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Proposing a Framework for Technology Planning at Industry Level

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Abstract
Whereas technology planning primarily concerns with selection of proper technologies and setting priorities to develop firm technological capabilities, crucial role of technology in supporting national prosperity and security highlights the need for technology planning at industry level (TPIL). The lack of an appropriate methodology for TPIL has forced practitioners and scholars to adapt firm- or national- level methodologies to industry level by some amendments. But, TPIL requires a specific methodology which considers requirements and characteristics of industry level.
In this paper, we develop an industry- level methodology for technology planning through in-depth case study. A qualitative approach based on the grounded theory has been applied. Starting with minimalist prior constructs deep into a substantive issue (TPIL process in this case), we interactively tested and formed theoretical constructs. For this purpose, a series of semi-structured interviews were organized and accomplished with top and middle managers of Iran Oil & Gas industry. Moreover, some interviews with university faculty members having experience in TPIL were conducted. Based on eighteen interviews, 529 initial codes, 150 final codes, 50 categories and 17 themes were explored. Finally, a general framework which consists of three main levels (reference, portfolio and option level) has been proposed.

Keywords:
Technology Planning, Industry level, Framework, Grounded Theory, Oil & Gas Industry

1. Introduction

Technology deals with theoretical and practical knowledge, skills, and artifacts that can be used to develop products and services as well as production and delivery systems (Burgelman et al., 2009). Great influence of technology on individuals, businesses, society and nature (Khalil, 2000) makes its management so vital. Management of technology (MOT) involves planning, development and implementation of firm's technological capabilities (NRC, 1987). Moreover, contribution of MOT on management of large, complex and interdisciplinary or inter-organizational systems (Li-Hua and Khalil, 2006) such as industries or sectors highlights its importance at industry level. Furthermore, crucial role of technological capabilities in supporting national prosperity and security overemphasizes the importance of taking strategic approach to technology planning at industry level (TPIL).

Strategies at supra-firm level can be grouped into three major classifications such as, network- level (Wet and Meyer, 2010), sectoral-level (Best, 1986), and national-level (Chandler, 1969) strategies. Sectoral level consists of a particular industry (such as, Oil & Gas) or a technology area (such as ICT or Bio Tech). Having a specific and appropriate strategy for each industry/sector is crucial for the national growth and competitiveness.

Phaal (2003) argues that technology planning at supra-firm level links specific technology areas, system performance and industry drivers. The critical issues such as structural complexity, interdisciplinary and inter-organizational nature of the industry indicate the necessity of using an integrated approach for shaping industry's technological capability proactively.

Review of academic studies and empirical works indicate that during past decades, many people have tried to develop methods and tools for technology planning and technology foresight (Phaal and Muller, 2011; Albright and Kappel, 2003; McMillan, 2003; Keenan, 2003) apt to prioritize the core technology areas of industries (e.g. kostoff and Schaller, 2001; Phaal, 2002). However, the lack of specific methodology which considers attributes of industry-level technology planning has compelled researchers and practitioners to employ micro-level technology planning methodologies (eg. Amadi-Echendu et al., 2011; Phaal and Muller, 2009) or macro-level methodologies (eg, Banuls and Salmeron, 2008; Karlsen& Christian, 2003; OG 21, 2006; Lee et al., 2014) for TPIL.

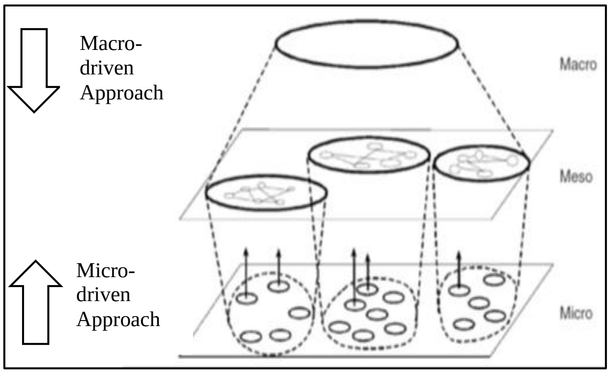
Whereas different contexts and characteristics of industries (such as, dissimilarities in convergence and/or the degree of fragmentation or integration) causes that content of technology planning vary from one industry to another, proposing a general frame work, which conceptualize the major phases of TPIL process assists industry managers, policy makers and experts who attempt to strategize technological capabilities of a particular industry/sector.

