Examining solar potential within electrical material flow

M.Sc. Ernesto Gonzalez Cabrera
Institute of Logistics, University of Miskolc, Institute of Logistics, Hungary; UCLV, Cuba
er92gcabrera@gmail.com

Dr. Béla Illés
Institute of Logistics, University of Miskolc, Institute of Logistics, Hungary

Dr. Ákos Cservenák
Institute of Logistics, University of Miskolc, Institute of Logistics, Hungary

DOI: http://dx.doi.org/10.25673/116284

Abstract

This paper highlights the challenges of integrating renewable energy into electricity distribution networks, focusing on modeling and optimizing electrical energy flows from sources such as nuclear, thermal, renewable, and geothermal to various consumers, including industrial, residential, commercial, and electric transportation sectors. It addresses a critical knowledge gap in managing the complexity of energy distribution with diverse sources and variable consumption patterns. The research aims to develop a comprehensive model that ensures voltage stability across grid levels and optimizes the allocation of energy from sources, including solar panels, over time intervals. The proposed model uses time constraint matrices and graph theory to represent energy flows between sources and consumers, and defines variables and constraints to maintain grid stability amidst demand fluctuations. The intended results include a detailed energy distribution framework with a clear implementation methodology designed for practical use by grid operators, policy makers, and researchers. By providing a structured approach to the integration of renewable energy, the results will support the development of more resilient and efficient electricity distribution networks, define the problem, and outline future research steps.

1. Introduction

Global energy consumption has been steadily increasing due to the growing world population, rapid industrialization, and technological advances. Research on solar energy adoption offers a multidimensional scope and warrants exploration from multiple perspectives, including political, economic, management, behavioral, policy, and innovation aspects[1]. This surge in energy consumption has significant environmental implications, leading to increased carbon emissions and depletion of natural resources. In response, European countries have made efforts to transition to more sustainable energy sources, such as solar and wind power. Hungary, as one of the largest energy consumers in Europe, has been working to diversify its energy mix and increase the use of renewable energy sources.

This shift toward clean energy technologies has been supported by policy initiatives and investments in the development of renewable energy infrastructure. In addition, mathematical models involving matrices have become essential tools for analyzing complex systems and solving equations in various fields of research and industry. These models are used to study and predict energy consumption patterns, optimize energy production, and improve the efficiency of energy distribution systems.

As the global demand for energy continues to grow, it is critical for countries to prioritize the development and adoption of sustainable energy solutions. This includes investing in renewable energy sources, improving energy efficiency, and promoting the use of clean technologies. By doing so, we can reduce the environmental impact of our energy consumption and ensure the availability of natural resources for future generations.

The flow of materials, logistics, and electrical power are critical components of modern industrial and commercial operations. The efficient movement of raw materials, components, and finished products is essential to the smooth functioning of supply chains and manufacturing processes. Logistics involves coordinating these movements and managing storage, transportation, and distribution activities. Meanwhile, electrical

energy is a fundamental requirement for powering machinery, equipment, and lighting systems in various industrial and commercial environments. Together, these three elements play a vital role in supporting the operations of businesses and industries worldwide.
After analyzing the bibliography of the Scopus database found with the keywords optimization, material flow, and energy flow, it was observed that more than 800 papers have been published from 1970 to the present. It is interesting to note that 433 of these papers have been published since 2018, indicating a significant increase in interest in these topics in recent years. This increase in scientific production reflects the growing importance given to the optimization of material and energy flows in various fields, such as engineering, logistics, and environmental management.
Analyzing the bibliography with the keywords: network, material flow, energy flow and mathematical model in Scopus, a total of 51 papers were found, of which 39 are articles, 9 are conference papers, 3 are reviews and 1 is a conference review. As of 2018, the design of low-carbon supply chain networks has started to develop, indicating that this research topic has not been widely explored for a considerable period of time, despite the increasing emphasis on the development of a low-carbon economy [2]. This indicates that there is great potential for future research and development in this area, especially in the application of mathematical models to optimize energy flow in industrial and commercial networks.
Below is a table of bibliographic references of different scientific fields used to solve material flow problems, as well as a reference to material flow in the special case of energy:

Table 1: Scientific field used to solve for Material and Energy Flows

Scientific field	References
Literature review	[1], [3]
Circular economy	[4], [5], [6], [7], [8]
Algorithms	[9], [10], [11], [12], [13], [14]
Simulation	[15], [16], [17]
Variables	[18], [19], [20], [21], [22], [23]
Material (energy) flow	[24], [25], [26]

In the present research work, different aspects related to material and energy flows are addressed, focusing on the Hungarian context. First, an analysis of the background and the first model used to understand the relationship between material flows and energy are presented. Subsequently, the energy situation in Hungary will be specifically examined, highlighting the challenges and opportunities facing the country. In addition, a mathematical matrix model is developed to analyze the relationship between electricity consumption and generation. Different matrices and graphs will be analyzed to better understand the dynamics of electricity demand and supply in a given system. Finally, the results obtained will be discussed and possible future research directions in this area will be proposed.
A brief state of the art report including literature review, research gaps and research questions will be formulated.

