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A new approach to Technology Roadmapping in the Open Innovation context: The Case of Membrane Technology for RIPI

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Abstract

Given the paradigm shift from "Closed Innovation" to "Open Innovation", there seems to be a need for a systematic mechanism for exploring and evaluating alternative external technologies, as well as the business models that may be appropriate for capturing value from such technologies. Although Traditional Technology Roadmapping (TTRM) used to play an important role in this regard, analyzing its utility in the context of Open Innovation reveals some shortcomings that need to be addressed in order to make the most of the Technology Roadmapping (TRM) concept. This paper elaborates on these limitations and suggests a modified approach, Open Innovation Roadmapping (OIRM), as an effective technological innovation management and planning tool in this new paradigm. The results of the application of the proposed approach in the case of the membrane technology roadmapping at the Research Institute of Petroleum Industry (RIPI) are also presented here. Further practical guidelines are also raised by the authors to give a more practical vision on the approach.

Keywords: Open innovation, Technology roadmapping, Intellectual property

1- Introd uction

Technology Roadmapping (TRM) is a structured means for exploring and communicating the relationships between evolving and developing markets and between products and technologies over time[1]. TRM had its early roots in the US Automotive industry, with Motorola, Philips, BP, ABB, Lucent Technologies, and Rockwell Automation being among companies which successfully adopted TRM in their strategic business planning [2, 3]. TRM's appeal to companies and its popularity [4], to some extent, stems from its flexibility, in terms of the different organizational aims that it can address, and the range of graphical forms that the roadmaps can take. TRM as a collaborative planning exercise helps align and organize the knowledge essential to innovation and, more specifically, has been used for scanning the environment and tracking the performance of individual technologies [1, 5]. It should also be pointed out that the application of TRM has not been limited to companies and there are frequent references to its application as a management technique for supporting innovation, strategy and policy at company, sector and national levels [1, 6, 7, 8, 9, 10].

Despite the diversity and evolution of the TRM literature, there exists a very common format for a company-level product-technology roadmap with a multi-layered time based chart - so called TTRM -, which can be characterized as [11]:

- Its knowledge sources being mostly located in-house [12].
- Aiming at bridging the gap between in-house Technology and Market Departments in order

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to maximize the commercialization of the company's own R&D outputs through its own products

This paper shows that the TTRM does not fit into the context of Open Innovation. To this end, a definition of Open Innovation along with its underlying logic is presented and the reasons why TTRM is not consistent with the new logic are set out.

The concept of OIRM as a modified type of TRM is presented which helps in overcoming the shortcomings of TTRM in a world of Open Innovation. The OIRM concept has been introduced by Bagheri et al for the first time[13]. The modified concepts OIRM then be compared with concept of TTRM in terms of their approaches to a set of points that differentiate the two concepts.

It is noteworthy that the contribution of this paper does not involve the OIRM process. Rather, the present paper departures from existing literature by introducing and stressing the above-mentioned points. Moreover, some practical guidelines have been presented to facilitate the implementation of the results of the paper. Finally, the outcomes of following OIRM approach in developing a technology roadmap in a research center are reflected and light has been shed on the main differences in following the two approaches based on the process and outcome of the real case.

2- Open Innovation and TRM

The closed innovation paradigm, which is based on trusting and sufficiently funding world-class research talents and waiting for them to come up with new innovations that will somehow find a path to market, Chesbrough [14] urges firms to be strongly self-reliant since one cannot be sure of the quality, availability and capability of others' ideas [15]. This is in contrast with the Open Innovation framework, also established by Henry Chesbrough, which suggests that as the knowledge monopolies built by the centralized R&D organization of twentieth century have ended; that firms can and should use external ideas, and internal/external paths to market, as they look to advance their technology [16].

In the era of Open Innovation the innovative solutions of in-house R&D are no longer the primary basis for competition and external sources of technology also play an incrementally important role. This makes the ability to scout, evaluate and utilize outside knowledge the most important competitive advantage of firms.