The major research questions of this study are: 1) what are the main decisions in TPIL process? ; 2) How are they connected together? For answering these questions grounded theory method based on paradigm approach (Strauss and Corbin, 1998) was conducted in Iran Oil & Gas industry. Following this introduction, Section 2 reviews the literature. The next section defines the research methodology. Section 4 concentrates on case elaboration, which is followed by data analysis (section 5). Results are discussed in section 6, and the work ends with a conclusion and possible future lines of research.

2. Literature review

2.1. Technology planning at industry level: is it the matter?

Practitioners and researchers are increasingly motivated to find out how technologies could be managed effectively? This interest is growing as the complexity, cost and rate of technological innovation increase (Phaal et al., 2006). Based on NRC (1987) definition, technology planning is the first and the most important function of MOT. It primarily concerns with selection of proper technologies and setting priorities to develop technological capabilities. Considering supra-firm level, Garcia and Bray (1997) argue that TPIL attempts to identify industry technological requirements and research priorities, which companies and research centers can support. Technology planning for a particular industry requires collaboration between industry, academia and government. It helps decision makers to understand and make relationships between specific technology area, system performance and industry drivers (Phaal, 2002). During past years, TPIL has been widely adopted (eg. Amer and Daim, 2010; Albright, 2003; Albright and Kappel, 2003; Phaal and Muller, 2009; Kostoff and Schaller, 2001), and conducted in different industries/sectors or technology areas[1] . Although there are considerable mentions concerning vital role of technology planning at supra-firm level, there is no framework elaborating process of TPIL[2]. Previous researches can be classified in two groups. The first one consists of studies which adopt macro/national- level methods for TPIL. We called it Macro-driven approach. The second group conducts micro/firm-level methods for TPIL, which is called Micro-driven approach in this paper. In this case, multi-level perspective (MIP) (Geels, 2002) aids us to clarify Macro and Micro driven approaches. Based on MLP, meso-level is positioned between macro and micro level; and is appropriate for analysis of technologies in the value chain of a particular industry (Schenk et al., 2007). (Fig. 1)



Source: Adapted from Geels (2002)

Figure 1. Schematic representation of macro, meso and micro levels.

[1] See for example SIA's international technology roadmap for semiconductors, UK foresight vehicle technology roadmaps, and industry Canada initiative.

[2] Probing the web sites such as, Science direct, Emerald, and Springer from 2000 to 2012 in the field of MOT, we found out, there is no framework elaborating TPIL.

2.2. Macro-driven Approach to TPIL

Literature review in the field of technology planning at supra-firm level indicates that some scholars and practitioners employed macro-level methods/techniques such as technology foresighting, clustering and scenario planning for TPIL. These methods/techniques involve with high level of aggregation. For instance, Banuls and Salmeron (2008) have used foresighting to identify key areas in IT industry. In the same industry, Lee et al. (2014) have applied clustering method to TPIL. Schainker (2006) conducted scenario planning and technology foresighting in order to identify and prioritize research needs of United States electricity power sector. Phaal (2002) attempted to identify technology and research themes for UK Road transportation sector by using TRM. In OG 21 (2006) a rational frame work including five major stages such as defining industry trends and drivers, setting industry vision, defining technological challenges, defining industry research path and selecting research and development themes has developed for planning technological capabilities of Norway Gas industry. Karlsen & Christian (2003) have proposed a sequential frame work containing five major phases: identification of industry strategic objectives, mapping and classifying technology areas, defining attractiveness criteria and finally prioritizing selected technologies. Lee and Song (2007) have used technology clustering technique for selecting key research areas of Nano-technology based on national R&D Programs in South Korea. Although these methods/techniques could be considered as a valuable monitoring and prognostic instrument (Focacci, 2003; Kaya, 1990), the lack of details due to the high aggregation level is their major disadvantage (Schenk et al., 2007). Moreover, this approach could not foresee any trend-breaking events (Craig et al., 2002) which is known as 'macro-bias' (Elzen et al., 2002) or 'economic paradigm' (van Beeck, 1999).

