Student Dormitory Development Plan with Linear Programming Method

Connie Susilawati
Petra Christian University
Surabaya, Indonesia

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Student dormitory is a very important facility which have to be provided by university. University should not only provide accommodation but also other supporting facilities. However, there are some constraints that should be considered by decision maker. In order to optimize the decision, linear programming has been used for this site allocation problem. This research wanted to calculate number of rooms and area of each facility which could satisfy the constraints and obtain optimum profit.

The method of this research is by conducting a survey to understand the required facilities, financial ability and the competitors' rent fee. Gathering information and developing mathematical model is the most difficult part of this research. Moreover, some facilities depend on number of students that could be counted by number of bedrooms.

This research recommend number of bedrooms and bathrooms also area of each facility, such as: living room, dining room, common room, cafeteria, book shop, mini market, phone booths, sport facilities and parking space. Since this investment is financially feasible, the student dormitory could be built in the future. Moreover, the result could be used as input for the further design.

Introduction

Student dormitory is an essential accommodation facility to be provided by University. However, not many universities furnish this facility. In Petra Christian University, off campus student accommodation have been built and managed by surrounding housing owner. The existing accommodation does not provide the study environment because they are separate from university facilities.

Barnhart and Barnhart (1983) mentioned that a dormitory is a building with many rooms for living and sleeping and each room consist of several beds. Webster New Collegiate Dictionary (1975) defined dormitory as:

- A room for sleeping; a large room containing numerous beds.
- A residence hall providing rooms for individuals or for groups usually without private baths.
- A residential community from which the inhabitants commute to their places of employment.

Decision of the President of 40 (1981) cited that student dormitory is a residential environment for students to stay and possible to have other supporting facilities, such as: library, book shop, cafeteria, sport and other facilities which are managed by students. Moreover, Matakupan (1994) mentioned that dormitory offer a room with minimal two beds. In some university in Indonesia, the dormitory has been used as a place for student training to achieve the vision and mission of the university.

Tjahjawati (1999) has done a survey on the market demand of student dormitory at Petra Christian University. The survey also analyzed the preferences on room type and facilities of the student dormitory. As a result, the students like to occupy the two and three bedroom. The students choose their preferences on main and supporting facilities. Study room, dining room, living room, common room and kitchen are the main facilities. Phone booths, mini market, cafeteria, book shop, sport facilities and parking space are the supporting facilities.

Linear Programming for Solving Site Allocation Problem

Linear Programming is a tool for optimization decision making process. Taha (1999) mentioned that linear programming is able to solve problems which can be identified the variables, constraints and objective function. Besides solving production mix problems, linear programming can be utilized to solve resources allocation problem.

Most real estate problems require the allocation of scarce resources to different type of uses so that investors can achieve the maximum profit (Susilawati, 1996). The student dormitory is a site allocation problem to optimize the land to satisfy the students' demand. There are some constraints and objective functions to be met by investors. Therefore, this problem could be solved by linear programming model. However, Susilawati (1998) mentioned that this model has excluded the qualitative factors such as social, politic or ethic issues which are very important in some cases.

Preliminary checking need to be conducted before applying linear programming model. There are four assumptions for utilizing this model (Eppen, Gould and Schmidt 1993; Wu 1976) which are necessary to be fulfilled. Since this is a deterministic model, all relevant data is assumed to be known with certainty. Moreover, there are linear relationships between variables, independent and infinitely divisible variables.

Firstly, decision variables must satisfy the above assumptions. In this study, number of rooms and the area of supporting facilities are the decision variables. However, some facilities depend on number of occupants which are based on number of rooms will be built. For examples, student dormitory has a common room which could be used by at least half of total occupants (Litaay and Parsaulian 1999, p.39). The similar requirements also applied for living room, dining room, and cafeteria and parking spaces. Therefore the above facilities are dependent variables and will be combined with the number of rooms.

Moreover, the previous survey (Tjahjawati 1999, p. 67) discovered that 60% of the respondent choose two bed room, only 15% choose three bed room and the other four types only 25%. The ratio between the favorable types is assumed to be constant. Four units of two-bedroom need to be built for each three-bedroom unit. Number of occupants for the above ratio is eleven students.

Therefore, the dependent facilities and two-bedroom unit required to be transformed to three bedrooms unit. The transformation of the above variables is shown in Table 1. For example, the area for a common room is half of number of occupants, which is multiplied by the design standard requirement. The common room = $0.5 * 11\ I_2 * 1.6 = 8.80\ I_{2.}$ The summation of the coefficient of each facility, which is calculated with the same method, composed the transformed variable. Thus, the transformed variable which is an independent one, met the LP assumption.