However, confusion over the management techniques required to help companies cope with and act effectively in this new era, has been noted as one of the major obstacles that prevent companies from achieving greater success with open innovation; management techniques are needed that can focus these efforts and keep transaction costs down [17].

Although TTRM used to be considered an effective internal integrating tool for bridging the gap between research and development, its internally focused approach is not what companies need to tackle the new challenges. Carefully reviewing the TRM literature and putting its principles into practice in a technology-intensive organization[1] clearly show that TTRM has been developed on the basis of a set of assumptions. However, as mentioned earlier, a new era has emerged and those assumptions are replaced with new ones as is seen in Table 1 [14]. These new assumptions require some modifications in the concept of TTRM to make it more compatible with the Open Innovation paradigm. Trying to address the need for a modified TRM concept, we have introduced the concept of Open Innovation Roadmapping (OIRM), which is essentially a modified TRM with an architecture and a process similar to TTRM while, simultaneously, overcoming TTRM's shortcomings by stressing some major points to be considered through the process. Although some of these points have been raised in the recent TRM literature before, their integration within a concept in order to make it consistent with the particularities of Open Innovation is what is sought by the authors of this paper.

3- Open Innovation Roadmapping

In this section we attempt to address the shortcomings of the TTRM approach in the Open Innovation context, and propose a modified type of TRM by emphasizing a set of points for overcoming those.

In the following paragraphs, the concepts of TTRM and OIRM will be compared in terms of their approaches to these points as summarized in Table 2.

3-1 Internal reliance vs. a more open approach

The success of TTRM is highly dependent on

1. This paper is based on observations made through the project for developing a technology roadmap for Research Institute of Petroleum Industry in the field of Membrane Technology for Gas Separation.

within the company, to workshops [18, 19]. TTRM assumes that a company's highly trained and experienced professionals are able to monitor significant technology and market developments in their own field of expertise and then apply them to developing the company's roadmap, i.e. making smart people work for us. A study conducted on the participants of the roadmapping process in the TRM literature have clearly revealed the results as is reflected in Table 3 [12]. This, to a large extent, fits into the mindset of closed Innovation [16, 20]. Such an assumption is, however, no longer valid since with the participants being from company's own personnel and being engaged in the company's day-to-day functions, they will not necessarily be informed about all the external sources of knowledge.

In the OIRM, on the other hand, the dominant mindset should be in compliance with the Open Innovation mentality, assuming that firms can and should use external, as well as internal, ideas and also internal and external paths to market. Special focus should be applied in the case of OIRM to grab widely distributed knowledge from both internal and external sources. One way to gain a wider view of potential opportunities and threats can be inviting experts in related fields from outside the organization. Extra attention should, however, be paid to avoid sharing the wrong information with the wrong people. Fortunately, getting the direct participation of people in OIRM workshops is not the only way for considering their expert opinions and Advisory Boards (AB), constituted mostly from selected well-informed people from outside the organization, can be used as an alternative to introducing an external input into the process.

Systematic retrieval of quantitative knowledge through other external sources such as technology reports from universities and consortia, marketing data, scientific and industry publications and patents are among the other ways to decrease the reliance of OIRM on qualitative, expert-based, in-house sources of information [21, 22]

There is no need to mention that patents, being a very rich source of data with the widest coverage, deserve special attention in OIRM for the timely recognition of technological changes [23, 24]. Since about 80% of the information disclosed in patents is not disclosed elsewhere, in most cases, patents are unique sources of technological knowledge [25]. Fortunately, the available patent databases have greatly enhanced the opportunity to systematically retrieve such data on a large scale [23].

Practical guideline (a): Make sure that relevant professionals and well-informed people from outside the organization are involved in the workshops so that no major piece of external knowledge is missed. In case of secrecy concerns, one can form ABs and try to find answers and options for specific questions and enquiries raised during the process.

