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Stochastic Linear Programming Method for Housing Investment Feasibility in West Jakarta

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Abstract

This research was conducted in light of a planned investment for residential housing construction in West Jakarta, given the minimal availability of land in the area in terms of land size, price, shape, and other factors, necessitating an investment feasibility study. The purpose of the investment feasibility study is to analyze the viability of this investment. Besides the limited land availability, there is often uncertainty during the sales stage. Thus, this study employs a two-stage stochastic programming model. The houses to be built are divided into two types: houses with a width of 4 meters and houses with a width of 4.5 meters. The two-stage stochastic programming model created consists of 2 stages: stage 1 during housing construction and stage 2 during sales. The objective function is to get the maximum net present value (Z_{max}). The overall time required for this investment is 4 years. After creating a two-stage stochastic programming model, the analysis was carried out using the Solver Add-in in Microsoft Excel. The analysis concluded that the maximum net present value expected in this investment is 4,092.036 million Rupiah; with a positive net present value, this investment is acceptable. This analysis was added with the calculation of IRR as a supporter of the net present value, resulting in an interest rate of 23.63%. Given a large enough IRR, it can be concluded that this housing development investment is acceptable.

Keywords: *investment, feasibility study, two-stage stochastic, net present value, internal rate of return*

I. INTRODUCTION

Housing development investment in Jakarta requires a detailed feasibility study. This is because the available land is very limited, both in terms of limited land area that can be built, expensive land prices, and irregular land shapes. Feasibility studies are carried out at the beginning of the investment so that investors can assess the risks and impacts that will occur, as well as whether the investment is profitable or not [1].

According to Shou [2], one of the most popular methods used is Net Present Value (NPV). This method calculates all estimated income and predicted as well as discounted costs over the life of the project. In addition to the NPV method, the Internal Rate of Return (IRR) method is also used to determine the percentage of the investment return rate. Both of these methods are used in investment analysis to determine maximum profit and reduce investment risk [1].

Housing development investment does not only focus on the effectiveness and efficiency of the construction phase; the sales stage needs to be considered. The sales stage can experience various events. Occasionally, sales can run quickly so that the house is sold out in a short period of time. However, it occasionally can take a long time. The uncertainty in the sale causes changes in the profit of an investment, especially sales in the long term, due to the discount factor while the house has not been sold.

Due to uncertainties, this study applied a stochastic programming model to determine the expected benefits of investing in housing development with uncertain sales stages. The stochastic programming model has been widely used in real-life decision-making, such as in the fields of management, engineering, and technology [3], [4].

The research was conducted on land with certain area limitations and will be built housing with two types of houses, namely, a type of house with a width of 4 meters and a type of house with a width of 4.5 meters. Using the stochastic programming method, this study analyzes the number of each type of house that must be built and the maximum NPV results that can be expected in this investment. Then, IRR analysis was conducted based on the stochastic programming model. The feasibility of this investment will be concluded from the results of the NPV and IRR.

II. LITERATURE REVIEW

A. Investment

According to Sujatmiko *et al.* [1], investment is a commitment to a certain amount of funds or other sources of funds made at present with the aim of obtaining a certain amount of profit in the future. Husnan and Suwarsono also expressed a similar definition in a study by Putri [5], in which an investment is a plan for allocating various resources that can be evaluated and implemented fairly.

In addition, according to Giatman in the study by Sujatmiko *et al.* [1], activities in investment are important activities that require large costs and impact for the business continuity period, so systematic and rational analysis is needed before the activity is realized. Inappropriate decisions can result in the company experiencing losses. Investment feasibility analysis aims to minimize the risk of loss when making investments.

B. Net Present Value (NPV)

According to Arshad, in a study by Shou [2] and Gaspars-Wieloch [6], NPV is the sum of all future cash flows to determine the present value. Cash inflows and outflows must be discounted at a certain rate when calculating cash flows. NPV is used to estimate whether the expected financial benefits of a project will be greater than the current investment and indicates that the project is worth running [2].

