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APPLICATION OF LINEAR PROGRAMMING FOR DORMITORY DEVELOPMENT PLAN AT PETRA CHRISTIAN UNIVERSITY

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ABSTRACT

Dormitory is a very important facility which have to be provided by a university. A survey to Petra Christian University's students has been conducted to understand the required facilities and their financial ability. Linear programming has been used to calculate number of rooms and area of each facility which could satisfy the constraints and to obtain optimum profit. Number of bedrooms, number of bathrooms, and area of each facility, such as: living room, dining room, common room, cafeteria, book shop, mini market, phone booths, sport facilities, and parking space are recommended. Since the investment is financially feasible, the dormitory could be built in the future.

Keywords: dormitory, facility, financial feasibility, linear programming.

INTRODUCTION

Dormitory is an essential accommodation to be provided by a University. Since Petra Christian University do not have student housing, many investors built off campus student accommodation. However, these accommodations do not provide study environment because they are separate from university facilities.

A dormitory is a building with many rooms for living and sleeping and each room consist of several beds [1, 2]. Webster New Collegiate Dictionary [3] 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.

Reference [4] cited that student dormitory is a residential environment for students with a posibility of other supporting facilities such as: library, bookshop, cafeteria, sport and other facilities managed by the students.

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Therefore, dormitory in this paper is defined as students residential which also have bookshop, cafeteria, sport, and other facilities.

LINEAR PROGRAMMING MODEL

Linear Programming is a tool to optimize decision-making process. Taha [5] mentioned that linear programming could be used to solve problems which variables, constraints and objective function can be identified. Beside 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 [6]. A dormitory is a site allocation problem in which the land should be optimized to satisfy the students' needs. There are some constraints and objective functions to be met by investors. Therefore, the site allocation problem of a dormitory could be solved by linear programming model. However, Susilawati [7] mentioned that this model excluded the qualitative factors such as social, politic or ethic issues which could be very important in some cases.

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Preliminary checking needs to be conducted before applying linear programming model. There are four assumptions for utilizing this model, which are necessary to be fulfilled [8, 9]. Firstly, since this is a deterministic model, all relevant data is assumed to be known with certainty. Secondly, there are linear relationships between variables. Thirdly, the variables must be independent. Finally, the variables must be infinitely divisible.

In this study, the number of rooms and the area of supporting facilities are the decision variables. The decision variables has been selected based on the survey on the market demand of student dormitory at Petra Christian University [10]. It is outlined in [10] that the students would like to occupy a two or three-bedroom compound. Their preferences on the main facilities were study room, dining room, living room, common room and kitchen. Phone booths, mini market, cafeteria, bookshop, sport facilities and parking space were the supporting facilities. The above items need to be evaluated before they could be used as decision variables.

Decision variables must satisfy the independent assumptions. However, the dimensions of some facilities depend on the number of occupants which are based on the number of rooms that will be built. For examples, student dormitory has a common room which could be used by at least half of the total occupants [4]. Similar requirements also apply for living room, dining room, cafeteria, and parking spaces. Therefore the above facilities are dependent variables and will be combined with the number of rooms.

The previous survey [10] discovered that 60% of the respondent choose two bed room, only 15% choose three bed room and the other 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. Thus, three bathrooms will be provided for one unit of one three-bedroom and four two-bedroom. The dependent facilities and two-bedroom unit required to be transformed to three bedrooms unit (I_2) shown in Table 1. Unlike the other variables, Cafeteria needs a fixed amount of area as a service area which could be seen in the last column (constant). Thus, the transformed variable is an independent one and met the linear programming assumption.

Table 1. Transformation of Dependent Variables (continuous variables)

Room/ Facility	Capacity	Design Standard (m^2 per person)	Area in I_2 (m^2)	Constant (m^2)
Common room	0.50	1.60	8.80	-
Living room	0.20	1.60	3.52	-
Dining room	0.25	1.90	5.23	-
Cafeteria	0.48	1.20	6.34	33.20
Parking space	average 0.30	14 per car	11.43	

Source: [4]

All the above variables represented by one integer variable, I_2 (see column 4 in Table 1). Beside 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 [4]

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

It is explicitly stated that the objective function, that is to maximize the net cash flow. The coefficient of the objective function could be calculated by the net present value of the cash flow for each variable, see equation 1. Table 3 illustrates the calculation of coefficient of variable I_2 which composes of independent and dependent variables. The net present value is calculated from the seven-year net cash flow which is discounted by 17% per annum. This discount rate is the target rate of Indonesian government in the year 2000 [11]. In the calculation of the coefficient of the first variable (I_2). the dependent variables which have been transformed have to be calculated.

Similar calculation process has to be done to determine the coefficient of other decision variables. Since other decision variable do not represent any dependent variables no conversion is needed. Detailed calculation of the coefficient can be seen in reference [4].

