

# Identifying potential R&D partners using SAO analysis in open innovation: A case study on dye-sensitized solar cells

Xuefeng Wang<sup>1</sup>, Yun Fu<sup>1</sup>, Liliana Mitkova<sup>2</sup>

<sup>1</sup> School of Management and Economics, Beijing Institute of Technology, Beijing, 100081, China

<sup>2</sup> IRG, University Paris-Est, 5 Boulevard Descartes, 77420, Champs-sur-Marne, France

**Abstract:** As markets and technology are changing rapidly, Research and Development (R&D) collaboration is becoming an effective ways used in many organizations, such as institutions and enterprises, and has also been considered as a useful means of technology acquisition. It becomes extremely significant to identify promising R&D partners for these organizations because of the collaboration risk. This paper aims to show a systematic methodology to identify and analyze the most prospective R&D collaboration partners using information contained in research documents. The originality of this approach consists in first, to build a SAO structure map that illustrates the technology development trends and the key organizations (firms or research institutes) with similar research themes and second, the process of analyzing potential partner can be summarized as three steps: what is the organizations current research themes; what they would do next according to the development trend of target field; analyzing the organizations' attributions in target research filed and get the organizations which can meet their requirements. The exploratory study is in DSSCs sector.

**Keywords:** Subject-Action-Object (SAO), partner identification, SAO structure map, open innovation, Dye-sensitized solar cells (DSSCs)

## Key points

The increased complexity, risk, cost and time of the innovation process leads firms and institutions to search beyond their internal boundaries for obtaining necessary technologies and capabilities from external sources (Ahuja, 2000; Nijssen et al., 2001). Firms set up partnerships to widen their internal knowledge (Hoang and Rothaermel, 2010), gain access to

complementary technological resources (Prahalad and Hamel, 1990), insulate from environmental uncertainty (Burgers et al., 1993), access new market (García-Canal et al., 2008) and preserve technological leaderships (Mortehan, 2004). As argued by Faria et al. (2010) and Hagedoorn et al. (2000) from the resource-based view the aim of any firms is to optimize the competitiveness and profit using external resources *via* knowledge exchanges and cooperation with various partners. Today, in a context of open innovation process (Chesbrough, 2003; Laursen and Salter, 2006) these technological exchanges are broadly recognized as a means of reinforcing in-house R&D (Lin et al., 2007) and encouraging both creation and value capture linked to technological developments. Recent studies have shown that firms' open strategies are directly linked to diverse technological sourcing practices, with the number of partner varying according to competitive and collaborative rationales (Lim et al., 2010). In the open model these practices are based on different forms of inter-organizational relationships such as R&D collaboration, technological alliances, joint-venture or licensing-in and licensing-out developing their absorptive and disruptive capabilities (Bianchi et al., 2011; Bogers, 2011; Hagedoorn et al., 2000; Jeong et al., 2012; Ulrich and Eckhard, 2010). Though, companies oriented to the external technological partnership often ignore potential losses from mismanagement of these exchanges (Ireland et al., 2002), especially when it comes to choosing the partners (Geum et al., 2013; Shah and Swaminathan, 2008) in an international setting (Donga and Glaister, 2006).

The partner selection is a specific decision impacting the success of technological collaboration independently of its form (Hitt et al., 1995; Wu et al., 2009). Researches have demonstrated that partner selection is perhaps the most essential step in creating the successful partnership in open perspective (Chen and Tseng, 2005; Elmuti and Kathawala, 2001; Hitt et al., 2000). Especially in the case of technological collaboration, the partner selection determines its performance and strategic mix of skills, knowledge and resources, the

operating policies and procedures (Arino and de-la-Torre, 1998; Child and Faulkner, 1998; Ireland et al., 2002). Because the technological partner offers not only tacit but also codified knowledge influencing the performance and results of the collaboration (Du et al., 2014). So an effective partner selection should be implemented to help organizations to identify potential partners.

