Research on the Optimal Promotion Path of Government Procurement Suppliers Based on Knowledge Graphs

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Abstract. Government procurement is an important form of support for enterprise development. In China, there are a large number of suppliers involved in government procurement, and the transaction data is large and diverse. For platforms that provide contract financing services to suppliers in government procurement, how to utilize this data to better achieve the promotion of target customers is an important issue. Knowledge graph, as a technology for organizing and presenting knowledge, has advantages such as efficient knowledge organization and improved data quality. In order to solve the service promotion needs of the financing service platform, this paper pooled data from multiple parties and proposed a government procurement supplier relational knowledge graph construction method after processing and analyzing the data. Furthermore, this paper also designs the optimal promotion path for the financing service platform to reach the target suppliers on the basis of the constructed knowledge graph. The experimental results prove that the optimal promotion path promotion method proposed in this paper has a greater improvement in the application effect than the original direct contact promotion method of the platform.

Keywords: government procurement contract financing, service promotion, relational knowledge graph, Neo4j, optimal paths

1 Introduction

In recent years, the role of government procurement in supporting the development of small and medium-sized enterprises has become more and more prominent, in order to solve the problem of the shortage of funds of government procurement suppliers, a new type of financing service platform for the original shortcomings of the financing of government procurement contracts have been improved [1]. So that suppliers, especially small and medium-sized enterprises can enjoy the unsecured, low-interest rate, simple and fast financing services with just a government procurement contract, which solves the problem of difficult, slow, and expensive financing for suppliers of government procurement.

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However, the promotion method of direct contact by telephone of the financing service platform has problems such as poor promotion effect and low telephone connection rate, and the good platform and good service are far from being known by the majority of suppliers. In order to solve the service promotion problem of such platforms and the application demand of data visualization, this paper takes a government procurement contract financing service platform (hereinafter referred to as the platform) as an example for research.

As shown in Fig. 1, in the process of government procurement and new type of contract financing, a large number of business dealings between the winning enterprise and the purchaser, the bidding agency, the platform, and the commercial bank form the basis of their relationship.

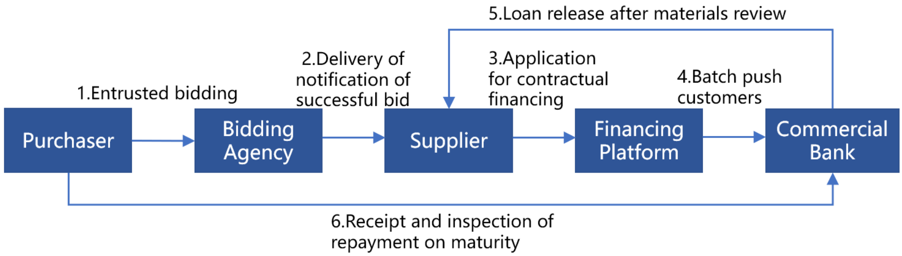

Fig. 1. Flowchart of Government Procurement and New Type of Contract Financing

In this paper, government procurement data, enterprise industrial and commercial data and business data of platform are fused to form structured data objects after processing through data cleaning and knowledge extraction. The entities in the government procurement and contract financing process are abstracted as nodes, the frequent business transactions between entities are abstracted as relationships between nodes, and the whole process is abstracted as a data graph model. At this point, the complex relationship search can be converted to path search in the data graph. With the advantage of path finding, the financing service platform can reach the target suppliers through the trusted node-to-node contact, and its promotion effect is much better than the promotion method of direct contact by platform phone.

2 Related Work

In the application of government procurement knowledge mapping for public resource transactions, Liu Lu [2] introduced government procurement knowledge mapping technology in the Q&A service of a government procurement e-enabled system platform and combined it with natural language processing technology and deep learning methods to realize intelligent Q&A service for government procurement. Zou Biao [3] used knowledge graph for government procurement and bidding audit, through the knowledge graph to quickly retrieve the association relationship between bidding individuals and enterprises, to determine whether there is the existence of bid-rigging behavior suspected. Peng Huai [4] and others use the improved seven-step method to construct an ontology library of government procurement information, propose a base entity extraction method based on the BERT-BiGRU-ATT-MRC model, and on this basis propose an automatic question and answer method based on knowledge graph for procurement information.

