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Combination of Excel Functions and VBA as Tools to Solve Linear Equation System (LES) Models (Simulation of Mathematical Model for Daily Nutritional Intake Portions for School-Aged Children Aged 7 to 9 Years Old)

1st Fuad Nasir
Department Mathematics Education, Faculty of Education and Sciences Universitas Swadaya Gunung Jati
Cirebon, Indonesia
fuadugj@gmail.com

2nd Syifa Qolbiyah Nasir
Department of Nutrition, Faculty of Medicine Universitas Negeri Semarang
Semarang, Indonesia
syifaqn@mail.unnes.ac.id

3rd Wiwit Estuti
Department of Nutrition Campus Cirebon, Polytechnic of Health
Tasikmalaya, Indonesia
estutiwesti68@gmail.com

Abstract**—The solution of Linear Equation Systems (LES) is essential in solving problems in various fields such as agriculture, healthcare, industry, economics, and engineering, providing a foundation for modeling and solving complex issues. The integration of Microsoft Excel's built-in functions and Visual Basic for Applications (VBA) offers an effective and efficient approach to solving these LES models. This study explores the theory behind converting LES to matrix equations, the advantages of using Excel functions and VBA, as well as the application of functions like MDeterm, MInverse, and MMult. In the research trials on LES models with daily intake portions (energy, protein, fat, carbohydrate) for school-aged children 7 to 9 years old with 4 variables (plant-based, animal-based, vegetables, fruits) and the algorithm in this study can be extended for n variables, also discussing the conditions for single solutions, multiple solutions, and no solutions. The discussion includes the creation of programming algorithms and VBA Excel code, as well as the visualization of the program's results.**

Keywords— ***Excel Functions and VBA; Linear Equation Systems; LES Models; Daily Nutritional Intake Portions***

I. INTRODUCTION

A linear equation system is a mathematical model for finding solutions of multiple variables for problems that can be expressed using linear equations [1]. This method aids in the most effective distribution of resources among strategic options. The solution of Linear Equation Systems (LES) plays a significant role in scientific and engineering computations. LES represent these systems in matrix equation form, simplifying calculations and aiding in the efficient use of computational tools [2]. The integration of Microsoft Excel's built-in functions and Visual Basic for Applications (VBA) offered an effective and efficient approach to solving these LES models. By leveraging Excel functions and VBA, the computation process can be accelerated, improving accuracy and productivity [3], [4].

LES has been used in many sectors other than computing and engineering which included optimalization or formulation. For example in optimalization of feed product [1] or food product development [5], [6]. To extend the used of LES in real problem, this study explores the theory behind converting LES to matrix equations, the advantages of using Excel functions and VBA, as well as the application of functions like MDeterm, MInverse, and MMult used in determining the daily nutritional intake for school-aged children aged 7 to 9 years old.

The challenge of solving the SPL model in engineering arises when dealing with more than three variables. To address this, a solution model was developed by integrating VBA with Excel functions in Microsoft Office. In a case study related to nutrition, this model was used to calculate the required nutritional intake for a group of people, making the process more efficient and streamlined. Therefore, the objective of the research is to develop a program based on Excel functions and VBA as a tool to solve linear equation systems [7] and simulate the mathematical model for daily nutritional intake portions for school-aged children aged 7 to 9 years.

II. METHOD

This study was conducted using Case Study Design methodology involving mathematical LES focused on exploring, analyzing, and solving a specific real-world problem or scenario that can be represented using a system of linear equations [8]. The research trials discussed the LES model with study case with 4 variables (energy, protein, fat, carbohydrate) and examined the conditions for single solutions, multiple solutions, and no solutions. The discussion included the creation of programming algorithms and VBA Excel code, as well as the visualization of the program's results.