2.3. Micro-driven Approach to TPIL

This section deals with using firm/micro-level methods/techniques for TPIL; called Micro-driven approach - One of these methods is technology road mapping (TRM), which is a powerful technique for supporting technology planning, in order to link technological resources with organizational objectives (Phaal et al, 2004). After first use of TRM in Motorola, it has been widely employed at supra-firm level (Amer and Daim, 2010; Phaal and Muller, 2006). For instance, Amadi-Echendu et al. (2011) have applied it to technology planning at mining sector. Lee et al. (2009) have used it for identification of primary technologies which should be developed in Energy sector of Southwest Korean. Holmes and Ferrill (2005) have conducted a research to identify and select emerging technologies improving operational capabilities of Singapore SMEs using TRM. Lee et al. (2007) have applied TRM to R&D planning in South Korean parts and materials industry. Moreover, some scholars employed decision making techniques for technology selection at industry/sector level. For instance, Hakyeon Lee et al. (2009) have attempted to identify core technologies of telecommunication by proposing an approach based on analytic network process (ANP). Shen et al. (2010) by integrating fuzzy Delphi method, analytic hierarchy process (AHP), and patent co-citation approach, have proposed a methodology for selecting key technology at supra-firm level.

Mirco-driven approach to TPIL tends to have some disadvantages. First, this approach concerns the system at low aggregation level, and is favored when dealing with specific problems that require 'engineering solutions' (Schenk et al., 2007). Second, applying micro-level methodologies, which has limited information about interaction of elements for analysis of a particular industry/sector, would result in questionable representative of data and allocation challenges (Benders et al., 2001; Heijungs and Huijbregts, 2004; Kok et al., 2001). Finally, micro-level analysis describes the functionality of system's elements; thus, it is a valuable evaluative/assessment instrument for product-level (see e.g., Damen and Faaij, 2003; Hondo, 2005; MacLean and Lave, 2003).

Consequently, using macro- or micro-level methodologies impose inaccuracy in analysis of meso-level elements. Moreover, studies indicate that Macro- and Micro-driven approaches tend to arrive at different conclusions (Unruh, 2000). Therefore, neither macro-level methods (methods/techniques for technology policy making), nor micro-level methods (firm-level technology planning methods/techniques) may not be appropriate for TPIL.

3. Methodology

Concerning the research question a qualitative approach has been applied, and grounded theory (GT) methodology (Strauss & Corbin, 1998), which is one of the most suited inductive research strategies in empirical research (Melnyk & Handfield, 1998), was employed. GT encompasses joint collection as well as coding and analysis of data in the underlying operation (Glaser and Strauss, 1967). It essentially attempts to explore, develop and generalize formulations about features of a particular phenomenon while simultaneously it grounds the account in empirical observations or data (Martin & Turner, 1986). Therefore, it needs a cyclical pattern of data collection, coding, theory generation, reflection and comparison with other data sources and concepts for testing purpose (Douglas, 2003). Application of GT in the research fields which lack substantive theory is one of its main advantages (Seidel & Recker, 2009). This methodology is primarily conducted based on two major principles. First, the process of theory building is highly iterative as a comparative analysis. Second, GT is built upon a theoretical sampling, which is a process of data collection and analysis. This methodology is driven by concepts emerged from the study. Moreover, it appears to be of relevance to the nascent theory (Strauss & Corbin, 1998). In this study, process of data analysis was conducted based on Strauss & Corbin (1998) paradigm model which employs three level of coding (open, axial and selective coding).

