Enhancing Fiscal Governance through Network Graphs

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Introduction

The National Budget (henceforth “the Budget”) is the clearest expression of any government’s socio-economic development agenda, a crucial tool for development by effectively allocating scarce resources to the most optimum uses, consequently fulfilling the socio-economic objectives and augmenting human development (Boncodin, 2008, as cited in Department of Budget and Management [DBM], 2016). Planning, directing, and controlling the Budget through public financial management (PFM) is essential to enabling and influencing the efficient and effective delivery of these goals. (The Chartered Institute of Public Finance and Accountancy [CIPFA], 2010), ensuring that such a system achieves aggregate fiscal discipline, allocative, and operational efficiency (Schick, 1998). Hence, a good PFM is critical for good governance, ensuring transparency, accountability, and efficient allocation of public resources.

Maintaining budget integrity ensures that public funds are utilized correctly and in line with citizen interests. Thus, budgets must be credible, and the expenditures should align with those authorized in the approved Budget (Public Expenditure and Financial Accountability Secretariat, 2011). Additionally, the data in fiscal and financial reports must be accurate, consistent, easily comparable to the Budget, and verified independently to be trustworthy (International Monetary Fund, 2015). Government spending should faithfully reflect the Budget sanctioned by Congress and remain truthful to the citizenry. Government managers rely on timely, precise, and consistent reporting of the utilization of public funds about the approved Budget to ensure expenditures conform to budgetary plans, address deviations in actual spending from the Budget, and confirm to citizens that they are using their taxes appropriately. Thus, budget integrity is vital for fostering accountability; it allows oversight bodies—such as the Commission on Audit and Congress—and the public to hold governmental institutions accountable for public funds' reasonable and practical use. This accountability framework establishes a solid foundation for proficient and effective public financial management, enhancing public trust in the PFM system and the government (DBM, 2012; International Budget Partnership, 2015).

Problem Statement

Efficient budget monitoring and management are vital for organizational financial stability, resource allocation optimization, and accountability. Traditional methods often need more visual representation and capture expense relationships, leading to decision-making inefficiencies and resource waste. As obligations grow in complexity and size, manual tracking becomes more difficult.

Innovative budget monitoring is necessary to address these issues, transcending conventional approaches. Such a mechanism may utilize network graph analysis to visually represent budget allocations, expenditures, and interdependencies among line items. Network graphs enable organizations to gain deeper insights into budget dynamics, identify inefficiencies, and make informed decisions, enhancing financial accountability and performance.

Project Overview

Graph data structures, comprising nodes connected by edges, offer a robust framework for representing and analyzing complex relationships between objects. Graph structures are widely utilized in various fields, such as social network analysis, recommendation systems, and computer networks (GeeksforGeeks, 2023), particularly promising for revolutionizing budget management.

This project demonstrates the application of network graphs in budget management, utilizing financial data from the Department of Human Settlements and Urban Development - National Capital Regional Office (DHSUD-NCR) for the fiscal year (FY) 2023. The graph structurally represents budget line items as nodes, with edges depicting their relationships. The following is the algorithm used to address the problem statement:

1. Project Setup
2. Prepare the Dataset
3. Prepare the node and edge data

4. Draw network graph with Networkx and Pyvis
5. Refine visualization and configuration
6. Perform analysis and derive insights

By leveraging insights from the graph, stakeholders gain the necessary tools to monitor spending, identify areas of overspending and underspending, and make informed decisions to implement cost-saving measures to achieve organizational objectives. This implementation aligns with the broader goals of PFM, thereby contributing to strengthened accountability and transparency.

Python Programming Log

Access to the project and its screencast is available through the following links: Pair-22-Code.ipynb and Pair-22-Video, respectively.

Project Setup

We install Pyvis for interactive graph visualization, import necessary libraries for effective graph rendering, and mount Google Drive to access the Excel file. Additionally, we define a function to convert the Network object into HTML for display.

Prepare the Dataset

We utilize the Financial Accountability Report of DHSUD-NCR for FY 2023. We import the cleaned data as a Pandas DataFrame and introduce a new column titled 'abs_variance,' which computes the absolute variance between the Authorized Appropriations (initial budget) and Obligations (actual expenditure), reflecting discrepancies.

