Postprint: Research on Optimal Service Decision-Making for Technology Competitive Intelligence Based on Two-Sided Matching

Authors: Su Huishuang, Ruiqi Liu, Ma Qiang, Qu Jiulong

Date: 2023-08-26T00:00:00+00:00

Abstract

[Purpose/Significance] The degree of matching between resource investment plans of both parties in the technical competitive intelligence service process is an important factor affecting the service process. To address the coordination problem between service providers and recipients in the technical competitive intelligence service process, a decision-making method for technical competitive intelligence services is constructed to enable both parties to better cooperate. [Method/Process] Based on describing and evaluating the matching of technical competitive intelligence service schemes, a satisfaction matrix for technical competitive intelligence service scheme combinations is established, a matching model for technical competitive intelligence service schemes is constructed and solved, and finally the optimal combination of technical competitive intelligence service schemes is determined under the condition of considering the success rate of each scheme. [Results/Conclusion] A practical example demonstrates that, based on evaluating the matching of technical competitive intelligence service schemes, using a bilateral satisfaction matching decision method to find satisfactory solutions acceptable to both parties is effective and feasible, and the application of this method can promote the effective implementation of technical competitive intelligence services.

Full Text

Abstract

[Purpose/significance] Whether the resources invested by both parties and the control of the service process are matched is an important factor affecting the smooth progress of competitive technical intelligence service between the two sides. Aiming at the coordination of the competitive technical intelligence service between the service provider and the service object, this paper proposes a decision analysis method to make the two sides cooperate better. [Method/process] On the basis of description of technology competitive intelligence service scheme and matching evaluation, this paper constructed the matching matrix of technology competitive intelligence service scheme. Then, technical competitive intelligence service scheme matching model is constructed and solved. Finally, the optimal combination of technical competitive intelligence service scheme is determined under the condition of considering the success rate of each scheme. [Result/conclusion] On the basis of evaluating on the matching of the competitive technical intelligence service, an illustrative example is given to indicate that it is effective and feasible to use the decision analysis method of two-sided matching to find the acceptable scheme to both sides and satisfactory solution. The application of the method can promote the smooth development of the competitive technical intelligence service.

Keywords: competitive technical intelligence; service scheme; two-sided matching; decision analysis method

Preamble

Vol. 62 No. 10, May 2018. Research on Optimal Service Decision-Making for Technical Competitive Intelligence Based on Two-Sided Matching. *ChinaXiv Cooperative Journal*. Su Huishuang, Liu Ruiqi, Ma Qiang, et al. Research on optimal service decision-making for technical competitive intelligence based on two-sided matching [J]. *Library and Information Service*, 2018, 62(10): 70-75.

Introduction

Previous research has systematically constructed a theoretical framework for technical competitive intelligence services based on open innovation theory, knowledge management theory, and competitive advantage theory, proposing a service process centered on key intelligence within technical competitive intelligence services [11]. Related research is relatively mature and has been applied in numerous fields.

3. Optimal Service Decision Method for Technical Competitive Intelligence Based on Two-Sided Matching

3.1 Description of Technical Competitive Intelligence Service Schemes

Technical competitive intelligence services require both service providers and clients to invest certain resources, necessitating that both parties clarify their resource commitments before service commencement. That is, after comprehensive consideration of their own resources, each party proposes several resource provision schemes. Assume the scheme set proposed by the technical competitive intelligence service provider is $A = \{A_1, A_2, A_i, \dots, A_m\}$, where A_i represents the ith scheme, $i \in I$, $I = \{1, 2, \dots, m\}$; the scheme set proposed by the service client is $B = \{B_1, B_2, \dots, B_j, \dots, B_n\}$, where B_j represents the jth scheme of the client, $j \in J$, $J = \{1, 2, \dots, n\}$, and assume $m \leq n$.

