Futuristic Computational Technologies: A Scenario Analysis

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ABSTRACT
Computational technologies are changing rapidly due to fast and huge demand for computational power for variety of applications, societal factors and advances in science and technology. It is difficult to forecast exact nature of future computational technologies due to multiple and dynamic factors influencing technology advances. The paper focuses on computational technology trend from macro perspective including technological, societal, behavioral aspects. The output of this paper is twofold, first it presents drivers behind the historical development and probable futuristic computational technologies using technology push and market pull concepts. Second, it describes futuristic computational technologies using the scenario method. Further the paper list the impact of futuristic technologies on economy, national development and enterprises.

General Terms
Technology forecasting, Computational technologies, Technology trend.

Keywords
Computational technology, Scenario analysis, Technology push, Market pull, social impacts of computational technology.

1. INTRODUCTION
Society and economy is undergoing a fundamental transformation because of advances in technologies. Advancements not only effect on wealth creation but also the way society operates. In 18th century we have witnessed the rapid growth in the field of physics, material science, transportation etc. Today, information and communication technology have significant impact on society and they are changing the way society operates. Society is more and more dependent on new technologies and becoming "knowledge society". Economy is shifting to "knowledge economy," where knowledge and information are essential and the key factor of production [1]. It creates a need to foresee the futuristic computationl technologies and it's impact on enterprises, nations and society. Though imperfect, technology foresse helps desoion makers in government, research organization, giant enterprises, small and medium scale enterprises and end user for better plans and decisions.

Different researchers have proposed different definitions of technology forecasting (TF). Various researchers see different meaning of technology forecasting in different disciplines. According to Firat et. al [2] technology forecasting refers to purposeful, focused and systematic attempts to understand the potential direction, rate, characteristics technological change. There are two main philosophical approaches to technological forecasting, exploratory techniques and normative techniques. Exploratory techniques project the present state of technology into the future. Among the exploratory techniques, the jury of executive opinion and formal survey methods are subjective whereas S–curve is objective. Extrapolation methods are better suitable for short term forecasting. Normative techniques work backward from the future to the present. Relevance trees, scenarios, morphological analysis, foresight etc are normative techniques [3].

	Exploratory	Exploratory / Normative	Normative
Discontinuous	Data Mining (Text Mining) Bibliometrics (literature, patents etc) Cross Impact Analysis	Delphi, Scenario Planning, Nominal Group Technique, Trend Impact Analysis	Backcasting AHP Relevance Trees Morphological Analysis
Continuous	Growth Curves System Dynamics Trend Extrapolation Analogies TFDEA	Technology Roadmap, Trend Impact Analysis, Delphi, Scenario Planning, Nominal Group Technique	Morphological Analysis AHP Relevance Trees Backcasting

Fig 1: A Matrix of technology forecasting tools (Taken from [4])

Paper [4] presents historical overview, analysis of characteristics, advantage / disadvantage, origins and chronological evolution in a variety of TF methods over 60 years. Figure 1 shows the categorization of methods into exploratory and normative.

Generally, TF methods are classified into two main approaches, quantitative methods and qualitative methods. There can be significant overlap between the two (see figure 2).

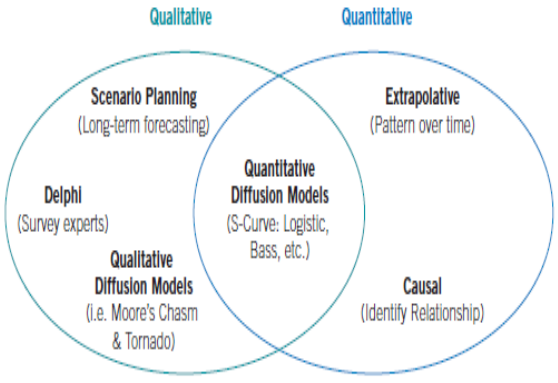

Fig 2: Forecasting methods (Taken form [5])

"Scenario planning is a powerful tool precisely because the future is unpredictable and shaped by many interacting variables" said Peter Schwartz, Cofounder and Chairman Global Business Network [6]. In literature it is often argued that scenario development is different from forecasting. Armstrong [7] reported few suggestions for future research in the area of technology forecasting. Armstrong suggested to present forecasts as scenarios. Authors [8] reevaluates the concepts and shows that how it is converging with contemporary forecasting practice.