However, the fusion of multi-party data and the application of path query in knowledge graphs have not been emphasized. Therefore, it is necessary to conduct more in-depth research on government procurement data to explore the construction of knowledge graph and its application in specific financial scenarios to improve the practicality of the research.

3 Construction of a Knowledge Map

3.1 Source of Data

The data source of this paper is provided by a government procurement contract financing service platform, the relevant tables stored in its internal relational database and its parent company, a credit bureau to provide the supplier information data query interface. Includes the following sections: a. The full amount of data on government procurement in a province accessed by the platform database, including contract data tables, tables of tender award notices, tables of successful tenders, tables of administrative divisions of purchasers, and so on. b. Business data of the platform, including supplier registration information sheet, supplier financing application information sheet, partner information sheet, financial institution push data sheet, etc. c. The main body information of the bidding agency and the main body information and relationship information of the suppliers (including enterprise legal person information, enterprise shareholder information, and enterprise supervisor information) exported through the supplier information query interface.

3.2 Design and Implementation of Knowledge Graph

Currently, there are two main ways of constructing knowledge graph: top-down and bottom-up [5,6]. The top-down construction method requires the definition of a Schema (or called Ontology), and then based on the input data to complete the process of knowledge extraction to the construction of the map. This approach is more suitable for the construction of professional knowledge maps for users in specialized fields. The knowledge graph constructed in this paper adopts the top-down construction method. The architecture of the knowledge graph is shown in Fig. 2.

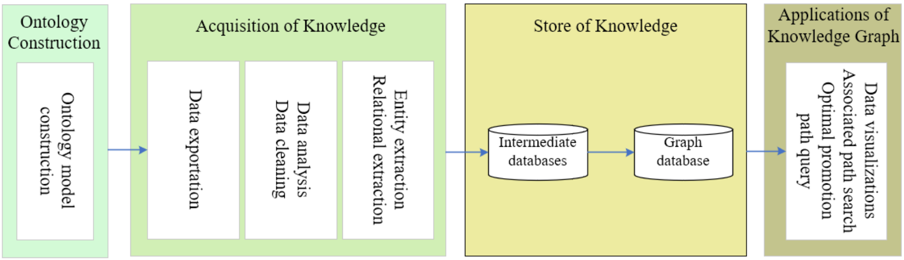

Fig. 2. Government Procurement Supplier Relational Knowledge Graph Construction Process

Ontology Construction.

The data was analyzed and combined with the platform's expert opinion based on the promotion requirements to determine what entities, relationships, and attributes on entities and attributes on relationships are available. The optimal construction model for the knowledge graph ontology was studied in depth, as shown in Fig. 3. The green lines indicate relationships constructed from platform business data; the lavender lines indicate relationships constructed from government procurement data; and the light blue lines are relationships constructed from supplier subject and relationship data. Table 1 is a description of the knowledge graph ontology Relationship types and key attributes.

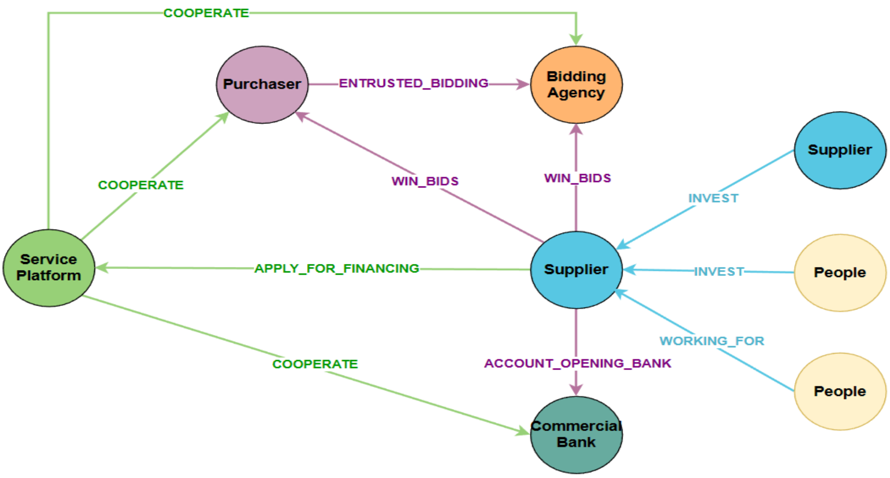

Fig. 3. The Model for Building Knowledge Graph Schema

Table 1. Relationship Types and Key Attributes

Entities on both sides of the relationship	Relationship type	Key attributes
Service Platform - Purchaser	COOPERATE	Duration of cooperation, Type of cooperation

