Asian Journal of Information and Communications 2016, Vol. 8, No. 2, 55-68

KISDI KOREA INFORMATION SOCIETY DEVELOPMENT INSTITUTE

Asian Journal of Information and Communications

# Exploiting technology intelligence in designing and manufacturing complex product systems

Mostafa Safdari Ranjbar*
Allameh Tabataba'i University

Namjae Cho**
Hanyang University

***Abstract***

Complex product systems (CoPS) involve a certain degree of technological novelty and innovation, so that high level of coordination and collaboration is required in the stages of design, production and implementation. As such, CoPS developers and producers should be capable of managing diverse knowledge, skills and tools. Indeed, making effective and efficient decisions in these areas demand high level of Technology Intelligence. However, most of the past studies related to technology intelligence concentrated on general aspects of technology intelligence at firm level. Furthermore, it is difficult or even impossible to find the study that focused on exploiting technology intelligence in developing complex product systems. In order to fill out this research gap, we examine technology intelligence in designing and manufacturing an Iranian gas turbine (IGT25) as a complex product system, and present some useful findings regarding technology intelligence processes, structure, methods and players.

*Keywords*: complex product systems, technology intelligence, gas turbine, Iran

## 1. Introduction

Hobday (1998) defined Complex product systems (CoPS) as any high cost, large scale, high technology, engineering-intensive product, sub-system, system or infrastructure supplied by a unit of production, purchased by one or more users, usually under one (or more) formal contracts within a recognizable single project. Also, CoPS are customized, one-off or small bached complex capital goods items and they are usually made in projects (Miller et al., 1995; Kiamehr et al., 2015). CoPS, as major complex capital goods play a critical role in diffusion of modern technology throughout the economy and shaping and enabling modern technological, industrial and economic progress. For instance, CoPS produced in the UK account for around 21 percent of gross value added of manufacturing and construction, approximately £133 billion in output, and roughly 1.4 million in employment (Acha et al., 2004). Some examples of CoPS include: flight simulators (Hobday and Brady, 1998), cellular mobile communication system (Davies, 1997), telecommunication networks and systems (Park, 2012), complex software (Hobday and Brady, 2000), aircraft engine control system (Prencipe, 2000), industrial gas turbine (Majidpour, 2013) and power generation equipment (Kiamehr et al., 2013).[1)]

The term 'complex' is used to denote the high number of customized components, the breadth and depth

* Corresponding author: safdariranjbar921@atu.ac.ir
** njcho@hanyang.ac.kr

1) To learn more about candidates of CoPS you can see (Hobday, 1998), Hobday and Rush (1999) and (Davies and Hobday, 2005)

of the technological capabilities, knowledge and skills required, and the extent of new knowledge involved in development and production (Acha et al., 2004). Also, they involve a certain degree of technological novelty and innovation and a high level of coordination and collaboration during design, production and implementation (Ren and Yeo, 2006). Therefore, CoPS developers and producers deal with an abundant number of capabilities, knowledge, skills, tools and players (suppliers, costumers, competitors and regulators) regarding to technological issues. Making effective and efficient decisions in these areas required high level of 'Technology Intelligence' (Kiamehr et al., 2015). Technology intelligence consists of the acquisition and transmission of technological information as part of the process whereby an organization is informed of technological threats and opportunities (Kerr et al., 2006).

Various aspects of technology intelligence have been examined until now by numerous scholars and researchers (Savioz and Blum, 2002; Szvioz, 2004, 2006; Lichtenthaler, 2003, 2004a, 2004b, 2004c, 2005, 2006, 2007; Kerr et al., 2006; Mortara et al., 2008, 2009; Arman and Foden, 2010, Yoon and Kim, 2012; Park et al., 2013). Most of the these studies have concentrated on general aspects of technology intelligence at firm level and finding some studies that have focused on exploiting technology intelligence in designing and manufacturing complex product systems is difficult or even impossible. In order to fill this gap, this paper aims to investigate technology intelligence in developing an Iranian gas turbine as a complex product system and explore some evidences regarding to technology intelligence processes, structure, methods, players and tools in the above-mentioned project.

The remainder of this paper is organized as follows. Section 2 encompasses literature and background related to Complex Product Systems and Technology Intelligence. Section 3 entails research design and methodology and includes designing case study, data gathering and analyzing. Section 4 comprises case introduction and research results and finings. Finally, Section 5 is allocated to discussion and conclusion.

## 2. Literature and background

### 2.1. Complex product systems

CoPS are defined as high cost, high technology complex capital goods made in projects and small batches that are made up of many interconnected customized components, exhibit emerging properties through time as they respond to the evolving needs of large users (Miller et al., 1995). In addition, CoPS were defined as high technology, high value capital goods by Davies and Hobday (2005). They used the term CoPS to distinguish complex high-technology capital goods from standard, mass-produced consumer goods and routinely produced and low-technology capital goods. The term 'complex' is used to denote the high number of customized components, the breadth and depth of the knowledge and skills required, and the extent of new knowledge involved in development and production (Acha et al., 2004).