The objective of this paper is to understand the development of computational technologies and foresee the future generation computational technologies. The quality of forecasts greatly depends on proper selection and application of appropriate method [2]. Paper [9] reported that multiple scenarios are useful in addressing and conveying uncertainty especially when the substitution or adoption of technology has not started yet. This is the main reason behind selection of scenario method for forecasting.

The main research questions are expressed as follows:

- What are the key drivers that produce these scenarios?
- Which are the alternative (technological) scenarios for computational technologies?
- What is the impact of these future computational technologies on society and enterprises?

The rest of the paper is organized as follows: In Section 2, related work on future information technology and scenario analysis for different technologies is described. Journey of computational technology is explained in Section 3. Section 4 describes technology push and market pull. Section 5 gives details of scenario of futuristic computational technologies and it's impact on enterprises and society. Finally, the conclusions of our study are outlined in Section 6.

2. RELATED WORK

This section describes the related work on future information technology and scenario analysis for different technologies.

2.1 Information technology

This section discusses the literature on development of information technology.

Paper [10] investigate the influence of technology and knowledge factors or market factors as enablers of innovation in computing technology. Technology factors refer to the speed and direction of technological knowledge. Market factors point to the rise or existence of a manifest or potential market for a product. Authors [10] concluded that development of computing technology has gone through three different phases: a demand enabled period between 1900 and 1960, and two knowledge enabled periods. The period between 1960 and 1990 was enabled by knowledge development in the field of microelectronics, while the period from 1990 to in fact the present was mainly enabled by knowledge developed for converging computing and telecommunications technology.

In the paper [11] author focused on two objectives in his study of future computer technology. First, how the computer features are used and second advances in computer hardware.

Authors [12] reported that prediction of future of information technology is hard. This paper presents some prediction techniques to forecast the future of information technology within the next five to ten years. Authors used extrapolation, crossover, demand-driven, embryo technologies, analogy, periodical waves techniques for prediction.

Author [13] presented few possibilities in computational technology development up to 2020 and 2030. These predictions are based on extrapolations of technologies.

Report presented four scenarios that address a set of uncertainties that will determine how ICT and the Internet will be a driver of economic activity in the next 10 years [14]. Report presented twelve driving forces behind computing and communications technologies.i) Exponential Improvements in Price/Performance, ii) Cloud Computing: Networked Intelligence at Scale, iii) Changing Times: Atemporality, the Long Now, Deep Time, and Total Recall, iv) Big Data, Analytics, Intelligent Interfaces, and The Transformations of Media, v) Integrating Virtual and Real: Sensors and the Internet of Things, vi) Sustainability, Energy and Green Computing, vii) Business Communications: Beyond Telephone Calls and Email, viii) Sociality and Digital Lifestyles, ix) Opening Up: Property, Markets, & Modes of Production) Mobile, Wearable, and Implantable Computing, xi) Globalization, xii) New Economic Models, and Approaches to Capital and Investment.

2.2 Scenario analysis

This section presents application of scenario method to different problems.

Authors [15] presented predictions and observations for the future of user interface tools.

The main purpose of the paper [16] is to clarify possible future advances in the Internet evolution. Four alternative evolution scenarios for the Internet are presented based on ideas and information gathered from brainstorming sessions and expert interviews. Authors reported that political, economic and social motives are at least as important as technical enablers.

Paper [17] describes a process for generating scenarios of future electricity network development. A set of electricity network scenarios for Great Britain is presented considering the years 2020 and 2050. The key Scenario drivers considered in this investigation are economic growth, environmental consciousness, technological growth and regulatory structure.