Basic Linear Equation Systems (LES) [2], [3]

A linear equation system (LES) with n variables can be represented in matrix equation form as follows:

$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + ... + a_{1n}x_n = b_1$

$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + ... + a_{2n}x_n = b_2$

$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + ... + a_{3n}x_n = b_3$

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$a_{n1}x_1 + a_{n2}x_2 + a_{n3}x_3 + ... + a_{nn}x_n = b_n$

with a_{nn} as constant coefficients, b_n as constants, n as the number of equations, and x_1, x_2, x_3, ..., x_n as variables. Using matrix multiplication, the LES above can be written as a matrix equation:

$$\mathbf{AX = B} \quad (1)$$

where:
A = $[a_{ij}]$ is an order n x n coefficient matrix,
X = $[x_j]$ is an order n x 1 column matrix (also called a column vector),
B = $[b_j]$ is an order n x 1 column matrix (also called a column vector).

That is:

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdots & a_{3n} \\ . & . & . & \cdots & . \\ . & . & . & \cdots & . \\ . & . & . & \cdots & . \\ a_{n1} & a_{n2} & a_{n3} & \cdots & a_{nn} \end{bmatrix}; X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ . \\ . \\ . \\ x_n \end{bmatrix}; B = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ . \\ . \\ . \\ b_n \end{bmatrix}$$

If the left and right sides of the matrix equation **AX = B** [9] are multiplied by the left inverse of matrix A, the matrix X will be obtained as follows:

- $\mathbf{A^{-1}\,AX = A^{-1}\,B}$ (where A^{-1} is the inverse of matrix A provided that det(A) ≠ 0)
- $\mathbf{(A^{-1}\,A)X = A^{-1}\,B}$ (where A^{-1}, the product of the inverse of matrix A and matrix A results in the Identity matrix of the same order as matrix A)
- $\mathbf{I\,X = A^{-1}\,B}$ (where I is the Identity matrix of the same order as matrix A)
- $\mathbf{(I\,X) = A^{-1}\,B}$ (where the product **I X = X** results in the matrix X itself)
- $\mathbf{X = A^{-1}\,B}$ where det(A) ≠ 0 (2)

III. RESULTS AND DISCUSSION

Based on matrix equations (1) and (2), the programming algorithm and code are obtained using a collaboration between Excel functions and VBA.

Advantages and Benefits of Excel Functions and VBA. [10], [11]

1. Automation: VBA allows for the automation of calculations and data processing, reducing human errors and speeding up analysis.
2. Efficiency: Built-in Excel functions such as MDeterm, MInverse, and MMult enable fast and accurate matrix computations.
3. Ease of Use: Excel's intuitive interface makes it easy for users to input data and view results in real-time.
4. Flexibility: VBA enables the creation of scripts tailored to specific user needs.
5. Compatibility: Excel easily integrates with other applications and supports various file formats.

Use of Excel Functions MDeterm, MInverse, and MMult [12]

1. **MDeterm**: Calculates the determinant of a matrix, which is crucial for determining the existence of a unique solution.
2. **MInverse**: Computes the inverse of a matrix, used to find solutions when the determinant is non-zero.
3. **MMult**: Performs matrix multiplication, essential for solving LES by multiplying the inverse of the coefficient matrix with the constant matrix.

Solutions for Linear Equation Systems (LES): [13]

1. **Single or Unique Solution**: Occurs when the determinant of the coefficient matrix A is non-zero, indicating the existence of a unique solution.
2. **Multiple Solutions**: Happens when there are free variables, usually when the number of equations is less than the number of variables, or when the system has parameters that can take on any value.
3. **No Solution**: Identified when the system of equations is inconsistent, meaning no common solution exists.

Application of VBA in Excel. [14], [15]

Using VBA in Excel allows for the automation of LES calculations and visualization of solutions. Below is the programming algorithm and VBA code in Excel to solve LES with 4 variables using the Excel functions MDeterm, MInverse, and MMult.