Service Platform - Bidding Agency	COOPERATE	Duration of cooperation, Type of cooperation
Service Platform- Commercial Bank	COOPERATE	Duration of cooperation, Type of cooperation
Supplier - Service Platform	APPLY_FOR_FINANCING	Registration Status, Number of applications for financing, Amount of financing requested
Purchaser - Bidding Agency	ENTRUSTED_BIDDING	Project name, Project amount, Number of business transactions
Supplier - Purchaser	WIN_BIDS	Project name, Project amount, Number of business transactions
Supplier - Bidding Agency	WIN_BIDS	Project name, Project amount, Number of business transactions
Supplier - Commercial Bank	ACCOUNT_OPENING_BANK	Project name, Project amount, Number of business transactions
Supplier - Supplier	INVEST	None
People - Supplier	INVEST	None
People - Supplier	WORKING_FOR	Title of position

Acquisition of Knowledge.

Knowledge capture based on constructed entities and relationships, including data export, data analysis cleaning and entity relationship extraction. Data export is mainly in the form of batch export from the platform database and interface. Data analysis and cleaning is mainly to remove useless fields and fields that have more empty data. By analyzing the government procurement data table, the contract data table, the award announcement table, the winning bid table using the VLOOKUP function will be associated with the three tables to match the linkage between the relationship between the three tables. Entity-relationship extraction is the process of extracting the required attribute values for each entity object and relationship from the data table and defining their labels and saving them to a CSV file.

Store of Knowledge.

The NoSQL intermediate library is used to back up the data. The graph database is used to store the latest graph data, support the basic query of the application layer and serve as the input of the graph algorithm model to satisfy the result generation of complex business scenarios. The Neo4j graph database is used as the database for knowledge graph storage. In this paper, CSV files are imported into Neo4j database by using LOAD CSV statement in Cypher syntax and Py2neo [7] library in Python. Finally, 150934 nodes and 711711 relationships were imported.

Applications of Knowledge Graph.

Application 1: Data Visualization.

Neo4j graph database provides Cypher declarative query language for querying and manipulating graph data. Users can visualize and analyze the Neo4j graph database by using Cypher's data query, filtering and conditional query, aggregation function, sorting and other functions. Users can also click on nodes and relationships to view their attributes or to view the nodes and relationships connected to the node.

Application 2: Linked Path Query.

Direct relationships between entity nodes can be visualized in the knowledge graph. However, when an entity is connected to a large number of other entities, indirect associative relationships are widely available but difficult to be discovered. Association path query [8,9] can discover the paths that exist between any two entities in the knowledge graph and can measure the closeness of the connection between the entities. In this paper, we use Neo4j's Cypher language to design the Linked Path Query statement. Fig. 4 shows all the association paths within three hops from the Financing Services Platform node (light green node) to the Supplier2 node (light blue node). Its Cypher statement is "MATCH p= (c: Service Platform {name:" Start Node Name"})-[*0..3]-(d: Supplier {name:" End Node Name"}) return p".

