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Mapping and Benchmarking Technological Innovation of Three International Petrochemical Companies

Safa Ali Alabbas

Graduate student, Dept. of Technology & Innovation Management
Arabian Gulf University, Bahrain.
safaama@agu.edu.bh

Prof. Refaat Hassan Abdel-Razek

Head of Dept. of Technology & Innovation Management
Arabian Gulf University, Bahrain.
rabdelrazek@sharjah.ac.ae

Abstract. Mapping technological innovation in organizations is one of the important activities that help companies to identify where organizations are clustering their innovation efforts, and where their unexplored innovation spaces are. Current published innovation mapping models do not take into consideration the comparison and benchmarking between organizations in one model. The objectives of this paper are to map innovation in three international petrochemical companies: Gulf Petrochemical Industries Company (GPIC), Saudi Basic Industries Corporation (SABIC), and Dow Chemical; compare and benchmark the results; and explore the possible areas for their innovation opportunities. An innovation mapping model was developed. Innovation data covering three years (2010-2012), were collected, analyzed and mapped on the model. The results showed that the three companies introduced a total of 194 innovations; 53% by Dow Chemical, 38% by SABIC and 9% by GPIC. Product innovations were the dominant type as they presented 57% of total innovations, where 54% of these were introduced by Dow Chemical, 46% by SABIC, and none by GPIC. Position and paradigm innovations were the least innovation type produced, where only 3% of the total innovations were in position and 1% in paradigm. The results also showed that multi-dimensional innovation represented 23.7% of total innovations, where 67.5% of these were produced by Dow Chemical, 28% by SABIC, and only 4.5% by GPIC. Product-process innovations represented 50% of the total multi-dimensional innovations. During this period only 5.7% of the total innovations were radical innovations; these were all introduced by Dow Chemical. The benchmarking results showed that product innovation was the strength in SABIC; process innovation was the strength in GPIC; and product, radical, product-position, process-position and product-paradigm were the strengths in Dow Chemical. For GPIC there are possible innovation opportunities in product, product-process and process-position innovations; for Dow Chemical and SABIC, in the process area. There are possible opportunities in radical innovation in GPIC and SABIC and plenty of innovation opportunities in the position and paradigm areas for

the three companies.

Keywords. Technological Innovation; Innovation Mapping Model; Petrochemicals; Benchmarking Innovation.

1 Introduction

Mapping innovation is one of the important topics in innovation management, where it helps organizations to examine their innovation efforts, to determine the current innovation focus, and to explore where it should focus in the future. Mapping innovation also helps the companies to ensure their incremental improvement is keeping them competitive or they should explore more radical improvements. Nowadays, organizations need to value all types of innovation; they need innovation in all types of innovations in order to survive in an ever-changing challenging environment (Abdel-Razek and Alsanad, 2014). In his study (Knight, 1967) described innovation types as being: product or service innovation, production process innovation, organizational structure innovation, and people innovation. In other study that was done by (Bower and Christensen, 1995), innovation has been classified to disruptive and sustaining. According to Cooper model, the innovation can have several aspects of each type, and has divided innovations into: product, process, administrative, technological, radical, and incremental. This model was called a multidimensional integrative model of innovation (Cooper, 1998). In study that was conducted by (Hovgaard and Hansen, 2004), innovation had been classified to product, process, and business systems innovation. Also, (Trott, 2012) classified innovation to product, process, organizational, management, production, commercial (marketing), and service innovation. According to Oslo Manual (OECD, 2005) the innovation types can be distinguished as: product, process, marketing, and organizational innovation. (Francis and Bessant, 2005) stated that innovation can be classified into four types: product, process, position, and paradigm; (Apax Partners Ltd., 2006) classifies innovation types as: architectural (using existing technologies in new ways), radical, incremental, and modular innovation (creating new technologies to solve existing problems). In his study (Abdel-Razek, 2014) proposed a framework for the classifications of technological Innovation and stated that there are interrelationships between the different types of innovations. In their frequent other studies (Abdel-Razek and Alsanad, 2013a; Abdel-Razek and Alsanad, 2013b; Alsanad and Abdel-Razek, 2016) they developed an innovation mapping model -the 10Ps model- as an outcome of merging the four types of innovations proposed by (Francis and Bessant, 2005) and by taking into account the overlap of each two types of innovations. This model classified innovation into: four one-dimensional innovation types and six two-dimensional innovations. This 10Ps innovation-type model includes: product, process, position, paradigm, product-process, product-position, product-paradigm, process-position, process-paradigm, and position-paradigm innovations. They implemented their 10Ps model by mapping the innovations in one of the largest Saudi petrochemical companies

(Saudi Basic Industries Corporations (SABIC) (Abdel-Razek and Alsanad, 2013a; Abdel-Razek and Alsanad, 2013b; Alsanad and Abdel-Razek, 2016).

The main objective of this paper is to map the technological innovation of three international petrochemical companies that are operating in GCC countries depending on classification of innovations in terms their types and degree of novelty. Moreover, to develop an innovation mapping model that is capable of mapping innovation for several organizations on the same model to compare and to benchmark each company and to determine their strengths and future opportunities.

2 Innovation Classifications

Damanpour has argued that the differentiation between innovation types is an imperative process in order to develop realistic theories of organizational innovations (Damanpour, 1987). The researchers can classify innovation in different approaches. The socio-technical system approach, classifies innovation according to where systems occur. Another approach classifies according to the source of innovation. A third approach classifies according to the attributes of innovation (Mohammed and Bardai, 2012).

The innovation process outcomes include any changes that occur in several aspects of the organizations. Moreover, the companies need to value all types of innovation, though introducing new products is an important element for organizations' success, the organizations need innovation in all aspects of the business in order to continue success in challenging environments (Kelley and Littman, 2006). There are several academic efforts to integrate all terms, frameworks, and models of innovation to formulate a classification system for innovation. In their study (Rowley et al., 2011), have provided theoretical review of models and frameworks of types of innovation, and have stated that the type of innovation is a key concept in the literature of innovation; (Miller and Miller, 2012) have attempted to develop a comprehensive classification system through describing all dimensions, types, and activity levels of innovation. To map innovation by using the 10Ps benchmarking innovation mapping model, each innovation in the organizations has been examined in terms of two dimensions: innovation type, and degree of novelty.