Ren and Yeo (2006) provided a list of defining characteristics of CoPS including: 1) CoPS are business to business (B2B) capital goods; 2) They have significant economic and political value for both CoPS suppliers and users; 3) CoPS have elaborate architecture and consist of many interconnected control units, sub-systems and components; 4) CoPS are a complex system that can perform multiple and important functions; 5) They are produced in one-off projects or small batches; 6) They involve a certain degree of technological novelty and innovation; 7) They are customized for specific customers; 8) They involve a high level of coordination and collaboration during design, production and implementation; 9) They involve a wide breadth of knowledge and skills; 10) They usually have a certain degree of embedded software; 11) They have a long product life cycle; and 12) They involve a high level of system integration.

Until now several scholars have focused on several topics related to CoPS such as: CoPS features as a distinctive area in innovation management studies (Hobday, 1998; Dedehayir et al., 2014); technical and applied methods and tools (Yeo and Ren, 2009; Magnaye et al., 2014); required capabilities for producing and developing CoPS (Chen et al., 2007; Su and Liu, 2012); project-based organizations (Hobday, 2000; Davies et al., 2011); government related issues (Davies and Brady, 1998; Majidpour, 2013); quantitative aspects of CoPS (Acha et al., 2004; Felipe et al., 2012); and catch-up and technological learning in latecomer countries (Choung and Hwang, 2007; Lee and Yoon, 2015).

## 2.2. Technology intelligence

The philosophy of technology intelligence(TI) is based on the relationship between two main groups of players in an organization named “Intelligence Users” and “Intelligence Brokers”. The former includes decision- makers and planners. These inevitably share some gaps in technological knowledge and also needs for intelligence as the entrance of decision-making process. There are relationships of both top-down and down-top kind between consumers and brokers (Kerr et al., 2006). Diverse definitions of technology intelligence have been presented by researchers, some of them as the following:

- Technology intelligence refers to activities which, through collection, analysis, and dissemination of relevant and proper information, create an essential and timely insight towards technological trends and facts (threats and opportunities) outside an organization and thus supports decision-making and planning processes regarding technological issues as well as the corporate management (Savioz, 2004).
- The University of Nottingham defines technology intelligence as a set of activities enabling a company to monitor technological advances which concern its products, raw materials, processes and markets and to examine its environment in order to tap into potential advantages in the course of technological changes (threats or opportunities) (Arman and Foden, 2010).

According to Savioz (2004) technology intelligence consists of some ‘direct activities’ such as identification of information needs, collection, analysis, dissemination, and application of properly relevant technological information, which would eventually lead, through an improved process of decision-making, to value creation for an organization. Still, there are also a number of ‘indirect activities’ employed as enablers for direct activities in technology intelligence which include technology intelligence management, technology intelligence mission and goals, technology intelligence structure, and technology intelligence tools.

So far, numerous researches have been done related to various aspects of technology intelligence. For instance, Lichtenthaler (2003) introduced different generations of technology intelligence. Kerr et al. (2006) presented a conceptual model for technology intelligence and Savioz (2006) proposed technology intelligent systems for large, medium, and start-up companies. Also, some scholars examined technology intelligence structures. For example, Lichtenthaler (2004b) studied the organization and integration of international technology intelligence activities and Lichtenthaler (2004c) proposed various organizing styles of technology intelligence such as: hierarchical, hybrid and informal. Furthermore, technology intelligence processes have been studied by some researchers. For instance, Lichtenthaler (2004a) examined technology scanning and monitoring process. Lichtehthaler (2006) studied stages of technology intelligence process and Lichtenthaler (2007) introduced different process styles of technology intelligence. Also, Araman and Foden (2010) proposed a model for technology intelligence process in an aerospace company.

In addition, several scholars examined or proposed technology intelligence methods. For example, Lichtenthaler (2005) introduced several methods for technology intelligence activities and Russo and Rizzi (2014) proposed a function oriented method for competitive technological intelligence and technology forecasting. Finally, some technology intelligence tools are proposed by some researchers such as: TRIZ-centered Intelligence Technology (Schuh and Grawatsch, 2003), a software tool in order to identify technological opportunities (Yoon, 2008), Technology intelligence toolbox (Mortara et al., 2009) and a software tool for technology strategic planning (Park et al., 2013).

## 3. Research design and methodology

For this empirical and explorative research, the 'case study' method was applied because it offers a flexible and holistic examination of this very complex research object. The case study method, by going into great depth in a single case, enables the researchers to understand the dynamics present within one setting. Theory developed from case study research is likely to have important strengths like novelty, testability, and empirical validity, which arise from the intimate linkage with empirical evidence (Eisenhardt, 1989). This method also enables the researchers to investigate important topics not easily covered by other methods, and can illuminate a particular situation, to get a close (that is to say, in-depth and first hand) understanding of it (Yin, 2003). In general, case studies are preferred research strategy when "How" or "Why" questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context (Yin, 2003). The process for the case study research followed the one described by Yin (2003) that includes: designing case study research, preparing for data collections, collecting data and evidences and analyzing data and evidences.