2. Methods or experimental part

The procedure developed is the result of the bibliographic analysis carried out, since it includes in a rational way what has been proposed by the different authors with respect to the flow of materials and the different models studied. Figure 1 shows the procedure for improving the model.

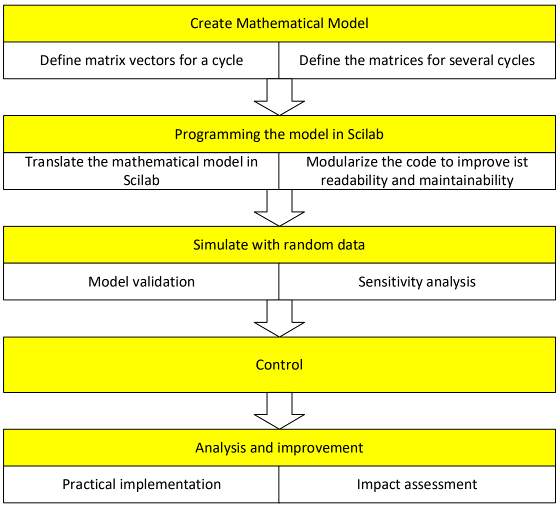

Figure 1: Methodology

2.1 Create Mathematical Model

A mathematical model based on matrices is proposed. Matrices are fundamental tools in various scientific disciplines and allow for the representation and solution of a wide range of problems. In this context, the chosen approach involves the development of a matrix system that captures the interactions and relationships between the relevant variables of the problem at hand [27]. This model would provide a framework for exploring and evaluating potential approaches. In addition, the flexibility and adaptability of the matrices would allow the model to be adapted to the specific needs of the problem and the constraints of the environment. The proposed model is:
Where n_f is the final number of elements for all the matrices in the model.

Where each element P_i represents the energy production of category i for one cycle.

$$P_{\text{i}} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ \vdots \\ i \\ \vdots \\ n_f \end{array} \begin{array}{c} 1 \\ \begin{bmatrix} p_{1,1} \\ p_{2,1} \\ p_{3,1} \\ \cdots \\ p_{i,1} \\ \cdots \\ p_{n_f,1} \end{bmatrix} \end{array} \quad (1)$$

Let be a matrix $cost_{p_i}$ of size $n\ x\ m$, where n represents the cost of the product for one cycle.

$$cost_{p_i} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ \vdots \\ i \\ \vdots \\ n_f \end{array} \begin{array}{c} 1 \\ \begin{bmatrix} mp_{1,1} \\ mp_{2,1} \\ mp_{3,1} \\ \cdots \\ mp_{i,1} \\ \cdots \\ mp_{n_f,1} \end{bmatrix} \end{array} \quad (2)$$

The matrix $t, inicial_{p_i}$ would represent the initial time for one cycle:

$$t, inicial_{p_i} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ \vdots \\ i \\ \vdots \\ n_f \end{array} \begin{array}{c} 1 \\ \begin{bmatrix} np_{1,1} \\ np_{2,1} \\ np_{3,1} \\ \cdots \\ np_{i,1} \\ \cdots \\ np_{n_f,1} \end{bmatrix} \end{array} \quad (3)$$

The matrix $t, final_{p_i}$ would represent the final time for one cycle:

$$t, final_{p_i} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ \vdots \\ i \\ \vdots \\ n_f \end{array} \begin{array}{c} 1 \\ \begin{bmatrix} tkp_{1,1} \\ tkp_{2,1} \\ tkp_{3,1} \\ \cdots \\ tkp_{i,1} \\ \cdots \\ tkp_{n_f,1} \end{bmatrix} \end{array} \quad (4)$$

Where each element C_i represents the energy production of the category i for one cycle

$$C_{\text{i}} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ \vdots \\ i \\ \vdots \\ n_f \end{array} \begin{array}{c} 1 \\ \begin{bmatrix} f_{1,1} \\ f_{2,1} \\ f_{3,1} \\ \cdots \\ f_{i,1} \\ \cdots \\ f_{n_f,1} \end{bmatrix} \end{array} \quad (5)$$

Let be a matrix $cost_{c_i}$ of size $n\ x\ m$, where n represents the cost for product for one cycle.