4. Case study

This study was conducted in Iran Oil & Gas industry. Iran holds the world's fourth- largest proven oil reserves and the world's second- largest gas reservoir. Oil & Gas industry has been the engine of Iran's economic growth, and its productivity directly affects national wealth and government revenue. Petroleum exports make up approximately 80% of Iran's total export, and 50% to 60% of its revenue. According to the annual report of Organization of Petroleum Exporting Countries (OPEC) in 2013, Iran exported around 2.6 million barrels of crude oil a day in 2012, as the second-largest oil export among in OPEC. Based on the Fifth Development Strategy, Iran needs $200 billion of investment in the Oil & Gas industry (Abbaszadeh et al., 2013). Taking in account the fact that, Oil and gas is a technology-intensive industry, and considering its crucial role in Iran's national wealth, it needs an integrated technology planning.

5. Data Analysis

Glaser and Strauss (1967) encourage researchers conducting GT methodology to use multiple data collection techniques since it allows considering multiple viewpoints from which an emerging concept can be analyzed, substantiated, and developed. Consequently, data collection process in this work involved semi-structured interviews and document analysis. In order to prevent from digressing in interview process, an interview protocol was designed and employed. Eighteen semi-structured interviews with selected top and middle level managers of Iran Oil &Gas industry were conducted. In addition, some interviews with faculties from different universities who have had the relevant experience in TPIL were accomplished.

5.1. Open Coding

Open coding is a micro analysis (Strauss & Corbin, 1998) employed to identify initial codes describing the phenomenon. In this stage, a line by line analysis of transcribed interviews is conducted to explore initial codes, which are unit of analysis of theory building. In this study, 529 initial codes were explored based on precisely review of eighteen transcribed interviews. After that, among explored codes, 53 final codes which were repeated or emphasized by interviewees or were noteworthy based on researches viewpoints were selected. Table 1 shows some of the explored initial codes detected in open coding process.

5.2. Axial coding

Axial coding is the second stage of data analyzing process in GT. This intermediate coding is conducted to develop main categories by interconnecting and clustering related final codes. In other words, axial coding links structure to the process of data generation. In this work, 50 categories were developed as the elements of TPIL process. Table 2, demonstrates some of these major categories.

5.3. Selective coding

The final analytical phase is selective coding which identifies the main categories or themes. In this phase, explored themes are connected to other categories systematically, and the connections are validated. In addition, categories which need refinement are developed. Analytical activities of this stage are not distinctively separate from each other. However, they are taken through an interactive process along with axial and open coding. In selective coding themes which are at higher level of abstraction are developed to integrate other categories. In this study, 17 themes were explored (Table 3).

To assess trustworthiness of results, nine criteria suggested by literature of interpretive research and grounded theory were applied. From interpretive approach, criteria such as credibility, transferability, dependability, conformability and integrity were focused (Hirschman, 1986; Lincoln and Guba, 1985; Wallendorf *et al*., 1989); in addition, fit, understanding, generality and control were employed based on GT literature (Strauss and Corbin, 1990). As demonstrated in table 4, we believe that rigor and relevance criteria (Gordon, 2008) of our study were met.

6. Results & Discussion

6.1. Hierarchical Approach

Among different challenges that tackle technology planning at supra-firm level, structural complexity and environmental uncertainties can be mentioned as major problems. On the one hand, responding to diversified environmental forces as well as different technological needs of an industry require different experts in decision making process (involving wide range of participants from policy makers, taking macro- level approach, to engineers, scientists and technical staffs, having micro-level priorities). Since their different point of views and priorities, gathering these diversified experts in a one- stage decision making decreases the productivity of planning process and may cause to reach imperfect technology options. On the other hand, at supra-firm level, technology selection- as a core function of technology planning- seems to be so complicated due to the vast number of possible technology options. Thus, a multi-stage decision making should be employed to systematically approach industry's technology tree. In this study, a hierarchical approach to TPIL is suggested to meet TPIL challenges. For instance by proposing three levels of decision making and gathering the experts with similar concerns in a specific level of analysis decision making complication decreases. Moreover, hierarchical approach decreases freedom of technology selecting process in a cascading direction. In other words, leaving out the less important technology areas and exclude none strategic technologies increase the efficacy of technology strategizing at industry level. In this case, a triple-layer process is proposed as a general frame work for TPIL. These layers are summarized in table 5.