Programming Algorithm

- **Input**

  Matrix A and Matrix B
- **Process**

  Calculate the Determinant of matrix A and matrix Ai (det(A) and det(Ai)) [16]:
  1. If det(A) = 0, the LES has a single or unique solution
     Calculate the inverse of matrix A and matrix X

2. If det(A) = 0 and det(Ai) ≠ 0, the LES has no solution
3. If det(A) = 0 and det(Ai) = 0, the LES has multiple solutions

- **Output**

  Message for Linear Equation System (LES) Solution. Determinant of matrix A, inverse of matrix A, and matrix X

VBA Code For Les With 4 Variables

```
Sub SolveSPLWithExcelFunctions_4Vars()
Dim A, B As Range
Dim DetA As Double
Dim X, InverseA As Variant
Dim n As Integer
Set A = Range("B12:E15")
Set B = Range("G12:G15")
n = A.Rows.Count
DetA = Application.MDeterm(A)
Cells(19, 5).Value = DetA
If DetA = 0 Then
   Dim DetAi As Double
   Dim i, j As Integer
   Dim Ai As Variant
   For i = 1 To n
      Ai = A.Value
      For j = 1 To n
         Ai(j, i) = B.Cells(j, 1).Value
      Next j
      DetAi = Application.MDeterm(Ai)
   Next i
   For i = 1 To n
      If DetAi = 0 And B.Cells(i, 1).Value <> 0 Then
         MsgBox "SPL ini Memiliki Banyak Solusi", vbInformation, "SOLUSI SPL"
         Range("B22:E25").Value = ""
         Range("G22:G25").Value = "~"
         Exit For
      Else
         MsgBox "SPL ini tidak Memiliki Solusi", vbExclamation, "SOLUSI SPL"
         Range("B22:E25").Value = ""
         Range("G22:G25").Value = ""
         Exit For
      End If
   Next i
Else
   MsgBox "SPL ini Memiliki Solusi Tunggal", vbInformation, "SOLUSI SPL"
   InverseA = Application.MInverse(A)
   Range("B22:E25").Value = InverseA
   X = Application.MMult(InverseA, B)
   Range("G22:G25").Value = X
End If
End Sub
```

Figure 1. VBA Code for Les with 4 Variables

The above VBA code can be extended for n variables by modifying the range of matrix A and matrix B, as well as the output range of matrix X. [17]

Program Testing Results for the Collaboration of Excel Functions and VBA. [10], [11]

LES Model with 4 variables:

$3x_1 + x_2 + 2x_3 + 2x_4 = 15$
$2x_1 + x_3 + 4x_4 = 10$
$-x_1 + 6x_2 - 3x_3 + 3x_4 = 30$
$3x_1 - 2x_2 + 5x_3 - x_4 = 40$

This LES can be written as:

$$AX = B$$

where:

$$A = \begin{bmatrix} 3 & 1 & 2 & 2 \\ 2 & 0 & 1 & 4 \\ -1 & 6 & -3 & 3 \\ 3 & -2 & 5 & -1 \end{bmatrix};\ X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix};\ B = \begin{bmatrix} 15 \\ 10 \\ 30 \\ 40 \end{bmatrix}$$

Steps to Use the Program:

1. Input matrix A and matrix B
2. Press **Run** to get the message box as shown in Figure 2.

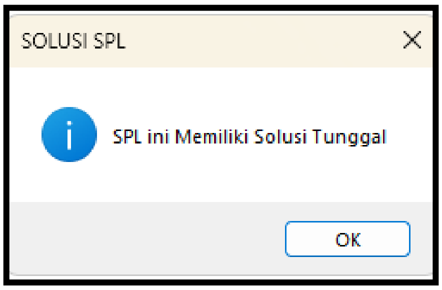

Figure 2. Message Indicating Les Has a Unique Solution

3. After pressing **Ok**, the following output will be obtained as shown in Figure 3.

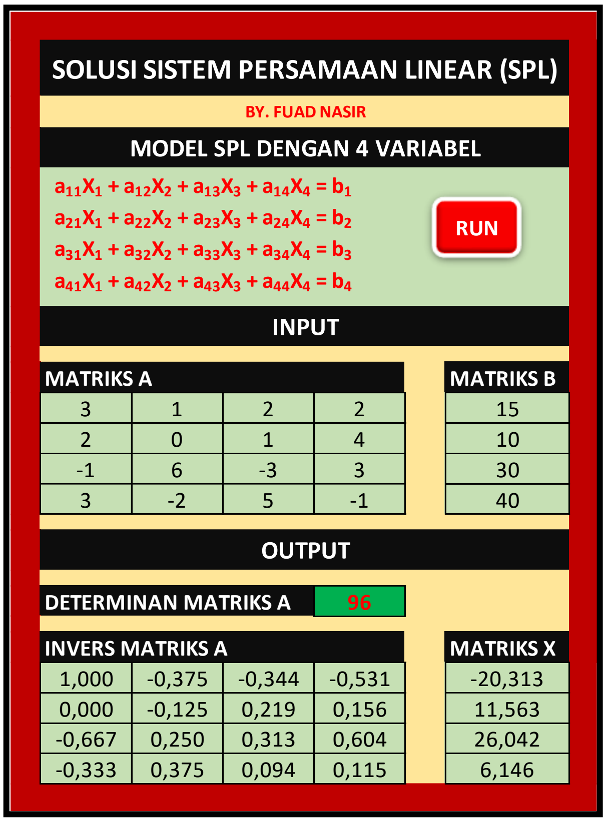

Figure 3. Output Indicating Les Has a Unique Solution

It is evident from Figure 3 above that the determinant of matrix A is not zero, which means the system of linear equations (LES) has a unique solution.

Example for LES with multiple solutions is as follows:

By replacing the first equation:
$3x_1 + x_2 + 2x_3 + 2x_4 = 15$ with the equation $4x_1 + 2x_3 + 8x_4 = 20$, we get:

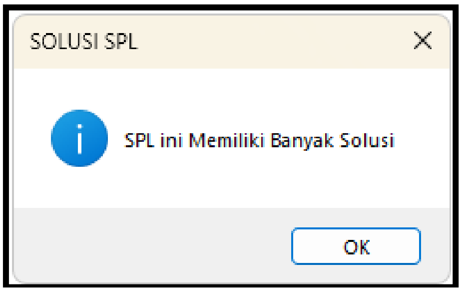

Figure 4. Message Indicating Les Has Multiple Solutions

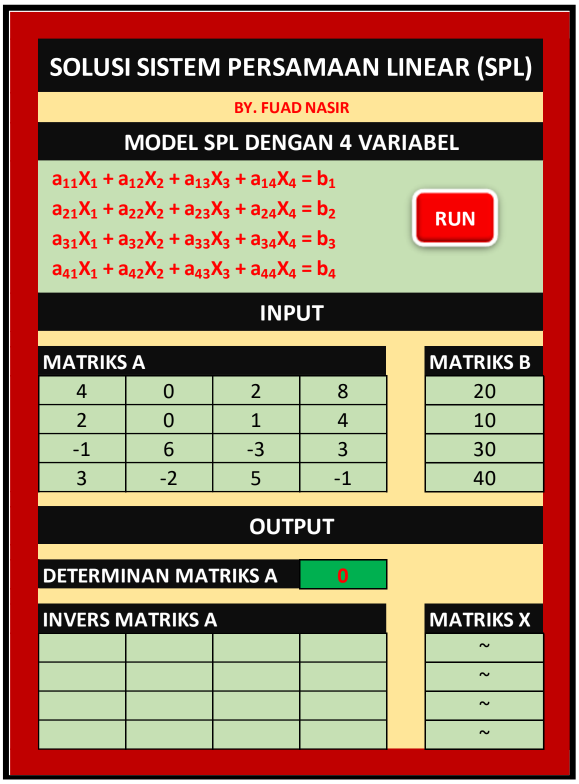

Figure 5. Output Indicating Les Has Multiple Solutions

It is evident from Figure 4 above that the determinant of matrix A is zero, and the elements in rows 1 and 2 are multiples, which means the system of linear equations (LES) has multiple solutions.