In recent years, many researchers propose different methods and strategies on partner identification. However, several limitations of these methods related to partner selection have been shown as below. Firstly, these methods are based mainly on existing partnerships, patent data or questionnaire to analyze the firm's decision-making concerning the future strategic partner selection (Geum et al., 2013; West and Bogers, 2013), which cannot reflect the profound relationships among organizations. Secondly, these methods (Byungun and Bomi, 2014; Inchaeta et al., 2014) have not used the information of the technology trend and effectively participation of the firms in the technical solutions' solving, which are considered as the primary factors of partner selection because of rapidly technology upgrading. In this paper we propose a systematic method overturning this gap using SAO based analysis with several cooperation opportunity analyses for the managers for the identification of the technological partner. First, in this research SAO semantic analysis is utilized to assess the characters of these diverse organizations' research which is more accurate than the existing bibliometrics method because of the SAO structures clear description of the core content of literature publications. Hence, the proposed method measures precisely the global scope of the technological processes and innovation competences in a real situation. Second, the SAO structure map was built on different technology types of each field, so one can easily find the organizations with similar research themes and this SAO structure map helps to highlight the technological development trends as well as the key organizations (firms or research institutes) involved in this development. This map also illustrates every organizations research

themes and contributions so each organization can estimate its own status as well as others which are very important for organizations to get the potential partners which can exactly meet their needs. Finally, Comparing with the existing methods, this approach does take into consideration the current cooperation status and thus can be used to investigate the potential collaborations desire. Every organization can recognize their positions and contributions in the target field which are also significant factors for them to evaluate other organizations. In a word, this research attempts to offer an appropriate approach that supplements the existing bibliometrics methods helping managerial decisions concerning the technological partners' selection in open perspective. This suggested method was applied to identify strategic potential partners and validate the practicability in the dye-sensitized solar cells (DSSCs) sector.

The paper is organized as follows. The first part gives a state of the art of the role played by partner's selection in open innovation model. It highlights the development of SAO analysis and proposes a method that helps to identify research partners for external R&D collaboration. The second part describes the method including constructions of SAO structure map and then the process of analyzing potential partners. The third part employs the proposed method to study the DSSCs sector. The forth part presents the discussion arising from this research which contains the attributions, limits and also future research plan.

## References

### **References**

- Ahuja, G., 2000. The duality of collaboration: inducements and opportunities in the formation of interfirm linkages. *Strategic Management Journal* 21, 317-343.
- Ahuja, G., Katila, R., 2001. Technological Acquisitions and the Innovation Performance of Acquiring Firms: A Longitudinal Study. *Strategic Management Journal*, 22, 197-220.
- Angue, K., Ayerbe, C., Mitkova, L., 2014. A method using two dimensions of the patent classification for measuring the technological proximity: an application in identifying a potential R&D partner in biotechnology. *Journal of Technology Transfer* 39, 716-747.
- Arino, A., de-la-Torre, J., 1998. Learning from failure: Towards an evolutionary model of collaborative ventures. *Organization Science* 9, 306-325.
- Arranz, N., Arroyabe, J.C.F.d., 2008. The choice of partners in R&D cooperation: An empirical analysis of Spanish firms. *Technovation* 28, 88-100.
- Baum, J.A.C., Calabrese, T., Silverman, B.S., 2000. Don't go it alone: Alliance network

composition and startups' performance in Canadian biotechnology. *Strategic Management Journal* 21, 267-294.

Belderbos, R., Carree, M., Lokshin, B., 2004. Cooperative R&D and firm performance. *Research Policy* 33, 1477-1492.

Benfratello, L., Sembenelli, A., 2002. Benfratello and Sembenelli, 2002. *Research Policy* 31, 493-507.

Bengtsson, M., Kock, S., 2000. Coopetition in Business Networks– to Cooperate and Compete Simultaneously. *Industrial Marketing Management* 29, 411-426.