A positive NPV means that the investment will add value to the company and the project can be accepted, while a negative NPV means that the investment will reduce value to the company and the project must be rejected [1], [2], [6]-[8]. A formula in Equation (1) is used to calculate NPV. Based on Equation (1), CF_t is the net cash flow, i is the discounted rate, n is the investment life period, and I_0 is the initial investment.

$$NPV = \Sigma_{t=1}^{n} \frac{CF_t}{(1+i)^t} - I_0 \quad (1)$$

C. Internal Rate of Return (IRR)

According to Harahap [8], IRR is the interest rate of an investment activity in a certain period of time. In addition, it can be defined as the interest rate that equates the present value of expected future cash flows, or cash receipts with the initial investment outlay. The NPV and IRR methods have a strong methodological basis and wide application in the scope of investment evaluation [2]. IRR is ubiquitous in investment analysis. However, it is relatively challenging to determine the interest rate due to trial and error in achieving an interest rate with an NPV of 0 (zero) [1], [2], [5]. IRR can be calculated based on Equation (2). In Equation (2), CF_0 is the initial investment and CF_n is the cash flow at the period of n.

$$CF_0 + \frac{CF_1}{(1+IRR)^1} + \frac{CF_2}{(1+IRR)^2} + \cdots + \frac{CF_n}{(1+IRR)^n} = 0 \quad (2)$$

Generally, NPV and IRR methods are applied to analyze a project with a similar conclusion. However, if observed from the equations, NPV is a linear transformation formula, while IRR is nonlinear [2].

D. Stochastic Programming

Dantzig first developed stochastic programming in 1955 [4], [9]. Stochastic programming is a mathematical programming with an objective function or condition (constraint) with uncertainty in the form of a probability distribution [9]. Uncertainty can stem from limited knowledge or complex processes (e.g., economic-dependent demand or customer choices) [10]. Uncertainty can be reduced by collecting more accurate data or using more accurate measuring instruments [10].

Although uncertainty can be defined precisely, practical use of uncertainty must be prepared in detail for several possible scenarios that may occur from the data [9]. Stochastic programming must include every scenario of uncertainty [9].

Scenario trees in stochastic programming are flexible and can be selected and prioritized. Too many scenarios can be impractical, especially for problems with many random factors. Focusing on a few relevant scenarios will help manage complexity and provide valuable information in decision-making under uncertainty. The scenarios selected are usually based on quartiles, past data, predictions, or simulation methods [9].

Two-stage stochastic programming is used in decision-making under uncertainty with two stages. The first stage is strategic-related, such as facility location and capacity. The second stage is tactical-related, such as production quantity, shipping route, and so on. The decision of each step can affect the next stage and cannot be determined individually. This process is closely similar to the business decision process, making the method preferable to be applied [3], [4], [11]-[13]. Another example of the two-stage stochastic application is optimizing military needs and emergency facilities with future unknown disasters, in which the affected demand is random. According to these characteristics, the research applied a two-stage stochastic programming model [14].

Equations (3), (4), and (5) are the fundamentals of two-stage stochastic programming. Equation (3) is the objective function, while equations (4) and (5) are the constraints or condition functions.

$$Min\ z = c^T\chi + E_\xi Q(\chi, \xi) \quad (3)$$

$$Constraint, A\chi = b \quad (4)$$

$$\chi \geq 0 \quad (5)$$

Based on Equations (3), (4), and (5), c^T is a real vector coefficient for the first stage. χ is a decision vector the first stage. E_ξ is a mathematical expectation related to random vector. $Q(\chi, \xi)$ is the cost function or objective function of the second stage with random arguments. $A\chi$ is a matrix value of χ in the first stage. b is the right-side constraint value in the first stage. Equation (5) is a statement that implies that the value of χ is greater than zero and is not negative.

Stochastic programming is not only limited to two stages, but can also be carried out in several stages (multiple stages) [3], [9]. The required stages depend on the number of processes that need to be analyzed at each stage.

III. METHOD

The research started by collecting the required data; secondary data was used for data collection. Secondary data is data obtained indirectly or through a second source [5]. Data were taken from company data in the form of site plan images, available budget plan, and previous housing sales data. It was then continued with creating a mathematical model with two-stage stochastic programming.

According to Hu in a study by Sinaga [9], the stochastic program is a mathematical framework designed to address decision-making situations involving uncertainty. This uncertainty is usually characterized by a probability distribution assigned to one or more parameters in the constraints and the objective function.

