Chapter 21

Technological Forecasting

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Technological forecasting is the probabilistic assessment of the feasibility of future technology transfer (Vogel, 1970). It is the forecast with reasonable level of confidence regarding the the expected technological advancement in a specified time period provided a level of support in the form of expert knowledge or data regarding the concerned domain. It need not predict precise form of technology in future application, rather itdescribes scientific knowledge, technical skills, and examples of systems and components which science and technology can be expected to produce over a specified time if supported by orderly programs of research and development (Cetron et al,1966).

Technological forecast is concerned with the investigation of new developments, disruptive technologies, and new dynamisms which could arise from the interaction of factors such as new policies, innovations, expectations and apprehensions of general public. Technological forecasting is considered as an instrument to visualise the probable direction, pace, and outcome of technological change (Kang et al,2013). Researchers make technology forecasts based on past experience and current technological developments.

There are four elements in a technological forecast (Martino, 1983):

1. A time period.
2. A specific technology.
3. Functional characteristicsofthe technology.
4. Statement of probability of the outcome.

Like other forecasts, technology forecasting can be helpful for both public and private organizations to make smart decisions. It is a crucial input for planning the future development

Some applications of technology forecasting

• Collecting information on the environment and other determinants of technological change,
• Identifying limits of future applications of technologies in terms of threats and opportunities
• Understanding how future scenarios might be shaped or affected by today's long-term technology investments, and
• Understanding consequences of technology change and development in the context of economic and social implications.

Limitations of Technological Forecasting

- Reliance on the quality of the data and the assumptions.
- Difficulty in predicting the probability
- Problems in giving weightage to the factors.

- Biasness of the researcher may creep into the quality of the forecast.
- Technological forecasts do not provide conclusive results.

The techniques, both qualitative and quantitative methods, used in technology forecasting can be classified into two broad categories(Ramarao,undated), viz. Exploratory forecasting and normative forecasting. Short brief of some of the technology forecasting techniques are given below followed by an overview of Delphi method.

A. Exploratory methods:

Exploratory technological forecasts are largely based either on aggregates of 'genius' forecasts or on the use of leading indicators and other simple trend line approaches (Roberts, 1969).Cetron (1966) has defined It as a prediction with a level of confidence of a technical achievement in a given timeframe with a specified level of support. It starts with given situation and tries to predict the innovations.

1. Intuitive methods depend on the experts having vast knowledge and experience in the field who are able to envision the future scenario. Some commonly used intuitive methods are:

i) Individual forecasting: Experts in particular domains often make predictions about probable scenarios. But it lacks rigour of collective interaction and biasness is more. Probability of failures is high.

ii) Opinion polls: Opinions of selected experts are collected and analysed. At least twenty Ambiguous questions may lead to wrong responses .Also the danger of majority opinion masking the minority opinion also exist..

iii) Panels: It involves interaction among a group of experts. Though it has the merit of being multi- disciplinary and knowledge pooling, it suffers the weakness of being overpowered by a dominant persons.

iv)Brainstorming: Brain storming is another approach to make out from pooled ideas. Even the wildest of ideas are encouraged, resulting in a large pool of ideas. This could act as the input for further forcasting.

v) Delphi: Itinvolves iterative process of data collection and analysis until consensus is reached among anonymous experts in relation to complex situation.Here the assumption is that collective wisdom is better than the individual 'guesstimate'. Delphi technique is discussed detailed manner in later part of this chapter.

Input-output method: The input/output method systematically relates technological change and final demand to industry growth rates (Ranard,1972). Input-out tables are mainly used by firms to understand market penetration.

Growth curves: Growth curves are used to predict the advance of some technologies. Sigmoid growth curve with initial slow pace of growth followed by speedy advancement before declining to a steady state is most commonly used .young (1993) has used nine types of technological growth curves to study the characteristics and assumptions behind this genre of models

Scenario Planning offers an opportunity to visualise the future and help to plan accordingly. It is used to specify a future technology with possible environment. It is a narrative method which outline potential course of events. There can be multiple scenarios on a given time horizon since future is uncertain.

Trend extrapolation:In this method historical data series is used make a trend which is further extrapolated using appropriate statistical methods linear or logarithmic extrapolation techniques.

Substitution: When competitive substitutions are available,substitutions models can be used provided the time period for initial few substitutions. , Extrapolation of the substitution curve can be used to predict the extent of substitution in the future.