2.1 Innovation Types

Distinguishing between different types of innovation is important for mapping innovation. In this paper, the innovation types are divided into two sections for purpose of clarification as the following:

- One-Dimensional Innovation Type

One-dimensional innovation types include product, process, position, and paradigm (4Ps). In this study, the classification of one-dimensional innovation is based on the following aspects:

1. When the innovation is based on changing its performance capabilities,

improving its characteristics, or adding new features to existing things that are offered by the organization, the innovation is called a product innovation.
2. When the innovation is based on changing its production methods, or using new machines to produce existing things that are offered by the organization, the innovation is called a process innovation.
3. When the innovation is based on changing its availability, and serving new market segments, the innovation is called a position innovation.
4. When the innovation is based on changing or reframes its image, its way to use things, or its way to look things, the innovation is called a paradigm innovation.

Furthermore, the definitions of innovation types by (Francis and Bessant, 2005) could help to distinguish between 4Ps innovation types:

1. Product innovation: the product innovation is related to what the company introduces to its customers or market.
2. Process innovation: the process innovation is related to how the company produces product or delivers service.
3. Position innovation: the position innovation is related to which market segments the product or process target.
4. Paradigm innovation: the paradigm is related to the company frame of product and service, or to the mental model of the company's work.

- Multi-dimensional Innovation Type

Multi-dimensional innovation types include product-process, product-position, product- paradigm, process-position, process-paradigm, and position-paradigm. When innovation effects on many aspects of organizations the innovation can be considered combined innovation, which consists of two innovation types. The classification of multi-dimensional innovation is based on the following aspects. First, when the innovation consists of two types of changes mentioned previously in (2.1.1), the innovation is called multi-dimensional innovation. For example, if the company produces some products to use in its production process, the innovation is product-process. If the company upgrades the existing products to meet requirements in the new markets, the innovation is product-position. Second, (Armstrong and Kotler, 2003) divided the markets into five types including: consumer markets, business markets, government markets, reseller markets, and international markets. Each type has some characteristics and special needs. The consumer markets include those who use product for personal consumption, while the business markets include the companies that buy the product to improve their production line. Hence, their argument is useful to classify the multi-dimensional innovation (product- process). The petrochemical companies are considered "business markets", and 'industrial buyers". Accordingly, the innovation is judged from two perspectives: the customer (buyer), and the petrochemical company (seller). For instance, when the company introduces materials (product) to improve its production line (process), it is both product and process innovations.

2.2 Degree of Novelty

Degree of novelty is that level of change in the new innovation unlike existing innovation. According to (AMA, 2006) incremental innovation applied science searches in incremental improvements of existing knowledge in order to add value in existing product for existing market or, to introduce new product with small changes for new market or existing market. On the other hand, Radical or breakthrough innovation depends on exploring new knowledge, and exploiting new opportunities. Determined degree of novelty for innovations is the level of change in new introduced innovation; such change can be occurred at component or sub-system level or across the whole system. Thus, when the company presents the new grade of existing product, this innovation can be considered incremental innovation in product, unlike the radical innovation, which involves changes at the whole system or major component (Tidd and Bessant, 2009).

3 Mapping Technological Innovation

Innovation maps are the visual graphic tools that are used for specific purposes. The literature shows several innovation maps, with several objectives and scopes of applications. In general, innovation mapping can be divided according to the application scope into: innovation maps at the country level and innovation maps at the firm level. At the country level, innovation maps aim to evaluate some of the innovation indicators of the country or the world, and to describe intensity of innovation in many areas of the world. In study that was conducted by (Kuah et al., 2009), has been investigated approaches and strategies for advancing productivity, innovation and competitiveness in the three small open economies of Singapore, New Zealand, and the Republic of Ireland, through mapping the organizational innovation capabilities between 1999 and 2008. In other study, has been mapped innovation in the UK regions to select which regions are the highest in terms of high-growth firms, patent applications, and creative clusters (Raconteur report, 2013). The result showed that the south- east regions of the UK are placed in the highest areas in terms of patent applications.

At the firm level, innovation mapping can be used to achieve several objectives. Winkless and Cooney developed “mapping innovation space tool” by combining both technical and customer aspects of innovation (Winkless and Cooney, 2004). This map is used to define problems that cause product failure. Some innovation maps are used in educational innovation (Kampylis et al., 2012) that suggests mapping framework of information and communication technology enabling innovation for learning. The framework for learning innovation is mapped across five trajectories: nature of innovation (Radical, incremental, or disruptive), implementation phase, access level (local, national, or cross-boarder), impact area, and target. An additional model for mapping innovation looks at the” 4Ps diamond model” that has been developed by (Francis and Bessant, 2005). According to their study, the “4Ps” model is based

on the hypothesis that successful innovation is related to positive change in four areas: product, process, position, and paradigm. Tidd and Bessant suggested a circle model for mapping innovation by combining the innovation types "4Ps" and degree of novelty (Radical and Incremental) (Tidd and Bessant, 2009). Another model was introduced by (Alsanad, 2012; Abdel-Razek and Alsanad, 2013a; Abdel-Razek and Alsanad, 2013b; Alsanad and Abdel-Razek, 2016). They suggested a modified model for mapping innovation, and have named it "10Ps" model. That model takes into consideration the mixed area between two types of innovation. Hence, they have classified innovations into ten types: product, process, position, paradigm, product-process, product-position, product-paradigm, process-position, process- paradigm, and position-paradigm. They used the 10Ps model to investigate the innovations in one of the largest Saudi petrochemical companies (Saudi Basic Industries Corporations (SABIC)). Figure (2), (3) and (4) display the mapping innovation models that are based on innovation types and degree of novelty.

3.1 Diamond diagram

Diamond diagram had been developed by (Francis and Bessant, 2005), It provides organizations with tool that enable to take better strategic decisions in innovation management, and locate innovation activities on product, process, position, and paradigm. But it doesn't consider degree of novelty and combination between opposite pairs of 4Ps.

3.2 The 4Ps of innovation space model

The model had been developed by (Tidd and Bessant, 2009), It helps organizations to identify where to focus their innovations, to identify the future opportunities and to develop the innovation strategies. In addition, this model helps the organizations to compare maps for different organizations (competitors benchmark), or to compare maps for one organization in different periods (self-benchmark). It takes into account the degree of novelty (radical or incremental) for evaluation. But it does not provide any combination between 4Ps.

3.3 10Ps Innovation Mapping Model

The model was developed by Abdel-Razek and Alsanad (2013a) and implemented by Alsanad and Abdel-Razek (2016). The model enables mapping one and multi-dimensional innovations. In addition, the mapping process is automated. But it does not enable benchmarking process between organizations on the same model.