Azaron *et al.*, in a study by Kungwalsong [11], formulated a two-stage stochastic programming model based on uncertainty in demand, supply, process, delivery, cost limitations in adding capacity, and facility disruptions. Stochastic programming was used to evaluate the feasibility of housing development investments. First, the objective function that would produce the maximum NPV of the investment made was inputted. The uncertainty required in stochastic programming was also included in the form of uncertain sales. However, the research was limited to two-stage stochastic programming.

As previously mentioned in the literature review, the two-stage stochastic programming model can be illustrated in Figure 1, which was based on data results available in the investment feasibility studies. The model made decisions in two steps. In the first step, the number of houses to be built was determined based on the number of available land plots. The uncertainty of sales was also considered. Then, considering the uncertainties, the number of houses sold each year was determined in the second step.

In two-stage stochastic programming, the decision variables are divided into two sets. The decision variables that are determined before considering the uncertainty parameter are called first-step variables. Meanwhile, the decision variables determined further after the random event to reduce the impact that may arise due to infeasibility are called second-step variables or recourse variables [4], [15].

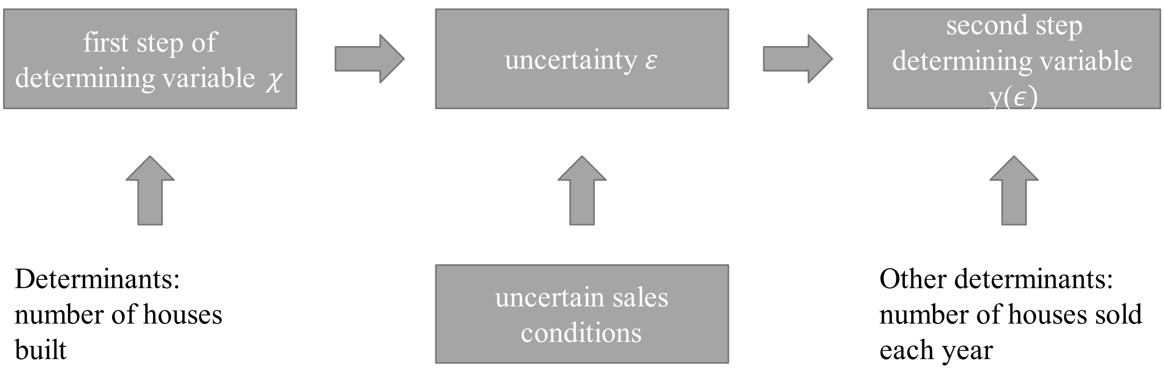

Figure 1. Methodological steps in stochastic programming

In Equation (3), there is $Q(\chi,\xi)$, the second-stage objective function, which can be expressed in a mathematical model as in Equation 6. q^T is the second-stage coefficient (real vector). y is the second-stage decision vector. W_y is the value of the matrix y of the second step. h is the right-side second-stage constraint value. T_χ is a technology matrix.

Before inputting data into the mathematical function, a scenario tree is first created to facilitate the limitations that will be the objective of two-stage stochastic programming. Based on Figure 2, three scenarios can originate from an event in the first stage (1), the housing development activity plan (S1). The second-stage event (2) is a continuation of the first-stage event, which is an uncertain event in sales. In this study, previous data was taken based on sales data on similar types and sizes of houses, resulting in three events that were most likely to occur: (S11) all houses would be sold out within 1 year, (S12) all houses would be sold out within 2 years, and (S13) all houses would be sold out within 3 years. The plan was to perform sales after all buildings were completed, and it was assumed that the sales would be the same each year if the houses were not sold out within 1 year.

$$Q(\chi,\xi) = \min\{q^T y | W_y = h - T_\chi, y \geq 0\} \tag{6}$$

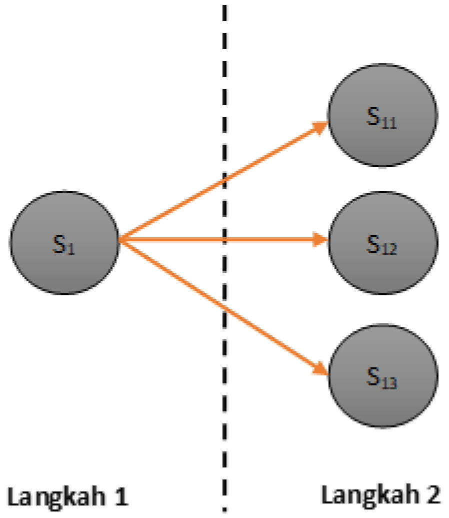

Figure 2. Scenario tree (langkah: step)

