ETM

ENGINEERING & TECHNOLOGY MANAGEMENT

Title: A Facility Layout Planning Model Using Binary Linear Programming

Course: EMGT 540/640
Term: Winter
Year: 1997
Author(s): R. Hammer and E. Oyer

Report No: P97005

Abstract: Using binary linear programming, the effectiveness of the current layout of offices and people in the offices is compared to an optimized solution.

A Facility Layout Planning Model Using Binary Linear Programming

R. Hammer, E. Oyer

EMP-9705

Survey for a Team Project Operations Research:
Facility Office Layout Planning

This little survey helps our group: Edouard Oyer, Raik Hammer, Suphakit Saengsin to gathering the data of communication requirements of each member of the EMP-Office.

To whom and how often do you communicate (Face to Face only!) with the mentioned members of the EMP? (Please fill *either* in the box per day *or* in the box per week!)
If the communication happens rather seldom, please use the column per week!

Filled out from: (Please check *your* name in the box)

	Faculty	Per Day	or	Per week
☐	Kocaoglu, Dundar			
☐	Anderson, Tim			
☐	Milosevic, Dragan			

	Staff	Per Day	or	Per week
☐	Wiltse, Mary			
☐	Hatmaker, Hiedi			
☐	Iparraguirre, Karen			
☐	Kuran, Dogus			
☐	Mueller, Don			
☐	Nguyen, Daniel			
☐	Setiowijoso, Liono			
☐	Uslu, Akin			
☐	White, Ann			

	GSA/Full Time Ph.D. Students	Per Day	or	Per week
☐	Abd Razak, Razif			
☐	Baygit, Mete			
☐	Daim, Tugrul			
☐	Desmond, Bert			
☐	Eden, Karen			
☐	Haris, Khaled			
☐	Williams, Gerry			
☐	Zhang, Janet			

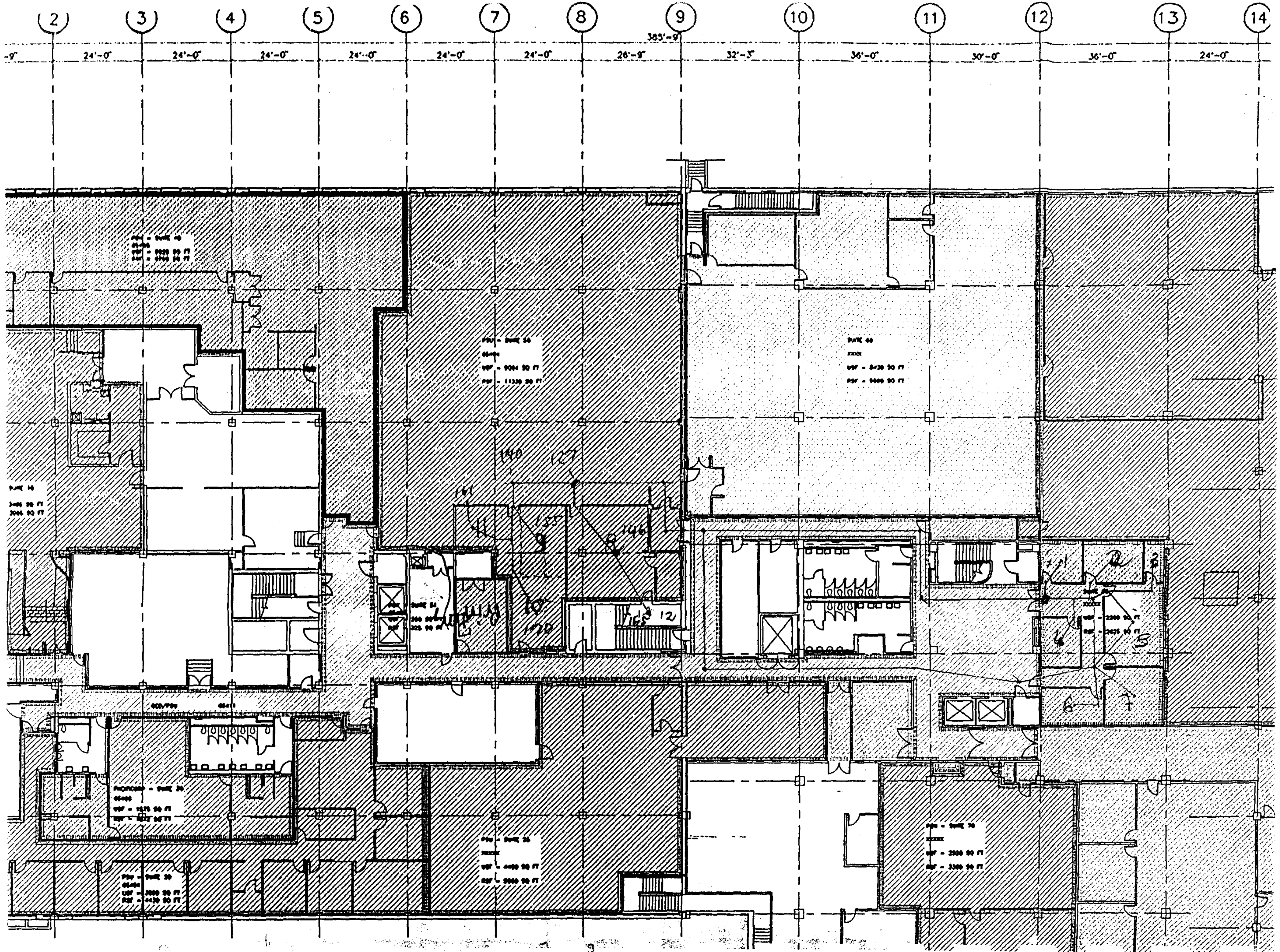
Thank you for the participation!