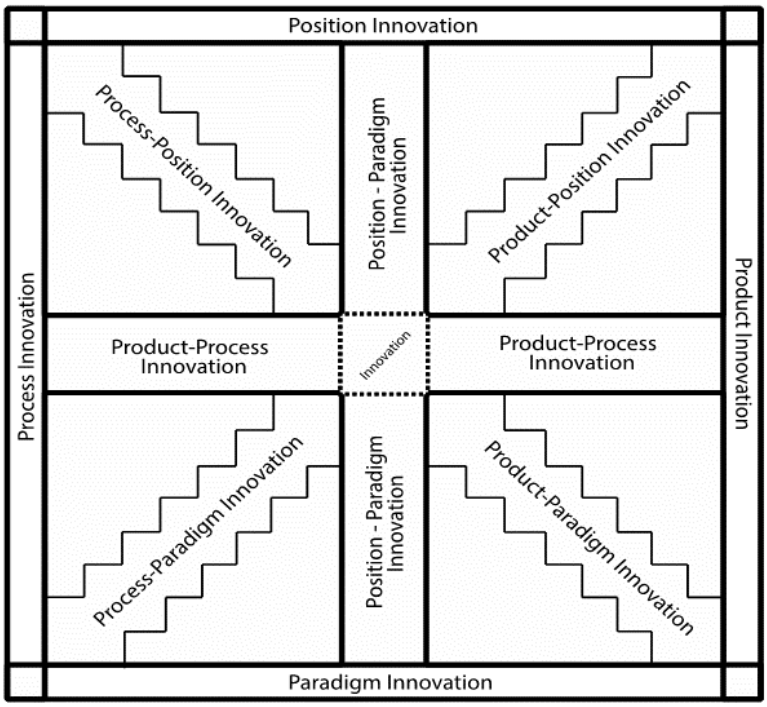

Fig. 1. 10Ps of Innovation Mapping Model (Abdel-Razek& Alsanad, 2013a, p.180)

4 10Ps Benchmarking Technological Innovation Mapping Model

The significance of this paper stems from presenting and applying the developed model of mapping innovation on the industrial organizations; especially the petrochemical companies leads to improve innovation in this sector. Moreover, Comparing several petrochemical companies helps to determine their strengths areas, to explore opportunities areas, and to develop innovations in these areas.

The 10Ps model provides the solutions for the weaknesses in the original model (4Ps) model. Where it takes into consideration the combined areas when innovations are mixture of two types of innovations. Also, it provides solutions for adjacent innovations in 4Ps model such as product- process. Finally, it makes a clear distinguishing between radical and incremental innovation, where radical innovation is represented by black circle, and incremental innovation is represented by white circle. However, the 10Ps model doesn't take into consideration the comparison and benchmarking between two or more organizations on the same model. In order to overcome this limitation, a modified model is suggested. Figure (2) shows the modified model that has been called "10Ps Benchmarking Innovation Mapping Model".

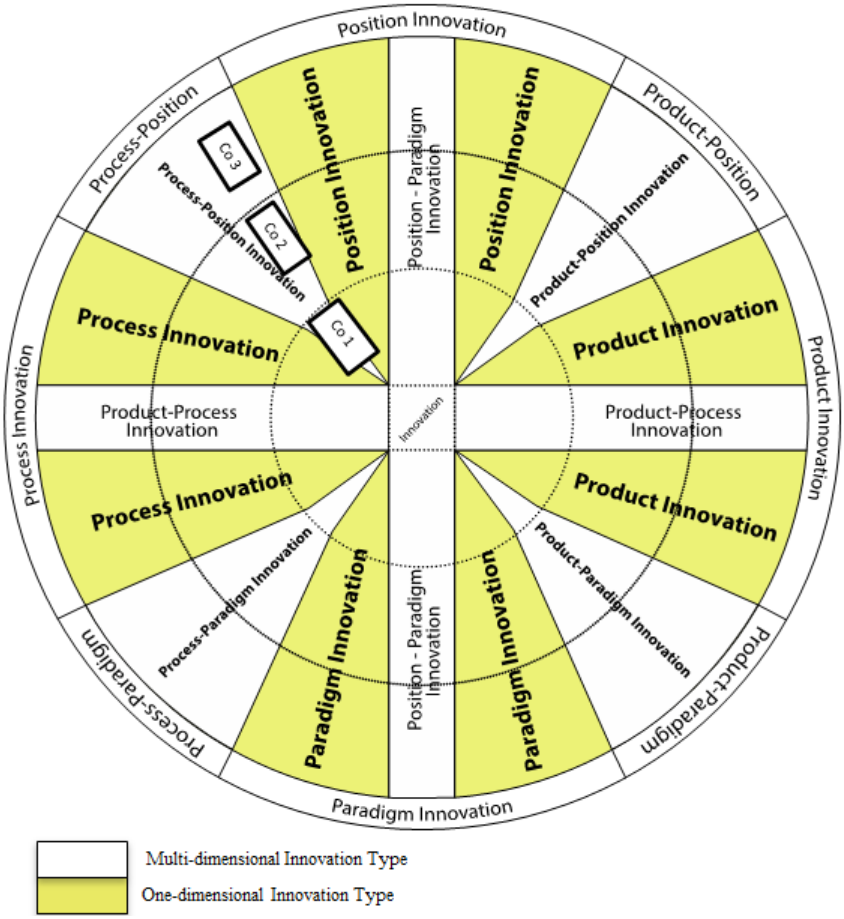

Fig. 2. 10Ps Benchmarking Innovation Mapping Model (Al-Abbas, 2014, p.26)

5 Application of 10Ps Benchmarking Innovation Mapping Model in the three International Petrochemical Companies

5.1 Innovation in the GCC Petrochemical Industry

The source of competitive advantages in the petrochemical industry is a technological differentiation, especially with the challenges that stem from the use of alternative feedstock and sustainability realities. Recreating the innovative mindset in the petrochemical industry is an imperative need (Gembicki, 2004). De Mello stated that the petrochemical industry faces challenges, such as environmental issues, unstable profits, and instability of oil supplies (De Mello, 2012). In his study, he seeks to map how petrochemical companies in Brazil are developing their incremental and radical innovation projects in order to help petrochemical companies to be more radically innovative.

The petrochemical sector in GCC countries represents the vital sector upon which the economies of those countries depend. According to (GPCA, 2013), GCC accounts for only 0.4% of the chemistry patents compared to the total number of patents issued worldwide in the past three years. An innovation survey was conducted (Gulf Petrochemicals & Chemicals Association GPCA, 2011) to investigate how do executives in the Arabian Gulf petrochemical and chemical industry perceives the role of innovation. The results showed that innovation in the petrochemical industry has an important role to secure competitive advantages, to develop proper innovation culture, and to support innovation strategies. The survey also showed that insufficient access to talents and inadequate innovation infrastructure are barriers to innovation. The study also showed that most innovative activities in the petrochemical companies are incremental product innovations.