$$cost_{c_i} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ \vdots \\ i \\ \vdots \\ n_f \end{array} \begin{array}{c} 1 \\ \begin{bmatrix} mf_{1,1} \\ mf_{2,1} \\ mf_{3,1} \\ \cdots \\ mf_{i,1} \\ \cdots \\ mf_{n_f,1} \end{bmatrix} \end{array} \quad (6)$$

The matrix $t, inicial_{c_i}$ would represent the initial time for one cycle:

$$t, inicial_{c_i} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ \vdots \\ i \\ \vdots \\ n_f \end{array} \begin{array}{c} 1 \\ \begin{bmatrix} nf_{1,1} \\ nf_{2,1} \\ nf_{3,1} \\ \cdots \\ nf_{i,1} \\ \cdots \\ nf_{n_f,1} \end{bmatrix} \end{array} \quad (7)$$

The matrix $t, final_{c_i}$ would represent the final time for one cycle:

$$t, final_{c_i} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ \vdots \\ i \\ \vdots \\ n_f \end{array} \begin{array}{c} 1 \\ \begin{bmatrix} tkf_{1,1} \\ tkf_{2,1} \\ tkf_{3,1} \\ \cdots \\ tkf_{i,1} \\ \cdots \\ tkf_{n_f,1} \end{bmatrix} \end{array} \quad (8)$$

Where each element P_{i^*,j^*} represents the energy production of category i^* at bar j^*

$$P_{i^*,j^*} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ \vdots \\ i \\ \vdots \\ n_f \end{array} \begin{array}{c} \begin{array}{ccccc} 1 & 2 & 3 & j & n_f \end{array} \\ \begin{bmatrix} p_{1,1} & p_{1,2} & p_{1,3} & p_{1,j} & p_{1,n_f} \\ p_{2,1} & p_{2,2} & p_{2,3} & p_{2,j} & p_{2,n_f} \\ p_{3,1} & p_{3,2} & p_{3,3} & p_{3,j} & p_{3,n_f} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ p_{i,1} & p_{i,2} & p_{i,3} & p_{i,j} & p_{i,n_f} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ p_{n_f,1} & p_{n_f,2} & p_{n_f,3} & p_{n_f,j} & p_{n_f,n_f} \end{bmatrix} \end{array} \quad (9)$$

The matrix $COST_{p_{i,j}}$ of size $n_p\ x\ \text{n}_{\text{cycle}}$, where n represents the cost of one product in j. cycle in time.

$$COST_{p_{i,j}} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ \vdots \\ i \\ \vdots \\ n_f \end{array} \begin{array}{c} \begin{array}{ccccc} 1 & 2 & 3 & j & n_f \end{array} \\ \begin{bmatrix} cost_{p_{1,1}} & cost_{p_{1,2}} & cost_{p_{1,3}} & cost_{p_{1,j}} & cost_{p_{1,n_f}} \\ cost_{p_{2,1}} & cost_{p_{2,2}} & cost_{p_{2,3}} & cost_{p_{2,j}} & cost_{p_{2,n_f}} \\ cost_{p_{3,1}} & cost_{p_{3,2}} & cost_{p_{3,3}} & cost_{p_{3,j}} & cost_{p_{3,n_f}} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ cost_{p_{i,1}} & cost_{p_{i,2}} & cost_{p_{i,3}} & cost_{p_{i,j}} & cost_{p_{i,n_f}} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ cost_{p_{n_f,1}} & cost_{p_{n_f,2}} & cost_{p_{n_f,3}} & cost_{p_{n_f,j}} & cost_{p_{n_f,n_f}} \end{bmatrix} \end{array} \quad (10)$$

The matrix $INT_{p_{i,j}}$ would represent the i intensity for the source for j cycle:

$$INT_{p_{i,j}} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ \vdots \\ i \\ \vdots \\ n_f \end{array} \begin{array}{c} \begin{array}{ccccc} 1 & 2 & 3 & j & n_f \end{array} \\ \begin{bmatrix} int_{p_{1,1}} & int_{p_{1,2}} & int_{p_{1,3}} & int_{p_{1,j}} & int_{p_{1,n_f}} \\ int_{p_{2,1}} & int_{p_{2,2}} & int_{p_{2,3}} & int_{p_{2,j}} & int_{p_{2,n_f}} \\ int_{p_{3,1}} & int_{p_{3,2}} & int_{p_{3,3}} & int_{p_{3,j}} & int_{p_{3,n_f}} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ int_{p_{i,1}} & int_{p_{i,2}} & int_{p_{i,3}} & int_{p_{i,j}} & int_{p_{i,n_f}} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ int_{p_{n_f,1}} & int_{p_{n_f,2}} & int_{p_{n_f,3}} & int_{p_{n_f,j}} & int_{p_{n_f,n_f}} \end{bmatrix} \end{array} \quad (11)$$

