*, given a_i (age of child *i*)
- $b_{i,j}$: a child *i* can be assigned to group *j*, according to $\mathrm{I}y$ and $\mathrm{J}y$, or not
- $c_{j,k}$: activity *k* can be done by group *j*, according to $\mathrm{J}y$ and $\mathrm{K}y$, or not

Variables

- $x_{i,k} \in \{0,1\}$: indicates if child *i* can realize the activity *k* ($k \in \mathrm{K}y$) or not
- $y_{i,j} \in \{0,1\}$: indicates if child *i* is assigned to group *j* ($j \in \mathrm{J}y$) or not
- $z_{j,k} \in \{0,1\}$: indicates if activity *k* is selected for group *j* or not

Model

$$[\text{MAX}]\ \Sigma_i \Sigma_k (e_{i,k} \cdot x_{i,k})$$

$$x_{i,k} = 1 \Leftrightarrow y_{i,j} = 1\ ;\ z_{j,k} = 1$$

$$\Sigma_j (b_{i,j} \cdot y_{i,j}) = 1\ \forall i\ \ ;\ \ \Sigma_i\, y_{i,j} \leq 15\ \forall j\ ;\ \ \Sigma_k (c_{j,k} \cdot z_{j,k}) = 4\ \forall j$$

Level 2: Scheduling

Data

- $y_{i,j} \in \{0,1\}$: child *i* is assigned to group *j* or not
- $z_{j,k} \in \{0,1\}$: activity *k* is selected for group *j* or not
- $f_{k,l} \in \{0,1\}$: activity k can be done in facility *l* or not
- g_l: maximum number of groups in facility *l*
- *T*: the number of time slots (t=1,…,T)

Variables

- $w_{j,k,t} \in \{0,1\}$: indicates if activity *k* done by group *j* is scheduled in slot *t* or not
- et_j: ending time of group *j* ($et_j \leq$ T)

Model

Minimize the costs to rent the facilities while considering the limited capacity of facilities:

- some facilities permit one or two groups simultaneously;
- some activities required two groups simultaneously.

Level 3: Routing

Data

- $d_{i,r} \in \{0,1\}$: indicate if route *r* is the one from the activity facility to child *i* home (destination may be different), or not
- *Cap*: the maximum number of children per bus

Objectives

1. Minimize the number of mid buses for all the necessary routes
2. Minimize the total distance of the routes

Constraints

Maximum time allowed of the route (ideally: 30 minutes)

Problem 2. Case study

- 150 children.

Ages	7-8	9-10	11-12	13-14	15-16	Total
Children	53	44	29	13	11	150
Groups	4	3	2	1	1	11

- 8 facilities, some of them permit 2 groups at the same time.
- 5 slots: from 5pm to 8.45 pm (45 minutes per slot)
- 6 predefined routes.
- Some children live in the city in which the activities are held. Only 86 children require transport.
- Transport combines mid buses, for roads, with sport utility vehicles or suburban utility vehicles (*SUVs*), for pathways.
- The capacity for mid buses is 25.