Team Project Operations Research

EMGT 540/640

Title: A Facility Layout Planning Model Using Binary Linear Programming

Project Team: Edouard Oyer and Raik Hammer



2
3
4
5
6
7
8
9
10
11
12
13
14
385'-9"
24'-0"
24'-0"
24'-0"
24'-0"
24'-0"
24'-0"
26'-9"
32'-3"
36'-0"
30'-0"
36'-0"
24'-0"

Dundar Kocaoglu	R10
Tim Anderson	R2
Dragam Milosevic	R4
Mary Wiltse	R8
Hiedi Hatmaker	R8
Don Mueller	R8
Daniel Nguyen	R8
Karen Iparraguirre	R9
Dogus Kuran	R9
Liono Setiowijoso	R1
Akin Uslu	R1
Ann White	R11
Tugrul Daim	R7
Razif Abd Razak	R6
Mete Bayyigit	R6
Bert Desmond	R6
Karen Eden	R7
Khaled Haris	R6
Gerry Williams	R7
Jannet Zhang	R7
Records	R12
Computer Lab	R5
Meeting room	R5
Library	R3

1. Introduction

Assigning offices to faculty and staff within an academic facility is a task, that is often done intuitively or on a heuristically basis. Existing buildings, where permanent walls limit the flexibility in remodeling space, cannot not be remodeled in that way that the offices (facilities) fit to the requirements of an organization, respectively institution. The task is complicated by vested interest and the variability of room as size, air conditioning, proximity to departmental offices, and other requirements. This work reports the implementation of a linear programming model (Integer Programming with Decomposition) used to allocate faculty and staff space to different offices.

1.1. Literature Review

This project refers to a facility location problem. The term facility is very widely used in Operations Research, so it is not surprising that facility location and layout research papers are published in a large number of seemingly unrelated problems.

Facility planning in terms of plant layout is viewed as a search for a geometric arrangement of centers which minimizes relevant costs and satisfies several feasibility constraints.[4]

Investigators have long been interested in the facility layout problem, but the emphasize has traditionally been on layout in factory situations.

The layout problem for plants is usually modeled as the quadratic assignment problem (QAP). [4]

The QAP was first formulated by Koopmanns and Beckmann.[7] As a matter of fact until now there was a lot of research done in the field of plant layout optimization.

Chan and Francis tried to find a layout of a given number of identical facilities so that the total (or average) linear rectilinear distances between facilities are minimized. [9]

A heuristic algorithm and simulation approach to relative location of facilities gave Armour and Buffa by determining suboptimum relative location patterns for physical facilities.[1]

In fact the focus of layout problems is laid on plant layout: the optimization of processes involved with production.

Facility layout problems in terms of offices were purely office layout problems targeted the optimization of paper flow travel using techniques such as two-dimensional templates and process charts. [11] For most office layouts paper flow falls in two categories, either paper flow is large

Comments

Those results are a function of the space we have allowed to the different member of the department. This explains why Jannet has been assigned in the room currently used by the library.
An interesting result is about Dr. Anderson, Dr. Milosevic, Liono, Akin, the computer lab and the library.
As it has been remarked in the actual configuration of the offices are functional but regarding the goal and constraint we have determine along this project the configuration is not necessary optimal.

By looking at the research done in the field office layout the work is rather rare compared to other fields in the Operations Research. It is not surprisingly that a common model for office layout does not exist, and therefore a special objective function had to be created with constraints applied for the specific case. As discussed later in this paper the creation of a very specific model is the probably the biggest disadvantage of applying the models in practice regarding the fact that an effort has to be done changing the model.

2. Problem Statement

2.1. Background

At the beginning of the year 1997, the Engineering Management Program offices moved to the 4th Avenue Building. The change of the location has implicated a redesign and allocation of the different offices of the Engineering Management Program (EMP). Right now the staff and faculty are placed.

The purpose of this work is to validate the proposed model of facility locations in terms of non-factory facility planning.

2.2. Organization and Efficiency

There are of course several criteria how to tackle this problem or how organizations might set their goals, respectively want to optimize processes. Operations Research can help with optimization of facilities to increase efficiency or achieve set goals.