Practical guideline (b): Define a parallel continuous activity throughout the process, to retrieve systematically quantitative knowledge from sources like technology reports, market intelligence studies, scientific journals and especially patents and prepare regular reports for the OIRM committee and workshop participants.

3-2 Business Model

In TTRM, market and technology drivers are identified and alternative technologies, to be used in a company's own products and services are analyzed. TTRM is also best suited for evaluating the commercial potential of a new technology when it addresses current markets with a known set of customers. It fits best for companies that fit into Chesbrough's type 3 which think of innovation from a product or technology perspective, taking the business model for granted [20].

For claiming the company's own portion of value in OIRM, one should take special measures to ensure that alternative business models will be systematically examined during the process.

Practical guideline: Allocate a specific time during every OIRM workshop to discuss the alternative business models in detail. This way OIRM can, for instance, become an effective tool for evaluating the commercial potential of a new technology outside the company's current markets and customers. This can help type 6 companies, which consider innovation itself as the company's business model [20], so that they can profitably employ target technologies.

3-3 Start-up's and Venture Capitalists' roles

Within the framework of TTRM, it is highly probable that only the major competitors and companies with an established market and technological record be considered, while start-up companies have proved to be important sources of new technologies and products [26].

According to the Open Innovation paradigm, the mere identification of market and technology drivers cannot be enough, and companies should additionally scout business plans of new and emerging firms to

3-6 False negatives and false positives

TTRM can be considered a powerful technique for managing the traditional product development funnel and avoiding false positives or Type I evaluation errors, by emphasizing communication between the technological and commercial functions of the business [28], where false positive means errors which occur when an R&D project goes entirely through the process and fails in the market [14]. However, Open Innovation companies should have a "second opinion" mechanism for correcting the false negatives too. False negatives or Type II errors are projects that seem unpromising inside a company due to not fitting with the company's business model, but which later turn out to be valuable [15].

In the context of OIRM, the "second opinion" mechanism is needed for enabling companies to minimize the possibility of both false positive and false negative errors. This is because, on one hand, it can be assumed that collective decisions made in the OIRM process are subject to less false positives. On the other hand, the presence of an AB with its members mostly from external independent and non-biased experts not only brings a new perspective and innovative ideas into the roadmap, but it also helps them reconsider initial judgments and review the outcomes of the roadmapping workshops. Combination of such a board should be so that it can bring external input into the process and address the main challenging issues, be they scientific, technical or business in nature. So it does not suffice for it just to be a Scientific Advisory Board (SAB) or Technical Advisory Board (TAB) [14, 16].

Practical guideline: prepare a list of the organization's projects which have been deemed unpromising in the workshops and killed accordingly. Discuss the list and the underlying rejection logics with the AB(s) to have viable comments and new inputs as a feedback to the upcoming workshops, which may help identify new paths-to-market for the organization's on-the-shelf technologies.

3-7 Internal R&D: an absorptive capacity-builder rather than a major source of knowledge

R&D managers' active participation is stressed and emphasized in the TRM literature [18, 28]. Although TTRM regards R&D as the main source of technological knowledge, it plays a more significant role in increasing a company's absorptive capacity in OIRM. As pointed out by

learn about new and promising technologies, as well

Cohen and Levinthal, the ability to evaluate and utilize outside knowledge largely depends on the level of prior related knowledge of the company itself [29]. Therefore, firms invest in R&D not only to pursue directly new process and product innovations, but also to develop and maintain their broader capabilities to assimilate and exploit externally available information [29].

Practical guideline: have a team of the organization's senior R&D personnel to scout external technological innovations and undertake a preliminary assessment and present the most relevant and promising options in the workshops.