The matrix $tInicial_{p_{i,j}}$ would represent the initial time i for the source for j cycle:

$$tInicial_{p_{i,j}} = \begin{matrix} & 1 & 2 & 3 & j & n_f \\ 1 & t_{i,p_{1,1}} & t_{i,p_{1,2}} & t_{i,p_{1,3}} & t_{i,p_{1,j}} & t_{i,p_{1,n_f}} \\ 2 & t_{i,p_{2,1}} & t_{i,p_{2,2}} & t_{i,p_{2,3}} & t_{i,p_{2,j}} & t_{i,p_{2,n_f}} \\ 3 & t_{i,p_{3,1}} & t_{i,p_{3,2}} & t_{i,p_{3,3}} & t_{i,p_{3,j}} & t_{i,p_{3,n_f}} \\ \vdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ i & t_{i,p_{i,1}} & t_{i,p_{i,2}} & t_{i,p_{i,3}} & t_{i,p_{i,j}} & t_{i,p_{i,n_f}} \\ \vdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ n_f & t_{i,p_{n_f,1}} & t_{i,p_{n_f,2}} & t_{i,p_{n_f,3}} & t_{i,p_{n_f,j}} & t_{i,p_{n_f,n_f}} \end{matrix} \quad (12)$$

The matrix $tFinal_{p_{i,j}}$ would represent the final time i for the source for j cycle:

$$tFinal_{p_{i,j}} = \begin{matrix} & 1 & 2 & 3 & j & n_f \\ 1 & t_{f,p_{1,1}} & t_{f,p_{1,2}} & t_{f,p_{1,3}} & t_{f,p_{1,j}} & t_{f,p_{1,n_f}} \\ 2 & t_{f,p_{2,1}} & t_{f,p_{2,2}} & t_{f,p_{2,3}} & t_{f,p_{2,j}} & t_{f,p_{2,n_f}} \\ 3 & t_{f,p_{3,1}} & t_{f,p_{3,2}} & t_{f,p_{3,3}} & t_{f,p_{3,j}} & t_{f,p_{3,n_f}} \\ \vdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ i & t_{f,p_{i,1}} & t_{f,p_{i,2}} & t_{f,p_{i,3}} & t_{f,p_{i,j}} & t_{f,p_{i,n_f}} \\ \vdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ n_f & t_{f,p_{n_f,1}} & t_{f,p_{n_f,2}} & t_{f,p_{n_f,3}} & t_{f,p_{n_f,j}} & t_{f,p_{n_f,n_f}} \end{matrix} \quad (13)$$

Where each element C_{i^*,j^*} represents the energy consumption of category i^* at bar j^*

$$C_{i^*,j^*} = \begin{matrix} & 1 & 2 & 3 & j & n_f \\ 1 & c_{1,1} & c_{1,2} & c_{1,3} & c_{1,j} & c_{1,n_f} \\ 2 & c_{2,1} & c_{2,2} & c_{2,3} & c_{2,j} & c_{2,n_f} \\ 3 & c_{3,1} & c_{3,2} & c_{3,3} & c_{3,j} & c_{3,n_f} \\ \vdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ i & c_{i,1} & c_{i,2} & c_{i,3} & c_{i,j} & c_{i,n_f} \\ \vdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ n_f & c_{n_f,1} & c_{n_f,2} & c_{n_f,3} & c_{n_f,j} & c_{n_f,n_f} \end{matrix} \quad (14)$$

The matrix $\mathrm{COST}_{c_{i,j}}$ of size $n_p\ x\ \mathrm{n_{cycle}}$, where n represents the cost of one product in j. cycle in time.

$$\mathrm{COST}_{c_{i,j}} = \begin{matrix} & 1 & 2 & 3 & j & n_f \\ 1 & cost_{c_{1,1}} & cost_{c_{1,2}} & cost_{c_{1,3}} & cost_{c_{1,j}} & cost_{c_{1,n_f}} \\ 2 & cost_{c_{2,1}} & cost_{c_{2,2}} & cost_{c_{2,3}} & cost_{c_{2,j}} & cost_{c_{2,n_f}} \\ 3 & cost_{c_{3,1}} & cost_{c_{3,2}} & cost_{c_{3,3}} & cost_{c_{3,j}} & cost_{c_{3,n_f}} \\ \vdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ i & cost_{c_{i,1}} & cost_{c_{i,2}} & cost_{c_{i,3}} & cost_{c_{i,j}} & cost_{c_{i,n_f}} \\ \vdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ n_f & cost_{c_{n_f,1}} & cost_{c_{n_f,2}} & cost_{c_{n_f,3}} & cost_{c_{n_f,j}} & cost_{c_{n_f,n_f}} \end{matrix} \quad (15)$$