5.2 Three International Petrochemical Companies in GCC

Two of the selected companies, SABIC and Dow Chemical, are operating in Saudi Arabia and are listed on the top ten chemical companies in the world (ICIS, 2013), while the third selected company GPIC, operating in Bahrain, is a joint venture between GCC members and is a vital economical power of Bahrain. The data needed for mapping innovation, has been obtained from annual reports and summaries of these companies' achievements. The data had been extracted that include any developmental activities for enhance the competitive advantages for the company such as a new developed products.

- Gulf Petrochemical Industries Co (GPIC)

GPIC was established in Bahrain in 1979 as a result of the cooperation between the GCC countries to use the natural gas in Bahrain and to produce petrochemical products and fertilizer. GIPC is a significant contributor to the Bahrain's national economy. Innovation, in GIPC's view, is the activation of the employees to enable the company to achieve its goals and its vision. In order to continue the successes in the future GPIC focuses on investment to upgrade the equipment in its plants and upgrade its management systems (GPIC Annual Report, 2010). The data needed to implement the 10Ps benchmarking innovation mapping model of GPIC has been gathered from the Company's Website (http://www.gpic.com), and the company's sources that include (GPIC Annual Reports, 2010; GPIC Annual Reports, 2011; GPIC Annual Reports, 2012).

Figure (3) shows the application of 10Ps benchmarking innovation mapping model in GPIC from 2010 to 2012, where the first area represents the innovations introduced by GPIC in 2010, while second area, and third area represent the innovations in 2011, and 2012 respectively. The results of mapping innovation in GPIC showed that the company had produced a total of seventeen innovations in the period from 2010 to 2012. 84% of the innovations were in process area, and 5% of them were in position. For example innovation number (2), which was added a new catalysis in the plant that can be considered process innovation (mapped on gray One-dimensional area), because the catalyst is

defined as a substance that increases the rate of a chemical reaction without itself undergoing any permanent chemical change. Furthermore, the multi-dimensional innovations represented by 11% of the total innovations, fell in the product-process area such as innovation number (1) that involved opening a new carbon dioxide recovery plant (CDR), to increase efficiency of production process through contribution to the limitation of Carbon Dioxide emissions, and to increase the production capacity of its methanol and its urea plants. Moreover, this innovation contributes to produce carbon dioxide Co2 and to use it in other plant. However, the clear gap was in other innovation types such as product, position, and paradigm. All innovations were incremental innovations that involved small improvements in existing processes (represented by white circles). The results also revealed that the largest number of innovations was produced in 2010 by 7 innovations, decreased to 5 innovations in 2011 and 5 innovations in 2012. The results also indicated that the best performance for GPIC in terms of the innovation number was in 2010 with 7 innovations, while the best performance in terms of diversity of innovation types was in 2012.

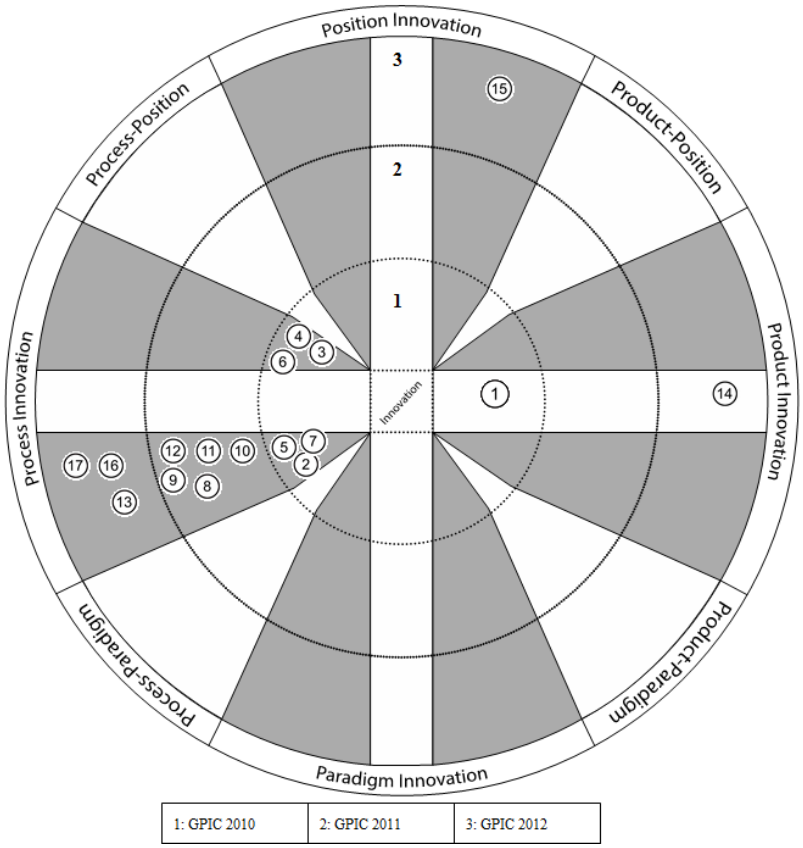

Fig. 3. Mapping Innovation of GPIC from 2010 to 2012 Using 10Ps Benchmarking Innovation Mapping Model

- Saudi Basic Industries Corporation (SABIC)

In 1976, SABIC began to benefit from natural resources in Saudi Arabia by producing petrochemical products and exporting them to other countries. Today, SABIC is the one of the world's largest petrochemicals manufacturers. In 2011, SABIC signed agreement with King Abdullah University of Science and Technology (KAUST) to build a new research and innovation center. Furthermore, SABIC is the second largest diversified chemical company in the world with 40,000 employees and more than 80 global operations (SABIC Annual Report, 2012). According to U.S-Saudi Arabian Business Council (2009) SABIC is the key player in petrochemical sector in the Kingdom of Saudi Arabia. The data needed to implement the 10Ps benchmarking innovation mapping model has been gathered from the company's sources, which include (SABIC Annual Reports, 2011; SABIC Annual Report, 2012; SABIC Sustainability Report, 2012; Company's Website (http://www.sabic.com/corporate/en/), in addition to (Al Sanad, 2012).