3-8 Identifying technology solutions vs. defining the problems

TTRM calls for identifying possible "technology solutions" that have the potential to deliver the company's product features [30]. Following this approach is equivalent to limiting the search for "technology solutions" only within the framework of company's own product and current business model. However, Open Innovation companies require a process of defining problems and then seeking, both internally and externally, new knowledge to solve them. OIRM can be viewed as a problem definition mechanism for connecting the roadmapping process with external sources of knowledge, such as Innovation Intermediaries. However, problem definition and formulating the challenges in ways that would encourage external people to volunteer solutions for them and, in the meantime, do not disclose organization's secret information, require deep knowledge, great skill, and intuition [20, 31]. As Chesbrough states: "A problem that is properly defined is half-solved" [8].

Practical guideline: Use a list of identified "knowledge gaps" at the end of every OIRM workshop as the starting point for the problem definition process. The items in the list should be prioritized and processed, maybe with the help of ABs, so that a shopping list of defined, but unsolved, problems can be obtained.

3-9 NIH and NSH

Reliance only on an internal knowledge pool will bring about certain inevitable phenomena called the not-invented-here (NIH) syndrome and not-sold-here (NSH) virus. NIH means if a technology was not produced inside a company, the company could not be sure of the quality, and availability of the particular technology; while NSH means if the

as business models that may be appropriate to capture company is not selling the technology in its own sales channels, it won't let anyone else sell it either [16]. In OIRM some measures can be taken to prohibit NIH syndrome and NSH virus.

Practical guideline (a): Offer an incentive program to reward anyone (including R&D staff) who comes up with an external technology that the company decides to use for preventing NIH.

Practical guideline (b): Review external technologies and opportunities with external experts, including AB members, as measures for vaccinating the company against NSH.

4. Case example study

4.1. RIPI and Membrane Technology

The Research Institute of the Petroleum Industry (RIPI), which is the largest Iranian research institute, has been active in various fields related to oil and gas industries ever since its establishment in 1959. Being one of the pioneers in industrial research, RIPI has always worked on new and innovative issues, especially in oil - and gas - related fields.

Due to the great importance and functionality of membranes in different industrial applications, like the separation and sweetening of oil and gas during the past two decades, RIPI has been interested in performing research and development in the field of membrane technologies.

The case described here illustrates the application of OIRM in the RIPI in the technological field of membranes for gas separation purposes. The decision to go through OIRM in this specific case was taken after the approval of a vision for the RIPI to become one of the active players in both national and international markets in the same technological field over a 10-year time horizon.

Membership of the OIRM committee consisted of professionals from the membrane technical team, IP department, marketing department, engineering and gas research divisions, membrane technology experts from the petrochemical industry, the feasibility study department, the technology policy unit, polymer synthesis units, and the facilitator team. Representatives from the R&D department of the Iranian National Gas Company (INGC) also participated in the OIRM workshops.

Trying to quantitatively grab widely distributed knowledge from external sources in the field of Membrane Technology, a comprehensive and continuous patent search and analysis is being performed at RIPI, which has try to document carefully the raised options and proven to be a very effective means of exploring the technological landscape in this emerging field. Table 4 presents a sample of the invaluable outcomes of this initiative.

4-2 OIRM Process

At least four major sub-technology areas were selected after reviewing 12 different areas in the first workshop: namely nitrogen, hydrogen, hydrocarbon separation from natural gases and gas sweetening.

The process continued with discussing alternative business models for claiming value in every sub-technology area; the value chain of the membrane business in the petroleum industry has been used for this. As a result, the whole spectrum was divided into five value-adding functions (Figure 1). Then, performance targets in all five stages of the value chain have been identified.

As a result, a 5×4 matrix of 20 different technological options was created.

Due to the great overlap of the "Consultation" chain in all four sub-technology areas, gaining market share in consultation in all of the chosen categories was integrated as a single target area, leaving 17 options available, 10 of which were eliminated from the matrix according to the criteria derived from market drivers. For instance, items with both the least domestic and overseas market potential were crossed out.