This study [18] combines the Delphi and scenario analysis methods to develop future scenarios for media industry in 2020. Presented three scenarios covers the effects of the macro driver, diffusion of tablets, discontinuity factor and changes in customer behavior.

Paper [19] used scenario development approach with cross impact analysis for factory planning projects. The main objective of this paper is to convey the future impact of today's decisions on production systems to employees involved in production planning processes.

Paper [20] used scenario approach to analyzing the environmental impact caused by the diffusion of fuel cells. Authors described three scenarios for diffusion of solid oxide fuel cells (SOFC) by combining assumed social situations and quantitative simulations using the three models, i.e., the residential energy system evaluation model, the product diffusion model, and the aggregator.

Authors [21] presented two scenarios namely mixed-signals scenario and the confluence scenario for nanotechnology.

The thesis [22] introduces four industry scenarios that define the future market of mobile voice. The presented four scenarios are based on the findings of the analysis of business dynamics.

3. JOURNEY OF COMPUTATIONAL TECHNOLOGY

Markus Bohm et al. [23]) presented summary of the history starting with the calculating machine, computers and the internet and eventually to the beginnings of cloud computing. Computational technology has completed a cycle from centralized systems to distributed systems and back to centralized systems. The journey of computational technology started with technologies like mainframes and minicomputers. After client–server, grid computing and cluster computing models, it has adopted cloud computing. Cloud computing is one of the transformational technology in the computing world. Cloud computing driven data centers and services helping organizations to leverage multiple business attributes like cost, reliability, ease of acquiring and maintaining technology systems are in ascend.

Mainframes: Invention of the transistor drives the advancements in the development of the computer industry. Mainframe computers are high end commercial machines with huge computing power and memory used primarily by corporate and governmental.

Minicomputers: It is middle range of the computing machines, in between the smallest mainframe computers and the microcomputers.

Cluster Computing: Clusters are usually deployed to improve performance and availability over that of a single computer, while typically being much more cost-effective than single computers of comparable speed or availability. Computer clusters have a wide range of applicability and deployment due to flexibility, scalability, openness.

Grid Computing: Grid computing combines computers from multiple administrative domains to reach a common goal, to solve a single task, and may then disappear just as quickly.

Autonomic Computing: In an autonomic environment, system components (hardware and software) are self-configuring, self-healing, self-optimizing and self- protecting.

Cloud Computing: Cloud computing is based on 'pay as you use' concept where resources are available on demand and 'as a service' through Internet. In recent times, this new computing model is strongly influencing IT world and enterprises.

4. TECHNOLOGY PUSH AND MARKET PULL MODEL

The concepts of technology-push and need-pull were introduced by Schon [24]. Two schools of thought, namely the TP and the NP, propose and support two different arguments. The TP school suggests that innovation is driven by science, and thus drives. The NP proponents argue that user needs are the key drivers of adoption. Technology-push (TP) and need-pull (NP) concepts are used to examine the key factors in the adoption decision [25]. Technology-push (TP) and need-pull (NP) concepts are borrowed from the engineering / R&D management literature [25]. Different researches investigated the effect of technology push and demand pull model of technology development. Both the models are important for the development of technologies [26].

Paper [27] suggests that much of the contention between the demand pull and technology push findings is due to different research objectives, definitions, and models.

4.1 Technology push

The technology push model also called as linear model is one of several theories developed over time to explain technological innovation. A "technology push" describes a situation where an emerging technology or a new combination of existing technologies provide the driving force for an innovative product and problem solution in the market place[28].

The process of innovation starts with basic research continues through applied research and then enters the development phase [29]. This model was dominant model for decades.

Steps of technology push:

- Basic science
- Applied science and engineering
- Manufacturing
- Marketing

4.2 Market Pull

The term "market pull" implies that the product or process innovation has its origins in latent, unsatisfied customer needs in the market place [28].