Table 1

First 5 rows of Financial Accountability Report for FY 2023

	Parent	Child	Authorized Appropriations	Adjustments	Obligations	Variance	abs_variance
0	Expenses	Personnel Services	40411000	-1947134.16	38463865.84	1947134.16	1947134.16
1	Personnel Services	Salaries and Wages	31383000	-3866393.70	27516606.30	3866393.70	3866393.70
2	Salaries and Wages	Basic Salary	31383000	-3866393.70	27516606.30	3866393.70	3866393.70
3	Personnel Services	Other Compensation	8128000	1118089.13	9246089.13	-1118089.13	1118089.13
4	Other Compensation	Personnel Economic Relief Assistance (PERA)	1320000	-46810.17	1273189.83	46810.17	46810.17

Prepare the Node and Edge Data

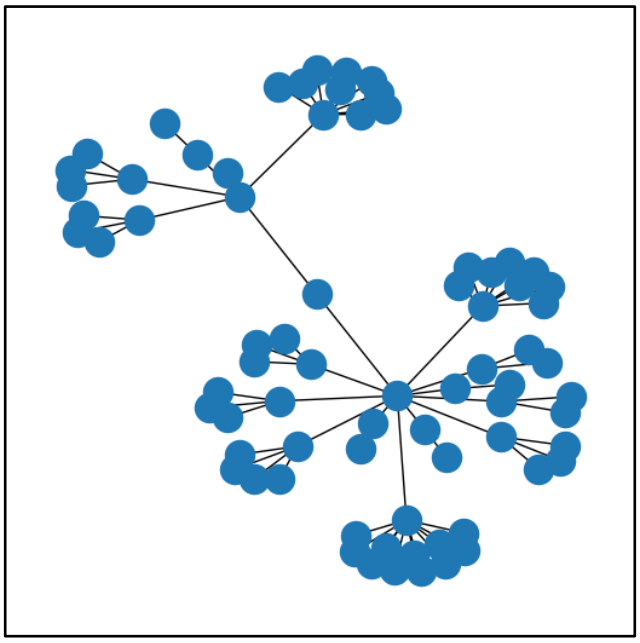
We create a network graph 'G' from the DataFrame using the 'from_pandas_edgelist' method. The 'source' and 'target' parameters specify the column names in the DataFrame representing each edge's source and target nodes, respectively. Then, we verify accuracy by retrieving the first five nodes and edges.

Draw Network Graph with Networkx and Pyvis

We set up a plot to specify the figure size and draw a graph using Networkx. However, the resulting layout lacks aesthetic appeal and intuitive parameters for analysis.

Figure 1

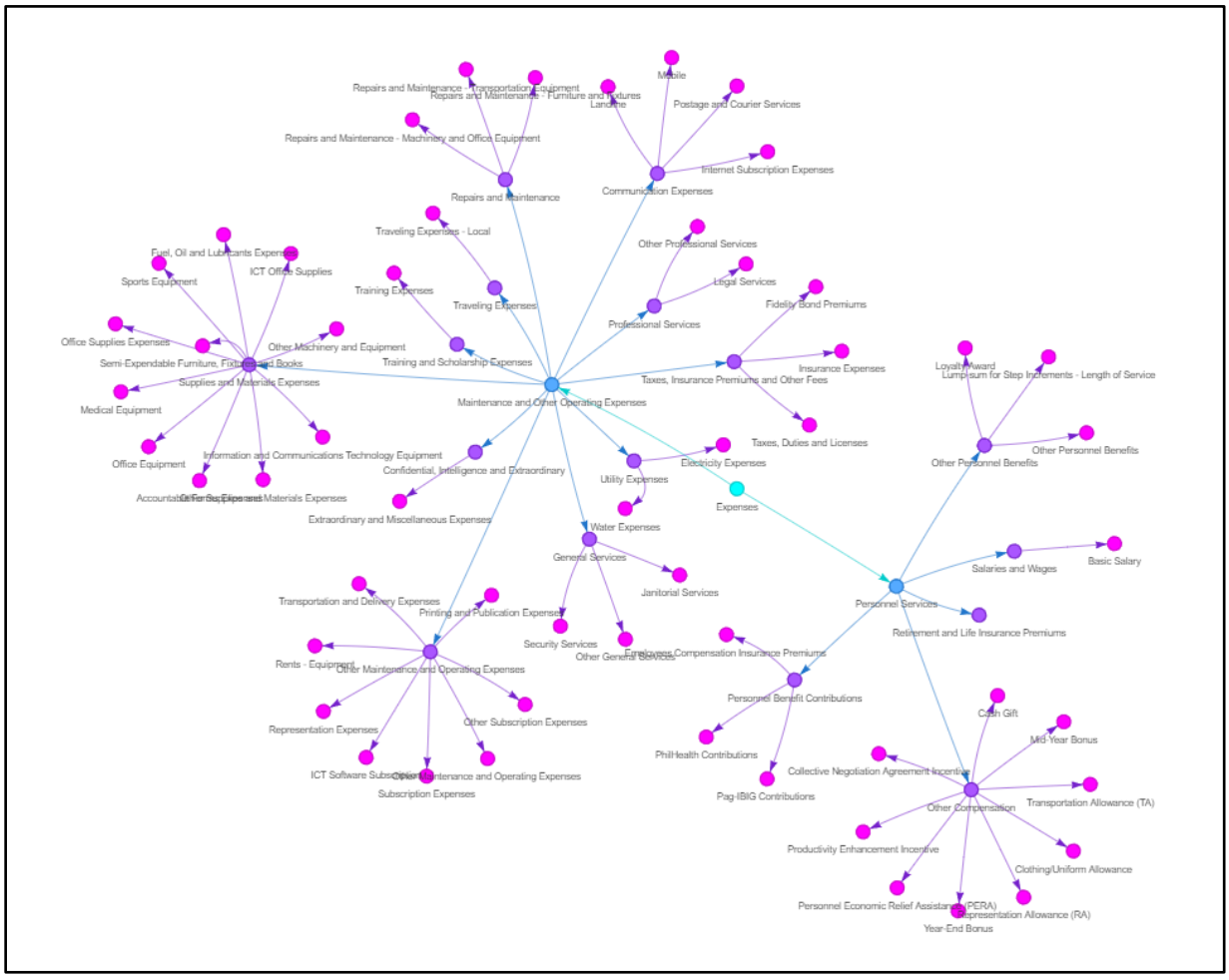
Generated graph using the default layout of Networkx