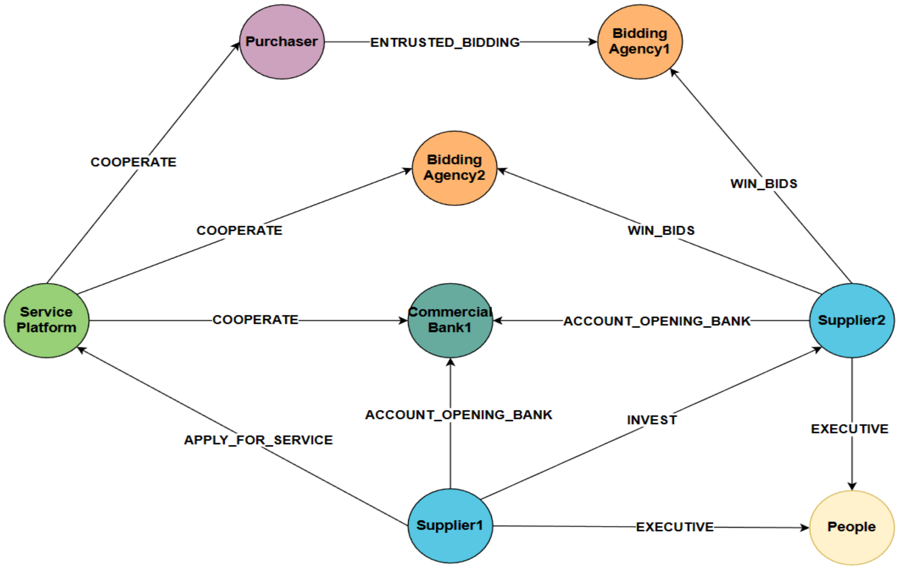

Fig. 4. Example of Linked Path Query

Application 3: Supplier Optimal Promotion Path Search.

In the mapping, there are often multiple reachable paths for platform node to reach supplier node. To better realize the promotion of suppliers, how to choose an optimal path from all the reachable paths for promotion, this research is very meaningful. The specific implementation of this part will be described in detail in the next section.

4 Realization of the Supplier Optimal Promotion Path Promotion Method

4.1 Preliminary

Combining the research of Goel et al [10] and real application scenarios, in this paper, the paths within 3 hops of all reachable paths from the platform node to the target supplier node are taken as pre-selected paths.

4.2 Calculation of Relationship Weights between Nodes

The measurement of the weight between two entity nodes is also a measure of the size of the trust between the two nodes, the greater the trust the greater the weight, in order to facilitate the calculation and comparison of the weight, this paper sets the range of values of the weight of the relationship between the nodes as [0,10]. The following describes the calculation of the weights for each relationship separately.

Calculation of Weights between Entities in the Government Procurement Process. The social exchange theory [11] in social psychology suggests that people form a cooperative relationship based on reciprocity and balance of interests during interaction. According to this theory, the more times two entities cooperate with each other, the higher their trust. As shown by the mauve-colored relationship in Table 1, the attribute of "Number of business transactions" between entities in the government procurement process can reflect the level of trust between two entities. Therefore, this study uses "Number of business transactions" as an evaluation index for weighting in the government procurement process. Combined with the real experience, the change curve of trust between two nodes with the number of cooperation is close to the sigmoid function, so this paper uses the variant of the sigmoid function to represent the relationship between the "Number of business transactions" and the weight between two nodes. By analyzing the "Number of business transactions", it is found that in all relationships, the number of business transactions between 1-10 accounts for more than 90%, so this paper sets that when the "Number of business transactions" reaches 10, the trust between the two nodes tends to be saturated, and its weight is close to the maximum value of 10. Therefore, the weight W1 between two nodes and the "Number of business transactions" number1 is calculated as follows:

$$W_1(number_1) = 10 / \left(1 + e^{-0.35\times(2\times number_1 - 9)}\right) \quad (1)$$

The image of the function of $W_1(number_1)$ is shown in Fig. 5.

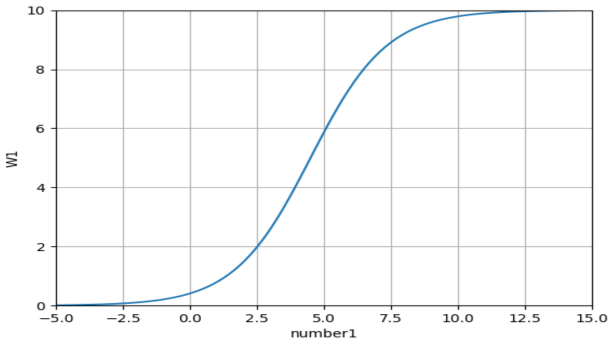

Fig. 5. Weight W_1 Corresponding to "Number of business transactions" $number_1$.

Calculation Method of Relationship Weights between Financing Platforms and Partners.