Table 1
Some of explored initial codes detected in open coding process

Quote	Initial codes
I suppose that defining the technological needs of the industry/ sector is starting point of TPIL process. Moreover, These requirements can be explored by identifying industry drivers and challenges as well as reviewing national policies and documents. Since the structural complexity of an industry, its TPIL has different phases which should be analyzed internally and externally at its proper level of analysis. Consequently, each phases of TPIL has its output which is the input of next phase.	▪ Identification of industry technological needs ▪ defining industry drivers ▪ Reviewing national policies ▪ Different phases ▪ Internal and external evaluation at each phase
There are two major stages in TPIL such as, pre-planning phase and planning phase. Defining industry boundary, reviewing industry's objectives, policies and plans, auditing of industry technological capabilities, analyzing macro factors affecting industry are some issues which should be taken in to account in this phase. At planning stage there are some activities such as identification of challenge regarding industry's vision and objectives, classification of challenges based on industry's sectors and time issues, prioritizing industry challenges concerning their importance and emergences, developing technological solutions (TS) regarding concerned challenges, evaluation the attractiveness of proposed TSs.	▪ Pre-planning phase of TPIL ▪ Defining industry boundary ▪ Review of industry objectives and policies ▪ Auditing industry technological capabilities ▪ Analyzing macro factors affecting industry ▪ Planning phase of TPIL ▪ Planning phase ▪ challenge identification regarding industry's vision and objectives ▪ classification of challenges ▪ prioritizing challenges ▪ importance and emergences of challenges ▪ developing technological solutions ▪ evaluation the attractiveness of proposed TSs
There are some main processes for planning technological assets of a particular industry, such as: goal setting, analysis of existing condition and industry trend evaluation, gap analysis and project management.	▪ Goal setting ▪ Analysis of existing condition ▪ Industry trend evaluation ▪ Gap analysis ▪ Project management
TPIL of a particular industry has two main stages of which consist different activities. For instance, Identifying industry's sub sectors and value chain, defining the requirements of industry's stakeholders as well as reviewing industry's mission and vision are some activities of first stage – input stage. After analyses of input information, at planning stage, the challenges of industry in achieving its vision and/or mission should be identified and prioritized based on their importance and emergence. Then technological solutions concerned with each selected challenge should be proposed. In addition, they should be analyzed and selected regarding indicators such as cost, outcomes, effectiveness as well as the effect of solution on value chain. Finally, R&D projects as well as external technology sourcing projects should be selected.	▪ input stage ▪ Identifying industry's sub sectors ▪ Identifying value chain ▪ Defining requirements of ▪ Review of industry's mission and vision ▪ Planning stage ▪ Challenges identification ▪ Prioritizing based on their importance and emergence ▪ Proposing technological solutions (TSs) ▪ Analyzing TSs ▪ Cost of TS ▪ Outcomes ▪ Effectiveness ▪ Assessment of solution effect on value chain ▪ Defining R&D projects ▪ Defining External technology sourcing projects
Complexity of a system causes its planning to be multi-layer. In addition, the conditions of an industry's resources affect the directions of its technology strategy.	▪ Multi-layer planning ▪ Industry condition ▪ Direction of industry technology strategy
There are some issues which must be considered in TPIL process like, identification of drivers triggering technology development in industry, technological requirements of industry's stake holders as well as industry's mission and objectives. Definition of industry's boundary, identification of industry network elements, current situation auditing, defining the vision of industry's technological capabilities, proposing technological solutions to tackle industry challenges and finally prioritizing technological solutions.	▪ Drivers triggering technology development ▪ Industry technological requirements of ▪ Stake holders requirements ▪ Industry's mission and objectives ▪ Definition of industry's boundary ▪ Identification of industry network elements ▪ Current situation auditing ▪ Defining the industry vision ▪ Proposing TSs to tackle industry challenges ▪ prioritizing TSs