Bergmann, I., Butzke, D., Walter, L., Fuerste, J.P., Moehrl, M.G., Erdmann, V.A., 2008. Evaluating the risk of patent infringement by means of semantic patent analysis: the case of DNA chips. *R&D Management* 38, 550-562.

Bianchi, M., Cavaliere, A., Chiaroni, D., Frattini, F., Chiesa, V., 2011. Organizational modes for open innovation in the bio-pharmaceutical industry: an exploratory analysis. *Technovation* 31, 22-33.

Blumberg, B.F., 2001. Efficient partner search: embedded firms seeking cooperative partners. *Journal of Mathematical Sociology* 25, 329-354.

Bogers, M., 2011. The open innovation paradox: knowledge sharing and protection in R&D collaborations. *European Journal of Innovation Management* 14, 93-117.

Brouthers, K.D., Brouthers, L.E., Wilkinson, T.J., 1995. Strategic alliances: Choose your partners. *Long Range Planning* 28, 18-25.

Burgers, W.P., Hill, C.W.L., Kim, W.C., 1993. A theory of global strategic alliances: The case of the global auto industry. *Strategic Management Journal* 14, 419-432.

Cascini, G., Fantechi, A., Spinicci, E., 2004. Natural language processing of patents and technical documentation. *Document analysis systems VI* 3163, 508-520.

Cascini, G., Zini, M., 2008. Measuring patent similarity by comparing inventions functional trees. *Computer-Aided Innovation* 277, 31-42.

Cassiman, B., Veugelers, R., 2002. R&D Cooperation and Spillovers: Some Empirical Evidence from Belgium. *American Economic Review* 92, 1169-1184.

Cassiman, B., Veugelers, R., 2006. In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition. *Management Science* 52, 68-82.

Chen, A.L., Tokuda, N., Adachi, H., 2003. Patent Document Retrieval System Addressing Both Semantic and Syntactic Properties, *PATENT '03 Proceedings of the ACL-2003 workshop on Patent corpus processing*, pp. 1-6.

Chen, H.-M., Tseng, C.-H., 2005. The performance of marketing alliances between the tourism industry and credit card issuing banks in Taiwan. *Tourism Management* 26, 15-24.

Chen, S.-H., Lee, H.-T., Wu, Y.-F., 2008. Applying ANP approach to partner selection for strategic alliance. *Management Decision* 46, 449-465.

Chesbrough, H., 2003. *Open Innovation – The New Imperative for Creating and Profiting from Technology*. Harvard Business School Press, Boston, Massachusetts.

Chesbrough, H., Brunswicker, S., 2013. *Managing open innovation in large firms*. Fraunhofer IAO, California.

Child, J., Faulkner, D., 1998. *Strategies of cooperation: managing alliances, networks, and joint ventures*. Oxford University Press, New York.

Choi, S., Kang, D., Lim, J., Kim, K., 2012b. A fact-oriented ontological approach to SAO-based function modeling of patents for implementing Function-based Technology Database. *Expert Systems with Applications* 39, 9129-9140.

Choi, S., Park, H., Kang, D., Lee, J.Y., Kim, K., 2012a. An SAO-based text mining approach to building a technology tree for technology planning. *Expert Systems with Applications* 39, 11443-11455.

Choi, S., Yoon, J., Kim, K., Lee, J.Y., Kim, C.-H., 2011. SAO network analysis of patent for

technology trends identification: a case study of polymer electrolyte membrane technology in proton exchange membrane fuel cells. *Scientometrics* 88, 863-883.

Dacin, M.T., Hitt, M.A., Levitas, E., 1997. electing partners for successful international alliances: Examination of US and Korean firms. *Journal of World Business* 32, 3-16.

Das, T.K., Teng, B.-S., 2000. A Resource-Based Theory of Strategic Alliances. *Journal of Management* 26, 31-61.