As shown in the green partnership in Fig. 3, the weight W_3 of the partnership between the Platform and the purchaser, the bidding agent and the commercial bank is assigned a value between 0 and 10 by the Platform's staff.

$$W_2 = [0,10] \tag{2}$$

Calculation of Relationship Weights between Financing Platforms and Suppliers.

As shown in the relationship "APPLY_FOR_FINANCING" in Fig. 3, the suppliers have registered on the official website of the platform or raised funds through the platform, which means that they have already known the platform very well and have a certain foundation of trust. The formula is as follows.

$$W_3(number_3) = 10 / \left(1 + e^{-0.35\times(2\times number_3 - 9)}\right) + 2 \tag{3}$$

Where W_3 weight, $number_3$ indicates the number of times the supplier has submitted financing applications to the platform, based on formula (1) plus base 2 is used to indicate that the supplier has registered on the platform's official website and has a certain degree of trust in the foundation.

Calculation of Weights for Relationships between Suppliers and Vendors and People.

Supplier—Supplier.

The relationships shown in red in Fig. 3 contain supplier-supplier investment relationships. Because the detailed information of business-to-business investment is not included in the business relationship data exported by the credit bureau, the supplier-supplier relationship is weighted W_4, considering that the investment behavior of a business indicates a high level of trust between the two businesses:

$$W_4 = 7 \tag{4}$$

Supplier—People.

Investment and tenure relationships between suppliers and people are included as shown in red in Fig. 3. The weight W_5 between the supplier node and the person node is calculated with reference to the enterprise incumbent rank to assign a value between 0 and 10. The weights of the incumbent relationships are differentiated according to the position and are assigned as follows:

$$W_5 = \begin{cases} 10, name = \text{"Chairman"} \\ 9, name = \text{"Vice chairman"} \\ 8, name = \text{"Board manager"} \, or \, \text{"Supervisor"} \, or \, \text{"Authorized representative"} \\ 7, name = \text{"General manager"} \\ 6, name = \text{"Deputy general manager"} \end{cases} \tag{5}$$

4.3 Implementation process of the optimal promotion path promotion method

Breadth-First Search Algorithm to Match Suitable Paths.

Use the breadth-first search algorithm to find the reachable path within 3 hops from the financing platform node to the target supplier node. With the help of the path query syntax of Neo4j graph database "MATCH p=(c : Financing platform {name: "Start node name"})-[*0..3]-(d : Supplier{name: "End node name"}) return p", we can get all the reachable paths within three levels from the financing platform node to the target supplier as alternative paths.

Evaluation of Optimal Paths.

In this paper, we use the average value of the weights of each hop in the path to evaluate the optimal promotion path, and the one with the largest average value is the optimal promotion path for the financing platform to reach the target suppliers. The difficulty of commissioning a 3-hop path increases dramatically, so this paper reduces its weights to make it more realistic. The formula for calculating the average value of weight $\overline{W}$ is as follows:

$$\overline{W} = \begin{cases} weight_1, hop = 1 \\ \left(weight_1 + weight_2\right) / hop, hop = 2 \\ \left(weight_1 + 2weight_2 / 3 + weight_3 / 3\right) / hop, hop = 3 \end{cases} \tag{6}$$

Where hop denotes the hop count of the path, weight denotes the weight of the relationship in the path, and the subscript of weight denotes the first entry. Among all alternative paths $\min(\overline{W})$ is the optimal promotion path.

5 Experimental Results and Analysis

5.1 Experimental Environment

The construction of the knowledge graph and the application of the optimal promotion path promotion method are carried out on the financing service platform, and the platform's promoters assist in the experiment. The platform promoters are divided into two groups with equal numbers, and the suppliers to be promoted daily are equally divided between the two groups, one group adopts the original promotion method of direct contact by phone to promote, and the other group uses the optimal path derived from the optimal promotion path promotion method to promote. A week for a cycle of experimental results of statistics, a total of four rounds of experiments. The effect of promotion is assessed by the number of successful promotion and the number of financing applications submitted. Successful promotion means that the promoted suppliers have paid attention to the platform public number or registered on the platform official website; submission of financing applications means that the promoted suppliers have registered on the platform official website and submitted financing applications.