The schemes can be defined from three dimensions: (1) **Resource Input Dimension**, including personnel input, information input, and knowledge level. Personnel input can be described from aspects such as the number of personnel, individual quality, and participation time. Information input can be described from aspects such as completeness of information input [10] and information sharing willingness. Knowledge level can be described from aspects such as professional knowledge reserves of personnel and their education levels. (2) **Organizational Structure Dimension**, including top decision-makers, project leaders, and participating members. Top decision-makers can be described from aspects such as understanding of technology development direction in the field, grasp of service strategy, and identification of main elements constraining the service [23]. Project leaders can be described from aspects such as accuracy of instruction communication, service participation level, and coordination and communication during the service process. Participating members can be described from aspects such as familiarity with business content, cooperation harmony, and professional knowledge comprehension ability. (3) **Management Process Dimension**, specifically including scope management, quality management, schedule management, and cost management. Scope management can be described from aspects such as overall service scope definition, intelligence source scope definition [24], and intelligence result scope definition. Quality management can be described from aspects such as intelligence source quality and intelligence result quality. Schedule management can be described from aspects such as intelligence planning progress, intelligence collection progress, intelligence processing progress, intelligence analysis progress, and intelligence feedback progress. Cost management can be described from aspects such as service cost estimation, service budget preparation, and service cost control [25].

3.2 Matching Evaluation of Technical Competitive Intelligence Service Schemes

Both service providers and clients hope to use schemes that consume fewer resources while achieving cooperation objectives. For example, both parties wish to invest fewer personnel, reduce their own responsibilities when defining scope, and select quality standards favorable to themselves. If the schemes used by both parties do not match well, it will lead to inefficiency, poor result quality, and service process obstruction during technical competitive intelligence service—outcomes neither party desires. Therefore, only when the matching degree between the two parties' schemes is high can sufficient coordination of cooperation interfaces and effective service development be ensured.

If the technical competitive intelligence service provider selects a certain scheme A_i, then A_i can be matched with all schemes $B = \{B_1, B_2, \dots, B_j, \dots, B_n\}$ proposed by the client, resulting in n combinations. Thus, the provider needs to determine which combination is most favorable when selecting scheme A_i, i.e., which has the best matching performance. Similarly, the technical competitive intelligence client must also complete this matching evaluation. Based on the above definition of technical competitive intelligence service schemes, a matching evaluation index system can be established from the three dimensions of resource input, organizational structure, and management process. Using methods such as Analytic Hierarchy Process (AHP), corresponding weights can be determined. Then, both the service provider and client can use fuzzy comprehensive evaluation and other methods to evaluate and rank scheme combinations. Assume the evaluation index set is $C = \{c_1, c_2, \dots, c_h, \dots, c_g\}$, where c_h is the hth index, and the corresponding weight set is $U = \{u_1, u_2, \dots, u_h, \dots, u_g\}$, where n_h is the weight of the hth index in the technical competitive intelligence service scheme matching evaluation index system. On this basis, both parties take one of their own schemes as a benchmark, form scheme combinations with all schemes of the other party, and evaluate and rank these combinations through calculated evaluation values. For the evaluating party, the higher the ranking of a scheme combination, the more favorable it is to them.

3.3 Establishing Satisfaction Matrix for Technical Competitive Intelligence Service Scheme Combinations

If the technical competitive intelligence service provider selects scheme A_i and the client selects scheme B_j, assume the provider's satisfaction with this combination is α_{ij} and the client's satisfaction is β_{ij}. From the connotation of scheme matching and satisfaction, the higher the matching evaluation of a scheme combination, the higher the satisfaction of the evaluating party. Therefore, satisfaction α_{ij} and β_{ij} can be expressed as:

$$\alpha_{ij} = \varphi(r_{ij}), \quad i \in I, j \in J$$

$$\beta_{ij} = \varphi(t_{ij}), \quad i \in I, j \in J$$

where $\varphi(\cdot)$ is a strictly monotonic decreasing function satisfying $\varphi(x) > 0$, $\varphi(1) = 0$. Thus, according to equations (1) and (2), calculate α_{ij} and β_{ij} $(i = 1, 2, \dots, m;\ j = 1, 2, \dots, n)$ to construct satisfaction matrices $\tilde{A} = [\alpha_{ij}]_{m\times n}$ and $\tilde{B} = [\beta_{ij}]_{m\times n}$. The sum of satisfactions of both parties for a scheme combination is called the bilateral overall satisfaction, denoted as $\gamma(\mu)_g$, where μ_g is all scheme combinations of both parties, $g \in G$, and

