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Technology Research Roadmapping:

The Case Study of Membrane Technology in Iranian Petrochemical Industry

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Abstract: Science and technology roadmaps are used in industry, government, and academia to portray the structural relationships among science, technology, and applications. In this paper, through technology strategic planning and based on the research and development priorities of membrane technology in Iranian petrochemical industry, we proposed the combined process and component research roadmap of this technology in the case study of Iranian petrochemical industry. In this roadmap, the path of three highlighted membrane technology development was drawn. This roadmap was aligned with the next six year vision of the industry and consist the main materials, types and modules of prior membrane technologies.
Keywords: Technology Research Roadmap; R&D Priority Setting; Membrane Technology

1. INTRODUCTION

Technology management addresses the effective identification, selection, acquisition, development, exploitation, and protection of technologies (product, process, and infrastructural) needed to maintain (and grow) a market position and business performance in accordance with the company's objectives[3]. It deals with all aspects of integrating technological issues into business decision making, and is directly relevant to a number of business processes, including strategy development, innovation and new product development, and operations management[4]. Technology management includes the five processes proposed by Gregory: identification, selection, acquisition, exploitation, and protection of technology (Gregory, 1995).

Technology roadmapping is a comprehensive approach to strategic planning for the integration of science/technology development into product and business aspects. Since its earlier introduction, in the late 1970s, technology roadmapping has been evolving as a new practice in technology management (Willyard & McClees, 1987). Currently, the roadmapping concept is widely adopted in industry, government, and academia to provide a way to develop a technology strategy, to identify gaps and opportunities in research

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development, and to plan for resource allocation (Gerdsri, 2007; Richey & Grinnell, 2004; Albright & Kappel, 2003; Wells & Phaal, 2004; Kostoff; Boylan R.; Simons, 2004; Probert, 2003).

In this paper, by introducing the all types and formats of roadmaps, we propose a hybrid roadmapping for membrane technology in petrochemical industry. To cover this purpose, in the case study section, firstly processed map of the membrane is shown and after that, priorities of this technology is explained and finally the roadmap of this technology for the next six years is proposed.

2. TECHNOLOGY ROADMAPPING IN INDUSTRY LEVEL

Generically, a "road map" is a layout of paths or routes that exists (or could exist) in some particular geographical space (Kostoff & Schaller, 2001). Technology roadmapping (TRM) represents a powerful technique for supporting technology management and planning in the firm. Roadmapping has been widely adopted in industry (Albright & Kappel, 2003) (Willyard & McClees, 1987; Barker & Smith, 1995; Bray & Garcia, 1997; EIRMA, 1997; Groenveld, 1997; McMillan, 2003).

Technology Strategy is a framework for technology roadmapping especially for the R&D sector, designed to support the needs of a specific program or project by providing a framework for planning and coordinating R&D efforts with operational requirements. Compared to the product technology roadmap, R&D-purposed TRM requires greater efforts in terms of selecting technology areas to be developed. Setting development targets in each technology area also requires more sophisticated techniques(Lee et al, 2009).

TRMs also enable R&D activities to be carried out in a more systematic manner (Lee et al., 2008), laying out an explicit plan about what, when, and how to develop core technologies and thus making it possible to determine which projects need to be carried out first (McCarthy et al., 2001).

Although each organization applies technology roadmapping for its own set of reasons, the main aims of technology roadmapping are widely seen to include the following:

·Identification of gaps;
·Prioritization of issues;
·Target setting/creating action plans; and
·Communication across the organization (Gindy et al., 2006).

The generic roadmap is a time-based chart, comprising a number of layers that typically include both commercial and technological perspectives. One of the reasons why organizations struggle with the application of roadmapping is that there are many specific forms of roadmap, which often have to be tailored to the specific needs of the firm and its business context[5]. Application of the technology roadmapping approach can be used at the sector level. In general, it is necessary to customize the roadmapping approach to suit the particular circumstances for which it is intended[6].