A mathematical model for the two-stage stochastic programming model was built based on the scenario tree and can be presented in Equation (7). All notations included in Equation 7 to Equation 12 will be explained in Table 1.

$$Max\ z = \sum_{i=1}^{n1}\sum_{k=1}^{n2} c_{ik}\chi_{ik} + \left(\sum_{i=1}^{n1}\sum_{j=1}^{m1}\xi_{ij}\sum_{t=1}^{m2} q_{ijt}y_{ijt}\right) \tag{7}$$

Constraint

$$\sum_{i=1}^{n1} a_{ik}\chi_{ik} \leq b_k \tag{8}$$

$$\sum_{t=1}^{m2} y_{ijt} = \sum_{k=1}^{n2}\chi_{ik} \tag{9}$$

$$y_{ij1} \leq \frac{\sum_{k=1}^{n2}\chi_{ik}}{j} + \left(1 - \frac{1}{j}\right), t = 1,2,\dots,j \tag{10}$$

$$y_{ijt} \leq \frac{\sum_{k=1}^{n2}\chi_{ik}}{j}, \quad t = j \tag{11}$$

$$\begin{gathered} i\ \epsilon\ n1, n1 = \{1,2\} \\ j\ \epsilon\ m1, m1 = \{1,2,3\} \\ t\ \epsilon\ m2, m2 = \{1,2,3\} \\ k\ \epsilon\ n2, n2 = \{1,2\} \\ x \geq 0 \\ y \geq 0 \\ x, y = integer \end{gathered} \tag{12}$$

Table 1. Definition of notations used in Equation (7) to (12)

Notation	Description
i	Type of houses built (i=1 for the type of 4-meter-width houses) (i=2 for the type of 4.5-meter-width houses)
j	Sales scenarios
t	Sales at year-
k	Housing rows
ξ	Probability of the scenario to occur
c	Coefficient of present value (PV) of house building cost
q	Coefficient of present value (PV) of house selling price
a	Width of house coefficient (meter)
b_k	Maximum land length coefficient for k-th row
χ	The number of house units built
y	The number of house units sold

According to Table 1, i is the type of houses being built or sold, while j is the sale scenario. For example, j has a value of 2 in the scenario S12. t is the year when the sales occurred. Because the objective function will obtain NPV, discounting must be done yearly to obtain the present value. k is the row in the housing that will be built. In this research, there are 2 housing rows; the value of k equal to 1 refers to row 1 in the housing.

Equation (7) is an objective function that will result in maximum NPV. Equation (8) limits the number of house units that can be built so that it cannot exceed the length of land available in the housing row. Equation (9) limits the number of house units that can be sold so that it cannot exceed the number of houses being built. Sales were assumed to be equal each year; therefore, Equations (10) and (11) limit the number of houses being sold to be equal in each year, and the number of houses sold in the first year must be 1 unit greater if the unit distribution cannot be equal each year. Those equations were then inputted into Microsoft Excel to be analyzed, assisted by the Solver Add-in program.

Solver Add-in was developed for Microsoft by the Frontline System Inc. [16]. Frontline also manages its official site (http://www.solver.com/), which contains various information on solving optimization problems [16]. Solver Add-in was commonly used in solving an optimization problem with particular constraints [17]. It is highly accessible to the public because it is part of the features of Microsoft Excel [16], [18]. Figure 3 presents the display of the Solver Add-in program in Microsoft Excel.

As presented in Figure 3, the objective cell in the research, which was NPV, was inputted to the "Set Objective" field. "*To*" refers to the preferred value; "*Min*" was chosen if the minimum value of the objective function would be analyzed, while "*Max*" was selected for the maximum value. Otherwise, "Value of" was chosen for a customized value. The decision variable was determined in the field of "*By Changing Variable Cells:*". The constraints of the model were initialized in the "*Subject to the Constraints:*". "*Select a Solving Method"* decides the analysis method of the *Solver Add-in*, in which "*GRG Nonlinear*" was chosen for the research. *Solver Add-in* would run the analysis after all fields were initialized and the "*Solve*" button was clicked.