Figure (4) shows the application of 10Ps benchmarking innovation mapping model for SABIC from 2010 to 2012. Where first area represents the innovations that have been introduced by the company in 2010, while second area, and third area represent the innovations in 2011, and 2012 respectively. The results showed that the company had produced a total of seventy-five innovations during the three years (2010-2012). The largest contributions were in product area by 68% of the total innovations, followed by process innovation by 12% of the total innovations, and few innovations in position area by 3%. For instance, innovation number (24) involved LNP Verton Composite Forms. It was a new grade of existing product that was developed with new features, and therefore it was pointed on the innovation map on the incremental product area (represented by white circle). In other example, innovation number (40), that was a new SAP system for customer services, was considered process innovation, because it developed the system to achieve customer services effectively. Innovation number (41) was a position innovation because it expanded markets for current product (MTBE).

The results also showed that 17% of total innovations were multi-dimensional innovations, where 9% of the total multi-dimensional innovations were in product-process area, and the remaining 8% distributed between product-position by 5%, and process-position by 3%. For example, innovation number (60), that introduced UMS foam. This innovation was combined from two innovation types (Product and Process): product innovation, because it was a new chemical material with advanced performance, and process innovation, because it affected customers' production process, which helped to reduce the cost of packaging. Furthermore, all innovations were incremental innovations and none in radical innovations. The results revealed that the number of innovations increased by 25% in 2011 compared to 2010, and by 20% in 2012 compared to 2011. Moreover, the best innovation number for SABIC was in 2012 with 30 innovations, while the best diversity of innovation types was in 2011.

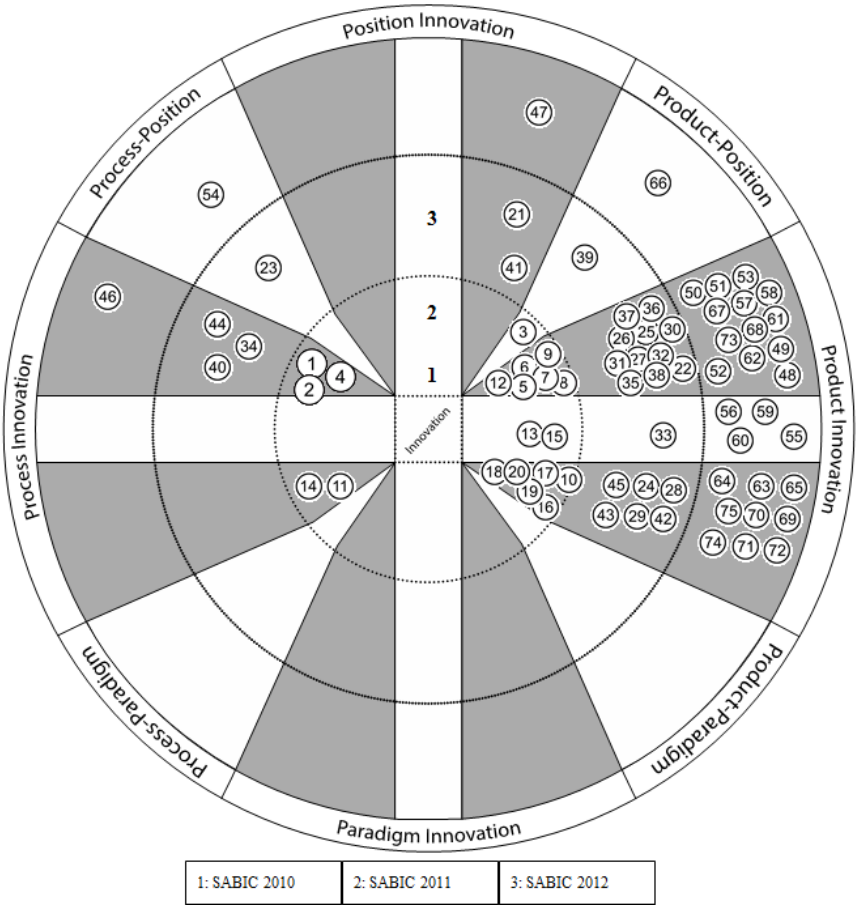

Fig. 4. Mapping Innovation of SABIC from 2010 to 2012 Using 10Ps Benchmarking Innovation Mapping Model

- Dow Chemical

Dow branch in Saudi Arabia was established in 2011. The innovation story of Dow started in 1897, when "Herbert Henry Dow" made his first discovery of the process of extracting bromine cheaply from brine. This was his first milestone of success, where his first bleach was sold in 1898 (Whitehead, 1968). Currently, the company employs about 53,000 employees worldwide**.** Dow Chemical completed more than 2000 projects and increased productivity improvement by 60% as a result of innovation in those projects (Accenture, 2007). In 2012, Dow was granted 412 US patents with an increase of 31 percent relative to 2011 (Dow Annual Report, 2012). Despite its name "Dow Chemical", Dow had been more than a chemical company. It had been consisted of six operating segments; each segment had served several industries, such as food, packaging, construction, and mining. The six operating segments had been Electronic and Functional Materials, Coatings and Infrastructure Solutions,

Agricultural Sciences, Performance Materials, Performance Plastics, and Feedstock and Energy (Dow Annual Report, 2012).

The data needed to implement the 10Ps benchmarking innovation mapping model has been gathered from the company's sources, which include (Dow Annual Reports, 2010; Dow databook, 2010; Ungerleider, 2011; Dow Annual Reports 2011; Dow databook, 2011; Dow Annual Reports, 2012; Dow databook, 2012; Company's Website (http://www.dow.com).

Figure (5) shows the application of 10Ps benchmarking innovation mapping model for Dow Chemical from 2010 to 2012, where the first area represents the innovations that was introduced by the company in 2010, while second area, and third area represent the innovations in 2011, and 2012 respectively. The results showed that the company had produced a total of one hundred and two innovations from 2010 to 2012. Most of the contributions of the company were in product innovation by 58%, and process innovation by 8%. Position and paradigm innovations represented by 3% and 1% respectively. Dow POWERHOUSETM Solar Shingle (innovation number 34 represented by black circle) was the solar panel that was placed on house roofs to provide alternative energy. Thus, it was considered product innovation (solar panel), position innovation because it targets the homeowners, and radical innovation (new to the world). Moreover, Innovation number (50), ACUSOLTM 845 Polymer, was a new grade of existing product that developed to meet customer requirements. Thus, it was an incremental product innovation. As for multi-dimensional innovation, the most contributions were in product-process innovations by 13%, and product-position by 11%. There were few contributions in product-paradigm, and process- position by 5%, and 1% respectively. For instance, innovation number (96), unlike the existing product, was developed to meet customer needs and to offer more options in industrial coatings (product). That product changed the viewpoint about coatings by exchanging it with another convenient choice of pre-mix; "low-VOC" concrete sealers (paradigm). So, it was considered incremental product- paradigm innovation. The results also showed that most innovations were incremental by 89% of the total innovations and 11% were radical innovation. The results also revealed that the number of innovations during the three years had increased by 20.7% and 8.6% in 2011 and 2012 respectively. The best performance in terms of innovation number, and diversity of innovation types occurred in 2012.