The matrix $INT_{c_{i,j}}$ would represent the i intensity for the source for j cycle:

$$INT_{c_{i,j}} = \begin{matrix} & 1 & 2 & 3 & j & n_f \\ 1 & int_{c_{1,1}} & int_{c_{1,2}} & int_{c_{1,3}} & int_{c_{1,j}} & int_{c_{1,n_f}} \\ 2 & int_{c_{2,1}} & int_{c_{2,2}} & int_{c_{2,3}} & int_{c_{2,j}} & int_{c_{2,n_f}} \\ 3 & int_{c_{3,1}} & int_{c_{3,2}} & int_{c_{3,3}} & int_{c_{3,j}} & int_{c_{3,n_f}} \\ \vdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ i & int_{c_{i,1}} & int_{c_{i,2}} & int_{c_{i,3}} & int_{c_{i,j}} & int_{c_{i,n_f}} \\ \vdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ n_f & int_{c_{n_f,1}} & int_{c_{n_f,2}} & int_{c_{n_f,3}} & int_{c_{n_f,j}} & int_{c_{n_f,n_f}} \end{matrix} \quad (16)$$

The matrix $tInitial_{c_{i,j}}$ would represent the initial time i for the source for j cycle:

$$tInitial_{c_{i,j}} = \begin{matrix} & 1 & 2 & 3 & j & n_f \\ 1 & t_{i,c_{1,1}} & t_{i,c_{1,2}} & t_{i,c_{1,3}} & t_{i,c_{1,j}} & t_{i,c_{1,n_f}} \\ 2 & t_{i,c_{2,1}} & t_{i,c_{2,2}} & t_{i,c_{2,3}} & t_{i,c_{2,j}} & t_{i,c_{2,n_f}} \\ 3 & t_{i,c_{3,1}} & t_{i,c_{3,2}} & t_{i,c_{3,3}} & t_{i,c_{3,j}} & t_{i,c_{3,n_f}} \\ \vdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ i & t_{i,c_{i,1}} & t_{i,c_{i,2}} & t_{i,c_{i,3}} & t_{i,c_{i,j}} & t_{i,c_{i,n_f}} \\ \vdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ n_f & t_{i,c_{n_f,1}} & t_{i,c_{n_f,2}} & t_{i,c_{n_f,3}} & t_{i,c_{n_f,j}} & t_{i,c_{n_f,n_f}} \end{matrix} \quad (17)$$

The matrix $tFinal_{c_{i,j}}$ would represent the final time i for the source for j cycle:

$$tFinal_{c_{i,j}} = \begin{matrix} & 1 & 2 & 3 & j & n_f \\ 1 & t_{f,c_{1,1}} & t_{f,c_{1,2}} & t_{f,c_{1,3}} & t_{f,c_{1,j}} & t_{f,c_{1,n_f}} \\ 2 & t_{f,c_{2,1}} & t_{f,c_{2,2}} & t_{f,c_{2,3}} & t_{f,c_{2,j}} & t_{f,c_{2,n_f}} \\ 3 & t_{f,c_{3,1}} & t_{f,c_{3,2}} & t_{f,c_{3,3}} & t_{f,c_{3,j}} & t_{f,c_{3,n_f}} \\ \vdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ i & t_{f,c_{i,1}} & t_{f,c_{i,2}} & t_{f,c_{i,3}} & t_{f,c_{i,j}} & t_{f,c_{i,n_f}} \\ \vdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ n_f & t_{f,c_{n_f,1}} & t_{f,c_{n_f,2}} & t_{f,c_{n_f,3}} & t_{f,c_{n_f,j}} & t_{f,c_{n_f,n_f}} \end{matrix} \quad (18)$$