Technology monitoring: It involve scanning the environment for getting information related to the Technology followed by evaluation and utilisation of information for forecasting. In some cases predictionis possible by monitoring the early signals of the innovation. This is mainly achieved by a literature review, intellectual property search etc for ideation of technologies

Multivariate analysis:multivariate analysis of relation between dependent variable and two or more explanatory variables will help in forecasting based on the estimated value of the coefficients

B.Normative methods

Normative methodsstart with future needs then work backward to identify the technologies, environment and actionsneeded to meet them in best possible manner. This is need-based approach where required skills and capabilities are identified for the realisation of the goals. It depends on Bayasian statistics, and other operational research tool (Roberts, 1969).It includes rational allocation of resources for creating futuristic technologies.

Some of the available normative techniques for TF are:

Network techniques: This involve formulation of elements of forecasting network for converting description of technology system into network These techniques are mainlyused for missionoriented planning exercises mainly to analyse the road blocks to achieve the final target of objective.

System for Event Evaluation and Review (SEER): This is a modified variance of Delphi ideal for corporate exercises not necessarily the ones aimed at consensus. This consists of a single round of event evaluation (Ramarao,n.d).

Cross-impact analysis: Different events in present and past interact with each other and impact each other. Forecasts are made based on these interactions. It can be considered as an extension of Delphi technique. The purpose here is to study the mutual influence of the interacting events and utilise it to forecast technical capabilities

Morphological Analysis It involves systematic assessment of the morphology of technology for identifying the potential for performance improvements (Yoon and Park,n.d). This involve organising the information to provide a framework for searching possible solutions for a problem

Relevance trees: Here a broad topic is divided into smaller subtopics and shows different ways to achieve the goals. These ways are different in terms of probability of success and cost.

Evaluation of these alternatives helps to forecast associated costs, durations and probabilities for each element.

Dynamic modelling: These are computer aided structural modeling techniques in which time varying effects can be explicitly considered. It involves construction of a model based on perceived idea about system performance and tested against past performance of the system. Sensitivity analysis will be done to identify the controlling variables and to calibrate it further. This model will be used for prediction of future performance of the system (Blackman,1971).

C. Delphi technique: An Overview

The Delphi technique is used for problems that do not lend themselves to p r ecise analytical techniques , but can benefit from subjective judgments on a collective basis . Morgenstern (2) considers the Delphi technique to be the single most noteworthy contribution to the fi e ld of technological forecasting.

The Delphi exercise involves number of steps to elicit the response of group of experts or members of intended audience andfurther to modify it. (Rothwell and Kazanas, 1997). The process starts with selection of experts. It is followed by development of questionnaire which can be structured (Rothwell and Kazanas, 1997), and comprehensive of the area of study or unstructured which mainly involves the open ended questions related to area of investigation (Lang, 1998). Thequestionnaire issent to the respondents through online or offline modes. The responses collected are analysed and used develop questionnaire for next round. The procedure is repeated until there is consensus.

The information generated is processed and used by the investigating team to develop a subsequent more focused questionnaire, which is distributed together with the results of the previous round to participants in the third step of the procedure. This process of synthesizing data and refining the questionnaire continues until there is agreement of opinion among participants (Lang, 1998).

Delbecq et al., (1975) described the Delphi technique with the following steps:

1. Formulation questionnaires: The questionnaire may be open ended or require response on a rating scale. They are revised for each round based on the responses from previous round
2. Selection of experts: Experts are selected using snow ball technique, where key informants identify and recommend the experts in the particular area.
3. Sample size: The sample usually varies between 10-30. Anecdotal evidence points out that a sample between ten to twenty is sufficient.
4. Distribute the questionnaire:Sent the questionnaires to selected respondents and collect the responses in prescribed time.
5. Data analysis.: Collected responses are analysed using appropriate statistical techniques to see whether sufficient degree of consensus exist among respondents.
6. Formulation of questionnaire for second round, distribution and collection of feedback: The questionnaire for second round has to be developed based on the feedback from first round. The respondents should be requested to review their responses in this round

7. Data analysis: The responses from send round also analysed for possibility of consensus among experts. If sufficient consensus is reached, the iteration can be stopped. Otherwise the process will continue to next round.