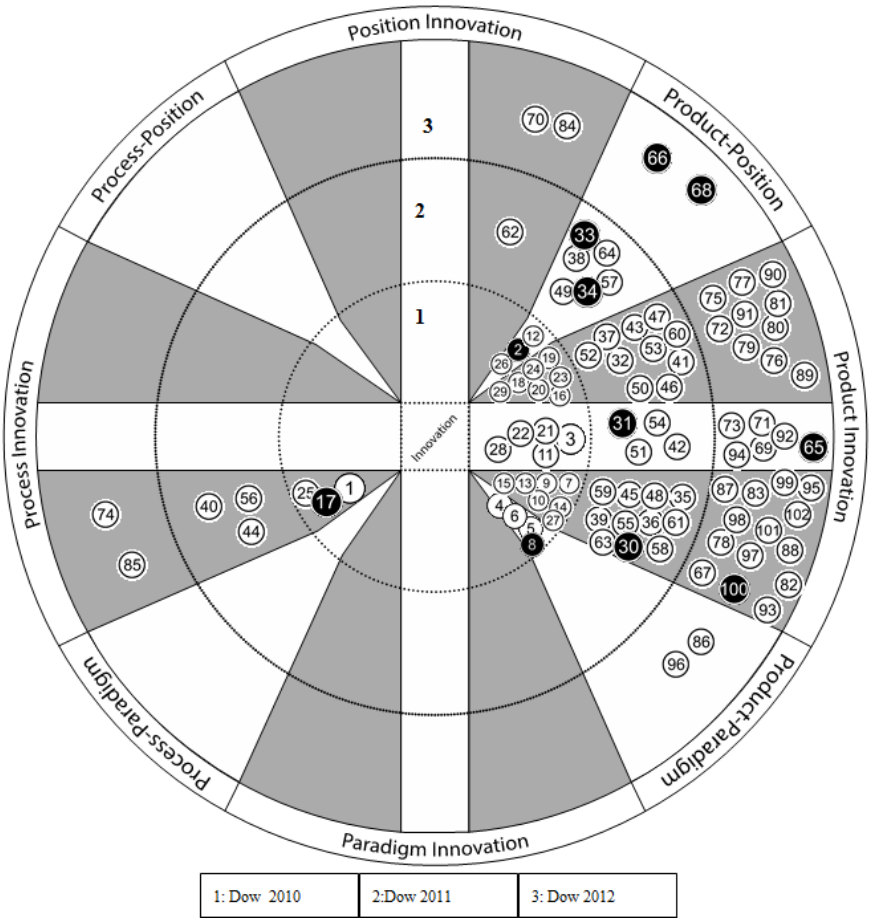

Fig. 5. Mapping Innovation of Dow Chemical from 2010 to 2012

5.3 Mapping Technological Innovation of the three Companies from 2010 to 2012

Figure (6) shows the application of 10Ps benchmarking innovation mapping model on the three international petrochemical companies from 2010-2012. The analysis showed that Dow Chemical has a highest number of innovations compared with GPIC and SABIC (102 by Dow Chemical, 75 by SABIC, and 17 by GPIC). Dow Chemical introduced 52.5% of the total innovations, SABIC introduced 38%, and GPIC 9%. The distribution by innovation types is shown in table (1). It shows that product innovations were most frequent (51 for SABIC, and 59 for Dow Chemical); process innovation was similar in each company; GPIC had the highest number of process innovations (14 innovations); paradigm innovation was the lowest recurrence; and only Dow Chemical produced paradigm and multi-dimensional innovation (product-paradigm). The results also revealed that the three companies produced 194

innovations in the three years table (1). Only 11 out of the 194 innovations were radical. The remaining 183 innovations were incremental, (91 by Dow, 75 by SABIC, and 17 by GPIC).

The results indicated that the strength of GPIC lies in process innovation, as it represents 84% of its innovations. However, the opportunities of GPIC lie in product, position, and paradigm innovations. As for SABIC, the strength area was in product and process innovations, as 68% of its innovations were in the product area, and 12% in the process area. The opportunities of SABIC lie in position and paradigm areas. The results also revealed that the strength of Dow Chemical lies in product and multi-dimensional innovation (product-process), as 58% of its innovations were product innovations and 13% for product-process innovations. The opportunities of Dow Chemical lie in position and paradigm innovations.