### 3.1. Designing case study

A research design is the logic that links the data to be collected and the conclusions to be drawn to the initial questions of study. For case studies, five components of a research design are especially important (Yin, 2003): a study's questions, its propositions (if any), its unit of analysis, the logic linking the data to the propositions and the criteria for interpreting the findings. The unit of analysis is a project which contains manufacturing and developing a gas turbine in Iran which was called IGT25 and took place from 2012 to 2014. The main question of this research is that: how technology intelligence has been applied in the project of developing Iranian gas turbine as a complex product system? In order to respond to this question we have to explore some answers to below questions:

- What is the technology intelligence process regarding to activities and their sequence?
- Which types of structure, players and methods have been applied?

### 3.1. Data gathering

Evidence for case studies may come from six sources (Yin, 2003): documents, archival records, interviews, direct observation, participant observation and physical artifacts. In this research, a total of 12 interviews were performed in Oil Turbo Compressor Company (OTC) and one of its subsidiary which was called Turbo Tech. Interviewed persons include some CEO manager, project managers, R&D managers, after sale service managers, design and engineering managers, project supervisors and technology management especialists. Also, several documents such as long-term planning documents, organizational charts and projects reports were studied and analyzed. Only through this multiple perspective data gathering methods was it possible to get an in-depth understanding of the technology intelligence process and its structure, players, methods and tools.

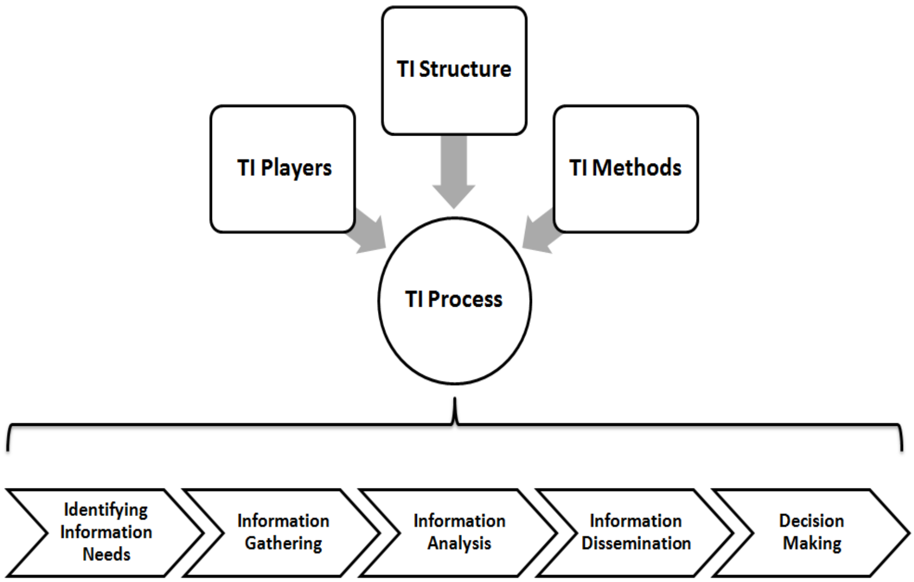
### 3.2. Data analysis

Data analysis consists of examining, categorizing, tabulating, testing or otherwise recombining both quantitative and qualitative evidence to address the initial propositions of a study. There are three strategies in order to analyze data in case study researches including (Yin, 2003): theoretical propositions, setting up a framework based on rival explanations and developing case descriptions. There are some previous theory and framework for exploiting and implementing technology intelligence in various levels of analysis and different types of companies (Savioz, 2004; Kerr et al., 2006; Lichtenthaler, 2006; Savioz, 2006; Mortara et al., 2009). By combining above-mentioned frameworks, we have proposed a conceptual framework in order to categorize and analyze gathered data and evidences and extract this research results and findings (Figure 1). Listed below, each element of conceptual framework was explained (Savioz, 2004; Lichtenthaler, 2006):

- *TI Structure*: the TI structure describes the arrangement of different elements of TI and the people involved. In other words, TI structures describe how TI activities are assigned to different units and people, and how they are organized.
- *TI Players*: the people who involve in different stages of TI process with various tasks and objectives.
- *TI Methods*: TI methods include information collection and analysis methods.
- *TI Process*: The TI process consists of different stages in the value-creation process of intelligence. The TI process is a value creating process. It is not a step-by-step process, but a parallel assembly of diverse interacting TI activities.

1. *Identifying information needs*: The 'identification of information needs' requires the selection of a needs assessment form, which is the type and number of people, and the choice of appropriate methods.
2. *Information gathering*: The process step 'information gathering' aims to gather the information required starting from a perceived information need.
3. *Information analysis*: The objective of the 'information analysis' step is to evaluate the importance of the gathered information.
4. *Information dissemination*: The process step 'information dissemination' aims to communicate the generated results in such a way that individual learning or organizational learning is enabled.
5. *Decision making*: the information generated should finally be integrated into the decision-making processes of strategic technology management. The CTO, the CEO, heads of R&D and marketing, technology strategy teams, and also R&D employees and project leaders were seen as users of the technology intelligence process.