After the NPV was obtained from the analysis result of the two-stage stochastic programming, the analysis was continued by calculating IRR to support the feasibility analysis of the investment. IRR calculations were performed using decision variables obtained from two-stage stochastic programming.

IV. RESULT AND DISCUSSION

The action plan for the investment can be seen in Table 2. The activity begins with purchasing land and other preparatory activities before construction is carried out. The housing construction will be carried out for one year and starts immediately after the land purchase ends. Sales activities are carried out after construction is completed, which means they start in the second year. The length of the sales period is accustomed according to each scenario, with the longest time being three years.

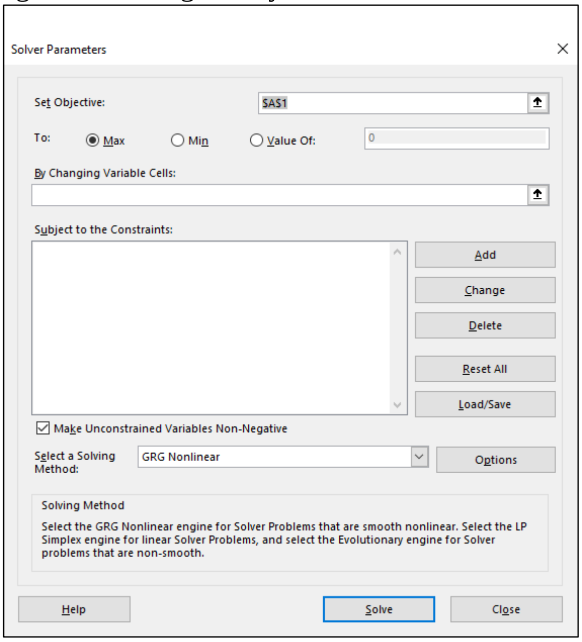

Figure 3. Solver add-in display

Table 2. Investment action plan

n-th Year	Action/Activity
T0	Land purchase
T1	Construction period
T2	First-year sales period
T3	Second-year sales period
T4	Third-year sales period

Next, data regarding the sales period is taken from previous data of the sales period, as shown in Table 3, which determines the sales probability. The probability of scenario S_{11} to occur is 30.4%, while that of scenarios S_{12} and S_{13} are 47.8% and 21.8%, respectively. The probabilities will be used proportionally in the second stage of two-stage stochastic programming. The data was obtained from the company's internal sales data of similar-sized houses. The sales period is calculated from the time the construction has been completed and the time the house starts being sold by the company's marketing department. The percentage of success is calculated from the number of projects with the same sales period divided by the overall number of projects.

Based on the land plot available, as can be seen in Figure 4, the construction of the houses will be carried out on two housing rows. The upper row (presented in the site plan image) is named Row 1 and has a length of 80 m. The lower row is named Row 2 and has a length of 77 m. The length of each row is used to determine the number of each type of house to be built.

Table 3. Percentages of housing sales period in west jakarta

Sales period (Year)	Average success rate percentage
1	30.4%
2	47.8%
3	21.8%

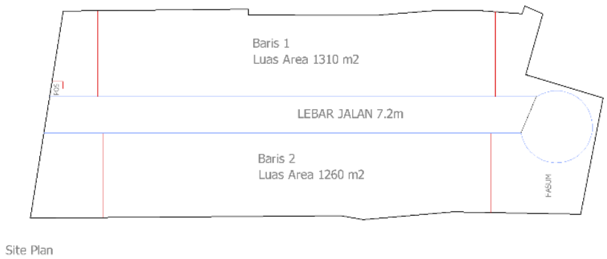

Figure 4. Site plan images

The decision variables in the two-stage stochastic programming for problem-solving in the research have a total of 16 variables, which can be seen in Table 4. The χ variable is the number of house units that must be built for each type of house and each housing row, and consists of four variables. The y variable, which consists of 12 variables, is the number of house units sold in each house type, each scenario, and each year of sales period in a scenario. The results of these variables will provide the maximum value of the objective function, which actually is the maximum NPV obtained from this investment.