Table 2
Some of developed categories in axial coding

Final codes	categories	Final codes	categories
Defining industry boundary based on value chain	Defining industry boundary	Defining industry challenges in achieving industry's vision	Identification of industry challenges
Defining boundary based on industry mission		Defining future key technologies	
Developing industry profile	Industry evaluation	Indenting needed infrastructures, process and services	
Evaluation of industry demand		Assessing environmental trends and drivers	Evaluation of industry and market trends and drivers
Identification stake holders and their needs		Prioritizing driver forces	
Probing entrance of new technology to the industry		Defining the effectiveness of technological solutions (TSs)	analysis of technology areas impact on key system requirements
Assessment of existing technology status		Assessing TSs based on market approach	
Defining technology development drivers		Assessing TSs based on impact index	
Probing related SIS		Feasibility study of each technology option (TO)	Risk assessment of TOs
Assessment of available resources		Assessing risk of internal development of TOs	
Identification of industry core	Prioritizing industry value chain	Assessing technical risk	
Prioritizing industry key sub sectors		Defining mode of TOs acquisition	Selecting the mode of acquisition of TOs

Table3
Explored themes constructing TPIL process

Themes	Themes
Triple-level TPIL	Trend evaluation of KTAs
Supporting studies	Defining industry acquisition approach regarding selected KTAs
Macro environment Assessment	Identification of technology options (TOs)
Setting industry vision and goals	Attractiveness evaluation of TOs
Defining primary technology development fields	Capability auditing regarding TOs
defining the under-planned system and its dimensions	Selecting strategic TOs
Identification of key system requirements (KSRs)	Defining TOs mode of acquisition
Identification of technology areas responding KSRs	
Developing portfolio of key technology areas (KTAs)	Feedback loop

Table 4
Validity of the Study and Findings: Interpretive and Grounded Theory Criteria

Validity Criteria	**Criteria focus** (Flint *et al*., 2002)	**Addressing approach in this study**
Credibility	Extent to which the results appear to be acceptable representations of the data.	Interviews were conducted five months and 23-page summary of initial interpretations was provided to the participants for feedback.
Transferability	Extent to which findings from one study in one context will apply to other contexts.	Theoretical sampling.
Dependability	Extent to which the findings are unique to time and place; the stability or consistency of explanations.	Participants had on many experiences covering recent events as well as past events.
Conformability	Extent to which interpretations are the result of the participants and the phenomenon as opposed to researcher biases.	More than 157 pages of interpretations and documents analyzed independently
Integrity	Extent to which interpretations are influenced by misinformation or evasions by participants.	Interviews were conducted professionally, with nonthreatening nature, and anonymous.
Fit	Extent to which findings fit with the substantive area under investigation.	Addressed through the methods used to address credibility, dependability, and conformability
Understanding	Extent to which participants buy into results as possible representations of their worlds.	Executive summary of findings to participants; asked if they reflected their stories. Presented a summary to practitioners.
Generality	Extent to which findings discover multiple aspects of the phenomenon.	Interviews had sufficient time and openness to elicit complex dimensions of phenomenon
Control	Extent to which organizations can influence aspects of the theory.	Some variables within the theory have aspects, which participants would have some degree of control.

Table 5.
Contents of TPIL's layers

	Process Nature	Aim (Selection of :)	Decision Making Drivers	Level of Analysis	Experts
Reference Level	Policy Making	industry/sector Technological Requirements	Key Factors of Macro Environment	main fields of technology development (MFTD)	Industry Policy Makers & Top Managers
Portfolio Level	Technology strategizing	Technology Area Portfolio	Industry/Market Key Trends & Drivers	Technology Area	Industry Middle Managers and Sector Experts
Option Level	R&D Planning	Key technology & Sub technologies	Performance Goals	Technology/R&D Projects	Engineers & Technical Experts

6.2. Reference level

At this level, main fields of technology development (MFTD) of concerned industry are selected by policy makers and top managers of industry network. This phase contains the highest level of aggregation, and its major modules are: evaluation of macro environment, auditing current situation, considering requirements of upper/national policies and defining the industry advantages (Fig. 2). Whereas a particular MFTD may not have exact flavor of technology, it addresses the major technology area of under-planned industry/sector and helps governments and private sector to focus their investment in the field of technology development.