Robert Phaal et. al. clustered different roadmaps into the following eight broad areas, based on observed structure and content: *Product planning, Service / capability planning, Strategic planning, Long-range planning, Knowledge asset planning, Programme planning, Process planning And Integration planning* (Phaal et al., 2001). They also identified eight types of roadmaps based on graphic formats and observed structure: *Multiple layers, Bars, Graphs, Pictorial representations, Flow charts, Single layer and Text* (Phaal et al., 2001) . *(fig 1)*

[5] *UNIDO TECHNOLOGY FORESIGHT MANUAL, volume 1, 2, 2005.*
[6] Ibid.

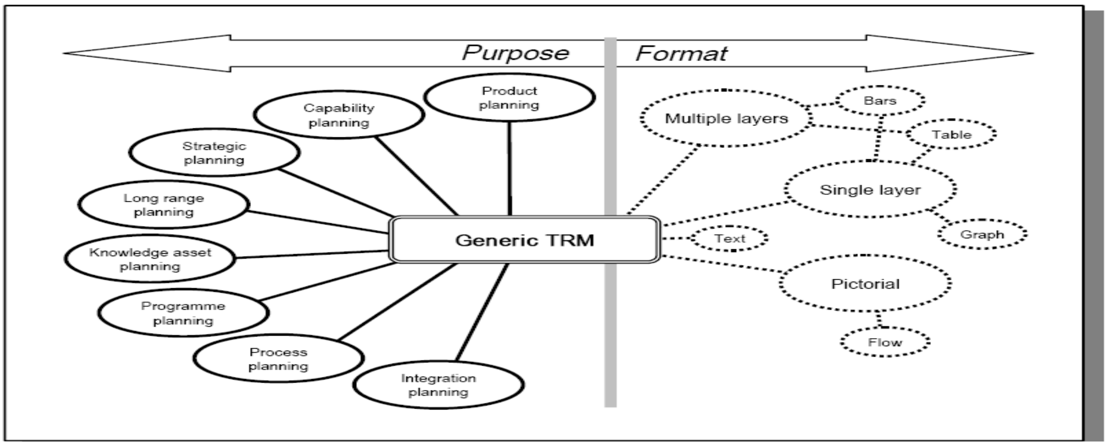

Fig 1: Characterization of roadmaps: purpose and format (Phaal, 2002)

Roadmaps do not always fit neatly within the categories identified above and can contain elements of more than one type, in terms of both purpose and format, resulting in hybrid forms. While some organizations choose to use the method for particular situations on a one off basis, others have taken roadmapping forward to form a significant part of their strategy and planning processes[7]. In this paper through a case study, after the selection of prior technologies, a hybrid roadmap of the technology has designed.

3. CASE STUDY: MEMBRANE TECHNOLOGY ROADMAPPING IN IRANIAN PETROCHEMICAL INDUSTRY

3.1. Case Description

Crude oil and natural gas after production from well are using in different areas. Petroleum refining is the main mission of the petrochemical industry. It is the physical, thermal and chemical separation of crude oil into its major distillation fractions which are then further processed through a series of separation and conversion steps into finished petroleum products. These products make great value added. The primary products of the industry fall into three major categories: fuels (motor gasoline, diesel and distillate fuel oil, liquefied petroleum gas, jet fuel, residual fuel oil, kerosene, and coke); finished nonfuel products (solvents, lubricating oils, greases, petroleum wax, petroleum jelly, asphalt, and coke); and chemical industry feed stocks (naphtha, ethane, propane, butane, ethylene, propylene, butylenes, butadiene, benzene, toluene, and xylene)[8]. Therefore, there are lots of processes and technologies in petroleum refineries. Membrane technology is one of the most important technologies in this field. The industry managers decide to develop membrane technology internally by using R&D sector and university capabilities. Resource limitations lead them setting priorities of technology achievement and technology roadmap consequently.

3.2. Membrane priority setting model

In order to draw the membrane technology roadmap in petrochemical industry, it was needed setting priorities of the technology. So, the 4 step model based on the Critical Technologies method was applied in this research. The main steps were as follows:

a) Location and selection of experts
b) Initial list of technologies
c) Prioritization
d) Final list of critical technologies

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[7] *UNIDO TECHNOLOGY FORESIGHT MANUAL, volume 1, 2, 2005.*
[8] EPA (1995), Profile of the Petroleum Refining Industry, EPA report.