Figure 1. Conceptual framework for technology intelligence




## 4. Case study and results

### 4.1. Oil Turbo Compressor Company (OTC)

OTC was officially established in January 2001. Technology-Transfer of industrial turbo-machineries has been OTC's ultimate strategy. In this respect, it has promptly entered into technical partnership with an internationally operating company such as Siemens, and at the same time developed, encouraged and cooperated with many local vendors, business partners and manufacturers to assemble and make many items and products in accordance to the latest international standards. The international partner's collaboration and supervision on the local manufacturers is some of the essential parts of the partnership. Nowadays, all locally made items have the international partner's approved certificates. Main activities of OTC include manufacturing, assembling, installation and commissioning of different types of turbo compressor and generators; repairing and maintenance of different types of turbo compressor and generators; designing and engineering of gas boosting, gas injection, gas storage and ethylene stations; designing and engineering of medium and small power plants; executing of various engineering procurement construction (EPC) projects in the petroleum and energy industries.[2)]

### 4.2. Iranian Gas Turbine (IGT25)

Through this project, Iran has acquired the knowledge and technologies required to designing and manufacturing a 25 megawatt gas turbine, called IGT25, to become one of the only five countries in the world with the technical knowledge. A total of 59 alterations were made to the model turbine in order to acquire patent

2) For more information about OTC see this website: http://otc-ir.com/OTC/

for IGT25. So far 31 inventions have been patented, with the remainders in the registration process. Operating in a knowledge-based company, 250 experts and specialists are working on the turbines, with 1.1 million man-hours spent so far on the project. IGT25 is an industrial gas turbine with 25 MW capacity, which can be increased to 30 MW. The IGT25 consists of 42,000 pieces and components. IGT25 is expected to be officially inaugurated in one of the country's gas compressor stations. Main goal of IGT25 projects was acquiring design and manufacturing knowledge and technologies and the project duration includes years from 2012 to 2014. IGT25 is the largest research contract have been supported by Iran's Oil Ministry and it's a joint venture agreement between National Iranian Gas Company and OTC.

### 4.3. Technology intelligence process

#### 4.3.1. Identifying information needs

Regarding to *identifying information needs,* Peiffer (1992) proposes a differentiation between "inside-out" and "outside-in" perspectives. The first focuses on observation of technologies within the existing area of action. The latter is an unbiased observation of general technological trends. The company studied in this research, use the strategic technology planning processes as the starting point for the *inside-out perspective.* The technology planning processes, such as technology road mapping and scenario analysis, integrate technology and market aspects in most cases and are organized cross-functionally. In doing so, new critical issues, such as emerging technologies or competitors, are identified. Also, the main drivers of industry development and product functionality from a customer point of view are identified. As a result, these most important topics and their underlying drivers are monitored systematically. Technologies which contribute particularly to critical product functions are monitored and potentially new technologies are explored. As such, not only short-term and medium-term but also long-term planning processes are used as a starting point to identify information needs holistically. On the long-term planning horizon, scenarios are used through defining of innovation fields which have to be monitored, and technology roadmaps are used particularly for short-term and medium-term planning in order to define technology fields and product functions which have to be monitored.

However, the company studied also uses an *outside-in perspective* on technology intelligence, starting from this inside-out approach. The outside-in perspective is covered only to a limited degree in the planning processes. Fields related to the industry are monitored by technology intelligence specialists. Many companies regularly scanned for new solutions to the product functions in the higher parts of the product hierarchy. The company studied therefore use several search strategies in parallel as a kind of heuristic for the outside-in perspective. The search strategies include technology fields, product functions, customer needs, regions, organizations and information sources which were identified. Interestingly, technology intelligence specialists had very different views of integrating themselves into the decision-making processes of their firms. By participating in important strategic decision-making processes, many technology intelligence specialists did acquire sufficient knowledge about information needs, and they could also communicate new important trends.

#### 4.3.2. Information gathering

The step of *information gathering* aims to gather the information required starting from a perceived information need. An information gathering form, including the type and number of people collecting data, as well as adequate information sources which give access to the searched information have to be chosen. Generally the company has used two categories of information sources: formal and informal. Formal sources of information include research program, articles, patents, conference proceedings, online databases, journals, newsletters and internet. Also, informal sources of information consists regular meetings, memberships, site visits, phone calls, accidental contact, small talk, interview and expert panels with some actors like competitors, clients, suppliers, start-up companies, VC funds, university professors, professional societies, conferences and alliance partners.

The time horizon emerged as one major contingency factor for the choice of information sources. Some information sources are more appropriate for short-term planning horizons; other sources better suit long-term planning horizons. Furthermore, the search perspective (inside-out vs. outside-in) influences the choice of information sources fundamentally. The search with an inside-out perspective, the so-called *monitoring,* requires an in-depth understanding of the changes in the environment. Therefore, highly specific information is gathered by the R&D employees as part of their daily task. In the other side, the search with an outside-in perspective, the so-called *scanning,* has to be limited to aggregated information classes in most cases, owing to resource restrictions.