The term organization refers to a unit or an overall institution, that produces services. So we do not deal with facilities in production processes, where a lot of effort in research was already put in. The created programming model refers to organizations of a different structure not involved with production. A good example might be an institution like DMV or each educational facility.

Objectives are defined in this paper as an overall target, means the objective is at the first level. An objective might be efficiency.

```
X(R11,Ann)=1;
X(R2,MR)=1;
X(R5,Lno)=1;
X(R5,Akn)=1;
X(R5,cpt)=1;
X(R2,lib)=1;
!results of the previous computations;
@FOR(list(J):@SUM(room(I):X(I,J))=1);
!rooms constraints;
@FOR(room(I):@SUM(list(J):A(J)*X(I,J))<=S(I));
!space constraints;
@FOR(room(I):
        @FOR(list(K)|((K#GE#Kgl)#AND#(K#LE#Mil)):
                X(I,K)<=Y(I,K);
                @SUM(list(J)|(K#NE#J):X(I,J))<=@SIZE(list)*(1-Y(I,K))));
!loneliness contraints;
@FOR(room(I):
@SUM(list(J)|(J#GE#Rzf)#AND#(J#LE#Jnt):X(I,J))<=@SIZE(list)*Z(I));
@FOR(room(I):
@SUM(list(J)|(J#LT#Rzf)#OR#(J#GT#Jnt):X(I,J))<=@SIZE(list)*(1-Z(I)));
!GAs loneliness;
@FOR(room(I):B(Ads)*X(I,Ads)<=(2*S(I)^0.5)
        -@SUM(list(J)|J#NE#Ads:B(J)*X(I,J)));
@FOR(room(I):B(Mil)*X(I,Mil)<=(2*S(I)^0.5)
        -@SUM(list(J)|J#NE#Mil:B(J)*X(I,J)));
@FOR(room(I):B(cpt)*X(I,cpt)<=(S(I)^0.5)
        -@SUM(list(J)|J#NE#cpt:B(J)*X(I,J)));
@FOR(room(I):B(MR)*X(I,MR)<=(S(I)^0.5)
        -@SUM(list(J)|J#NE#MR:B(J)*X(I,J)));
!board constraints;
```

Our model tries to tackle the communication requirements of an organization and in addition to this the personal requirements of members of the organization, which varies with the level of status of this person. The task was to optimize the location of offices and assign people of an organization to these offices (facilities).

2.3. Information Gathering

The general assumption in this project is that a crucial organizational requirement is the communication. The model puts a lot of emphasize in it. Even in a time of world-wide-networking and intranets the communication issues face-to-face are urgent problems. This has to be satisfied. Different requirements are task related by looking at the function of a person where an assignment of an office with defined operations to a location-cluster is given. The communication issue is expressed through the stepwise optimization approach of our linear programming model. By optimizing the communication needs however the communication will be defined, interrelated cluster (groups of people, or teams) will be set close together, assuming that the type of organization is a stabile one. The problem of the type of organization is that the organization might change their requirements due to different tasks.

Our approach gathers individuals with tasks that is related and connected together and satisfies the communicational needs of the individuals.

The stepwise approach to apply our model in organizations is:

A. Define related tasks in an organization
B. Identify the communicational needs/ structure
C. Group discussion about assumptions of personal needs
D. Run the optimization model
E. Prove the Solution
F. Discuss the optimum
G. Implementation

The general assumption is that solutions obtained are not the final placement of the person to offices and offices to several locations. The solution shows an optimum, that can be in practice

X(R1, ADS)	1.000000	0.0000000E+00
X(R2, LIB)	1.000000	0.0000000E+00
X(R2, MR)	1.000000	0.0000000E+00
X(R2, TGL)	1.000000	0.0000000E+00
X(R4, MIL)	1.000000	0.0000000E+00
X(R5, LNO)	1.000000	0.0000000E+00
X(R5, AKN)	1.000000	0.0000000E+00
X(R5, BRT)	1.000000	0.0000000E+00
X(R5, KLD)	1.000000	0.0000000E+00
X(R5, CPT)	1.000000	0.0000000E+00
X(R7, JNT)	1.000000	0.0000000E+00
X(R8, OFC)	1.000000	0.0000000E+00
X(R9, KGL)	1.000000	0.0000000E+00
X(R10, PT)	1.000000	0.0000000E+00
X(R10, RZF)	1.000000	0.0000000E+00
X(R10, MT)	1.000000	0.0000000E+00
X(R10, KRN)	1.000000	0.0000000E+00
X(R10, GRR)	1.000000	0.0000000E+00
X(R11, ANN)	1.000000	0.0000000E+00
X(R12, RCD)	1.000000	0.0000000E+00

The interesting result of this computation is X(R2,lib)=1. This solution must be include in the next sets of constraint to met this objective during the computation af the others.

By identifying such clusters of individuals the objective function is solved level by level minimizing distances.