In order to determine the feasibility of investment with the NPV method, a discount rate or MARR is required, which is determined for this investment at 20%. After determining the discount rate, it is necessary to know the nominal income (cash in) and nominal costs (cash out) by calculating the cost budget plan for the nominal costs and obtaining the projected selling price of the house. The nominal obtained will be calculated according to the discount rate to obtain the present value (PV).

The results of the present values are presented in Table 5. The PV of sales mentioned is the selling price of the house minus the house sales commission, and the result is discounted. In the general section of Table 5, the data presented includes the marketing costs for house sales in each year of sales. In addition, initial costs include land purchasing costs, land permit processing fees, and other supporting facilities, with a total cost of 22,674 (in millions of Rupiah).

The obtained decision variables and collected data can be substituted into the two-stage stochastic programming model formulations, which include Equations (7) to (11). The equations can then be rewritten as follows.

Table 4. Decision variables

Decision Variables	4-meter-width house	4.5-meter-width house
Total number of houses in Row 1	χ_{11}	χ_{21}
Total number of houses in Row 2	χ_{12}	χ_{22}
The number of houses sold within 1 year	y_{111}	y_{211}
The number of houses sold within 2 years in the first-year sales period	y_{121}	y_{221}
The number of houses sold within 2 years in the second-year sales period	y_{122}	y_{222}
The number of houses sold within 3 years in the first-year sales period	y_{131}	y_{231}
The number of houses sold within 3 years in the second-year sales period	y_{132}	y_{232}
The number of houses sold within 3 years in the third-year sales period	y_{133}	y_{233}

Table 5. Calculation results of present values

PV (Present Values)	4-meter-width house	4.5-meter-width house
PV of house construction cost	869	932
PV of house sales in the first year of sales	1613	1806
PV of house sales in the second year of sales	1411	1580
PV of house sales in the third year of sales	1235	1383
	General	
PV of marketing budget cost in the first year of sales	80	
PV of marketing budget cost in the second year of sales	67	
PV of marketing budget cost in the third year of sales	55	

*In millions of Rupiah

$$Max\ z = \sum_{k=1}^{2} -869\chi_{1k} + \sum_{k=1}^{2} -932\chi_{2k} - 22674$$
$$+(0{,}304(1613y_{111} + 1806y_{211} - 80)) + (0{,}478(1613y_{121} + 1411y_{122} + 1806y_{221} + 1580y_{222} - 147))$$
$$+(0{,}218(1613y_{131} + 1411y_{132} + 1235y_{133} + 1806y_{231} + 1580y_{232} + 1383y_{233} - 202)) \quad (13)$$

Constraint

$$4\chi_{11} + 4{,}5\chi_{21} \leq 80 \quad (14)$$

$$4\chi_{12} + 4{,}5\chi_{22} \leq 77 \quad (15)$$

$$y_{111} = \sum_{k=1}^{2} \chi_{1k} \quad (16)$$

$$y_{211} = \sum_{k=1}^{2} \chi_{2k} \quad (17)$$

$$\sum_{t=1}^{2} y_{12t} = \sum_{k=1}^{2} \chi_{1k} \quad (18)$$

$$\sum_{t=1}^{2} y_{22t} = \sum_{k=1}^{2} \chi_{2k} \quad (19)$$

$$\sum_{t=1}^{3} y_{13t} = \sum_{k=1}^{2} \chi_{1k} \quad (20)$$

$$\sum_{t=1}^{3} y_{23t} = \sum_{k=1}^{2} \chi_{2k} \quad (21)$$

$$y_{111} \leq \sum_{k=1}^{n2} \chi_{1k} \quad (22)$$

$$y_{211} \leq \sum_{k=1}^{n2} \chi_{2k} \quad (23)$$

$$y_{121} \leq \frac{\sum_{k=1}^{n2} \chi_{1k}}{2} + 0{,}5 \quad (24)$$

$$y_{122} \leq \frac{\sum_{k=1}^{n2} \chi_{1k}}{2} \quad (25)$$

$$y_{221} \leq \frac{\sum_{k=1}^{n2} \chi_{2k}}{2} + 0{,}5 \quad (26)$$

$$y_{222} \leq \frac{\sum_{k=1}^{n2} \chi_{2k}}{2} \quad (27)$$

$$y_{131} \leq \frac{\sum_{k=1}^{n2} \chi_{1k}}{3} + 0{,}67 \quad (28)$$

$$y_{132} \leq \frac{\sum_{k=1}^{n2} \chi_{1k}}{3} + 0{,}67 \quad (29)$$

$$y_{133} \leq \frac{\sum_{k=1}^{n2} \chi_{1k}}{3} \quad (30)$$

$$y_{231} \leq \frac{\sum_{k=1}^{n2} \chi_{1k}}{3} + 0{,}67 \quad (31)$$

(32)