### 4.3.3. Information analyzing

The objective of the information analysis step is to evaluate the importance of the gathered information. The starting point for such an analysis may vary significantly. Considering the studied company, we distinguished between "individual analysis" and "group analysis" approaches. *Group analysis* can trigger organizational learning by initiating the learning of the participants. In the some cases, the analysis methods are used as part of the participatory decision-making and planning processes. The precision of the method is seen as less important than the fact that the method is understood by the participants and enables communication. Scenario building and road mapping particularly support such learning processes. In addition, *individual analysis* aims at the individual learning of the person doing the assessment and the user of the results. As the methods have to be explained to only a few people, the company studied sometimes uses very complicated and costly methods, in order to get as precise an analysis as possible. Selected specialists use methods such as simulations and literature citation analyses, patent analysis and present the results to individual members of top management.

### 4.3.4. Information dissemination

The process step *information dissemination* aims to communicate the generated results in such a way that individual learning or organizational learning is enabled. In many interviews it was emphasized that the value of technology intelligence processes depends not only on a systematic observation of all the important technological trends in the environment but on the quality of the analysis. It is rather fundamental for the success of a technology intelligence process if the effectiveness of decisions can be improved. Besides choosing the right persons to communicate the information, it was considered to be critical for the success of the intelligence process to choose adequate communication media for the communication task. In the studied company, the communication media range from letters and e-mails to telephone and face-to-face communication. These media differ in their ability to transfer complex information. Written media are seen as 'poorer' media than telephone or face-to-face communication. Face-to-face communication is considered the 'richest' communication medium. Thus there is much communication between different participants of the technology intelligence process. However, the information generated should finally be integrated into the decision-making processes of strategic technology management. The CTO, the CEO, heads of R&D and Marketing, technology strategy teams, and also R&D employees and project leaders were seen as users of the technology intelligence process. We found that, the corporate culture and the decision-making style strongly influence how widely and openly strategic information is distributed.

#### 4.3.5. Decision making

TI supports decision-making in technological and general management concerns. Decision-making not only depends on the most reliable information, but also on intuition, traditions, resources, etc. Thus, TI is a supporting task, which can be pursued systematically or informally. Since decisions can be made within a planning process or spontaneously, TI has a reactive as well as proactive character. Technological trends may have an impact on any potential of the organization. Therefore, TI influences both technological and general management concerns (Savioz, 2004). Several strategic and operational decisions in terms of technological issues were made in the process of manufacturing and developing IGT25 gas turbine by OTC's managers. The evidences show that, TI activities have influenced on these decisions effectively and significantly. Some of these decisions include:

- Selecting Siemens as a foreign partner in order to collaborate in the process of technology transfer and acquisition
- Choosing SGT600 gas turbine as a base model for acquiring its knowledge and technologies and localizing its technologies in Iran
- Acquiring an Iranian knowledge-based company named Petro Gas Khavarmianeh as research and development center in order to obtain design knowledge and technologies
- Adopting bottom-up approach instead of top-down approach in order to acquire design knowledge and technologies through benchmarking with some latecomer firms such as Hitachi and Zorya
- Choosing some key sub-systems and components of IGT25 gas turbine in order to register some new inventions through analyzing patents related to this gas turbine

### 4.4. Technology intelligence structure

Technology intelligence structure describes how TI activities are assigned to different units and people, and how they are organized (Savioz, 2004). In the other words, technology intelligence structure involves determining how technology intelligence activities are allocated to individuals and divisions, how these people are organized; and defining relationships and interactions therein (Safdari Ranjbar and Tavakoli, 2015). Lichtenthaler introduced three different structures for technology intelligence activities (Lichtenthaler, 2004c) as "structural," "hybrid," and "informal." We found that, in the examined company all types of technology intelligence structures are being used. In terms of structured organization style, tasks and responsibilities are assigned to positions and organizational units through a hierarchical order, with full-time specialists of technology intelligence in these units observing rivals, universities, and fledgling companies to track the latest technological trends. Regarding to the hybrid structure, however, involves projects with certain and limited terms which are conducted in order to adapt to particular issues of technology intelligence related to IGT25 project. And lastly, informal structure of organization attempts to steer independent and spontaneous behaviors of data collection and dissemination.