3.3. Faculty and Staff of the Engineering Management Program

We have classified the members of the EMP facility in term of function.
Followed is a list of the different functions present in the EMP offices.

3.3.1. Faculty

Head department	Dundar Kocaoglu
Teacher	Tim Anderson
	Dragan Milosevic

3.3.2. Staff

Office coordinator	Mary Wiltse
Student assistant	Hiedi Hatmaker
	Daniel Nguyen
	Don Mueller
PICMET assistant	Dogus Kuran
	Karen Iparraguirre
System specialist	Liono Setiowijoso
Application Specialist	Akin Uslu
IEEE Editorial Assistant	Ann White

3.3.3. GSA/Full Time Ph.D. Students

Teacher Assistant	Tugrul Daim
GA	Razif Abd Razak
	Mete Bayyigit
	Bert Desmond
	Karen Eden
	Khaled Haris
	Gerry Williams
	Jannet Zhang

Sixth objective: Placing the library such as minimizing the distance with Dr. Kocaoglu, Dr. Anderson and Dr. Milosevic.

LINGO Model

```
MODEL:
SETS:
list/@FILE(C:\Edouard\Emgt540\project\list.csv)/:A,B;
room/@FILE(C:\Edouard\Emgt540\project\room.csv)/:S;
alone(room,list):Y;
!Binary variable needed by the loneliness constraints;
distance(room,room):D;
!distance between the rooms;
decision(room,list):X;
!decision variable;
ENDSETS


MIN=@SUM(room(I):(D(I,R9)+D(I,R4)+D(I,R1))*X(I,lib));
@FOR(decision:@BIN(X));
@FOR(alone:@BIN(Y));
!declaration of the binary variable;
X(R8,ofc)=1;
X(R1,Ads)=1;
X(R4,Mil)=1;
X(R12,rcd)=1;
X(R9,Kgl)=1;
X(R10,PT)=1;
X(R11,Ann)=1;
X(R2,MR)=1;
X(R5,Akn)=1;
X(R5,Lno)=1;
X(R5,cpt)=1;
```

2. Assign enough space to each one.
3. Assign room such as if boards are needed, they can fit in the room.
4. Some people need to be alone in their room.

In order to consider all these objectives, while at the same time coping with the large dimension of this assignment problem, a binary integer goal programming has been formulated.

The fact was that the problem is too big to be handled in only one single step by the software we were able to use. So we have decided to split the problem in smaller ones. To do so we have built a hierarchy of our objectives. The next stage was to solve after the objective stepwise. Each new solution provided new constraints for the next computation to be sure that when an objective is solved, the previous ones are met.

3.6. Decision Variables

Since the intent is to assign rooms to each member of our classification, the binary decision variable is expressed as X_{ij} whether (value=1) or not (value=0) if room I is assigned to member j.

3.7. Model Constraints

3.7.1. Room Constraints

We have to assign a room, and only one, to each member of the department, this is the *room constraints*:

$$\sum_{i \in R} X_{ij} = 1 \qquad j \in L \qquad (1)$$

where R is the set of rooms {R1,....R12} and L the set of member of the department as we have defined them previously {Kgl,...,cpt}. We can see that for each member of the department, this constraint force only one decision variable X_{ij} to be equal to one while some rooms could remain unoccupied.

```
X(R11,Ann)=1;
X(R2,MR)=1;
!result of the previous computations;
@FOR(room(I):
        @FOR(room(J):Z1(I,J)>=X(I,cpt)+X(J,Lno)-1);
        @FOR(room(K):Z2(I,K)>=X(I,cpt)+X(K,Akn)-1));
!#AND#s constraints;
@FOR(list(J):@SUM(room(I):X(I,J))=1);
!room constraints;
@FOR(room(I):@SUM(list(J):A(J)*X(I,J))<=S(I));
!space constraints;
@FOR(room(I):
        @FOR(list(K)|((K#GE#Kgl)#AND#(K#LE#Mil)):
                X(I,K)<=Y(I,K);
                @SUM(list(J)|(K#NE#J):X(I,J))<=@SIZE(list)*(1-Y(I,K))));
!loneliness constraints;
@FOR(room(I):B(Ads)*X(I,Ads)<=(2*S(I)^0.5)
        -@SUM(list(J)|J#NE#Ads:B(J)*X(I,J)));
@FOR(room(I):B(Mil)*X(I,Mil)<=(2*S(I)^0.5)
        -@SUM(list(J)|J#NE#Mil:B(J)*X(I,J)));
@FOR(room(I):B(cpt)*X(I,cpt)<=(S(I)^0.5)
        -@SUM(list(J)|J#NE#cpt:B(J)*X(I,J)));
@FOR(room(I):B(MR)*X(I,MR)<=(S(I)^0.5)
        -@SUM(list(J)|J#NE#MR:B(J)*X(I,J)));
!board constraints;


DATA:
A=@FILE(C:\Edouard\Emgt540\project\area.csv);
B=@FILE(C:\Edouard\Emgt540\project\board.csv);
D=@FILE(C:\Edouard\Emgt540\project\dist.csv);
```

3.8. *Algebraic Model*

3.8.1. First Objective

According to the survey we have run, and the hierarchy of the department, the first member to be gathered must be the main office (ofc) and the record (rcd) on one hand, and Dr. Kocaoglu (Kgl) and the main office on the other hand.