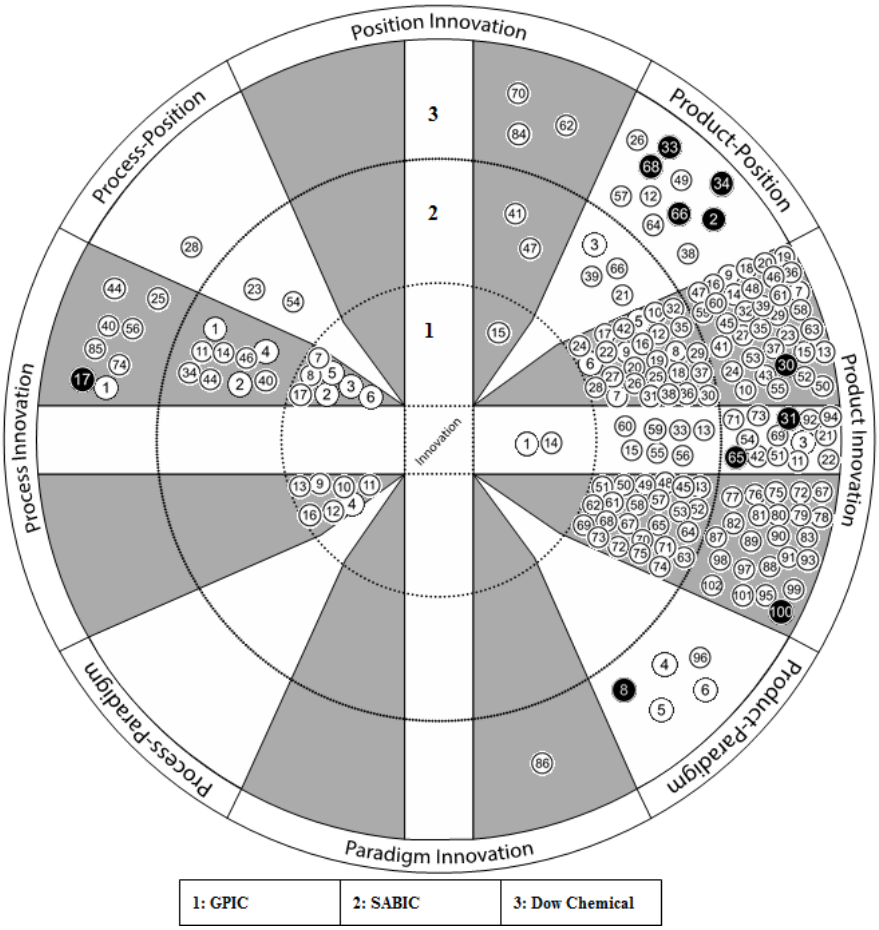

Fig. 6. Mapping Innovation of the Three International Petrochemical Companies from 2010 to 2012

Table 1. Innovation number, Types, and Percentage of change in innovations number for the three companies (2010-2012)

Company	Years	Innovation Types										Total	% Change in Number of innovations (2010-2011)	% Change in Number of innovations (2011-2012)	% Change in Number of innovations (2010-2012)
		One-Dimensional Innovation Types				Multi-Dimensional Innovation Types									
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10				
GPIC	2010	-	6	-	-	1	-	-	-	-	-	7	-28.5%	0	-28.5%
	2011	-	5	-	-	-	-	-	-	-	-	5			
	2012	-	3	1	-	1	-	-	-	-	-	5			
	Total	-	14	1	-	2	-	-	-	-	-	17			
SABIC	2010	12	5	-	-	2	1	-	-	-	-	20	25%	20%	50%
	2011	17	3	2	-	1	1	-	1	-	-	25			
	2012	22	1	1	-	4	1	-	1	-	-	30			
	Total	51	9	3	-	7	4	-	2	-	-	75			
Dow Chemical	2010	14	3	-	-	4	3	4	1	-	-	29	20.7%	8.6%	31.03%
	2011	21	3	1	-	4	6	-	-	-	-	35			
	2012	24	2	2	1	6	2	1	-	-	-	38			
	Total	59	8	3	1	14	11	5	1	-	-	102			

P1= Product P2= Process P3= Position
P4= Paradigm P5= Product- Process P6= Product- Position
P7= Product-Paradigm P8= Process- Position P9= Process- Paradigm
P10= Position-Paradigm

6 Conclusions

A technological innovation mapping model has been developed to overcome the weaknesses in the current published models. The developed model has been

called "the 10Ps benchmarking innovation mapping model". It clearly distinguishes between one dimensional and multi-dimensional innovation types, and it can map the innovation of several organizations simultaneously. The model was used to map the technological innovation in three international petrochemical companies: GPIC, SABIC, and Dow Chemical, during three years, from 2010 to 2012. It is concluded that the modified mapping tool is useful.

The results showed that the three companies produced 194 innovations during the three years. Dow Chemical was the largest producer of innovations, generating 102 innovations (53%), followed by SABIC 75 innovations (38%), then GPIC 17 innovations (9%). The dominant types of innovation had been compared in the three companies, and the results showed that the product innovations were dominant (56%) of the total innovations, this was distributed as: (53%) for Dow Chemical, (46%) for SABIC, and none in GPIC. As for process innovation, the three companies produced 31 innovations, which represent 16% of the total innovations. The process innovations distributed as: 45% produced by GPIC, 29% by SABIC, and 26% by Dow Chemical. The position, and paradigm innovations were the lowest in terms of the number of innovations, where only 3% of the total innovations were position, and (0.5%) were paradigm innovations, they were all introduced by Dow Chemical.

The comparison also showed that the three companies produced 46 multi-dimensional innovations and they were distributed as: 67.5% produced by Dow Chemical, 28% by SABIC, and 4.5% by GPIC. The product-process represented (50%) of the multi-dimensional innovations; 60.9% of the product-process innovations were produced by Dow Chemical, 30.4% by SABIC, and 8.7% by GPIC. The analysis also revealed that there were few contributions in product-position area by (32.6%) of the multi-dimensional innovations, process-position area by (6.5%), and product- paradigm area by (11%). Furthermore, the most innovations were incremental (94.3%) and only few were radical innovation, which accounted for (5.7%), all radical innovations were produced by Dow Chemical. In the three years from 2010 to 2012, the number of produced innovations increased by 50% in SABIC and by 31% in Dow Chemical. On the other hand, GPIC witnessed a decline in innovations number by 28.5%.

7 Recommendations

The application of 10Ps benchmarking innovation mapping model on the three international petrochemical companies revealed that there are number of opportunities to improve innovations in these companies in the following innovation areas:

1. For GPIC, exploiting the opportunities in product, position, and paradigm innovation.
2. For SABIC, there are opportunities in paradigm innovation.
3. For Dow Chemical, identify the opportunities in paradigm with possible improvements in radical innovations.

4. Exploiting the opportunities in radical innovations for the three companies.

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8 Appendix

8.1 Development of a Web-Based Application for 10Ps Benchmarking Innovation Mapping Model

In order to develop an automated benchmarking innovation mapping process, web-based application were designed especially to fulfill the following benefits:

- Enables the user to map innovation on several organizations automatically.
- Easy to use for identification mapping innovation in one company, or to compare the innovation maps for 2 to 5 companies.
- Provides "Tooltip" tool, which is a description inside the application, which includes: the innovation number, title, type, degree of novelty, and company name.
- It supports Google Chrome, Firefox, and latest Internet Explorer (IE) browsers.

The following are the steps in the implementation process of web-based application for 10Ps benchmarking innovation-mapping model:

1. Open the following link http://www.innovation-mapping-model.com
2. On the user interface, register, type username and password to access the program, then click "new chart".