2.1. The model in Scilab

Using Scilab for data modeling and analysis provides a robust and versatile platform for researchers and professionals in various scientific and technical fields. With its wide range of functions and numerical computing capabilities, Scilab becomes an invaluable tool for creating and analyzing complex mathematical models. This latest model developed in Scilab takes advantage of these features in a realistic approach to simulate and analyze a variety of scenarios. In addition, Scilab's visualization capabilities, such as the creation of bar graphs for the generated matrices, facilitate the interpretation and understanding of the results obtained. These features make Scilab a powerful tool for research and data analysis in scientific and technical environments. The code to represent the mathematical model is:

```
function generate_random_matrix(n, m):
   // Generate a random matrix between 0 and 100 as integers
   matrix = new matrix of size n x m
   for each row i in the matrix:
      for each column j in the matrix:
         matrix[i][j] = round(random_number() * 100)
   return matrix

// Size of the matrices
n_ = 3 // Number of producers
m = 3 // Cycles
// Generate all matrices from the model
P = generate_random_matrix(n_, m)
C = generate_random_matrix(n_, m)
COST_p = generate_random_matrix(n_, m)
```

```
T_INITIAL_p = generate_random_matrix(n_, m)
T_FINAL_p = generate_random_matrix(n_, m)
COST_c = generate_random_matrix(n_, m)
T_INITIAL_c = generate_random_matrix(n_, m)
T_FINAL_c = generate_random_matrix(n_, m)
INT_p = generate_random_matrix(n_, m)
INT_c = generate_random_matrix(n_, m)
// Show all generated matrices
print 'Matrix P:'
print P
print 'Matrix C:'
print C
print 'Matrix COST_p:'
print COST_p
print 'Matrix T_INITIAL_p:'
print T_INITIAL_p
print 'Matrix T_FINAL_p:'
print T_FINAL_p
print 'Matrix COST_c:'
print COST_c
print 'Matrix T_INITIAL_c:'
print T_INITIAL_c
print 'Matrix T_FINAL_c:'
print T_FINAL_c
print 'Matrix INT_p:'
print INT_p
print 'Matrix INT_c:'
print INT_c
// Create bar chart for matrix P
create_chart(P, 'Matrix P')
// Create bar chart for matrix C
create_chart(C, 'Matrix C')
```

The approach used to develop the methods in the code is a procedural approach. The code defines a function to generate random matrices and then calls this function to generate the matrices needed for the model. It also includes visualization steps to create bar graphs for the P and C matrices. Alternative methodological approaches that exist could include object-oriented programming paradigms where classes and objects are used to encapsulate data and methods related to the matrices. In addition, functional programming approaches could be used, where functions are treated as first-class priorities and operations are performed by function composition and higher-order functions. These approaches could provide different perspectives on how to structure and manipulate data and operations within the program.

3. Results and Discussion

In the context of this study, a computational approach using the Scilab programming language is used for data generation and analysis. The following code in Scilab is used to enter the results obtained under the appropriate heading. The `generate_random_matrix' function is used to generate random matrices of predefined dimensions representing different parameters of the model. The generated matrices are then displayed with relevant information such as associated costs, start and end times, and other relevant variables. In addition, bar charts are presented to better visualize the data contained in the P and C matrices in relation to the categories and the corresponding energy. This computational approach provides a solid basis for detailed analysis of the results and their interpretation. Presentation and interpretation of results, presentation of limitations and generality of results.

3.1. Errors encountered

The difficulties and errors encountered with the AI-generated codes were as follows:

1. Random matrix generation error: An error indicated that a scalar was expected as an input argument to the `rand' function, but a matrix was provided instead. This was due to improper use of the `rand' function. The workaround was to correct the `rand` function call to properly generate random matrices.
2. Visualization of matrices in the console: Initially, the generated matrices were not displayed in the console, making it difficult to verify the results. The solution was to add the `disp` function to display the generated matrices in the console.

These solutions successfully addressed the identified problems and improved the readability and usefulness of the generated code.

3.2. Improvements

The code provided had several bugs and areas for improvement. Below is a detailed comparison between the original code and the suggested improvements:

The bugs and improvements in the provided code:

3. Matrix definition: The matrices `P' and `C' were not defined correctly and their dimensions did not match the provided model.
4. Random matrix generation: Matrices `P' and `C' were incorrectly generated using `rand(n, m) * 100', resulting in an error due to incorrect argument size. This has been fixed by removing the multiplication by 100.
5. Matrix visualization: Generated matrices were not displayed in the console for verification, making code debugging difficult. The `disp` function has been added to display them.

The bugs and improvements in the proposed code:

1. Matrix definition: The dimensions of the matrices ` COST_p', ` INT_p', ` T_INITIAL_p' and ` T_FINAL_p' were set correctly according to the provided model.

2. Random matrix generation: Random matrices were correctly generated with the `rand(np, ncycle)` function.
3. Construction of matrices according to the model: The matrices ` COST_p', ` INT_p', ` T_INITIAL_p' and ` T_FINAL_p' were constructed correctly according to the given model in the `for' loop.
4. Matrix visualization: The `disp' function was used to display the generated matrices in the console.
5. Data plotting: A section has been added to plot the data of each matrix column by column for better visualization.

3.3. Example to verify and validate my methodology

The following is a simple example of different energy producing sources and their consumers, based on the data provided and the answer obtained in the Scilab software. The number is randomly generated. In the next research step, the method for determining the numbers will be created.