Dekker, H.C., 2004. Control of inter-organizational relationships: evidence on appropriation concerns and coordination requirements. *Accounting, Organizations and Society* 29, 27-49.

Ding, R., Dekker, H.C., Groot, T., 2013. Risk, partner selection and contractual control in interfirm relationships. *Management Accounting Research* 24, 140-155.

Donga, L., Glaister, K.W., 2006. Motives and partner selection criteria in international strategic alliances: Perspectives of Chinese firms. *International Business Review* 15, 577-600.

Du, J., Leten, B., Vanhaverbeke, W., 2014. Managing open innovation projects with science-based and market-based partners. *Research Policy* 43, 828-840.

Ellram, L.M., 1990. The supplier selection decision in strategic partnerships. *Journal of Purchasing and Materials Management* 26, 8-14.

Elmuti, D., Kathawala, Y., 2001. An overview of strategic alliances. *Management Decision* 39, 205-218.

Faria, P.d., Lima, F., Santos, R., 2010. Cooperation in innovation activities : The importance of partners. *Research Policy* 39, 1081-1092.

García-Canal, E., Valdés-Llaneza, A., Sánchez-Lorda, P., 2008. Technological flows and choice of joint ventures in technology alliances. *Research Policy* 37, 97-114.

Gassmann, O., Bader, M.A., 2006. Intellectual property management in inter-firm R&D collaborations. *Taiwan Academy of Management Journal* 6, 217-236.

George, G., Zahra, S.A., Wheatley, K.K., Khan, R., 2001. The effects of alliance portfolio characteristics and absorptive capacity on performance- A study of biotechnology firms. *Journal of High Technology Management Research* 12, 205-226.

Geringer, J.M., 1991. Strategic determinants of partner selection criteria in international joint ventures. *Journal of International Business Studies* 22, 41-62.

Gerken, J.M., Moehrle, M.G., 2012. A new instrument for technology monitoring: novelty in patents measured by semantic patent analysis. *Scientometrics* 91, 645-670.

Geum, Y., Lee, S., Yoon, B., Park, Y., 2013. Identifying and evaluating strategic partners for collaborative R&D: Index-based approach using patents and publications. *Technovation* 33, 211-224.

Goldfire Innovator, <http://inventionmachine.com/products-and-services/innovation-software/goldfire-innovator/>. Retrieved April 10, 2015.

Guardo, M.C.D., Harrigan, K.R., 2012. Mapping research on strategic alliances and innovation: a co-citation analysis. *The Journal of Technology Transfer* 37, 789-811.

Guo, K., Li, M., Fang, X., Bai, L., Luoshan, M., Zhang, F., Zhao, X., 2014. Improved properties of dye-sensitized solar cells by multifunctional scattering layer of yolk-shell-like TiO<sub>2</sub> microspheres. *Journal of Power Sources* 264, 35-41.

Guo, Y., Ma, T., Porter, A.L., Huang, L., 2012. Text mining of information resources to inform Forecasting Innovation Pathways. *Technology Analysis & Strategic Management* 24, 843-861.

Hagedoorn, J., 2002. Inter-firm R&D partnerships: an overview of major trends and patterns since 1960. *Research Policy* 31, 477-492.

Hagedoorn, J., Link, A.N., Vonortas, N.S., 2000. Research partnerships. *Research Policy* 29, 567-586.

Hamel, G., Doz, Y.L., Prahalad, C.K., 1989. Collaborate with Your Competitors and Win. *HARVARD BUSINESS REVIEW* 1-2, 133-139.