To address this issue, we visualize the network graph with Pyvis. We define the function 'show_graph' to visualize the graph, with nodes color-coded based on their shortest path lengths from the 'Expenses' node. A Pyvis network object gets instantiated with specific attributes. Then, we convert the Networkx graph 'G' into a Pyvis network using the 'from_nx()' method. The function iterates over each node in the Pyvis network, retrieves the corresponding shortest path length from the previously calculated dictionary of shortest paths, computes color for each node, converts it to hexadecimal format using the 'rgb2hex()' function, assigns the calculated color to the color attribute of the node. Finally, the visualization is saved to an HTML file using the 'show()' method and displayed using the 'display()' function.

Figure 3

Generated graph using Pyvis with specified attributes

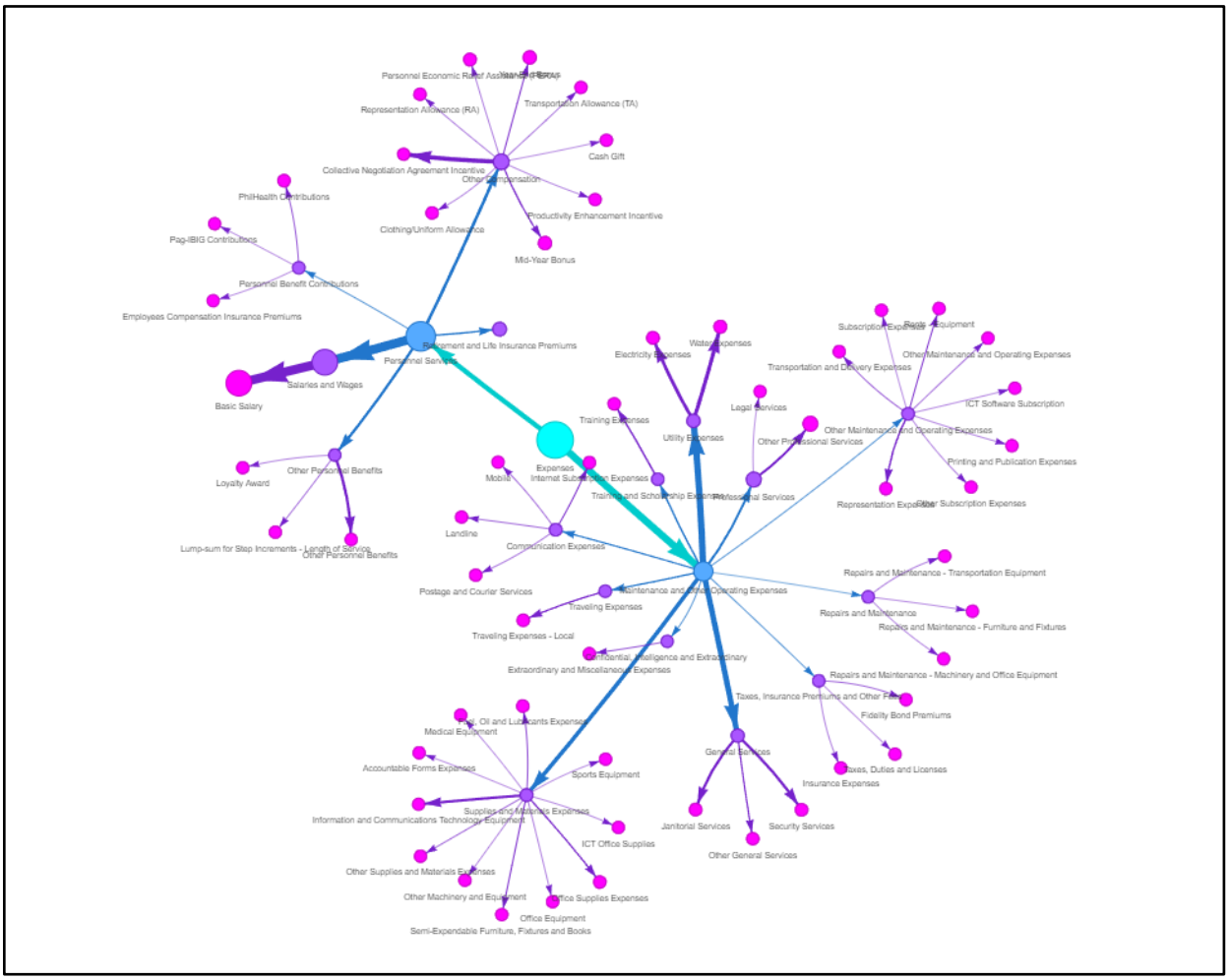


Refine Visualization and Configuration

Setting node and edge attributes is paramount to conveying vital analysis information. We begin by creating dictionaries that contain relevant node details, including absolute variances and information on Authorized Appropriations, Adjustments, and Obligations. Subsequently, we generate title information for each node and build a dictionary to store the edge attributes. Finally, we apply node and edge attributes accordingly before displaying the graph visualization.

Figure 4

Node size dynamically reflects authorized appropriation, while edge width adapts to adjustments made



Perform analysis and derive insights

The graph provides a comprehensive overview of Expenses appropriated and obligated throughout FY 2023, offering valuable insights into financial dynamics. Node sizes correspond to the Approved Appropriations, visually representing the magnitude of each category's allocation. Edge width indicates the variance between appropriations and obligations, highlighting adjustments made over time.

The largest node, 'Expenses,' encompasses all line item allocations. Within this category, 'Personnel Services' (PS) and 'Maintenance and Other Operating Expenses' (MOOE) emerge as subclasses, each branching into various groups and objects. The 'Basic Salary' within PS stands out, indicating a significant allocation towards compensating employees and underscoring their role in fulfilling agency objectives. Additionally, 'Other Professional Services' receives substantial funding, reflecting a reliance on Contract of Service Personnel to supplement the workforce.