### 4.5. Technology intelligence players

People of various expertise at multiple organizational levels have decisive roles in how successful technology intelligence may be as they are often involved in a diversity of activities including data gathering, analysis and dissemination across the organization (Safdari Ranjbar and Tavakoli, 2015). Some of the players related to technology intelligence issues and activities in the examined company mentioned as follows:

- People work in *centralized technology intelligence units,* support the decision-making of top management and have a coordinating role for other technology intelligence structures and projects. Furthermore, these units are seen as intermediaries for all employees to communicate trends to top management.
- *Internal informant networks*, which have dedicated monitoring tasks, but can also come up with new trends or information needs. Often the units also form specific technology intelligence teams for special projects on behalf of top management, which allows including the most-suited persons for a limited amount of time.
- If decision-making is more decentralized, often *decentralized technology intelligence units* do exist at multiple levels of the organization. These decentralized units have the same role as the central units but support decentralized decision-making processes.
- Lead-user/lead-supplier analyses are often used to learn early on about new technology trends in one's own industry.
- *External expert networks* can be used to learn about trends within the own industry or to learn about technologies currently outside of the search routines of one's own industry.
- *Individual R&D employees* are the most important part of technology intelligence processes. In their search routines as part of normal work, they learn about many important trends much earlier than any intelligence specialist could.
- In order to enable discussion of informally gathered trends, the company supports the creation of *informal R&D networks* through intranet platforms and supplementary travel expenses. Department heads and project leaders can play an important role in an assessment of the trends identified in informal R&D networks, because they often have the relevant knowledge on how a new trend fits into the overall company strategy.

### 4.6. Technology intelligence methods

As well as people and organizational structure of technology intelligence system, methods required play crucial part in the advancement of the execution process. As a matter of fact, in order to confront technological threats and tap into related opportunities, technology intelligence system demands its respective efficient methods and tools (Safdari Ranjbar and Tavakoli, 2015). A number of technology intelligence methods that have been applied by the studied company include: paper and publication analysis, patent analysis, S-curve analysis, benchmarking studies, portfolio analysis, Delphi studies, experts panel, Expert Interview, product and technology roadmap, simulation, scenario analysis, and quality function development.

Functional expectations from methods are influential in adopting a certain method and the way it would be assessed. There are two methodological functions distinguishable, i.e. information generation and learning. The former, in turn, can be carried out through three methods, i.e. extrapolative, explorative, and normative. Learning, however, comes in two individual and organizational forms (Lichtenthaler, 2005).

## 5. Discussion and conclusion

To be able to make efficient and effective decisions in the technology field, there has to be acquaintance about changes of product, materials, processes and business technologies. Responding to technological changes and the reduction of related risks can, to a very large extent, be achieved using an efficient technology intelligence system, which is equipped with an early alarming apparatus and can assess potentials of new technological advances (Safdari Ranjbar and Tavakoli, 2015). Making effective and efficient decisions about technological issues in both strategic and operational level required systematic technology intelligence activities in an organization. In the other hand, most of the studies related to technology intelligence concept have concentrated on general aspects of technology intelligence at firm level and finding some studies that have focused on exploiting technology intelligence in developing complex product systems is difficult or even impossible. Complex product systems (CoPS) involve a certain degree of technological novelty and innovation and a high level of coordination and collaboration during design, production and implementation. So, CoPS developers and producers deal with an abundant number of capabilities, knowledge, skills, tools and players regarding to technological issues. In order to fill this gap, this paper have examined technology intelligence in designing and manufacturing an Iranian gas turbine, IGT25 as a complex product system in Oil Turbo Compressor Company (OTC) and have found some evidences regarding to technology intelligence processes, structure, methods, players in this project.

Regarding to technology intelligence process, we found that the examined company have used both inside-out and outside-in perspectives in order to identify information needs. Also, the company has used various formal and informal information sources to gather required information. In addition, both individual and group analysis approaches have been applied in order to analyze information and enhance individual and organizational learning. Finally, different kinds of media (email and letters) and communication ways (face to face or telephone contacts) have been applied in order to disseminate information among various actors and players. In terms of technology intelligence structure, evidences show that, the studied company has used all three kinds of coordination forms: structured, hybrid and informal. Also, a large number of players including people in centralized and decentralized technology intelligence units, internal and external expert network and R&D employees are allocated to technology intelligence activities. Furthermore, there are many kinds of technology intelligence methods that have been applied in the studied company for information generation or learning in individual and organizational level.

A number of managerial implications are as follows:

- In view of the different generations of technology intelligence suggested by Lichtenthaler (2003), managers are advised to make efforts to implement third generation technology intelligence (which interconnects technology strategy and business strategy, decision-making processes and participatory planning and coordinates technology planning and market in different time periods, etc.), which is aligned with the third-generation technology management.
- Considering the philosophy of technology intelligence (Kerr et al., 2006), managers should define procedures and mechanisms required to establish communication between intelligence users (managers and decision makers) and intelligence brokers. Also, they are advised to exactly identify data needs of intelligence users and facilitate boosting of spontaneous behaviors aimed at identification of technological trends (opportunities and threats) through intelligence brokers.
- Missions and objectives of the technology intelligence system should be precisely determined in an organization because each of the objectives, such as decision making improvement in the technology field (Savioz, 2004), identification of technological threats and opportunities (Arman and Foden, 2010), facilitation and boosting of open innovation (Veugelers et al., 2010) and enhancement of technological learning, rest on observing a number of specific requirements and using some certain mechanisms.
- They can choose the proper structure for the system of technology intelligence in their companies considering various factors effective on the structure of technology intelligence system such as company's culture, technology life cycle, company's main structure, innovation strategy of the company, decision

-making style and the industry involved (Savioz, 2004) and understanding the characteristics, strengths and weaknesses of intelligence organizing styles (structured, compositional and informal) (Lichtenthaler, 2004a, 2004b, 2004c).