- Hill, C.W.L., Rothaermel, F.T., 2003. The Performance of Incumbent firms in the Face of Radical Technological Innovation. *Academy of Management Review* 28, 257-274.
- Hitt, M.A., Dacin, M.T., Levitas, E., Arregle, J.-L., Borza, A., 2000. Partner selection in emerging and developed market contexts: resource-based and organizational learning perspectives. *Academy of Management Journal* 43, 449-467.
- Hitt, M.A., Tyler, B.B., Hardee, C., Park, D., 1995. Understanding strategic intent in the global market place. *Academy of Management Executive* 9, 12-19.
- Hoang, H., Rothaermel, F.T., 2010. Leveraging internal and external experience: exploration, exploitation, and R&D project performance. *Strategic Management Journal* 31, 734-758.
- Ireland, R.D., Hitt, M.A., Vaidyanath, D., 2002. Alliance management as a source of competitive advantage. *Journal of Management* 28, 413-446.
- Janghyeok Yoon, H.P., Kwangsoo Kim, 2013. Identifying technological competition trends for R&D planning using dynamic patent maps: SAO-based content analysis. *Scientometrics* 94, 313-331.
- Jeong, S., Lee, S., Kim, Y., 2012. Licensing versus selling in transactions for exploiting patented technological knowledge assets in the markets for technology. *The Journal of Technology Transfer* 38, 251-272.
- Katsikeas, C.S., Paparoidamis, N.G., Katsikea, E., 2004. Supply sourceselection criteria: the impact of supplier performance on distributorperformance. *Industrial Marketing Management* 33, 755-764.
- Keil, T., Maula, M., Schildt, H., Zahra, S.A., 2008. The effect of governance modes and relatedness of external business development activities on innovative performance. *Strategic Management Journal* 29, 895-907.
- Lane, P.J., Lubatkin, M., 1998. Relative Absorptive Capacity and Inter-organizational Learning. *Strategic Management Journal* 19, 461-477.
- Laursen, K., Salter, A., 2006. Open innovation: the role of openness in explaining innovation performance among U.K. manufacturing firms. *Strategic Management Journal* 27, 131-150.
- Li, S.X., Rowley, T., 2002. Inertia and evaluation mechanisms in inter-organizational partner selection: Syndicate formation among US investment banks. *Academy of Management Journal* 45, 1104-1119.
- Li, X., Zhou, Y., Xue, L., Huang, L., 2014. Integrating bibliometrics and roadmapping methods: A case of dye-sensitized solar cell technology-based industry in China. *Technological Forecasting and Social Change* 97, 205-222.
- Lim, K., Chesbrough, H., Ruan, Y., 2010. Open innovation and patterns of R&D competition. *International Journal of Technology Management* 52, 295-321.
- Lin, B.W., Chen, C.J., Wu, H.L., 2007. Predicting Citations to Biotechnology Patents Based on the Information from the Patent Documents. *International Journal of Technology Management* 40, 87-100.
- Lin, H., Li, X., Liu, Y., Li, J., 2009. New Concept and New Directions on the Development of Solar Cell. *Rare Metal Materials and Engineering* 38, 722-725.
- Lopez, A., 2008. Determinants of R&D cooperation: evidence from Spanish manufacturing firms. *International Journal of Industrial Organization* 26, 113-136.
- Mann, D., 2001. An introduction to TRIZ: The theory of inventive problem solving. *Creativity and Innovation Management* 10, 123-125.
- Miotti, L., Sachwald, F., 2003. Co-operative R&D: why and with whom?: An integrated framework of analysis. *Research Policy* 32, 1481-1499.
- Moehrl, M.G., Walter, L., Geritz, A., Muller, S., 2005. Patent-based inventor profiles as a basis for human resource decisions in research and development. *R&D Management* 35, 513-524.
- Mortehan, O., 2004. The role of Firms' Collaborative Agreements in the Information

Technology Industry Transformation. *Technology Analysis & Strategic Management* 16, 53-65.

Mowery, D.C., Oxley, J.E., Silverman, B.S., 1998. Technological Overlap and Interfirm Cooperation: Implications for the Resource-Based View of the Firm. *Research Policy* 27, 507-523.

Narula, R., 2004. R&D collaboration by SMEs: new opportunities and limitations in the face of globalisation. *Technovation* 24, 153-161.