8. Formulation of questionnaire for third round, distribution and collection of responses:Provide the summary of second round to respondents and ask them to review their responses in light of the collective feedback. The collect the responses

9. Data analysis:Consensus is examined using different measures.

10. Develop the conclusion and prepare final report.

Measuring Degree of Consensus

It was observed that, most of the researchers used quantitative and statistical measures such as mean, median, mode, standard deviation, skewness index, interquartile range, and rank for assessing the degree of consensus (Trexler et al., 2006). Some researchers have opined that criteria of consensus need to be identified based on the topic of the research (Kantz, 2005). The method is lacking a universally accepted measure of consensus. It is one of the major drawbacks of Delphi method. (Hung et al., 2008; Murry and Hammons, 1995). Single measure of consensus was followed earlier, but to add more rigour to the method 2-3 criteria are used in recent researches.This could help overcome the problems associated with single measure of consensus.

Some of the measures of consensus are listed below (Birko, Dove and Özdemir,2015;Rayens and Hahn,2000; English and Kernan, 1976).

1. De Moivre index (DM): It takes a value of 0 or 1 only depending on whether all respondents have agreement in their opinion.

2. Interquartile Range:It is a measure of variability in data, which can be calculated by taking the difference between largest and smallest values in the middle half of observations.

3. Coefficient of variation (CV): It is the measure of relative variability calculated as the ratio of standard deviation to mean in a set of observations.

4.Pairwise Agreement: Pairwise Agreement is the corresponding average measure of pairwise agreement over all possible pairs of experts

5. Clustered Pairwise Agreement: Based on the pairs of agreement in each consensus cluster.

6. Extremities Version of the Clustered Pairwise Agreement: It is modifiedClustered Pairwise Agreement, it takes only the agreements falling in upper or lower bound of the scale (e.g., 1-2-3 and 8-9-10 respectively in our simulation).

English and Kernan (1976) reported that if the value of the coefficient of variation (CV) more than 0.5 and less than or equal to 0.8, it means less than satisfactory degree of consensus and there is possible need for additional round. If CV is less than or equal to 0.5, there is no need for additional round. Elwyn*et al*., (2006) opined that consensus will not be there if 30 per cent or more of the ratings fall simultaneously in the lower third and in the upper third of the scale. Hackett *et al*., (2006) considered Fifty-one per cent of experts responding to the highest category as the criteria of consensus, while Beattie and Mackway-Jones(2004) and Roberts-Davis and Read(2001) argues for agreement by more than 75 per cent of experts.The concept ofapplying more than one

consensus criteria is based on the premises of methodological triangulation wherein the methods will substantiate one another (Creswell, 2007; Mason, 2002; Silverman, 2005).

Number of Rounds

The number of rounds in the process of iteration varies depending on the nature and purpose of the exercise. Normally, consensus is reached in two or three rounds (Delbecq et al.,1975). In case of heterogeneous audience, more rounds will be required. In case of homogenous groups, one or two rounds are sufficient. As the number of rounds increases there is a threat of reduction in response rate (Alexander, 2004; Rosenbaum, 1985; Thomson, 1985).

Panel Size

There exists no clear cut rule regarding the size of the panel. It depends on the nature of the study, degree of complexity, required precision and expertise. It can be large or small, geographically dispersed or confined, homogenous or heterogeneous etc. But the rule of thumb is15-30 people for a homogeneous population i.e., experts coming from the same discipline (e.g. nuclear physicists) and 5-10 people for a heterogeneous population, people with expertise on a particular topic but coming from different social/professional stratifications such as teachers, university academics and school principals (Delbecq et al., 1975; Uhl, 1983; Moore, 1987). According to Adams (2001), by increasing the size beyond 30, reliability and validity hardly improves. It has been pointed out that more than 13 respondents are suffient to achieve satisfactory level of reliability (Dalkey,1969). Hasson, Keeney,and McKenna (2000) points out that achieving impartiality in recruiting panel members is often difficult. There will be selection bias very often make a case for seeking impartiality in recruiting panel members, but this

Survey Instrument

Delphi questionnaires can be open ended or requiring response on 5-point likert type scale. In some cases, open ended questionnaires are used in first round to have sufficient information base. In the repeated round likert type scales are used based on the first round.

Confidentiality

Responses to the Delphi questionnaires need to be treated with complete confidentiality, and the anonymity of experts in panel was thoroughly maintained throughout the data collection.

Mode of Communication

The mode of communication may be on line or through mailed questionnaires. With the advent of Information and communication technologies there are many possibilities to fasten the process. The applications like ‘Google form and Survey monkey’ can be effective used for the purpose

Statistical analysis used

Descriptive statistical analysis such as mean, median, mode, percentage, interquartile deviation (IQD), standard deviation and coefficient of variation were used for analysing the data.

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