$$\gamma(\mu_g) = \omega_1 \alpha_{ij} + \omega_2 \beta_{ij}, \quad i \in I, j \in J$$

where ω_1 and ω_2 are the weights of both parties in overall satisfaction evaluation, satisfying $0 \leq \omega_1, \omega_2 \leq 1$, $\omega_1 + \omega_2 = 1$.

3.4 Constructing the Matching Model for Technical Competitive Intelligence Service Schemes

Based on the satisfaction matrices $\tilde{A}$ and $\tilde{B}$ of both parties, introduce 0-1 variable x_{ij}, let

$$x_{ij} = \begin{cases} 1, & \lambda(A_i) = B_j \\ 0, & \lambda(A_i) \neq B_j \end{cases}$$

where $x_{ij} = 1$ indicates that the provider's scheme and the client's scheme may be an optimal match, and $x_{ij} = 0$ indicates they are not an optimal match, thus constructing matching matrix $X = [x_{ij}]_{m\times n}$. Since the provider has m schemes and the client has n schemes, there are mn scheme combinations available. For any scheme combination (A_i, B_j), to ensure stable cooperation, it must either be superior to combinations of A_i with other client schemes or superior to combinations of B_j with other provider schemes [26-27]. Therefore, it should satisfy the following constraint:

$$x_{ij} + \sum_{k:r_{ik}<r_{ij}} x_{ik} + \sum_{l:t_{lj}<t_{ij}} x_{lj} \geq 1, \quad i \in I, j \in J$$

Based on the above considerations, establish the following single-objective optimization model:

$$\max Z = \omega_1 \sum_{i,j} \alpha_{ij} x_{ij} + \omega_2 \sum_{i,j} \beta_{ij} x_{ij}$$

subject to:

$$\sum_j x_{ij} = 1, \quad i \in I \quad \text{(4b)}$$

$$\sum_i x_{ij} \leq 1, \quad j \in J \quad \text{(4c)}$$

$$x_{ij} + \sum_{k:\alpha_{ik}>\alpha_{ij}} x_{ik} + \sum_{l:\beta_{lj}>\beta_{ij}} x_{lj} \geq 1, \quad i \in I, j \in J \quad \text{(4d)}$$

$$x_{ij} \in \{0, 1\}, \quad i \in I, j \in J \quad \text{(4e)}$$

In this model, equation (4a) is the objective function; equations (4b) and (4c) indicate that since $m \leq n$ is assumed, each row in matching matrix X has exactly one element equal to 1, and each column has at most one element equal to 1. Since the above programming model is a 0-1 programming model with mn variables and at most $2mn$ feasible solutions, research by D. Gale et al. shows it must have feasible solutions. Therefore, optimization software packages such as LINGO 11.0 and CPLEX 9.0 can be used to calculate the optimal solution. Through the establishment and calculation of this single-objective model, the optimal matching set for technical competitive intelligence services based on stable matching conditions is obtained.

3.5 Determining the Optimal Combination of Technical Competitive Intelligence Service Schemes

To further select the optimal service scheme combination from the optimal matching set, define the arithmetic mean of both parties' matching evaluation results for a scheme combination (A_i, B_j) in the optimal matching set μ^* as the matching degree ϕ_{ij} of that matching scheme. Although in μ^*, both the provider and client have found optimal satisfactory matching objects for their proposed schemes, for either party, the implementation difficulty and applicable environment of their own schemes differ. In other words, during service participation, any party will evaluate all its own schemes from aspects such as difficulty level, contribution to its own development, and environmental requirements, regardless of cooperation and scheme matching. Therefore, in the optimal service scheme selection process, if the final effect of implementing a matching scheme selected by both parties from the optimal satisfactory matching set is σ_{ij}, then