Table 3. Calculation of Coefficient of Variable I_2

Facility	Transformed ($\ln I_2$)	Income	Cost	NPV @17% p.a.	Conversion NPV
Two-bedroom	1	Rent	Furniture/fixture and construction cost	16,346,847.35	16,346,847.35
Three-bedroom	4	Rent	Furniture/fixture and construction cost	6,669,811.68	26,679,246.72
Bathroom	3	N/A	Furniture/fixture and construction cost	-2,505,000.00	-7,515,000.00
Common room	8.80 m^2	Rent	Furniture/fixture and construction cost	-547,188.39	-4,815,257.82
Living room	3.52 m^2	N/A	Furniture/fixture and construction cost	-611,456.20	-2,152,258.40
Dining room	5.23 m^2	N/A	Furniture/fixture and construction cost	-604,644.80	-3,159,269.10
Cafeteria	6.34 m^2	Rent	Construction cost	1,564,218.78	-9,910,890.19
Parking space	11.43 m^2	N/A	Construction cost	-30,000.00	-343,035.00
Total					34,952,096.51

Source: [4]

This project received income from renting the bedroom (two and three bedroom units). common room, cafeteria, bookshop, mini market, and phone booths, while the expenses mainly for construction cost and the furniture cost (Table 3). However, some facilities such as cafeteria, bookshop, and mini market are not furnished. The leassee will provide the furniture for doing their businesses.

Beside independent variables, the objective function also contained the net present value of fixed cost as a constant (equation 1). 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.

$$\text{Max } Z = 34{,}952{,}096.51\ I_2 - 576{,}000\ X_1 + 1{,}564{,}218.78\ X_2 + 1{,}564{,}218.78\ X_3 + 1{,}564{,}218.78\ X_4 - 50{,}000\ X_5 - 49{,}529.5\ X_6 - 1{,}385{,}557{,}930 \quad (1)$$

The next stage is checking the relation of the alternative course of action which must be interrelated through a set of constraints. There are three constraints which are applied in this model, that are physical constraints, regulation constraints, and market constraints. The physical constraints consist of the land area, minimum room capacity and layout.

It is planed to construct a three story residential building and one story building for some collective facilities, such as common room, cafeteria, bookshop, mini market and phone booths. The first floor of the main building comprises of living room, dining room, kitchen, bedrooms, and bathrooms (constraints Y_2). The upper floors only have living room, bedrooms, and bathrooms (constraints Y_3).

The Building Coverage Ratio (BCR) in this region is 50% of total area (constraint Y_1), while the total building and land area constraints are determined in constraint Y_4. The land area is 4050 square meters. The market demand restrained the preferable facilities and their sizes. The allowable ranges of sizes of the facilities (constraints Y_5 to Y_{13}) are determined based on the design requirement and other similar building in the neighborhood. For examples. constraints Y_4 and Y_5 restrict the kitchen size. While the rest control the sizes of bookshop. mini market. phone booths and sport facilities (Table 4).

Finally, the linear programming model, which consists of the objective and constraint functions, could be solved by computer software which can solve mixed integer and linear programming model. In this study, SOLVER a simple tool in MS-Excel. is utilized to optimize the model. Table 4 exhibited the coefficient of objective and constraint functions. Since the constant (see equation 1) in this calculation can be eliminated for optimizing the problem. it is not shown in the Table 4.

Table 4. Objective and Constraint Functions

	I_2	X_1	X_2	X_3	X_4	X_5	X_6		RHS
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

Notes:
Z = objective function
Y_i = constraint function i
I_i = decision variable i (integer variable)
X_i = decision variable i (continuous variable)
RHS = right hand side
Source: [4]

RESULTS AND RECOMMENDATION

The software output only presents the objective and the independent variables values which are shown in Table 5. The fix cost, Rp.1,385,557,930.00, has to be deducted from the objective value giving the maximum net cash flow to be Rp 392,952,557.00.

Table 5. Computer Output

Decision Variables	Description	Value	Unit
I_2	Bedroom	35.00	rooms
X_1	Kitchen	73.15	m^2
X_2	Book Shop	149.33	m^2
X_3	Mini Market	169.29	m^2
X_4	Phone Booths	49.29	m^2
X_5	Sporting facilities	381.43	m^2
X_6	Garden	0.00	m^2

Objective value = Rp 1,778,510,487
Maximum net cash flow = Rp 1,778,510,487 – Rp 1,385,557,930 = Rp 392,952,557

The above outputs have to be transformed to the other dependent variable to present the site allocation decision, Table 5 shows total area of each facility in the linear programming model, while Table 6 shows the composition of rooms (two or three bedrooms) for each floor which are adjusted from design layout, The linear programming output could creatively be utilized in the design layout [12],

Table 6. 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
Bookshop		149.34
Mini market		169.30
Phone booths		49.30
Total building area		4,213.20
Parking space		400.20
Sport facilities		381.43
Total open space area		781.63
Total development area		4,994.83

Source: [4]

CONCLUSION

This study suggests that all supporting facilities, except garden, need to be supplied, The total development area is 4,994.83 square meters (see Table 6), The maximum net cash flow is Rp 392,952,557.00 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 simultaneous constraints, however, it requires some modification. The composition of usage in each area, which has been shown in Table 6, need to be arranged. The composition of rooms (two or three bedrooms) for each floor needs to be adjusted.

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