Preparing the materials of membrane research roadmap is needed for identification of technologies in industry scope and after that setting priority of this technology in different levels of technology process. So in this paper, we identified and drew the overall and prior technologies maps.

3.3 Membrane Technology Identification and Drawing Technology Map

After the determination of petrochemical industry domain and membrane applications, in this part the focus is on material, membrane, module and membrane separation process.

According to Madaeni (2006) “Membrane is a material through which one type of substance can pass more readily than others, thus presenting the basis of a separation process”. The key property of membranes is their ability to control the permeation rate of a chemical species. Also the most attractive features of membrane separation systems are cost effectiveness, environmental friendliness, versatility, and simplicity. In Addition, Membrane processes have properties such as easy up and down scaling, operating in ambient temperature, avoiding any change or degradation of products and having high efficiency.

Disadvantages of applying membrane are concentration polarization and membrane fouling, pretreatment requirement, low reliability and mechanical stability. Therefore using membrane in most applications is in doubt and needs careful technology selection decision making.

Industrial plants use membranes in packages called module. Several types of modules are plate-and-frame, tubular, spiral wound and hollow fiber.

Membrane technology is including several technologies hence for prevention of any faults and guarantees the efficiency of activities, technical team studied different aspects of the membrane technology such as material, membrane structure, application etc. and drew their maps.

After analysis of strength and weaknesses of each map, membrane process map in Petrochemical Industry was prepared by combining the material, structure and application maps. These maps were drawn according to the sequence of technology, application, material, kind of membranes used and modules. Figure 2 shows the order of parts in the map. First level of process map is shown in Figure 3.

Fig 2: Order of parts in process map of membrane technology

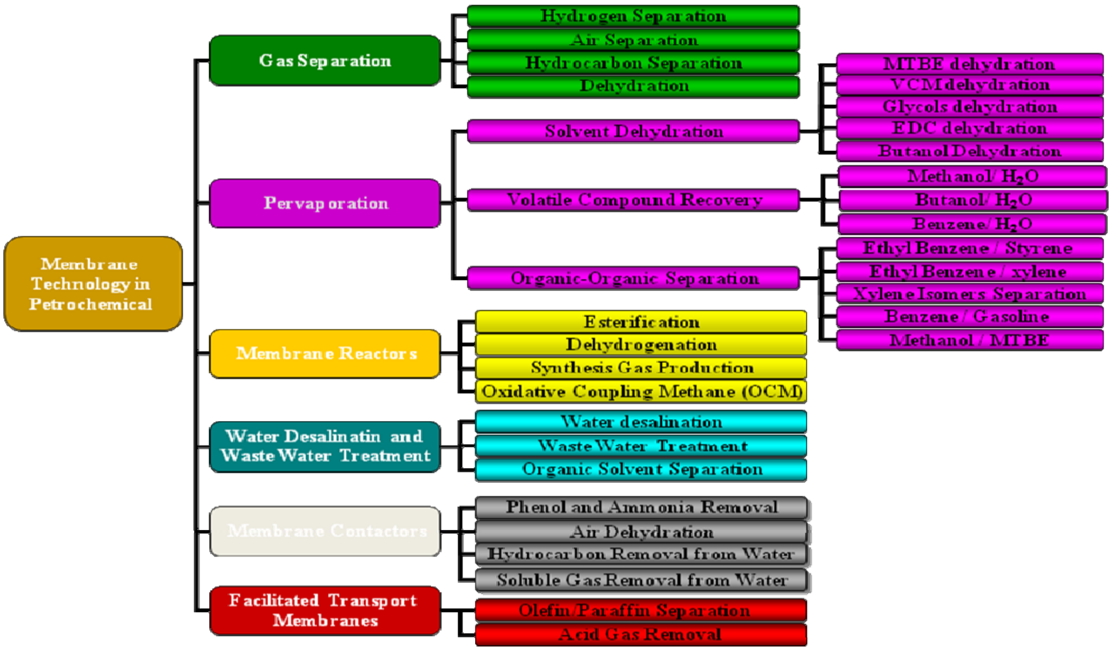

Fig 3: First level of Membrane technology process map in petrochemical industry

According to figure 2 process map was completed in next levels for each technology. For example, process map related to Hydrocarbon separation is shown in figure 4.