Matrix P:

$$P = \begin{bmatrix} 65 & 75 & 85 \\ 99 & 41 & 6 \\ 5 & 61 & 83 \end{bmatrix} \tag{19}$$

Matrix C:

$$C = \begin{bmatrix} 93 & 82 & 12 \\ 57 & 6 & 73 \\ 57 & 56 & 27 \end{bmatrix} \tag{20}$$

Matrix COST_p:

$$COST_p = \begin{bmatrix} 55 & 0 & 26 \\ 99 & 59 & 63 \\ 74 & 31 & 12 \end{bmatrix} \tag{21}$$

Matrix T_INITIAL_p:

$$T\_INITIAL\_p = \begin{bmatrix} 61 & 3 & 24 \\ 68 & 52 & 51 \\ 33 & 39 & 42 \end{bmatrix} \tag{22}$$

Matrix T_FINAL_p:

$$T\_FINAL\_p = \begin{bmatrix} 29 & 35 & 29 \\ 9 & 71 & 65 \\ 62 & 52 & 9 \end{bmatrix} \tag{23}$$

Matrix INT_p:

$$INT\_p = \begin{bmatrix} 45 & 24 & 51 \\ 72 & 43 & 52 \\ 90 & 97 & 56 \end{bmatrix} \tag{24}$$

Matrix T_INITIAL_c:

$$T\_INITIAL\_c = \begin{bmatrix} 56 & 79 & 43 \\ 47 & 98 & 25 \\ 78 & 82 & 92 \end{bmatrix} \tag{25}$$

Matrix T_FINAL_c:

$$T\_FINAL\_c = \begin{bmatrix} 10 & 4 & 61 \\ 47 & 52 & 19 \\ 40 & 83 & 2 \end{bmatrix} \tag{26}$$

Matrix COST_c:

$$COST\_c = \begin{bmatrix} 84 & 1 & 75 \\ 7 & 19 & 94 \\ 85 & 49 & 21 \end{bmatrix} \tag{27}$$

Matrix INT_c:

$$INT\_c = \begin{bmatrix} 58 & 91 & 26 \\ 26 & 81 & 41 \\ 44 & 81 & 36 \end{bmatrix} \tag{28}$$

These matrices likely represent a system where energy is produced and consumed by different entities, and the values within these matrices are used to model and analyze different aspects of this energy system, such as costs, time, and intensities. The matrices provide a rich dataset for further analysis using the Scilab software.

4. Limitations and Conclusion

Conclusions:

The presented model provides a comprehensive representation of energy producing sources and their consumers, accompanied by various associated parameters, including costs, production, consumption times, and interruptions. By using the matrices provided, one can gain deeper insights into the dynamics of energy production and consumption within a given system. In addition:

- The suggested AI code improves the clarity and accuracy of the provided model implementation.
- Bugs in the original code have been fixed and improvements have been made to allow better visualization of the generated data.
- A dedicated section for plotting the data of each matrix has been included, which improves the understanding of the results.

Limitations:

Despite its utility, the model has certain limitations that require attention to strengthen its applicability. Notable limitations include:

- The simplicity of the model may overlook nuances inherent in real-world energy systems.
- External factors such as demand fluctuations or environmental changes are not considered.
- Variability in the accuracy of the data provided could affect the validity of the model.

Possible Future Research:

To refine the model and optimize its practical utility, future research could explore the following avenues:

- Integration of additional variables and parameters to more accurately reflect the complexity of energy systems.

- Validate the model against authentic data sets, coupled with comparative analyses against alternative methodologies to assess effectiveness and accuracy.
- Explore the applicability of the model in different contexts and sectors, ranging from energy management in buildings and industrial facilities to power distribution networks.

5. References

[1] C.R, V. and J. John, Reflections on solar energy adoption research: a semi-systematic review. International Journal of Energy Sector Management, 2024. ahead-of-print(ahead-of-print).

[2] Chen, C., R. Qiu, and X. Hu, The Location-Routing Problem with Full Truckloads in Low-Carbon Supply Chain Network Designing. Mathematical Problems in Engineering, 2018: p. 21.

[3] Perotti, S. and C. Colicchia, Greening warehouses through energy efficiency and environmental impact reduction: a conceptual framework based on a systematic literature review. The International Journal of Logistics Management, 2023. 34 (7): p. 199-234.

[4] Obrecht, M., R. Singh, and T. Zorman, Conceptualizing a new circular economy feature – storing renewable electricity in batteries beyond EV end-of-life: the case of Slovenia. International Journal of Productivity and Performance Management, 2022. 71 (3): p. 896-911.

[5] Järvenpää, A.M., et al. Data-Driven Management of Material Flows in Circular Economy by Logistics Optimization. in Springer Proceedings in Complexity. 2023. Springer Science and Business Media B.V.