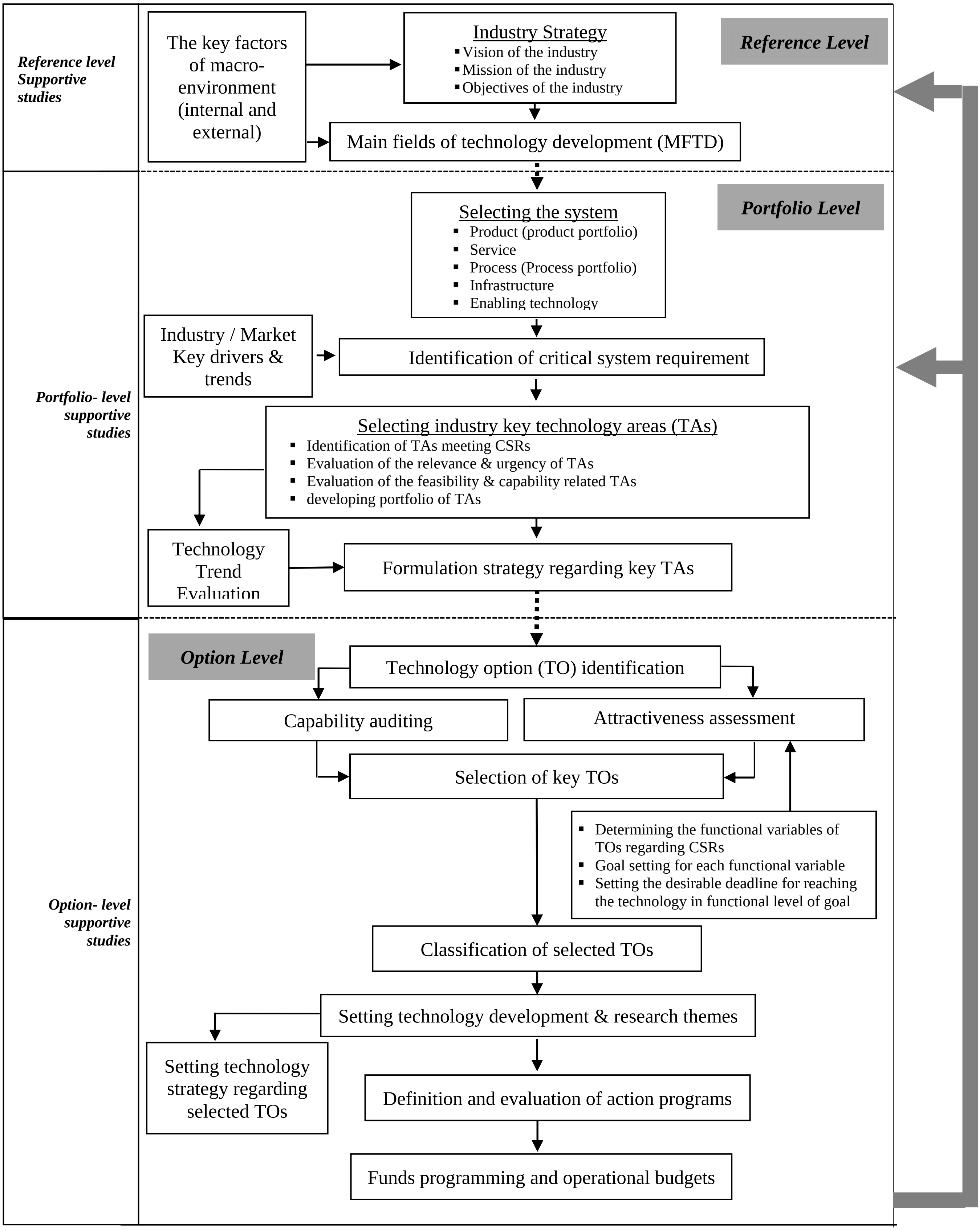
6.3. Portfolio Level

This level is the second phase of TPIL, in which portfolios of key technology areas (TAs) are selected to support industry's/sector's MFTDs. System identification is the first step of portfolio level. Regarding industry's nature and characteristics, the system can be defined as product, service, process, as well as infrastructure and/or enabling technology. For instance, product portfolio in Auto industry, process and infrastructural challenges in Oil and Gas industry and middle / final products in Aerospace sector are some illustrations which reveal the difference of required systems in different industries. In other words, one of the main differences of TPIL in different industries is dissimilarity in the system which must be taken into account. The next module is defining critical system requirements (CSRs) by considering industry/market trends and drivers. Then, TAs which are able to respond industry CRSs should be identified. After that, TAs portfolio is developed based on evaluations containing relevance, urgency or attractiveness assessment. Moreover, it is needed to assess the industry capability in each TAs and/or of feasibility assessment of TAs development. Finally, based on the result of portfolio analysis and precise evaluation of technology trend/trajectory regarding each key TAs, required technology strategy for each TAs should be formulated.

6.4.Option Level

Option level is the final phase of TPIL, containing lowest level of aggregation, which focuses on selecting key technology options (TOs). At this phase, Level of analysis is technology/sub technology or R&D project. Selected MFTDs at reference level in addition to key TAs defined at portfolio level are major drivers of selection key TOs. Option level is rather similar to firm-level technology planning and R&D strategizing. Some of the consisting modules of this level are: identification of TOs, attractiveness evaluations, capability auditing, classification of selected TOs, defining research themes, technology strategy formulation regarding key TOs.

Figure 2.
General frame work for technology planning at industry level (TPIL)



7. Conclusion