TABLE 1 DEPENDENT VARIABLES

Room/Facility	**Capacity**	**Design Standard (m^2 per person)**	**Area in I_2 (m^2)**	**Constant (m^2)**
Common room	0.5	1.6	8.80	
Living room	0.2	1.6	3.52	
Dining room	0.25	1.9	5.23	
Cafeteria	0.48	1.2	6.34	33.2
Parking space	average 0.3	14 per car	11.43	

Source: Litaay and Parsaulian (1999, p.39)

All the above variables represented by one integer variable (I_2), because number of units have to be an integer variable. Besides the above dependent facilities, there are six continuous variables (non integer) for other supporting facilities (X_1 to X_6). The decision variables for this model are shown in the Table 2.

TABLE 2 DECISION VARIABLES

Decision Variables	**Description**	**Type**
I_2	Bedroom	Integer
X_1	Kitchen	Continuous
X_2	Book Shop	Continuous
X_3	Mini Market	Continuous
X_4	Phone Booths	Continuous
X_5	Sporting facilities	Continuous
X_6	Garden	Continuous

Source: Litaay and Parsaulian (1999, p.43)

Secondly, objective function must be explicitly stated that is to maximize the net cash flow. The coefficient could be calculated by the net present value of the cash flow for each variable. The seven year net cash flow is discounted by 17% per annum. The discount rate is the target rate of Indonesian government in the year 2000 (“Bank Mulai ….”, 1999). In the calculation of the coefficient of the first variable (I_2), the dependent variables have to be counted.

This project received income from renting the bedroom (two and three bedroom units), common room, cafeteria, book shop, mini market and phone booths. While the outcome mainly for construction cost and the furniture cost. However, some facilities do not furnished, such as cafeteria, book shop and mini market. The lessees need to provide the furniture for doing their business.

The dependent variables which has transformed to the variable $\mathbf{I_2}$ drew in monthly cashflow. The net present value of the cash flow of the transformed variable produce the coefficient of the independent variable $\mathbf{I_2}$. The kitchen ($\mathbf{X_1}$) construction cost and finishes cost is 576,000 per square meter which is drawn in the initial period. The producing income facilities such as cafeteria ($\mathbf{X_2}$), book shop ($\mathbf{X_3}$) and mini market ($\mathbf{X_4}$) will produce income from the end of first year. The remainder variables only contribute outcome which is shown by negative sign in front of each variable.

Besides variables, the objective function also contained the net present value of fixed cost as a constant (see equation below). Although it will not influence the proportion of variable value, it will affect the objective value. The biggest component of the fixed cost is land cost.

$$\begin{aligned}\textbf{Max } Z = {} & 34{,}952{,}096.51\, I_2 - 576{,}000\, X_1 + 1{,}564{,}218.78\, X_2 + 1{,}564{,}218.78\, X_3 \\ & + 1{,}564{,}218.78\, X_4 - 50{,}000\, X_5 - 49{,}529.5\, X_6 - 1{,}385{,}557{,}930\end{aligned}$$

Thirdly, the alternative course of action must be interrelated through a set of constraints. There are three types of constraints which are applied in this model, that are physical constraints, regulation constraints and market constraints. The land area, minimum room capacity and design layout have constrained the variable value.

The designer plan to construct a three story building and one story building for some collective facilities, such as common room, cafeteria, book shop, mini market and phone booths. The first floor of the main building comprises of living room, dining room, kitchen, bedrooms, and bathrooms. The upper floors only have living room, bedrooms and bathrooms.

Meanwhile, Building Coverage Ratio (BCR) in this region is 50% of total area (constraint Y_1). The land area is 4050 square meters. At last, the market demand restrained the preferable facilities and their size. The allowable range of size is determined based on the design requirement and other similar building in the neighborhood.

Finally, the above model could be solved by computer software which can solved mixed integer and linear programming model. In this study, SOLVER that is a simple tool in MS-Excel is utilized to optimize the model. Table 3 exhibited the coefficient of objective function and constraint functions. Since the constant in this calculation can be eliminated for optimizing the problem, it is not shown in the Table 3.

Results and recommendation

The software output only presented the objective value and the value of the independent variables which are shown in Table 4. The objective value has to be deducted by the fixed cost which is excluded from the model. Therefore, the maximum net cash flow is Rp 392,952,557.

TABLE 3 OBJECTIVE AND CONSTRAINT FUNCTIONS

	I_2	X_1	X_2	X_3	X_4	X_5	X_6		
Z	$3.5.10^7$	$-5.7.10^5$	$1.6.10^6$	$1.6.10^6$	$1.6.10^6$	-5.10^4	-5.10^4		
Y_1	11.43	0	0	0	0	1	1	≤	2,025
Y_2	14.02	1	0.5	0.5	0.5	0	0	≤	995.9
Y_3	137.1	1	3	3	3	0	0	≤	5,975.4
Y_4	148.53	1	3	3	3	1	1	≤	8,000.4
Y_5	2.09	-1	0	0	0	0	0	≤	0
Y_6	3.81	1	0.25	0.25	0.25	0	0	≤	497.95
Y_7	0	0	1	0	0	0	0	≥	100
Y_8	0	0	1	0	0	0	0	≤	150
Y_9	0	0	0	1	0	0	0	≥	125
Y_{10}	0	0	0	1	0	0	0	≤	170
Y_{11}	0	0	0	0	1	0	0	≥	40
Y_{12}	0	0	0	0	1	0	0	≤	50
Y_{13}	0	0	0	0	0	1	0	≥	381.43