$$\sigma_{ij} = \phi_{ij} \times \pi_i \times \pi_j, \quad i \in I, j \in J$$

where π_i is the provider's judgment of the success probability of its own scheme, and π_j is the client's judgment of the success probability of its own scheme, satisfying $0 \leq \pi_i, \pi_j \leq 1$. Finally, compare the calculation results of σ_{ij} for all matching schemes in the optimal satisfactory matching set to prioritize the optimal technical competitive intelligence service scheme combination. A higher σ_{ij} indicates better coordination effectiveness after combining the schemes of both service parties.

4. Numerical Example

Organization A is a professional technical competitive intelligence service institution that can provide competitive intelligence services to clients. Meanwhile, Company B needs to obtain competitive intelligence through external forces to enhance its competitiveness. To ensure smooth cooperation, after fully considering both parties' existing resources and technical levels, Organization A developed three alternative service schemes (A_1, A_2, A_3) for Company B's needs, while Company B proposed four coordination schemes (B_1, B_2, B_3, B_4) to support Organization A's service work. Both parties considered their actual situations and constructed evaluation systems from three dimensions—resource input, organizational structure, and process management—determining evaluation index weights through expert scoring. On this basis, both Organization A and Company B used fuzzy comprehensive evaluation methods to evaluate the matching performance between their own schemes and the other party's schemes. For example, the matching evaluation results of service provider scheme A_1 with client schemes (B_1, B_2, B_3, B_4) are E_{11}, E_{12}, E_{13}, and E_{14} respectively. Similarly, using Organization A's other schemes as benchmarks, the matching evaluation values with all of Company B's schemes were calculated sequentially. Considering space limitations and that both AHP and fuzzy comprehensive evaluation are relatively mature methods, the calculation process is omitted here, and the matching evaluation results of both parties are presented directly in Table 1 and Table 2 .

The matching evaluation results are converted into preference order matrices. After organization, matrices R and T are obtained as:

Assuming the satisfaction function is $\varphi(x) = 1/x$, according to equations (1) and (2), calculate α_{ij} and β_{ij} ($i = 1, 2, 3$; $j = 1, 2, 3, 4$) to construct satisfaction matrices $\tilde{A} = [\alpha_{ij}]_{3\times4}$ and $\tilde{B} = [\beta_{ij}]_{3\times4}$ as follows:

$$\begin{bmatrix} 0.33 & 0.50 & 1.00 & 0.25 \\ 0.50 & 1.00 & 0.33 & 0.25 \\ 1.00 & 0.50 & 0.33 & 0.25 \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} 1.00 & 1.00 & 0.50 & 1.00 \\ 0.33 & 0.33 & 0.33 & 0.50 \\ 0.50 & 0.50 & 1.00 & 0.33 \end{bmatrix}$$

Assuming both parties have equal influence on scheme matching selection ($\omega_1 = \omega_2 = 0.5$), construct the single-objective optimization model according to equations (3) and (4) and solve it using the LINGO 11.0 software package. The resulting matching matrix is $X^* = [...]_{3\times4} = [...]$, with an objective value $Z^* = 2.165$. The satisfactory matching result is $\mu^* = \{(A_1, B_3), (A_2, B_2), (A_3, B_1)\}$, meaning Organization A's scheme A_1 matches with Company B's scheme B_3, A_2 matches with B_2, and A_3 matches with B_1. Both parties can make further selections within this matching set, while scheme B_4 remains unmatched.