- In case the nature of the industry and related activities have made international technology intelligence indispensible, managers are advised to follow mechanisms suggested for international technology intelligence such as international R&D units, technology ambassadors, listening posts and dispatching teams to international conferences and exhibitions (Lichtenthaler, 2004a, 2004b, 2004c).
- To adopt proper methods of data collection and analysis, managers are also advised to consider issues like functions expected from methods, the level of uncertainty, time horizon, industry and technology change rate, company's culture and restraints of time, human resources and finance (Lichtenthaler, 2005).
- Considering the key role of ICT infrastructures and tools which have much been emphasized by researchers (Yoon, 2008; Veugelers et al., 2010; Yoon and Kim, 2012; Park et al., 2013), mangers are suggested to take advantage of Internet and intranet infrastructures and tools (software systems and databases).

Also, there are a number of implications for future research as follows:

- Much of the studies carried out in line with technology intelligence addresses mass-production consuming goods companies and organizations (Lichtenthaler, 2004a, 2004b, 2004c, 2006, 2007; Arman and Foden, 2010), while similar studies in companies and organizations in the CoPS sector seem to be equally important.
- Identifying and prioritizing of challenges and barriers to the design and implementation of the technology intelligence system particularly in CoPS producers and suppliers are recommended.
- Also, it is recommended to research on the methods which are possible to be used in the process of technology intelligence (Lichtenthaler, 2005), as it is not exactly clear which methods are to be applied in every stage of the technology intelligence process. With that said, the exact location of methods along the process is recommended as a research subject.

## References


Acha, V., Davies, A., Hobday, M. and Salter, A. (2004). Exploring the capital goods economy: complex product systems in the UK. *Industrial and Corporate Change, 13*(3), 505-529.

Arman, H. and Foden, J. (2010). Combining methods in the technology intelligence process: application in an aerospace manufacturing firm. *R&D Management, 40*(2), 181-194.

Chen, J., Tong, L. and Ngai, E. W. T. (2007). Inter-organizational knowledge management in complex products and systems (Challenges and an exploratory framework). *Journal of Technology Management in China, 2*(2), 134-144.

Choung, J. Y. and Hwang, H. R. (2007). Developing the complex system in Korea: the case study of TDX and CDMA telecom system. *International Journal of Technological Learning, Innovation and Development, 1*(2), 204-225.

Davies, A. (1997). The life cycle of a complex product system. *International Journal of Innovation Management, 1*(3), 229-256.

________ and Brady, T. (1998). Policies for a complex product system. *Futures, 30*(4), 293-304.

________ and Hobday, M. (2005). *The Business of Projects (Managing innovation in complex product systems).* Cambridge University Press, New York.

________, Brady, T., Prencipe, A. and Hobday, M. (2011). Innovation in complex products and systems: implications for project-based organizing. In G. Cattaui, S. Ferriani, L. Frederiksen and F. Tăube(Eds.) *Project-Based Organizing and Strategic Management. Advances in Strategic Management, 28*, Emerald Group Publishing Ltd., 3-26.