Source: Litaay and Parsaulian (1999, p.67)

TABLE 4 OUTPUT

Decision Variables	**Description**	**Value**
I_2	Bedroom	35.00
X_1	Kitchen	73.15
X_2	Book Shop	149.33
X_3	Mini Market	169.29
X_4	Phone Booths	49.29
X_5	Sporting facilities	381.43
X_6	Garden	0.00

Objective value=1,778,510,487

The above outputs have to be transformed to the other dependent variable to present the site allocation decision. There is two tables exhibit number of rooms and total area of all facilities. Table 5 shows total area of each facility. Meanwhile, the room arrangement of each floor in the main building have to adjusted according to the design layout.

TABLE 5 OPTIMIZATION RESULTS

Facility	Number	Area (m^2)	
Three-bedroom	35	708.75	
Two-bedroom	140	1,715.00	
Bathroom	105	472.50	
Living Room		130.02	
Dining Room		182.88	
Kitchen		73.15	
Common Room		308.00	
Cafeteria		254.96	
Book shop		149.34	
Mini market		169.30	
Phone booths		49.30	
Total building area			4213.20
Parking space		400.20	
Sport facilities		381.43	
Total open space area			781.63
Total development area			4994.83

Source: Litaay and Parsaulian (1999, p.72)

Conclusion

This study suggests that almost all supporting facilities need to be supplied, except garden. The total development area is 4,994.83 square meters (see Table 5). Meanwhile, the maximum net cash flow is Rp 392,952,557 which is discounted by 17% per annum for seven years cash flow.

The linear programming can be utilized as a useful tool for decision making to optimize the decision and satisfy the simultaneously constraints. Therefore, the architect could use the results as design input. However, it requires some modification.

Although the composition of usage in each area has been shown in Table 5, some arrangement is needed. The composition of rooms (two or three bedrooms) for each floor need to be adjusted. Moreover, the user of linear programming output could creatively utilize the computer results.

The computer results need to be rechecked before implementation to design stage. For example, the vacant land area is calculated from the computer results, that is 1,243.6 square meters. Although the output shows that no garden is recommended ($X_6 = 0$), the vacant land can be used as garden and access road.

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References

"Bank Mulai Turunkan Bunga Depositonya". 1999. *Suara Indonesia*, Juni 8, p. 3., c. 5-7.

Barnhart, Clarence L. and Barnhart, Robert, K., 1983. World Book Dictionary, vol. 2. Double Day Company, Inc. USA

Decision of the President of 40, 1981. "Pembangunan Asrama Mahasiswa untuk Perguruan Tinggi di seluruh Indonesia". In Desire L. Litaay and A. Parsaulian, 1999. *Optimasi Rencana Pengembangan Fasilitas Asrama Mahasiswa UK Petra dengan Metode Linear Programming.* Bachelor's Thesis, School of Civil Engineering, Universitas Kristen Petra, Surabaya.

Eppen, G.D., Gould, F.J. and Schmidt, C. P. 1993. *Introductory Management Science*. 4th Edition, Prentice Hall, Englewood Cliffs, New Jersey.

Litaay, Desire L. and Parsaulian, A., 1999. *Optimasi Rencana Pengembangan Fasilitas Asrama Mahasiswa UK Petra dengan Metode Linear Programming.* Bachelor's Thesis, School of Civil Engineering, Universitas Kristen Petra, Surabaya.

Matakupan, B.C., 1994. *Asrama Mahasiswa Perguruan Tinggi Swasta di Malang*. Bachelor's Final Project. School of Architecture, Petra Christian University, Surabaya.

Susilawati, C. , 1996. *Property Investment Decisions: Mathematical Programming Approach*, Master's Thesis, Curtin University of Technology, Perth.

Susilawati, C. , 1998. *Optimal Residential Property Development and Linear Programming,* 4th Pacific Rim Real Estate Society Conference, Perth.

Taha, H., 1999. *Operations Research: an Introduction*, 5th Edition, Prentice-Hall International, Singapore.

Tjahjawati, E., 1999. *Perencanaan "Student Dormitory" Universitas Kristen Petra Ditinjau dari Analisa Pasar dan Analisa Finansial*.

Webster's New Collegiate Dictionary, 1975. Philippines: G&C Merriam Co.

Wu, Mi-yin. 1989. *Application of Linear Programming: A Case Study*, Land Development Studies, vol. 6, no. 3, September, pp. 201-216.