Market pull sometimes starts with potential customers asking for improvements for existing products. Focus groups are often central to this, when testing a conceptual design or an existing product [29]. Alternative future scenarios provide the socioeconomic context in which technological systems can be forecast and assessed [30].

Steps of market pull:

- Market Need
- Development
- Manufacturing
- Sale

5. SCENARIO ANALYSIS FOR COMPUTATIONAL TECHNOLOGIES

This section presents scenario for future computational technologies and it's impact, drivers behind the change and methodology adopted.

The main characteristics of the scenario analysis in this study are

i) Identify the driving forces behind computational technology change using the technology push and market pull model.
ii) Foresee future state.
iii) It is not extrapolating trends from the present
iv) Foster strategic thinking for development of computational technologies

5.1 Methodology

In literature researchers have reported steps for scenario building.

Paper [31] reviews different techniques used for developing scenarios. The paper reported eight categories of techniques that include a total of 23 variations used to develop scenarios

with their strengths and weaknesses. Authors [32] presented comparison of various approaches of Scenario techniques.

In literature large number of future trend forecasting / foreseeing investigation are done based on technical strengths and weakness of the past and current technology under study. This paper does not focus on identifying the technical strengths and weakness of past and current computational technologies to identify the future trends. The paper focuses on computational technology trend from macro perspective including technological, societal, behavioral aspects. The methodology adopted in this paper is qualitative and based on genius judgment.

1. Identify the drivers behind journey of computational technologies.
2. Identify the probable drivers in future using market pull model and technology push model.
3. Identify the parameters that describe the scenarios.
4. Describe the scenarios.
5. Impact of different scenarios on enterprises, nations and society.

5.2 Market pull model

Computational technology need has changed drastically in last century from,

- Military applications
- Productions systems for control crisis
- Demand for communication technologies
- Automation of systems
- Today computational systems are used by business sectors, university campuses, home users, governments, large or medium companies, defense etc. Computational systems are becoming integrated part of human life.

In present the main drivers for increasing use of computational technology change are need of high performance, improve recourse utilization, increase cost effectiveness, guaranteed availability, ease of access from any location, minimize IT overhead, and improve scalability.

Market pull drivers behind futuristic technology:

a) Society and governments

Technologies are tools for economic and social development. In literature numbers of studies are done to investigate the relationship between technology development and society.

- Change in society perspective / maturity
- Solution for global problems
- Market need for technology advances
- Government need for technology advances

b) Human aspiration- for capitalism / socialism

5.3 Technology push model

The technology push drivers behind the past computational technology are

- Microelectronics
- Software technology

Technology push drivers behind futuristic technology:

- Technology advances in computing technology
- Technology advances in communication technology
- Technology advances in material science and technology
- Innovations from science

5.4 Scenarios and it's impact

This section presents three scenarios for future computational technologies (see table 1).

Scenario 1: Self configuring / expanding, public funded, intelligent computing power generating and distributing stations leveraging advanced smart materials having high conductivity

Scenario 2: Remote controlled Intelligent robots taking over the menial jobs, eliminating the role of laborers, drawing computational power / electric power wirelessly from state facilities

Scenario 3: Mammoth computing engine shall be constructed in space, energized by space based solar stations, which gets replicated to cater to multiple geographies

Information and communications technology, including hardware, software, telecommunications, and the Internet is the dominant driver of growth and innovation in the United States and throughout the global economy [33]. The computing and communications revolution has numerous economic and social impacts on modern society [34].

The influence of development in technology on society is wide covering many areas such as government, public sector, defense, economy, research and development, production and many more.

This section focuses on impact of presented futuristic technology scenarios on following issues.