A requirement associated with this first objective is that respectively, the main office and Dr. Kocaoglu cannot share their office. This requirement is translated by the introduction of a new set of constraints, the *loneliness constraints*:

$$X_{ij} \leq Y_{ij} \qquad i \in R, \qquad (4.1.a)$$

$$\sum_{k \neq j} X_{ik} \leq M(1 - Y_{ij}) \qquad j \in \{Kgl, ofc\} \qquad (4.2.a)$$

Where M is a number high enough, we have chosen M equals to the number of member of the department, and Y_{ij} a binary variable expressing whether (value = 1) or not (value=0) the room i is assigned to the member j.

Those constraints translate the fact that if member j is assigned to room I, no one else can be assigned to this room.

We have considered that it was more important that the records are close to the main office than the Dr. Kocaoglu is close to the main office. This assumption is motivated by the fact that even if Dr. Kocaoglu is important in the department, it was more important that the employees of the main office do not have to leave it for a long time. With this assumption, the objective function is:

$$\text{minimize} \sum_{i \in R} \left(\sum_{j \in R} d_{ij}^2 Z1_{ij} + \sum_{k \in R} d_{ik} Z2_{ik} \right) \qquad (5.a)$$

where $Z1_{ik}$ and $Z2_{ij}$ are some help variables. $Z1_{ij}$ represents the fact that the main office is assigned to the room i while the records are assigned to room j. $Z2_{ik}$ represents the fact that Dr.

X(R2, RZF)	1.000000	0.0000000E+00
X(R2, KLD)	1.000000	0.0000000E+00
X(R2, JNT)	1.000000	0.0000000E+00
X(R4, ADS)	1.000000	0.0000000E+00
X(R5, LIB)	1.000000	0.0000000E+00
X(R5, LNO)	1.000000	0.0000000E+00
X(R5, KRN)	1.000000	0.0000000E+00
X(R5, GRR)	1.000000	0.0000000E+00
X(R5, CPT)	1.000000	0.0000000E+00
X(R6, MT)	1.000000	0.0000000E+00
X(R6, TGL)	1.000000	0.0000000E+00
X(R6, BRT)	1.000000	0.0000000E+00
X(R8, OFC)	1.000000	0.0000000E+00
X(R9, KGL)	1.000000	0.0000000E+00
X(R10, PT)	1.000000	0.0000000E+00
X(R10, AKN)	1.000000	0.0000000E+00
X(R11, ANN)	1.000000	0.0000000E+00
X(R12, RCD)	1.000000	0.0000000E+00

The interesting result of this computation is X(R2,MR)=1. This solution must be include in the next sets of constraint to met this objective during the computation af the others.

$$\sum_{k \neq j} X_{ik} \leq M(1 - Y_{ij}) \qquad j \in \{Kgl, ofc, Ann\} \qquad (4.2.b)$$

The objective function is such as gathering Ann White and Dr. Kocaoglu and gathering the PICMET office and Dr. Kocaoglu

$$\text{minimize} \sum_{i \in R} d_{ia} X_{i,Ann} + d_{ia} X_{i,PT} \qquad (5.b)$$

where d_{ia} is the distance between the room i and the room a, assigned to Dr. Kocaoglu.

3.8.3. Third objective

Dr. Anderson and Dr. Milosevic must be close to the main office and closed from Dr. Kocaoglu. Moreover Dr. Anderson and Dr. Milosevic have to be alone in their room.
The result of the computation of the previous objective must be added to the set of constraints

$$X_{d, Ann} = 1 \qquad (7.d)$$

$$X_{e,PT} = 1 \qquad (7.e)$$

where d and e are the room assigned respectively to Ann White and the PICMET. Those constraints are added to the set of constraints to meet the previous objective.
Because it was required that Dr. Milosevic and Anderson must be alone, the *loneliness constraints* become

$$X_{ij} \leq Y_{ij} \qquad i \in R, \qquad (4.1.c)$$

$$\sum_{k \neq j} X_{ik} \leq M(1 - Y_{ij}) \qquad j \in \{Kgl, ofc, Ann, Ads, Mil\} \qquad (4.2.c)$$

Fourth objective: Placing the meeting room such as minimizing the distance with Dr. Kocaoglu, the main office, Dr. Anderson, Dr. Milosevic.