Dedehayir, O., Nokelainen, T. and Makinen, S. K. (2014). Disruptive innovations in complex product systems industries: a case study. *Journal of Engineering and Technology Management, 33*, 174-192.
Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review, 14*(4), 532-550.
Felipe, J., Kumar, U., Abdon, A. and Bacate, M. (2012). Product complexity and economic development. *Structural Change and Economic Dynamics, 23*(1), 36-68.
Hobday, M. (1998). Product complexity, innovation and industrial organization. Research Policy, 26, 689-710.
__________ (2000). The project-based organisation: an ideal form for managing complex products and systems?. *Research Policy, 29*(7-8), 871-893.
__________ and Brady, T. (1998). Rational versus soft management in complex software: lessons from flight simulation. *International Journal of Innovation Management, 2*(1), 1-43.
__________ and Brady, T. (2000). A fast method for analyzing and improving complex software processes. *R&D Management, 30*(1), 1-22.
__________ and Rush, H. (1999). Technology management in complex product systems (CoPS) – ten questions answered. International Journal of Technology Management. 17(6), 618-638.
Kerr, C. I. V., Mortara, L., Phaal, R. and Probert, D. R. (2006). A conceptual model for technology intelligence. *International Journal of Technology Intelligence and Planning, 2*(1), 73-93.
Kiamehr, M., Hobday, M. and Kermanshah, A. (2013). Latecomer systems integration capability in complex capital goods: the case of Iran's electricity generation systems. *Industrial and Corporate Change*, 1-28.
__________, Hobday. M. and Hamedi, M. (2015). Latecomer firm strategies in complex product systems (CoPS): the case of Iran's thermal electricity generation systems. *Research Policy, 44*(6), 1240-1251.
Lee, J. J. and Yoon, H. (2015). A comparative study of technological learning and organizational capability development in complex products systems: distinctive paths of three latecomers in military aircraft industry. *Research Policy, 44*(7), 1296-1313.
Lichtenthaler, E. (2003). Third generation management of technology intelligence processes. *R&D Management, 33*(4), 361-375.
______________ (2004a). Technological change and the technology intelligence process: a case study. *Journal of Engineering and Technology Management, 21*(4), 331-348.
______________ (2004b). Coordination of technology intelligence processes: a study in technology intensive multinationals. *Technology Analysis and Strategic Management, 16*(2), 197-221.
______________ (2004c). Technology intelligence processes in leading European and North American multinationals. *R&D Management, 34*(2), 121-135.
______________ (2005). The choice of technology intelligence methods in multinationals: towards a contingency approach. *International Journal of Technology Management, 32*(3/4), 388-407.
______________ (2006). Technology intelligence: identification of technological opportunities and threats by firms. *International Journal of Technology Intelligence and Planning, 2*(3), 89-323.
______________ (2007). Managing technology intelligence processes in situations of radical technological change. *Technological Forecasting and Social Change, 74*(8), 1109-1136.
Magnaye, R., Sauser, B., Patanakul, P., Nowicki, C. and Randall, W. (2014). Earned readiness management for scheduling, monitoring and evaluating the development of complex product systems. *International Journal of Project Management, 32*(7), 1246-1259.
Majidpour, M. (2013). Promoting industrial competitiveness in complex product systems: Iran industrial policy case study. *Economic Development: Industrial and Financial Policy* (Chapter 1).
Miller, R., Hobday, M., Lerouxdemers, Th. and Olleros, X. (1995). Innovation in complex systems industries: the case of flight simulation. *Industrial and Corporate Change, 4*(2), 363-400.
Mortara, K., Kerr, C. I. V., Phaal, R. and Probert, D. (2009). A toolbox of elements to build technology intelligence system. *International Journal of Technology Management, 47*(4), 322-345.
____________________________________________ (2008). Technology intelligence practice in UK technology-based companies. *International Journal of Technology Management, 48*(1), 115-135.

Park, H., Kim, K., Choi, S. and Yoon, J. (2013). A patent intelligence system for strategic technology planning. *Expert Systems with Applications, 40*(7), 2373-2390.

Park, T. Y. (2012). How a latecomer succeeded in a complex product system industry: three case studies in the Korean telecommunication systems. *Industrial and Corporate Change, 22*(2), 363-396.

Peiffer, S. (1992). *Technologie-Frühaufklärung: Identifikation und Bewertung zukünftiger Technologien in der strategischen Unternehmensplanung*. Hamburg, S&W Steuer- und Wirtschaftsverlag.

Prencipe, A. (2000). Breadth and depth of technological capabilities in CoPS: the case of the aircraft engine control system. *Research Policy, 29*(7-8), 895-911.

Ren, Y. T. and Yeo, K. T. (2006). Research challenges on complex product systems (CoPS) innovation. *Journal of the Chinese Institute of Industrial Engineers, 23*(6), 519-529.

Russo, D. and Rizzi, C. (2014). A function oriented method for competitive technological intelligence and technology forecasting. *International Conference on Engineering, Technology and Innovation (ICE), Bergamo*.

Safdari Ranjbar, M. and Tavakoli, Gh. R. (2015). Toward an inclusive understanding of technology intelligence: a literature review. *Foresight, 17*(3), 240-256.

Savioz, P. (2004). *Technology Intelligence; Concept Design and Implementation in Technology-based SMEs*. New York: PALGRAVE MACMILLAN.

________ (2006). Technology intelligence systems: practices and models for large, medium-sized and start-up companies. *International Journal of Technology Intelligence and Planning, 2*(4), 360-379.

________ and Blum, M. (2002). Strategic forecast tool for SMEs: how the opportunity landscape interacts with business strategy to anticipate technological trends. *Technovation*, *22* (2), 91-100.

Schuh, G. and Grawatsch, M. (2003). TRIZ-based technology intelligence. *European TRIZ Association Meeting TRIZ Futures*.

Su, J. and Liu, J. (2012). Effective dynamic capabilities in complex product systems: experiences of local Chinese firm. *Journal of Knowledge-based Innovation in China, 4*(3), 174-188.

Veugelers, M., Bury, J. and Viaene, S. (2010). Linking technology intelligence to open innovation. *Technological Forecasting and Social Change, 77*(2), 335-343.

Yeo, K. T. and Ren, Y. T. (2009). Risk management capability maturity model for complex product systems (CoPS) projects. *Systems Engineering, 12*(4), 275-294.

Yin, R. K. (2003). *Case Study Research: Design and Methods*. 3rd edition. Sage publication.

Yoon, B. (2008). On the development of a technology intelligence tool for identifying technology opportunity. *Expert Systems with Applications, 35*(1-2), 124-135.

Yoon, J. and Kim, K. (2012). TrendPerceptor: a property–function based technology intelligence system for identifying technology trends from patents. *Expert Systems with Applications, 39*(3), 2927-2938.