5.2 Experimental Results

A comparison of the promotion effects of the original direct connection promotion approach and the optimal promotion path promotion approach is shown in Fig. 6 and Fig. 7.

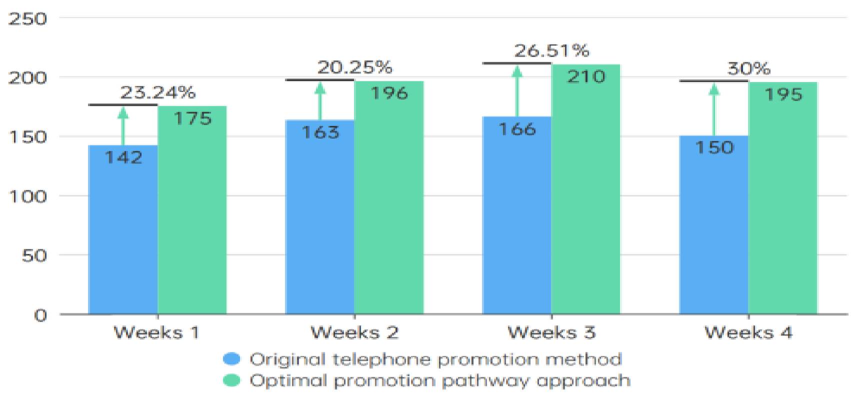

Fig. 6. Comparison of the Number of Suppliers Successfully Promoted by the Original Direct Contact and the Optimal Promotion Path Promotion Methods

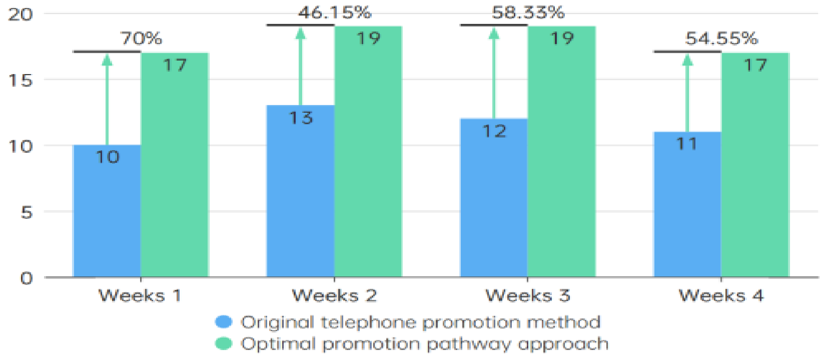

Fig. 7. Comparison of the Number of Suppliers Submitting Financing Applications between the Original Direct Contact and the Optimal Promotion Path Promotion Methods

After applying the optimal promotion path method, the number of suppliers successfully promoted by the platform increased by 25.00% and the number of suppliers submitting financing applications increased by 57.26%. It proves that the optimal promotion path method is effective in the Intra-platform applications and effectively improves the suppliers' trust in the promotion of the platform.

6 Conclusions

The visualized query provided by the knowledge graph is conducive to the in-depth analysis of government procurement data by the financing service platform to improve the value and utilization of the data. At the same time, the knowledge graph can also be combined with the graph database declarative query language to help the platform obtain the required information more quickly and improve the efficiency and accuracy of data acquisition. In addition, through the experimental results, it can be obtained that the optimal promotion path promotion method proposed in this paper on the basis of knowledge graph construction has been effectively verified within the financing service platform. It provides a solution idea for entities with similar promotion needs. However, the data sources in this paper are limited and do not more comprehensively reflect the strength of trust between the nodes of the two entities. Plus, this paper is more subjective in evaluating the trust between the two entity nodes, and there is more room for improvement in the evaluation of its trust.

Of course, the government procurement supplier optimal promotion path promotion method also has its limitations, only applies to the important customers for the precise promotion of the scenario, and does not apply to a wide range of promotion, the promotion of the lower efficiency. The influence maximization problem [12] studies how to promote through as few nodes as possible in the social network graph, so that the influence spreads as far as possible to cover the entire social network, which can greatly improve the efficiency of service promotion and reduce costs. This is also the direction of the author's future efforts to try.

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