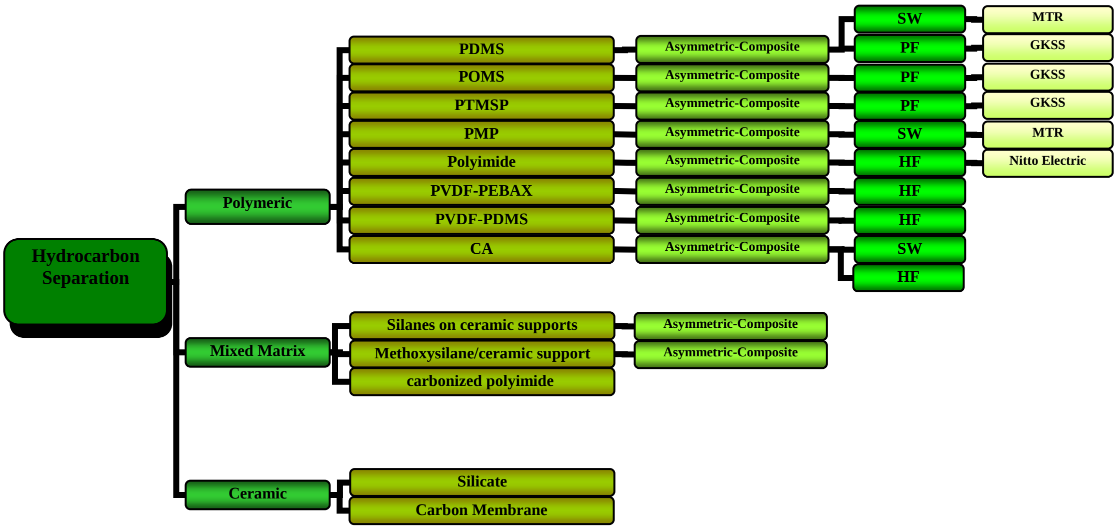

Fig 4: Process Map related to Hydrocarbon separation

By completing this map and covering the whole industry, the team was identified 34 distinct membrane technology.

3.4. Setting Research Priorities of membrane technologies

Membrane technology selection was done through evaluation of feasibility and attractiveness of each technology (application). According to CSIRO method (Hawkins, 1992), attractiveness is composed from potential benefits and industry's ability to capture benefits. Also feasibility is composed from R&D potential and R&D Capacity. For evaluation of each factor it is needed to use some criterion. After searching through internet, documents and some reports, a list of useful criteria was generated and adjusted to this field by expert opinions in expert panels. Evaluation of these criteria was done by expert interviews and filling of questionnaire designed based on those criteria (Appendix1). Totally 22 questionnaire was sent to experts of membrane technology and filled correctly and completely. All contributed experts in this research were Iranian and they contributed to this research since it had done for National Iranian Petrochemical Industry Company which is the most important company in the Iranian Petrochemical industry. Thirty percent of experts had academic background, fifty percent was from Industry, and twenty percent was experts from National Iranian Petrochemical Industry Company.

We put the results gained by questionnaires in the Feasibility-Attractiveness matrix which is a two-dimensional analytical matrix developed for technology priority setting.

3.5 Drawing Membrane research Roadmap

According to the membrane process map, sub technologies of prior membranes were identified and approved in the expert panels. In Fig. 5, the priorities of membrane technology research are shown. According to this chart, among 34 technologies, the most attractive ones that proposed to Petrochemical industry are Hydrogen Separation, Hydrocarbon Separation and Membrane bioreactors technologies. Also from four modules and six membranes, two modules and two membranes including Asymmetric-composite and Integrally membranes are selected as the priorities respectively. Finally among numerous known materials three ones are proposed as the most attractive materials for each technology.