In this study, we employed grounded theory method to develop a general frame work for technology planning at industry level (TPIL). For this purpose, a series of semi-structured interviews were organized and explored data from transcription of interviews were analyzed by using open, axial and selective coding. Whereas there are considerable differences among industries' characteristics and context such as, dissimilarities in convergence and/or the level of fragmentation or integration, this study attempted to propose a systematic approach to TPIL. Constitution of TPIL frame work from three different levels indicates that for planning technological resources of a particular industry dissimilar considerations as well as different level of analyses are required. For instance at portfolio level, technology areas should be considered; however, at option level, unit of analysis is R&D project. Moreover, hierarchical approach to TPIL systemically decreases freedom of technology selection and focuses the decision making process on required options.

Results of this study have five major implications for policy makers and managers, who want to plan industry's technological assets systematically. First, in order to selection, development and exploitation of new technology areas, whole value chain of the industry should be considered to be sure about the appropriateness of entering technologies with industry needs and condition. Second, technology planning at supra-firm level should be started by identification of MFTDs, employing precise evaluation of macro context and considering industry's upper documents. Third, portfolio of key technology area should be selected in the way that it would be able to support industry MFTDs. Forth, among different alternatives those technology options should be selected, which can respond critical requirements of under-planned system (such as, product, service, process, infrastructure and/or enabling technologies). Finally, industry decision makers should be aware of valuable information which is derived from lower level of TPIL (such as option- level) and are able to support upper levels (such as reference- level) in a backward direction.

Although this study has sought to address a general framework for TPIL, some limitations remain. Frist, with regard to methodological aspects, this work has studied just Iran Oil and Gas industry, thus in order to generalize the result of this study, future researches could usefully concentrate on employing TPIL framework in other industries. Second, concepts of vertical and horizontal alignment in TPIL in addition to required processes supporting these alignments are critical issues that can be focused by other researchers.

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