LINGO Model

```
MODEL:
SETS:
list/@FILE(C:\Edouard\Emgt540\project\list.csv)/:A,B;
room/@FILE(C:\Edouard\Emgt540\project\room.csv)/:S;
alone(room,list):Y;
!Binary variable needed by the loneliness constraints;
distance(room,room):D;
!distance between the rooms;
decision(room,list):X;
!assignment variable;
ENDSETS


MIN=@SUM(room(I):(D(I,R9)+D(I,R8)+D(I,R1)+D(I,R4))*X(I,MR));
!Place MR such as minimizing the distance with Kgl,ofc, Ads, Mil;

@FOR(decision:@BIN(X));
@FOR(alone:@BIN(Y));
!declaration of the binary variable;
X(R8,ofc)=1;
X(R12,rcd)=1;
X(R9,Kgl)=1;
X(R10,PT)=1;
X(R11,Ann)=1;
X(R1,Mil)=1;
X(R4,Ads)=1;
!result of the previous computations;
@FOR(list(J):@SUM(room(I):X(I,J))=1);
```

The result of the computation of the previous objective must be added to the set of constraints such as the previous objective is met

$$X_{h,\,MR}=1 \qquad (7.h)$$

where h is the room assigned to the meeting room.

The objective function is such as minimizing the distance between the computer lab and respectively Liono and Akin

$$\text{minimize} \sum_{i\in R}\left(\sum_{j\in R} d_{ij} Z1_{ij} + \sum_{k\in R} d_{ik} Z2_{ik}\right) \qquad (5.e)$$

where Zi_{ij} and $Z2_{jk}$ are some help variable define by the following constraints

$$Z1_{ij} \geq X_{i,cpt} + X_{j,Lno} - 1 \qquad i,j\in R \qquad (6.c)$$

$$Z2_{ik} \geq X_{i,cpt} + X_{k,Akn} - 1 \qquad i,k\in R \qquad (6.d)$$

Those relations force $Z1_{ij}$ to be equal to one when Liono is assigned to room j while the computer lab is assigned to room i, and forces $Z2_{ik}$ to be equal to one when Akin is assigned to room j while the computer lab is assigned to room i. Those constraints are local and do not need to be used further.

3.8.6. Sixth objective

The library must be close from the teacher and close from Dr. Kocaoglu.

The result of the computation of the previous objective must be added to the set of constraints

$$X_{l,cpt}=1 \qquad (7.I)$$

$$X_{m,Lno}=1 \qquad (7.j)$$

$$X_{n,Akn}=1 \qquad (7)$$

X(R5, LNO)	1.000000	0.0000000E+00
X(R5, GRR)	1.000000	0.0000000E+00
X(R6, MR)	1.000000	0.0000000E+00
X(R6, KRN)	1.000000	0.0000000E+00
X(R6, KLD)	1.000000	0.0000000E+00
X(R7, LIB)	1.000000	0.0000000E+00
X(R7, AKN)	1.000000	0.0000000E+00
X(R7, RZF)	1.000000	0.0000000E+00
X(R7, TGL)	1.000000	0.0000000E+00
X(R7, BRT)	1.000000	0.0000000E+00
X(R8, OFC)	1.000000	0.0000000E+00
X(R9, KGL)	1.000000	0.0000000E+00
X(R10, PT)	1.000000	0.0000000E+00
X(R10, MT)	1.000000	0.0000000E+00
X(R10, JNT)	1.000000	0.0000000E+00
X(R11, ANN)	1.000000	0.0000000E+00
X(R12, RCD)	1.000000	0.0000000E+00

The interesting results of this computation are X(R1,Mil)=1 and X(R4,Ads)=1. Those solution must be include in the next sets of constraint to met this objective during the computation af the others.

$$\text{minimize} \sum_{i \in R} \sum_{j \in \{Rzf, Mt, Tgl, Brt, Krn, Grr, Jnt\}} (d_{if} + d_{ig} + d_{il}) X_{ij} \qquad (5.f)$$

where d_{il} is the distance between the room i and the room l, assigned to the computer lab.

4. Programming Results

The results in Appendix II show that our model delivers a solution that is applicable to an assignment situation. The solution makes sense and reflect the optimum considering the minimization of distances between individuals that are strongly task-related.

Solutions are obtained in this way that according to our stepwise solving important individuals (tasks) are been related (clustered). This optimum is then fixed and then the objective function is solved after the other variables.

4.1. Solving Limitations of Number of Constraints and Variables

As already mentioned the approach to reduce the number of constraints and variables a decomposition of the model was done in that way that the objective function was solved stepwise.

4.2. Sensitivity Analysis

Sensitivity analysis is concerned with how changes in an LP's parameters affect the optimal solution. This analysis is concerned in this paper with changing of the different weighted distances, respectively changing the coefficient of the objective function.

In the research there are different opinions about sensitivity analysis in integer programming.

Sensitivity Analysis could imply in our case a changes of the coefficient, here the distance value assigned to each individual.

5. Model Assumptions and Limitations

Assigning office space to a new location is one task in facility planing is a problem to define new locations of offices, receptively departments to new locations of a building. Assigning these

Third objective: gathering Dr. Kocaoglu, the main office, Dr. Anderson and Dr. Milosevic.