Example for LES with no solutions is as follows:

By replacing the first equation:
$3x_1 + x_2 + 2x_3 + 2x_4 = 15$ with the equation $4x_1 + 2x_3 + 8x_4 = 15$, we get:

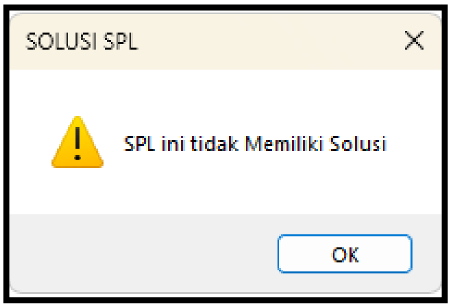

Figure 6. Message Indicating Les Has No Solution

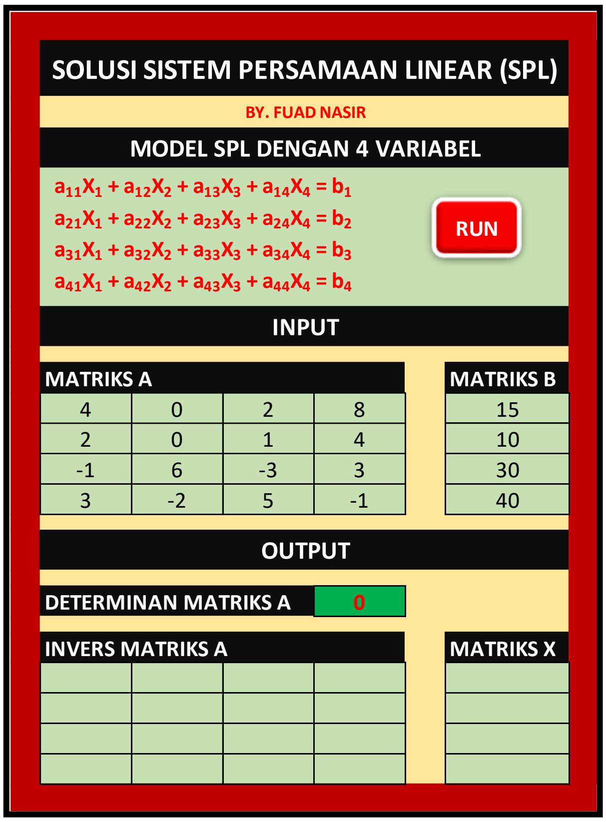

Figure 7. Output Indicating Les Has No Solution

It is evident from Figure 7 above that the determinant of matrix A is zero, and the elements in each row or column are not multiples of each other, which means the system of linear equations (LES) has no solution.

Development of a Mathematical Model for Daily Nutritional Intake Portions for Children Aged 7 to 9 Years and Program Simulation

Based on the Indonesian Food Composition Table Year 2017 [18] and the Regulation of the Minister of Health Year 2019 [19], several nutritional contents (energy, protein, fat, carbohydrates) from various types of food ingredients [18] and the daily nutritional needs for children aged 7 to 9 years are obtained as shown in tables 1 and 2 below. [19]

TABLE 1. DAILY FOOD INTAKE PORTIONS WITH 4 TYPES [18]

Composition (100 gram)	Rice	Fried Chicken	Green Beans	Papaya
Calories (kcal)	180	287	30	46
Protein (gram)	3	31	2,2	0,5
Fat (gram)	0,3	15,7	0,2	12
Carbohydrate (gram)	39,8	1,7	6,4	12,2
Source: Indonesian Food Composition Table Year 2017				

TABLE 2. DAILY NUTRITIONAL NEEDS FOR SCHOOL-AGED CHILDREN AGED 7 TO 9 YEARS OLD/DAY AND 30% FOR MEALS [19]

Composition (100 gram)	Daily Nutritional Needs for Children Aged 7 - 9 Years	30% for Meals
Calories (kcal)	1650	495
Protein (gram)	40	12
Fat (gram)	55	16,5
Carbohydrate (gram)	250	75
Source: Regulation of the Minister of Health No. 28 Year 2019		