At this stage, every remaining item was decomposed into its major activities that had to be successfully undertaken for the objective to be attained.

This decomposition took place on a timely basis. In this way, a time-directed map of the unfolding evolution of actions along with their linkages and dependencies was developed. A timetable of potential objectives to be attained was also prepared.

An activity map for getting a foothold in the market of the "process design for the nitrogen separation using membrane technology" (one of the remaining 7 options) has been shown in Figure 2.

To estimate the cost of pacing each of these 7 routes, the cost of undertaking each action item was evaluated on the third workshop and all assumptions underlying the cost estimations were carefully documented.

Besides, all risk factors associated with every route - and their relevance to the corresponding action items in that route - were listed and their reasoning behind both their approval and rejection.

degrees of severity were estimated quantitatively during the risk analysis phase.

On the other hand, RIPI's background and its earlier achievements and capabilities in each of these 7 technological areas were reviewed and accordingly ranked.

The final scores of these 7 routes were calculated by developing an attractiveness-capability matrix in which the attractiveness factor was derived from the combination of two factors, namely market size and the overall contribution of the targeted objectives to RIPI's mission.

With the market trend analysis available up to 2015 in each of these four major sub-technology areas, an expert committee assigned the total potential market size of each area to every item on its value adding function. For instance, having identified the estimated global market size of the nitrogen separation sub-technology as being about 100 million dollars up to 2015, the expert committee assigned 35 percent of it to the process design function.

The capability factor was also based on the combination of the cost and risk indexes. Therefore, analyzing the funding limitations of RIPI's Membrane Group against the estimated cost of achieving each target, on the one hand, and evaluating RIPI's potential to avoid or minimize the related risk factors, on the other, revealed the attractiveness of each related target area for RIPI.

4.3. OIRM Output

In the end, three target areas with the highest priority (according to Table 5) were chosen. The roadmap (milestones, quantified targets), and the cost estimation of these were also obtained as the by-products of the process. It was also decided that the OIRM workshops be held at certain fixed intervals corresponding to the milestones of the chosen routes, where the progress could be monitored and the possible fine-tunings be applied. It is noteworthy that the first action item on every route is the "managerial and technical monitoring", according to which related quantitative knowledge from technology reports, market intelligence studies, scientific journals and especially patents should be systematically retrieved, analyzed and reported to the upcoming workshops. It has been stressed that all active players in the same field of technology should be identified, with special focus on SMEs with potentially attractive technologies.

4.4. OIRM versus TRM

The RIPI's roadmapping process in the field of membrane technology, was performed in accordance with the proposed OIRM framework, which is different from the traditional TRM from several aspects, including:

a. During the preparation phase of the roadmapping, intensive searches were performed and the results, especially those related to market share and global trends in the technology mentioned, were quantitatively used for decision making. It was also agreed that the "managerial monitoring" be taken more seriously over the three chosen paths and that the results be used as inputs for the next workshops.

b. Contrary to TTRM, there were no presumptions about the business model throughout this roadmapping experience. Essentially, discussion of alternative business models in every workshop and the application of the "value chain" concept to identify values to be claimed are clear indications of this attitude change. Traditionally, choosing a technology area in RIPI automatically meant doing basic research and trying to commercialize the outcomes by RIPI itself. In this experience, however, not only was no basic research planned ahead but also even the preliminary phases of the value chain (production of the membrane and membrane module fabrication) were not basically chosen.

c. A quick glance over the strategy developed clearly shows that RIPI should seek access to membranes and membrane modules already fabricated by other companies, while perusing its objectives in the consultation and process design functions. The same strategy requires a high emphasis to be placed on SMEs, which usually lack the engineering design capabilities necessary for presence in global markets, and which may have a greater inclination to cooperate with RIPI according to the model developed.