Based on the bilateral scheme matching evaluation results, the matching degree ϕ_{ij} is calculated using the arithmetic average method. The matching degrees for scheme combinations in the optimal matching set are $\phi_{13} = 71.1009$, $\phi_{22} = 70.0897$, and $\phi_{31} = 71.1239$. From the perspective of cost, revenue, and actual operational conditions, Organization A estimates the success probabilities of schemes A_1, A_2, A_3 as 80%, 60%, and 40% respectively. Company B, considering the enhancement of core capabilities and impact on existing business, estimates the success probabilities of schemes B_1, B_2, B_3 as 90%, 70%, and 50% respectively. The final implementation effects for all matching schemes in the optimal matching set are calculated as $\sigma_{13} = 28.4403$, $\sigma_{22} = 29.4377$, and $\sigma_{31} = 25.6046$. The final ranking of bilateral optimal matching combinations by matching degree is $\sigma_{22} > \sigma_{13} > \sigma_{31}$. Therefore, selecting the optimal service scheme combination formed by Organization A's scheme A_2 and Company B's scheme B_2 is most beneficial for the smooth development of bilateral service work.

Conclusion

This paper addresses the bilateral scheme matching problem in the technical competitive intelligence service process using modeling and optimization approaches. The main contributions can be summarized in three aspects:

(1) **Proposed a matching-perspective-based decision-making approach for technical competitive intelligence services.** Aiming at

the current situation where existing research rarely involves intelligence service decision-making processes, this study establishes a decision-making approach centered on scheme matching and optimization from the internal logic of both parties' scheme selection, based on three dimensions: resource input, organizational structure, and management process. Compared with existing research, this approach better aligns with the realistic context of technical competitive intelligence services and helps explore how to improve service quality from the micro perspective of decision-making subjects and processes.

(2) **Constructed a technical competitive intelligence service scheme matching model.** Based on evaluating the matching performance of technical competitive intelligence service scheme combinations, satisfaction matrices are constructed. A single-objective optimization model is established with the objective of maximizing bilateral satisfaction and the main constraint of ensuring stable cooperation. Solving this model yields the optimal matching combination set.

(3) **Designed a method for selecting optimal matching combinations.** Considering the main factors in scheme selection, an evaluation method for the final implementation effect of matching schemes is designed, taking into account factors such as implementation difficulty, actual value to the party, and environmental requirements, thereby enhancing the operability of the matching-perspective-based technical competitive intelligence service decision-making method.

In summary, the optimal scheme selection method for technical competitive intelligence services based on two-sided matching proposed in this paper can help service providers and clients judge the implementation effects of different scheme combinations and make reasonable judgments based on their own circumstances, thereby ensuring smooth service implementation. This method is applicable to intelligence service decision-making scenarios where both parties have multiple resource allocation schemes to choose from and can conduct sufficient communication and negotiation on the service process. However, the process of determining the optimal technical competitive intelligence service scheme combination does not provide a method for both parties to estimate the success probabilities of their own schemes, which needs to be addressed in future research.

References

[1] SALVETAT D, LAARRAF Z. Competitive intelligence key players within firms: the case of high-technology European firms[J]. Human systems management, 2013, 32(2): 121-130.

[2] JIN T, JU B. Towards understanding the perceptions of information professionals about competitive intelligence work[J]. Journal of information & knowledge management, 2014, 13(2): 773-358.

[3] RAPP A, AGNIHOTRI R, BAKER T L, et al. Competitive intelligence collection and use by sales and service representatives: how managers' recognition and autonomy moderate individual performance[J]. Journal of the academy of marketing science, 2014, 43(3): 357-374.

[4] Chen Shengqun. Bilateral matching decision method based on distributed ordinal relations[J]. *Operations Research and Management Science*, 2016, 25(3): 146-150.

[5] GARCIA ALSINA M, COBARSÍ MORALES J, ORTOLL E. Competitive intelligence theoretical framework and practices: the case of Spanish universities[J]. Aslib journal of information management, 2016, 68(1): 57-75.

[6] Liu Xiwen, Ma Feicheng. Construction of theoretical framework for technical competitive intelligence services[J]. *Library and Information Service*, 2016, 60(7): 139-144.

[7] Zhang Canying, Liu Dehong. Exploration of technical competitive intelligence service model for enterprise open innovation[J]. *Journal of Intelligence*, 2012, 31(7): 76-80.