From tables 1 and 2, a linear equation system model with four variables is obtained as shown in the equations below:

$$
\begin{aligned}
180a + 287b + 30c + 46d &= 495 \\
3{,}0a + 31b + 2{,}2c + 0{,}5d &= 12 \\
0{,}3a + 15{,}7b + 0{,}2c + 12d &= 16{,}5 \\
39{,}8a + 1{,}7b + 6{,}4c + 12{,}2d &= 75
\end{aligned}
$$

Subsequently, the mathematical model for daily nutritional intake portions for children aged 7 to 9 years was simulated using the created VBA program with the following results:

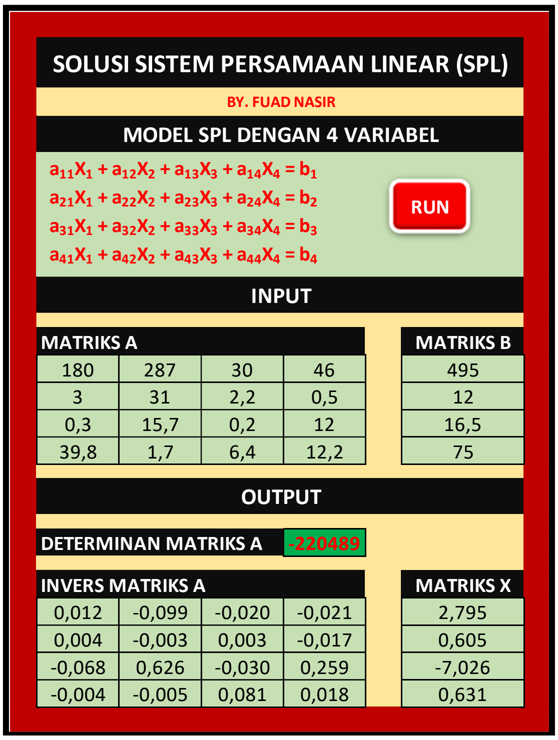

Figure 8. Output Les Simulation

It is evident from Figure 8 above that the determinant of matrix A is not zero, which means the system of linear equations (LES) has a unique solution.

Based on the above calculations, the portions are 2.795 (279.5 grams) for rice, 0.605 (60.5 grams) for fried chicken, -7.026 (-702.6 grams) for green beans, and 0.631 (63.1 grams) for papaya. For the variable values obtained, they must not be negative or within adjusted constraints; hence, the above model would be better suited using linear programming optimization. This program will be further examined in future research.

The findings of this study demonstrate the effectiveness of linear programming (LP) in optimizing solutions for complex problems, particularly in the context of optimizing daily nutritional intake for school-aged children 7-9 years old. The results indicate that the proposed LP model, implemented using VBA and Excel functions, provides an efficient, user-friendly approach to solving systems with multiple variables.

Comparing these results with previous studies, several key observations emerge. First, our approach aligns with findings by [20], [21], which also highlighted the efficiency of LP in handling multi-variable constraints. However, unlike traditional methods that rely on standalone optimization software such as MATLAB or Lingo, our model leverages commonly available tools, making it more accessible for practical applications.

Another important consideration is accuracy. Previous research has suggested that LP models integrated with specialized solvers tend to yield slightly more precise results, especially for large-scale optimization problems [22]. While our model achieved comparable accuracy for moderate-scale problems, future enhancements could involve integrating more advanced solvers to improve precision and scalability.

Overall, this study contributes to the growing body of research advocating for LP as a valuable optimization tool. By demonstrating its practical application using accessible software, we provide a framework that can be adapted across various fields. Future research should focus on refining the model by incorporating additional constraints, exploring nonlinear programming extensions, and testing performance against alternative optimization techniques.

IV. CONCLUSIONS

The use of Excel functions and VBA to solve LES models provides efficient and accurate solutions, particularly in handling complex problems in various fields. Excel's automation and visualization capabilities make it a highly valuable tool for many real-world issues across multiple sectors. However, problems with specific constraints on their variables, especially in the mathematical model for daily nutritional intake portions for school-aged children aged 7 to 9 years, require further study with linear programming optimization.

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