d. The IP department of RIPI is an active player in the OIRM committee and plays a leading role in the roadmapping process. Establishment of a strong patent portfolio in the selected areas is anticipated as a requirement for achieving the selected goals, attaining which requires the IP department's participation in project meetings and provision to researchers of directions stemmed from reviewing the corresponding IP landscape. Furthermore, this department provides the technology intelligence teams with technical assistance in conducting a professional patent search and analysis in the selected fields. On the other hand, assessment of the proprietary technologies to be acquired through other technology providers in the process with regard to its subject matter and scope, is where the IP department will clearly have a key role to play.

e. Another point worthy of mention about this case is the active participation of the R&D department of INGC with the highest interest in the technology and also as a partial financer thereof. This is further complemented through the participation of experts from the operational units of the Iranian Gas Industry, e.g. gas refineries, in OIRM workshops. Further inputs are acquired through the information gained from foreign partners of RIPI in the same technological field, by such means as filling in questionnaires. This leads to tapping into the major source of external knowledge and also contributing to a shared vision among nearly all the stakeholders.

f. The inputs of RIPI's membrane research team to the OIRM process substantially enriched the outputs of the process and proved that the prior in-house research can largely contribute to the OIRM process not as an only source of knowledge input but also as a factor that increases the absorptive capacity of the company. This is, in part, a result of the proper management of the process so as to avoid the NIH syndrome.

5- Conclusion

This paper presents the concept of OIRM, as a modified TRM with an architecture and process similar to TTRM, which can be an effective planning tool in the Open Innovation era. Despite the usefulness of TTRM in the companies with a Closed Innovation mentality, there are short-comings attached to it that inhibit it from continuing to be as useful in the context of Open Innovation as it used to be. The paper argues that there is an increasing need for a focal, integrating device for bringing together internal and external knowledge, making a balance between them, matching them with proper business models, and doing this effectively and quickly. It also suggests that OIRM can be helpful in this regard by overcoming TTRM's shortcomings through emphasizing some major points to be considered through out the process.

The major points have been discussed in this paper in detail and the outcomes of taking them into consideration in the OIRM process, were highlighted. In order to facilitate understanding and to pinpoint the best uses for the suggested approach, some corresponding practical guidelines were introduced for every major point. These guidelines can be of help to executive managers, technical workers and policy makers.

Application of the OIRM model to the membrane technology projects of RIPI reveals that the outputs of this roadmapping case is well beyond a mere "research agenda" and can surely be considered as "options" created for RIPI to position itself in the future global market of this technology owing to the nature of the OIRM process.

The authors believe that this paper can be a starting point for further work to define the intricacies of applying TRM as a management technique for supporting innovation in the context of Open Innovation. A few of the areas that could benefit from such research in the future would include:

- The mechanisms for making targeted use of the external sources of information and knowledge throughout the process while minimizing the negative side-effects of doing so, such as disclosure of the organization's secrets.
- The different dimensions of the role played by IP experts in the process and possible mechanisms for conducting this in a systematic manner.

Table 1) Closed and Open Innovation

Closed Innovation	Open Innovation
Smart people work for us	Smart people tap into world
Discover, develop, market	Claim own portion of value
First to discover, First to market	Profit from Research by others
The First, Fastest, Fittest	Better business model first
Create most ideas	Use most ideas
Control closed IP	Trade IP

Table 2) Comparison between TTRM and OIRM

	perspectives of comparison	TTRM	OIRM
1	*Knowledge source*	*Internal reliance*	*More open approach*
2	*Business Model*	*Takes for granted*	*Alternative business models will be systematically examined.*
3	*Start-up's & Venture Capitalists' roles*	*Only major competitors are considered / no VC participation*	*Start-up companies are important and VCs' participation is a way for tapping into start-ups' information*
4	*IP*	*Minimal role*	*IP at the heart of the process*
5	*Main Function*	*Developing research agenda*	*Option Creation and processing*
6	*Evaluation errors*	*Helps to avoid false positives*	*Minimizes both false positives and false negatives*
7	*In-house R&D's role*	*main source of knowledge*	*absorptive capacity-builder*
8	*Technology quest*	*Identifies Technology Solutions*	*Also defines the problems*
9	*NIH & NSH*	*NIH and NSH are quite common*	*Vaccinates against NIH and NSH*