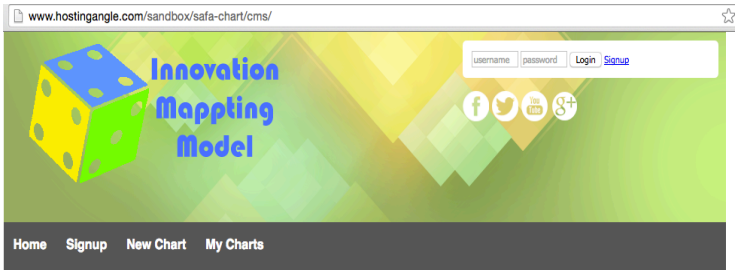

Fig. 7. The 10 Ps Innovation Benchmarking Mapping Model: Registration and Login

3. Put title of the new chart, then click "Create".
4. Start mapping innovation by inter the innovation data (innovation title, types, and degree of novelty). The data will be entered using a web form similar to as shown below:

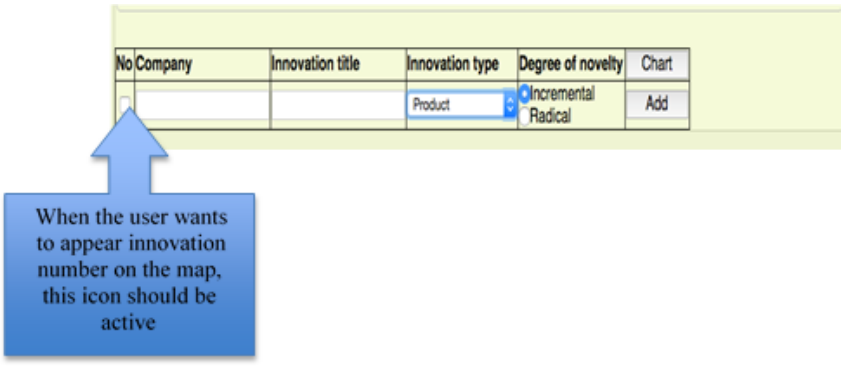

Fig. 8. Illustration of the Data Input for Each Innovation

When "add" is pressed (and all fields are filled), the data will be saved in the database, and will be shown in the table below.

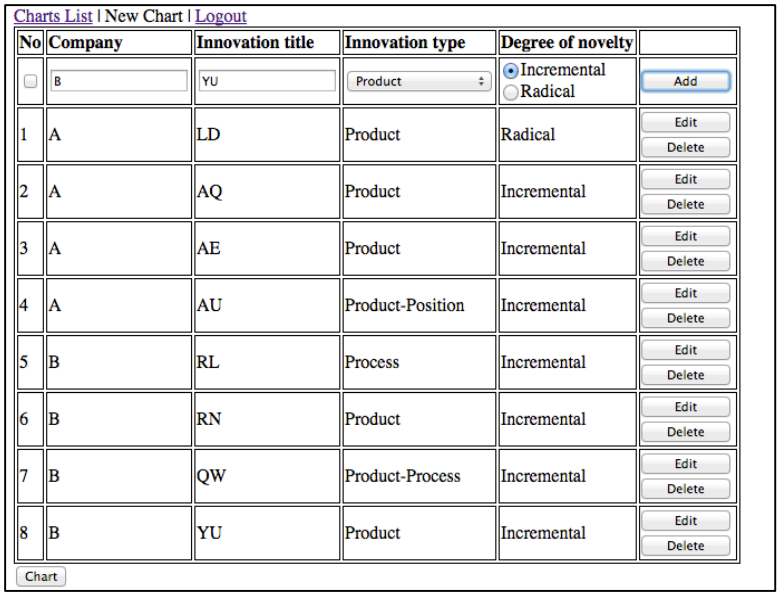

Fig. 9. Illustration of Innovations' List of the Model

5. Click "Chart" to map innovation.

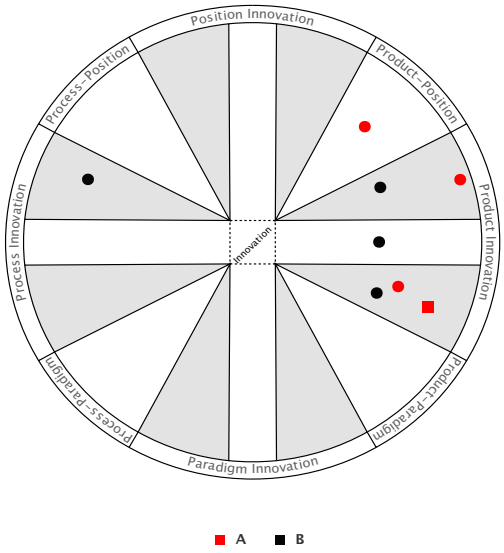

Fig. 10. Illustration of a Produced Chart of the Model

Also, when the user hovers over innovations on the map, the description inside

a tooltip will be shown and it will include: the innovation number, title, type, degree of novelty, and company name.

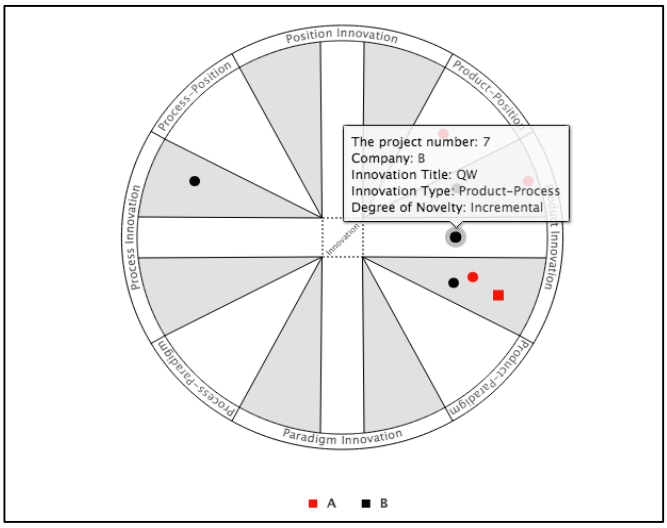

Fig. 11. Illustration of the Details Given for Each Innovation on the Chart

6. Click to print or to save the innovation map as the form that user will be choose.

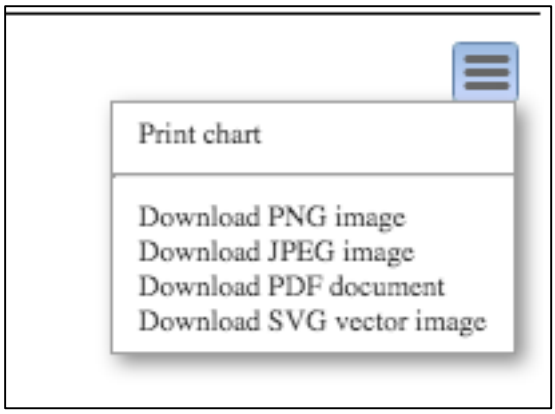

Fig. 12. Options for Saving and Printing

7. To modify innovation data click “Edit”, and to delete it click “Delete”.
8. To show the database of innovation click “Chart List”, then choose the file.