$$y_{233} \leq \frac{\sum_{k=1}^{n2} \chi_{1k}}{3} \quad (33)$$

$$\chi_{ik} \geq 0\ and\ integer;\quad i = 1{,}2; k = 1{,}2 \quad (34)$$

$$y_{ijt} \geq 0\ and\ integer;\quad i = 1{,}2; j = 1{,}2{,}3; t = 1{,}2{,}3 \quad (35)$$

The objective function, which is expressed as in Equation (7), will transform into Equation (13) after all of the coefficients are initialized. The substitution of constraint values of each row to Equation (8) will transform the equation into Equations (14) and (15). Equations (16) to (21) are derived from Equation (9) after all variables have been initialized. Likewise, equations (22) to (33) are constraint functions derived from equations (10) and (11). Equations (34) and (35) are constraint functions to ensure that the value of the decision variable is a positive integer number.

Those equations were then inputted into Microsoft Excel to be processed by the Solver Add-in. The results can be seen in Table 6. The optimal number of houses with house type 1 (houses with a width of 4 m) to be built is 2 house units, consisting of only 2 house units on Row 1. The number of type-2 houses, each with a width of 4.5 meters, that are optimal to be built is 33 house units, consisting of 16 units on Row 1 and 17 units on Row 2. In the second stage of programming, the number of houses sold follows the assumption stated previously; that is, the number of *houses* sold each year is equal. For scenario S_{11}, all type-1 and type-2 houses are sold out in the first year. For scenario S_{12}, 1 unit of type-1 houses is sold each year, while 17 units of type-2 houses are sold in the first year and 16 units in the second year. For scenario S_{13}, 1 unit of type 1 houses are sold in the first year and another 1 unit in the second year, while type 2 houses are sold 11 units each year. Thus, the final result of the objective function is 4,092.036 million Rupiah.

The result of the objective function is the maximum NPV value expected by investors in the investment. The NPV value is positive, so this housing development investment is feasible to run. In addition to NPV, IRR calculations are carried out to determine the investment interest rate. The IRR value obtained *is* 23.63%. When compared to the MARR that has been determined, the IRR interest rate is greater than the MARR, so it can be stated that this housing development investment is feasible to run.

Table 6. The number of house units in each decision variable

Decision variable	House units	Decision variable	House units
χ_{11}	2	χ_{21}	16
χ_{12}	0	χ_{22}	17
y_{111}	2	y_{211}	33
y_{121}	1	y_{221}	17
y_{121}	1	y_{221}	16
y_{131}	1	y_{231}	11
y_{132}	1	y_{232}	11
y_{133}	0	y_{233}	11

V. CONCLUSIONS

Based on the analysis results of the two-stage stochastic programming model assisted by the Solver Add-in, the optimal number of type-1 houses (houses with a width of 4 meters) to be built is 2 units consisting of 2 units on Row 1 only. On the contrary, the number of type-2 houses (houses with a width of 4.5 meters) to be built is 33 units, consisting of 16 units on Row 1 and 17 units on Row 2. The number of units was then inputted into the objective function to obtain the maximum NPV (Z_{maks}), resulting in an NPV of as much as 4,092.036 million Rupiah.

The positive value of NPV reflects that the investment is feasible to be accepted. This statement is also supported by the IRR of 23.63%, indicating that the investment will increase the value of the company.

The decision of the two-stage stochastic programming model resulted in a remaining 0.5 m of land length in Row 2 (77 meter). The remaining land can be used to increase the width of the house for 1 house unit of type-2 house that initially has a width of 4.5 meters to 5 meters, thus increasing the investment return.

The two-stage stochastic programming model used in this study should be developed for housing with more than 2 rows. However, this model is still limited only to types of houses with same house length. This also supports the development of the model in this study.

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