[8] Zeng Dechao, Xu Mingjin, Peng Lihui. Research on technical competitive intelligence service model for SMEs from the perspective of open innovation[J]. *Library*, 2015(1): 101-103.

[9] Cui Xiaowei, Wu Xinnian. Analysis of industrial technical competitive intelligence needs for open technology innovation environment[J]. *Library and Information Service*, 2015, 59(9): 88-96.

[10] Yang Caixia, Chen Wei, Zhai Donghui, et al. Research on technical competitive intelligence service system for high-tech industrial clusters[J]. *Library Science Research*, 2015(12): 44-49.

[11] Liu Xiwen. Review of competitive intelligence and technical competitive intelligence service process construction[J]. *Library and Information Service*, 2016, 60(7): 139-144.

[12] Chen Shengqun. Bilateral matching decision method based on distributed ordinal relations[J]. *Operations Research and Management Science*, 2016, 25(3): 146-150.

[13] GALE D, SHAPLEY L S. College admissions and the stability of marriage[J]. The American mathematical monthly, 1962, 69(1): 9-15.

[14] Shao Qingyi, Ding Yuan. Matching configuration and operation mechanism of knowledge sharing in intelligence alliance networks[J]. *Information Studies: Theory & Application*, 2014, 37(12): 33-37.

[15] Zhang Liang. A Web service matching method based on semantic similarity[J]. *Information Science*, 2016, 34(2): 21-23, 36.

[16] Li Jinhua, Quan Wei, Sun Zuoxu. Semantic query, matching and composition for scientific workflow service discovery[J]. *Information Studies: Theory & Application*, 2015, 38(6): 115-120.

[17] ROTH A E. On the allocation of residents to rural hospitals: a general property of two-sided matching markets[J]. Econometrica, 1986, 54(2): 425-427.

[18] GUSFIELD D. The structure of the stable roommate problem: efficient representation and enumeration of all stable assignments[J]. Society for industrial and applied mathematics, 1988, 17(4): 742-769.

[19] FLEINER T. A fixed-point approach to stable matchings and some applications[J]. Mathematics of operations research, 2003, 28(1): 103-126.

[20] Wang Dingwei. Multi-objective transaction matching problem in electronic intermediaries and its optimization method[J]. *China Journal of Information Systems*, 2007(1): 102-109.

[21] Wan Shuping, Li Dengfeng. Multi-index bilateral matching decision method for venture capitalists and venture enterprises with different types of information[J]. *Chinese Journal of Management Science*, 2014, 22(2): 40-47.

[22] Le Qi. Bilateral matching decision considering matching willingness in intuitionistic fuzzy environment[J]. *Chinese Journal of Management Science*, 2017, 25(6): 161-168.

[23] Wang Zhijin, Han Zhengbiao, Zhou Peng. Research on enterprise technical competitive intelligence strategy in dynamic and complex environment[J]. *Library and Information Knowledge*, 2011(5): 76-81.

[24] Han Zhengbiao, Wang Zhijin, Qu Weiqun, et al. Research on technical competitive intelligence sources for enterprise strategy and tactics[J]. *Information Studies: Theory & Application*, 2014, 31(10): 10-14.

[25] Tian Shuo, Lu Ping, Su Huishuang, et al. Research on identification and coordination strategies of technical competitive intelligence service interface[J]. *Library and Information Service*, 2016, 60(10): 76-86.

[26] VATE J H. Linear programming brings marital bliss[J]. Operations research letters, 1989, 8(3): 147-153.

[27] ROTH A E, ROTHBLUM U G. Stable matchings, optimal assignments, and linear programming[J]. Mathematics of operations research, 1993, 18(4): 803-828.

Author Contributions

Su Huishuang: Conceptualization and manuscript writing; Liu Ruiqi: Numerical calculation; Ma Qiang: Provided revision suggestions on research ideas, methods, and paper content; Qu Jiulong: Provided revision suggestions on research ideas, methods, and paper content.