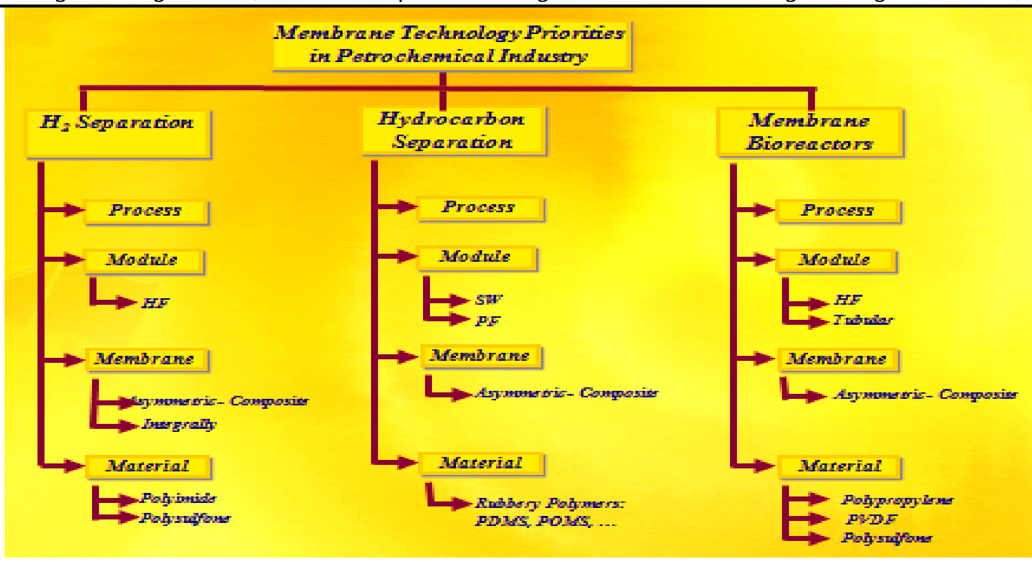

Fig 5: Membrane technology priorities in Petrochemical Industry

According to prior technologies, the research roadmap of technology achievement was drawn and proposed in expert panel. The resulting roadmap was returned to the same experts. Experts were approved and validated the map by a little modification with their technical insights about the industry environment. Through long discussion about priorities and regarding some restrictions in the country, 3 identified technologies should be developed through 6 next years. This decision was made across the long term planning of petrochemical industry. The 2015 vision of industry is “20 Billion dollar annual production revenue by emphasis on gas-driven industries”. Considering all priorities mentioned above and regarding the internal R&D acquisition, the Membrane Research Roadmap of this industry is presented in figure 6. According to figure 3, proposed roadmap is a time-based, multi layer one by the combined purpose of long range process planning. In proposed roadmap the vertical dimension shows the components of membrane technology development which result reaching the 2015 vision in this field.

Fig 6: Membrane technology research roadmap in Petrochemical Industry

The path of component development for each technology through the time is drawn. As figure shows, industry should start research on Hydrogen Separation membrane technology materials and other components. The target of this technology achievement is 2012. Consequently for next two technologies the target is 2013 and 2015. Regarding this roadmap, detailed projects for each level are defining in R&D center of industry.

4. CONCLUSION

In this paper we drew a hybrid roadmap for membrane technology in Iranian petrochemical industry. This roadmap was designed for the next six year vision of industry and formed from five separate levels. Three high prior technologies are Hydrogen Separation, Hydrocarbon Separation and Membrane bioreactors technologies. Also, related components of these technologies were highlighted. This roadmap was aligned with the 2025 vision of the country and will continue the technology development through the next 10 following years. It should be mentioned that results of this research are applying in National Iranian Petrochemical Industry Company which is the most important company in the Iranian Petrochemical industry.

APPENDIX1: QUESTIONNAIRE

(THE EVALUATION OF FEASIBILITY AND ATTRACTIVENESS OF MEMBRANE TECHNOLOGY'S APPLICATION IN PETROCHEMICAL INDUSTRY)

This questionnaire is divided into 3 sections. Section 1 (through question 1 to 7) evaluates the Attractiveness of membrane technology's application. These questions are in two categories: Questions examining the potential benefits; Questions examining the ability of petrochemical industry to attract the benefits.

Section 2 (through question 8 to 19) evaluates the Feasibility of membrane technology's application. These questions are in two categories - Questions examining the potential of R&D; Questions examining the capacity of R&D.

Section 3 (through question 20 to 22) evaluates the internal technology development's methods or technology transfer from overseas.

1- The Attractiveness of membrane technology's application

1-1- Potential benefits

In case researches have results and intended membrane technology's application start in on industrial level, to what extend it has potential benefits?