LINGO Model

```
MODEL:
SETS:
list/@FILE(C:\Edouard\Emgt540\project\list.csv)/:A,B;
room/@FILE(C:\Edouard\Emgt540\project\room.csv)/:S;
alone(room,list):Y;
!Binary variable needed by the loneliness constraints;
distance(room,room):D;
!distance between the rooms;
decision(room,list):X;
!Assignement variable;
ENDSETS


MIN=@SUM(room(I):(D(I,R9)+D(I,R8))*X(I,Mil))
        +@SUM(room(I):(D(I,R9)+D(I,R8))*X(I,Ads));
!gather Kgl and teachers, Mary and teachers;

@FOR(decision:@BIN(X));
@FOR(alone:@BIN(Y));
!@FOR(help:@BIN(Z));
!declaration of the binary variable;
X(R8,ofc)=1;
X(R12,rcd)=1;
X(R9,Kgl)=1;
X(R10,PT)=1;
X(R11,Ann)=1;
!result of the previous computation;
@FOR(list(J):@SUM(room(I):X(I,J))=1);
!room constraints;
```

an explosion of the number of constraints and variables. However the computation time is significantly reduced and the optimal solution, if any, is global.

5.4. Hard Data versus Soft Data

The data used for gathering communicational needs are subjective data. These are quite different than data about length, space, etc. This problem arises often by using methods of Operations Research in Human Resource Management.

5.5. Human Dimension

The human dimension of our concept is that the model represents an optimization basis for human working in an organizational environment. By looking at organizations difficulties may arise by defining efficiency and trying to implement this in a model. Furthermore are the benefits not easy to measure if any, because there might benefits that not directly influence the efficiency.

```
X(I,K)<=Y(I,K);
@SUM(list(J)|(K#NE#J):X(I,J))<=@SIZE(list)*(1-Y(I,K))));
!loneliness constraints;
@FOR(room(I):B(Ads)*X(I,Ads)<=(2*S(I)^0.5)
    -@SUM(list(J)|J#NE#Ads:B(J)*X(I,J)));
@FOR(room(I):B(Mil)*X(I,Mil)<=(2*S(I)^0.5)
    -@SUM(list(J)|J#NE#Mil:B(J)*X(I,J)));
@FOR(room(I):B(cpt)*X(I,cpt)<=(S(I)^0.5)
    -@SUM(list(J)|J#NE#cpt:B(J)*X(I,J)));
@FOR(room(I):B(MR)*X(I,MR)<=(S(I)^0.5)
    -@SUM(list(J)|J#NE#MR:B(J)*X(I,J)));
!Board constraints;


DATA:
A=@FILE(C:\Edouard\Emgt540\project\area.csv);
B=@FILE(C:\Edouard\Emgt540\project\board.csv);
D=@FILE(C:\Edouard\Emgt540\project\dist.csv);
S=@FILE(C:\Edouard\Emgt540\project\surf.csv);
ENDDATA
```

<u>Results</u>

Variable	Value	Reduced Cost
X(R1, ADS)	1.000000	0.0000000E+00
X(R2, LNO)	1.000000	0.0000000E+00
X(R2, JNT)	1.000000	0.0000000E+00
X(R4, MIL)	1.000000	3.186992
X(R4, MT)	1.000000	1.138211
X(R5, AKN)	1.000000	0.0000000E+00
X(R5, RZF)	1.000000	0.0000000E+00

References

[1] Armour G, Buffa E. A Heuristic Algorithm and Simulation Approach to relative Location of Facilities *Management Sci., Vol. 9, No. 2 (January, 1963), pp.294-309*

[2] Larry Ritzmann, John Bradford, Robert Jacobs A multiple Objective Approach to Space Planning for Academic Facilities *Management Sci., Vol. ?, No. 2 (January, 19??)*

[3] Vollmann, Thomas E., Nugent, Christopher E., Zartler, Robert L. A Computerized Model for Office Layout *The Journal of Industrial Engineering, Vol. 19, No. 7, 1968*

[4] Ritzmann, Larry P. The Efficiency of Computer Algorithms for Plant Layout *Management Science, Vol. 18, No. 5, January , Part I, 1972*

[5] Brauer, D. C., Naadimuthu, G. Office Facility Planning Considering Organizational Constraints *Computers Operation Research Vol 17, No. 3 pp. 273-281*

[6] Hillier, F. S. Connors, M. N. Quadratic Assignment Problem Algorithms and the Location of Indivisible Facilities *Management Sci.,Vol. 13, No. 1 (September 1966), pp. 42-57*

[7] Koopmanns, T.C. Beckmann, M. Assignment Problems and the Location of Economic Activities *Econometrica 25, pp. 53-76, 1957*

[8] Lee, R. C., Moore, J. M. CORELAP-Computerized Layout Planning *J. Industrial Engineering, Vol. 18 No. 3, (March 1967), pp. 195-200*