Nielsen, B.B., 2005. The Role of Knowledge Embeddedness in the Creation of Synergies in Strategic Alliances. *Journal of Business Research* 58, 1194-1204.

Nijssen, E.J., Reekum, R.V., Hulshoff, H.E., 2001. Gathering and using information for the selection of technology partners. *Technological Forecasting and Social Change* 67, 221-237.

Noseleit, F., Faria, P.d., 2013. Complementarities of internal R&D and alliances with different partner types. *Journal of Business Research* 66, 2000-2006.

Park, H., Ree, J.J., Kim, K., 2013. Identification of promising patents for technology transfer using TRIZ evolution trends. *Expert Systems with Applications* 40, 736-743.

Park, H., Yoon, J., Kim, K., 2012. Identifying patent infringement using Sao based semantic technological similarities. *Scientometrics* 90, 515-529.

Petruzzelli, A.M., 2011. The impact of technological relatedness, priorities, and geographical distance on university-industry collaborations: a joint-patent analysis. *Technovation* 31, 309-319.

Pidduck, A.B., 2006. Issues in supplier partner selection. *Journal of Enterprise Information Management* 19, 262-276.

Pisano, G.P., 1990. The R&D Boundaries of the Firm: An Empirical Analysis. *Administrative Science Quarterly* 35.

Prahalad, C.K., Hamel, G., 1990. The Core Competence of The Corporation *HARVARD BUSINESS REVIEW* 68, 79-91.

Sampson, R.C., 2007. R&D alliances and firm performance: The impact of technological diversity and alliance organization on innovation. *Academy of Management Journal* 50, 364-386.

Shah, R.H., Swaminathan, V., 2008. Factors influencing partner selection in strategic alliances: the moderating role of alliance context. *Strategic Management Journal* 29, 471-494.

Somaya, D., 2012. Patent Strategy and Management: An Integrative Review and Research Agenda. *Journal of Management* 38, 1084-1114.

Stuart, T.E., Podolny, J.M., 2007. Local search and the evolution of technological capabilities. *Strategic Management Journal* 17, 21-38.

Tyler, B.B., Steensma, H.K., 1995. Evaluating technological collaborative opportunities: A cognitive modeling perspective. *Strategic Management Journal* 16, 43-70.

Ulrich, L., Eckhard, L., 2010. Technology Transfer across Organizational Boundaries: Absorptive and Desorptive Capacity. *California Management Review* 53, 154-170.

Wang, X., Qiu, P., Zhu, D., Mitkova, L., Lei, M., Porter, A.L., 2015. Identification of technology development trends based on subject-action-object analysis: the case of dye-sensitized solar cells. *Technological Forecasting & Social Change* 98, 24-46.

West, J., Bogers, M., 2013. Leveraging external sources of innovation: a review of research on open innovation. *Journal of Product Innovation Management* 31, 814-831.

William, F., Gibson, D.V., 1990. *TECHNOLOGY TRANSFER: AN INTERNATIONAL GOOD PRACTICE GUIDE FOR PHARMACEUTICALS AND ALLIED INDUSTRIES*. Davis Healthcare International Publishing.

Wu, W.Y., Shih, H.-A., Chan, H.-C., 2009. The analytic network process for partner selection criteria in strategic alliances. *Expert Systems with Applications* 36, 4646-4653.

Yoon, B., Song, B., 2014. A systematic approach of partner selection for open innovation.



Industrial Management & Data System 114, 1068-1093.

Yoon, J., Kim, K., 2011. Identifying rapidly evolving technological trends for R&D planning using SAO-based semantic patent networks. *Scientometrics* 88, 213-228.

Zhang, Y., Zhou, X., Porter, A.L., M, J., Gomila, V., Yan, A., 2014. Triple Helix innovation in China's dye-sensitized solar cell industry: hybrid methods with semantic TRIZ and technology roadmapping. *Scientometrics* 99, 55-75.