Row	Question
1	From the technical performance view (like confidence ability, performance's easiness, energy consumption, flexibility, and scale up), what is the position of membrane technology in this application relative to its most important competitor? Very weak 1 — 5 — 9 very strong
2	What would be the market growth level of membrane technology in this application? Very low 1 — 5 — 9 very high
3	What would be the effect of membrane technology in this application in reduction of environmental pollutants? Very unhelpful 1 — 5 — 9 very helpful
4	How much the membrane technology in this application could be used in other areas (like oil, gas, purification industries …)? Very little 1 — 5 — 9 very much

1-2- The ability of petrochemical industry to attract the benefits

These questions are representative of petrochemical industry's ability in converting research results into industrial and commercial outcome.

Row	Question
5	With the application of this technology, To what extent the country's petrochemical industry can compete in international level? Very little 1 5 9 very much
6	Are the main materials required to membrane production to be used in this application produced internally? If your answer in negative, what following situation is more accurate? - The procurement of main materials from overseas is simply possible. - The procurement of main materials from overseas is possible although there are some limitations. - Because of sanctions, the procurement of main materials from overseas is impossible.
7	To what extent there is the possibility of entrance into global market value chain from membrane production to its application in the process for Iran's petrochemical industry? Very little 1 5 9 very much

2- The feasibility of membrane technology's application

2-1- R&D potential

This question evaluates the technical potential of membrane technology's R&D areas.

Row	Question
8	Please determine the position of membrane technology to be used in this application in the life cycle. Germinal (and laboratorial) ❐ Growth ❐ Maturity ❐

2-2- R&D capacity

These questions measure the efficacy to reach the R&D's potential as well as reach the intended technologic goals in determined time framework.

Please answer following three questions once for the evaluation of membrane production feasibility (question 9 to 11), once for the design and production of module (question 12 to 14), and once for the evaluation of membrane process application and designing (question 15 to 17).

Row	Question
Equipments and laboratories	What is the situation of Iran's laboratories and equipments to design and produce membrane as well as the application of it into industrial processes to be used in this application? hardly sufficient 1 5 9 very sufficient
Technical knowledge	What is the situation of technical knowledge to design and produce membrane as well as utilized module to be used in this application? hardly sufficient 1 5 9 very sufficient
Human resource	What is the situation of expert and efficacious human resource (having enough experience and knowledge) to produce membrane as well as module to be used in this application? hardly sufficient 1 5 9 very sufficient

9) . . .
10) . . .
11) . . .
12) . . .

13) . . .
14). . .
15) . . .
16) . . .
17) . . .

Row	Question
18	Is this technology utilizing in the processes of Iran's petrochemical industry? 1) Yes 2) No To you, what following item is more accurate about the current level of Iran's capability (laboratorial or industrial) in this application? 1) There is not any capability in this application 2) Membrane is producing in Iran 3) Module is producing in Iran 4) Processes are designing in Iran 5) Processes are only performing in Iran 6) All above mentioned
19	Where is the proper point to start in the way of achieving the technology in the intended application? 1- Membrane production → 2- Module → 3- Process design → 4- consultation to process's application

3- Technology development methods (internal development or technology transfer)

Row	Question
20	Is access to the intended technology through technology transfer from overseas possible easily? If the answer is negative, which following item(s) is the main barrier? 1) Lack of expert human resources, familiar with technology in the country, which are ready to achieve and utilization of that technology 2) The absence of required structure to achieve technology 3) The monopoly of intended technologies in countries or organizations which do not like to surrender them to Iran 4) The existence of political and legal barriers in the way of achieving the intended technology (like sanction and so on) 5) The lack of financial resources 6) Other factor; please mention them
21	In your opinion, what is the priority of possession of this technology through internal R&D instead of transferring it from overseas? 1 5 9 there is not any priority it is of high priority
22	How do you approximately estimate the costs of achieving membrane technology in this application through internal R&D in comparison to technology transfer from overseas? 1) Costs of internal R&D is definitely less than technology transfer's costs 2) Costs of internal R&D is approximately equal to technology transfer's costs 3) Costs of internal R&D is definitely more than technology transfer's costs

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