[9] Chan, Albert W. Francis, Richard L. A Least Total Distance Facility Configuration Problem Involving Lattice Points *Management Science, vol. 22, No. 7, March 1976*

[10] Schroeder, Roger G. Resource Planning in University Management by Goal Programming *Operations Res., Vol. 22, No.4 (Juli August 1974), pp.700-710*

[11] Robichaud, Beryl Selecting Planning and Selecting Office Space *Noma Series in Office Management, Mc Graw Hill Book Company, New York 1967*

[12] Becker, Franklin D. Workspace: Creating Environments in Organizations *Preager Publishers, 1981*

X(R4, ADS)	1.000000	0.0000000E+00
X(R4, MT)	1.000000	0.0000000E+00
X(R5, BRT)	1.000000	0.0000000E+00
X(R5, KLD)	1.000000	0.0000000E+00
X(R5, GRR)	1.000000	0.0000000E+00
X(R7, MR)	1.000000	0.0000000E+00
X(R7, AKN)	1.000000	0.0000000E+00
X(R7, TGL)	1.000000	0.0000000E+00
X(R7, KRN)	1.000000	0.0000000E+00
X(R8, OFC)	1.000000	69437.25
X(R9, KGL)	1.000000	0.0000000E+00
X(R10, LIB)	1.000000	0.0000000E+00
X(R10, LNO)	1.000000	0.0000000E+00
X(R10, CPT)	1.000000	0.0000000E+00
X(R11, MIL)	1.000000	0.0000000E+00
X(R12, RCD)	1.000000	0.0000000E+00

The interresting solution are X(R9,Kgl)=1, X(R8, Ofc)=1 and X(R12, Rcd). Those solution must be include in the next sets of constraint to met this first objective during the computation af the others.

The content of the files are

The list of the member of the department:

list.csv:Kgl,ofc,Ann,Ads,Mil,lib,MR,rcd,Lno,PT,Akn,Rzf,Mt,Tgl,Brt,Krn,Kld,Grr,Jnt,cpt

The surface area (in square meter) needed by the member previously described:

area.csv:18.4,49.7,9.7,8.9,9.8,3.5,6.8,7.3,6.7,12.3,3.5,3.5,3.5,7,3.5,3.5,3.5,3.5,3.5,16

The length of the board (in meter) needed by the member of the department:

board.csv:0,0,0,3.1,3.1,0,3.1,0,0,0,0,0,0,0,0,0,0,0,0,3.1

The number of board of each member of the department.

nboard.csv:0,0,0,2,2,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1

The room of the department:

room.csv:R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12

The surface area (in square meter) of the rooms:

surface.csv:10.6,17.3,4,13.3,35.9,15.1,24.0,56.7,25.0,27.5,12.0,9.3

dist.csv:

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12
R1	0	23	37	32	29	47	45	156	165	180	171	175
R2	23	0	25	24	21	39	37	166	175	190	181	185
R3	37	25	0	37	27	50	46	176	185	200	184	188
R4	32	24	37	0	32	36	34	162	171	186	177	181
R5	29	21	27	32	0	27	24	169	178	193	184	188
R6	47	39	50	36	27	0	23	185	194	209	200	204
R7	45	37	46	34	24	23	0	181	190	205	196	200
R8	156	166	176	162	169	185	181	0	46	61	52	17
R9	165	175	185	171	178	194	190	46	0	35	30	63
R10	180	190	200	186	193	209	205	61	35	0	27	78
R11	171	181	184	177	184	200	196	52	30	27	0	69
R12	175	185	188	181	188	204	200	17	63	78	69	0

The distance matrix room to room (in length unit).

First objective: gathering Dr. Kocaoglu, the main office and the records.

LINGO Model

```
MODEL:
SETS:
list/@FILE(C:\Edouard\Emgt540\project\list.csv)/:A,B;
room/@FILE(C:\Edouard\Emgt540\project\room.csv)/:S;
alone(room,list):Y;
!Binary variable needed by the loneliness constraints;
distance(room,room):D;
!distance between the rooms;
help(room,room):Z1,Z2;
!Help variable ;
decision(room,list):X;
!Assignment variable;
ENDSETS


MIN=@SUM(room(I):@SUM(room(J): (D(I,J)^2)*Z2(I,J))
        +@SUM(room(K):D(I,K)*Z1(I,K)));
!gather rcd, ofc, Kgl;

@FOR(decision:@BIN(X));
@FOR(alone:@BIN(Y));
@FOR(help:@BIN(Z1));
@FOR(help:@BIN(Z2));
!declaration of the binary variable;
@FOR(room(I):
        @FOR(room(J):Z1(I,J)>=X(I,ofc)+X(J,Kgl)-1);
        @FOR(room(K):Z2(I,K)>=X(I,ofc)+X(K,rcd)-1));
!Computation of ofc#AND#rcd, ofc#AND#Kgl;
@FOR(list(J):@SUM(room(I):X(I,J))=1);
```