Table 3) Roadmapping Process Participants

	Tabrizi and Walleigh	Lehtola et al.	McCarthy	Groenveld	Phaal et al.	Albright	Rautiainen et al.
Senior Management	X						X
Product Management		X		X		X	X
Sales and Channel Partners		X					
Customers		X					X
Representatives of R&D			X	X	X	X	X
Technology Management			X				
Representatives of Business Development			X				
Representatives of Finance			X		X		
Representatives of Marketing				X	X	X	
Representatives of Engineering				X			
Representatives of Manufacturing					X	X	
Representatives of Services						X	X

Table 4) High-priority target areas

1	Process design – Gas sweetening
2	Process design – Nitrogen Separation
3	Consultation - Gas separation using Membrane Technology

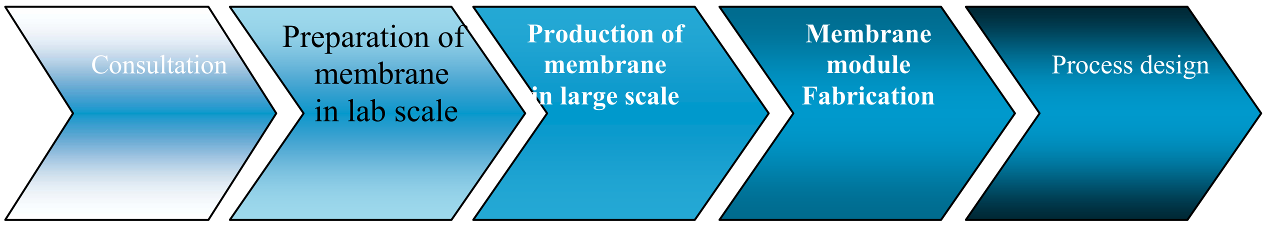

Figure 1) Membrane value chain

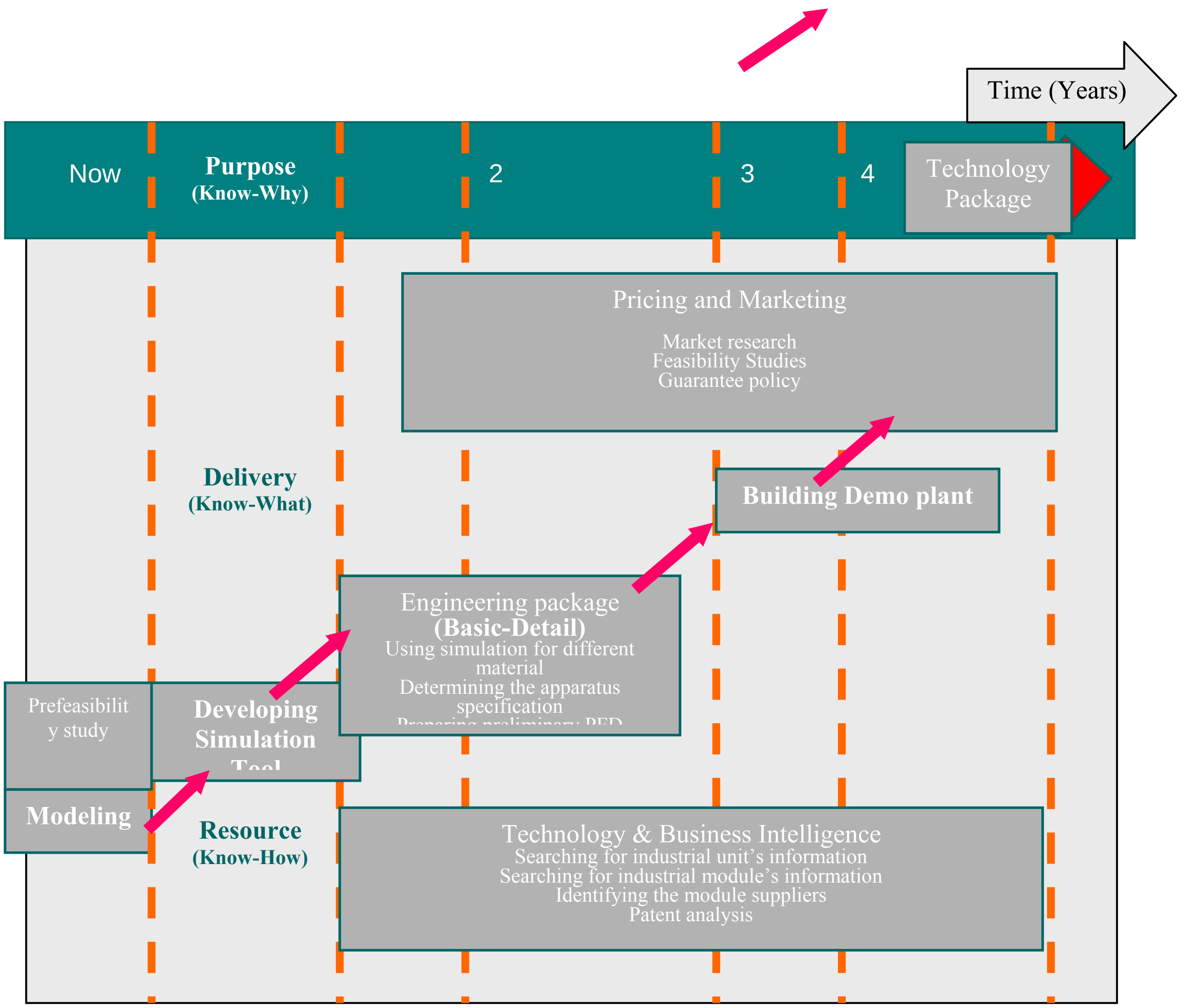

Figure 2) Process design Milestones – Nitrogen Separation

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رویکردی جدید به نقشهٔ راه فنّاوری در فضای نوآوری باز: مطالعهٔ موردی فنّاوری غشا در پژوهشگاه صنعت نفت