Hovering each node reveals essential details, enhancing the viewer's understanding of the fiscal landscape. Edge width, dynamically adjusted to represent the absolute variance between appropriation and obligation, serves as a gauge of PFM agility and adaptability. 'Basic Salary' exhibits the most significant adjustment, reflecting fluidity in meeting personal needs. 'Utility Expenses' and 'General Services Expenses' also reflect operational requirements and resource allocation strategies.

Conclusion

The network graph offers invaluable insights into funding distribution and adjustments to meet agency needs, revealing priorities and areas of significant expenditure variance. This understanding is pivotal for strategic financial planning, resource allocation, and decision-making, enhancing efficiency and accountability in budget management.

By leveraging insights from the graph, government agencies can make informed decisions when formulating future budget proposals. Visual representations of node sizes and edge widths

clearly understand line items receiving substantial appropriations and adjustments, guiding effective resource allocation.

Detailed breakdowns of expense categories and their subclasses help agencies identify priority areas for resource allocation. For instance, if underspending is evident in a particular line item, agencies can reallocate resources to meet operational needs more effectively.

Furthermore, accessing specific details on Approved Appropriations, Adjustments, and Obligations by hovering over each node gives agencies a detailed understanding of expenditure patterns. This transparency fosters accountability and enables agencies to justify budget allocations based on concrete data.

Incorporating insights from the network graph into budget proposals enhances their accuracy and relevance, ensuring alignment with organizational goals. By leveraging data-driven insights, agencies can streamline budgeting processes, optimize resource allocation, and improve fiscal management practices for the benefit of stakeholders and constituents.

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