Problem 2. Scheduling

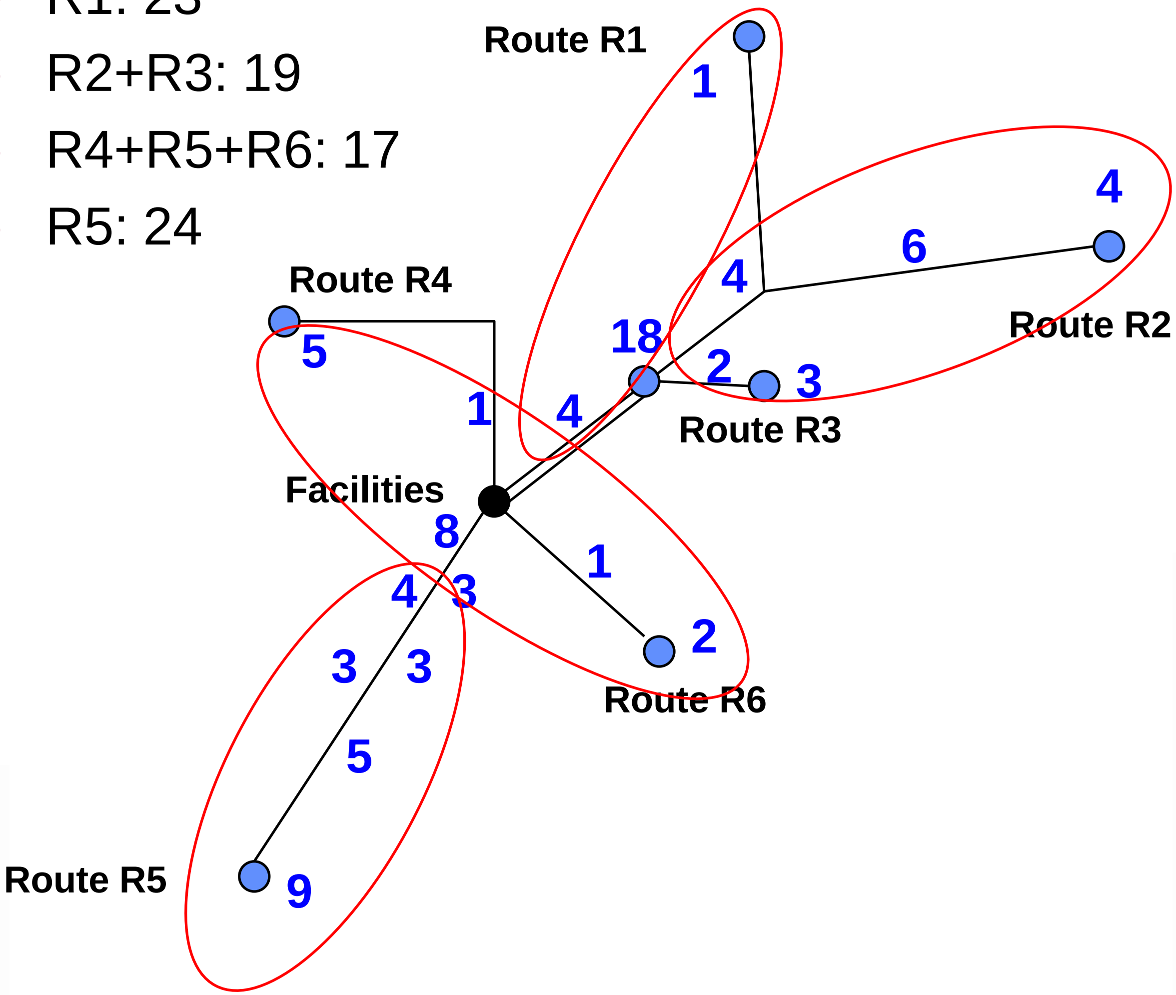
- An example of schedule is:

t	J1a	J1b	J1c	J1d	J2a	J2b	J2c	J3a	J3b	J4	J5
t=1	11	10	5	3	13	13	11	-	-	-	-
t=2	5	4	11	10	1	5	5	13	13	9	9
t=3	10	11	13	13	3	1	3	2	2	4	4
t=4	13	13	10	11	4	4	1	4	3	10	10
t=5	-	-	-	-	-	-	-	10	10	13	13

Problem 2. Routing

If all finish at the same time:

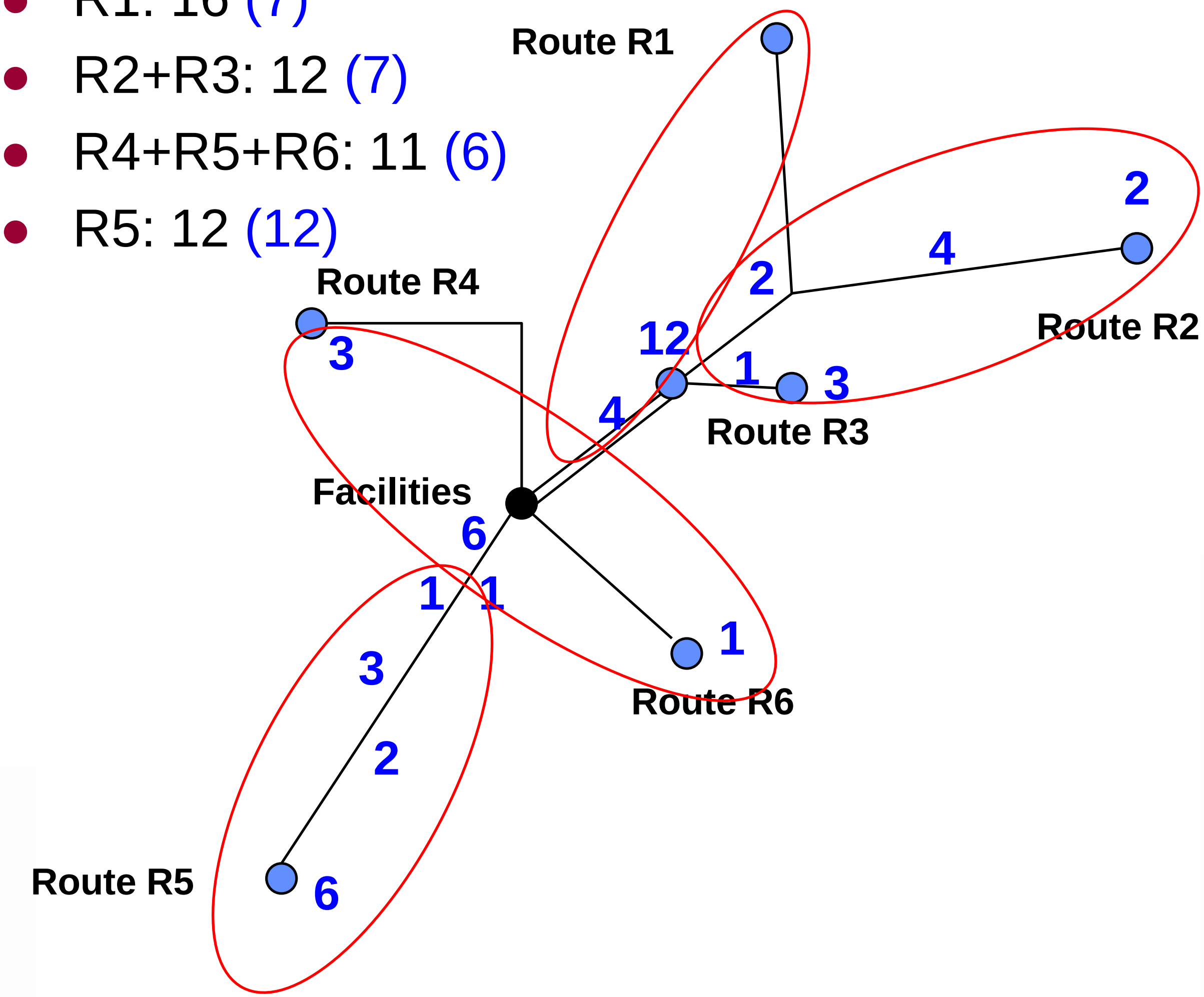
- R1: 23
- R2+R3: 19
- R4+R5+R6: 17
- R5: 24



Problem 2. Routing handicap

But if not all finish at the same time and routes are quite long:

- R1: 16 (7)
- R2+R3: 12 (7)
- R4+R5+R6: 11 (6)
- R5: 12 (12)



Conclusions

- Two problems in which assignment, scheduling and routing are combined.
- Up to now, the solutions given are done based on concatenated decisions (several steps, in which a kind of decisions are taken at each one).

- For a future research:
  - Possibility of a single formulation for the whole problems
  - Sensitivity analysis on the data
  - Consider them as multicriteria problems instead of giving priority to a criterion.

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Thank you for your attention!