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چکیده:

پس از گذر از عصر نوآوری بسته و «پاگذاشتن به فضای نوآوری باز»، به سازوکارهای نظام‌مندی نیاز است تا بتوان به اتکای آن‌ها برای پایش و ارزیابی گزینه‌های فنّاوری خارج از سازمان و مدل‌های کسب‌وکار مناسب برای کسب ارزش از آن فنّاوری‌ها اقدام کرد. هرچند پیش از این، مدل سنتی نقشهٔ راه فنّاوری نقش مهمی در این پایش و ارزیابی داشته، اما بـه کارگیری آن در فضای «نوآوری باز» با کاستی‌هایی همراه است که رفع آن‌ها می‌تواند زمینه را برای کارآمدی هرچه بیش‌تر مفهوم نقشهٔ راه فنّاوری فراهم آورد. مقالهٔ حاضر این کاستی‌ها را معرفی می‌کند و رویکرد نوینی به‌نام «نقشهٔ راه نوآوری باز» به‌دست می‌دهد. همچنین، نتایج به‌کارگیری نقشهٔ راه فنّاوری مبتنی بر این رویکرد نوین در ارتباط با به‌کارگیری فنّاوری غشایی در جداسازی گازها در پژوهشگاه صنعت نفت و نکات کاربردی برای تسهیل پیروی از این رویکرد، در این مقاله منعکس شده است.**

کلیدواژه‌ها: نوآوری باز، نقشهٔ راه فنّاوری، فنّاوری غشا، مالکیت فکری

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