[6] Vimpolšek, B. and A. Lisec, CATWOOD – REVERSE LOGISTICS PROCESS MODEL FOR QUANTITATIVE ASSESSMENT OF RECOVERED WOOD MANAGEMENT. Promet - Traffic and Transportation, 2022. 34 (6): p. 881-892.

[7] Barykin, S.Y., et al., Algorithmic foundations of economic and mathematical modeling of network logistics processes. Journal of Open Innovation: Technology, Market, and Complexity, 2020. 6 (4): p. 1-16.

[8] Li, H., et al. A Survey of General Ontologies for the Cross-Industry Domain of Circular Economy. in ACM Web Conference 2023 - Companion of the World Wide Web Conference, WWW 2023. 2023. Association for Computing Machinery, Inc.

[9] Sathkumara, T.M., A.S. Waidyasekara, and H.C. Victar, The feasibility of transparent solar panels for high-rise building façade in Sri Lanka. Construction Innovation, 2023. ahead-of-print(ahead-of-print).

[10] Hackbarth, A., T. Tremml, and S. Löbbe, Preferences for service bundles in the energy sector – a survey of German private households. International Journal of Energy Sector Management, 2022. 16 (6): p. 1214-1239.

[11] Charters, B., T. Heffernan, and M. Daly, When individual action requires collective approval: a roadmap for solar power adoption by strata property owners. Journal of Social Marketing, 2023. 13 (1): p. 100-120.

[12] Cao, J., P. Zhao, and G. Liu, Optimizing the production process of modular construction using an assembly line-integrated supermarket. Automation in Construction, 2022. 142.

[13] Bulat, A., et al., Solution of the problem to optimize two-stage allocation of the material flows. Mining of Mineral Deposits, 2020. 14 (1): p. 27-35.

[14] Bátorfi, J.G., M. Andó, and J.J. Sidor, Analytical Model for the Material Flow during Cold Rolling. Acta Polytechnica Hungarica, 2023. 20 (2).

[15] Zanghi, E., M. Brown Do Coutto Filho, and J.C. Stacchini de Souza, Collaborative smart energy metering system inspired by blockchain technology. International Journal of Innovation Science, 2024. 16 (2): p. 227-243.

[16] Monek, G.D. and S.J.I. Fischer, IIoT-supported manufacturing-material-flow tracking in a DES-based digital-twin environment. 2023. 8 (4): p. 75.

[17] Bohács, G. and A. Rinkács, Development of a novel material flow simulation model for the integration of spatial and process relevant information. Logistics Journal, 2016. 2016 (04).

[18] Yassin, A.M.M., M.A. Hassan, and H.M. Elmesmary, Key elements of green supply chain management drivers and barriers empirical study of solar energy companies in South Egypt. International Journal of Energy Sector Management, 2022. 16 (3): p. 564-584.

[19] Usmonov, J., et al. Modeling of cargo flow processes in the logistics of the transport system. in E3S Web of Conferences. 2023. EDP Sciences.

[20] Didenko, N., et al., The impact of digital transformation on the micrologistic system, and the open innovation in logistics. Journal of Open Innovation: Technology, Market, and Complexity, 2021. 7 (2).

[21] Pourmehdi, M., M.M. Paydar, and E. Asadi-Gangraj, Scenario-based design of a steel sustainable closed-loop supply chain network considering production technology. Journal of Cleaner Production, 2020. 277.

[22] Madera, A.G., Optimization of Manufacturing Processes and of Systems Under the Conditions of Uncertainty. ARPN Journal of Engineering and Applied Sciences, 2020. 15 (2): p. 548-558.

[23] Vojtov, V., et al., Modeling of reliability of logistic systems of urban freight transportation taking into account street congestion. Eastern-European Journal of Enterprise Technologies, 2019. 4 (3-100): p. 15-21.

[24] Alborov, I.D., Y.S. Petrov, and I.Y. Zorina, Principles of energy supply of mining enterprises using natural energy resources of mountain provinces. Mining Informational and Analytical Bulletin, 2018. 2018 (7): p. 196-204.

[25] Barykin, S., et al. Digital Logistics Approach to Energy Service Socio-economic Mechanisms. in Transportation Research Procedia. 2021. Elsevier B.V.

[26] Kragelj, D., et al., Discrete event simulation of distributed energy supply systems. Elektrotehniski Vestnik/Electrotechnical Review, 2019. 86 (4): p. 185-191.

[27] Gonzalez Cabrera, E., B. Illés, and Á. Cservenák, Modelling and optimizing material flows in electrical energy distribution–first model. Advanced Logistic Systems-Theory and Practice, 2023. 17 (4): p. 51-57.