- Economy
- National Productivity
- Global spending on research in science and technology
- Public spending on E-governance / Mobile governance/ free wireless communication services
- Enterprise

Table 1. Scenarios for futuristic computational technologies

Parameters that describes scenario	**Scenario 1**	**Scenario 2**	**Scenario 3**
	Self configuring / expanding, public funded, intelligent computing power generating and distributing stations leveraging advanced smart materials having high conductivity	Remote controlled Intelligent robots taking over the menial jobs, eliminating the role of laborers, drawing computational power / electric power wirelessly from state facilities	Mammoth computing engine shall be constructed in space, energized by space based solar stations, which gets replicated to cater to multiple geographies
Change in Society perspective / maturity	In align with societal aspiration	Beyond societal dynamics	Beyond societal understanding
Solution for Global problems	Catering	Very limited contribution to solve Global bottlenecks	Futuristic
Market need for technology advances	It drastically improves the process of wealth creation	It drastically improves the process of value creation	It creates mammoth wealth and value creation
Government need for technology advances	Set aside funds to promote research and development through state run institutions	Governments shall extend these kind of new approaches for creating robust defense build up	Governments all over the world shall collaborate in funding for research and building facilities
Human aspiration	Drives innovations	Drives automation	Drives break through Technologies
Technology advances in computing power	Aligning with captioned technology	Contribute to captioned technologies	It is in sync
Technology advances in communication	Contribute to the captioned technology	Contribute to the captioned technology	Minimum condition for afore mentioned developments
Technology advances in material science	Breakthrough in Material technology shall happen	Not much of influence	Massive contribution in space based solar energy

Table 2. Impact of futuristic computational technologies

Parameters getting influenced	**Scenario 1**	**Scenario 2**	**Scenario 3**
	Self configuring / expanding, public funded, intelligent computing power generating and distributing stations leveraging advanced smart materials having high conductivity	Remote controlled Intelligent robots taking over the menial jobs, eliminating the role of laborers, drawing computational power / electric power wirelessly from state facilities	Mammoth computing engine shall be constructed in space, energized by space based solar stations, which gets replicated to cater to multiple geographies
Economy	Becomes more efficient	Economy shall follow a kind of Laffer curve as in supply side Economics	Economy immensely benefits out of elimination of non value adding activities
National Productivity	Improves as newer technologies penetrates deeper in the geographies	Improves significantly and compensates for lack of sufficient number of skilled personals	Improves dramatically taking advantage of reduction in overhead cost.
Global spending on research in science and technology	Slows down as the global market place shall shed extreme competiveness for collaboration and cooperation as newer world order emerges	New work culture emerges and spending shall increase in the realm of mobile, helicopter robots and its variants	New world order emerges underpinning the maxim of " yours is also mine", drastic cut down on competitive research and focusing on collaborative efforts to minimize human suffering/ heighten the

			experience of simple living
Public spending on E-governance / Mobile governance / free wireless communication services	Massive investment initially to align with new technology, there after it decreases	Not significant change on public spending to maintain existing systems	Saves on internet bandwidth and cost of maintenance
Cost of Running Business	Go down as technology stabilizes	No significant change	Go down as technology stabilizes
New start up ventures	Leverages new public facility to create new business model	Mass customization of robots	Energizing from existing business models to create lean ventures
Spending on IT infrastructure	Drastically coming down	Not much change	Initial capital expenditure goes up initially and operating cost decreases

6. CONCLUSIONS

Accurate prediction of computational technologies is difficult due to large technical, economical, political and social factors. Multiple scenarios are useful to understand few probable situations in the future. This paper presents three scenarios for futuristic computational technologies based on the drivers identified using technology push and market pull models.

Society has witnessed the change in need, penetration and philosophy behind computational technologies. The drivers behind the change can be well explained by demand pull and technology push models. After two knowledge driven segments from 1960 to present date, we foresee that it is time for demand driven era due to social and global problems. Today, information technologies, communication technologies are mature. Technological advancements in other disciplines such as robotics, space technology and communication technology are going very rapidly. With combination of such multidisciplinary technologies we can see the next generation computational technologies.

Futuristic computational technologies will help enterprises by reducing the initial start-up cost, IT expenditure and cost of running business. They also influence the public and government spending and improve the productivity.

7. REFERENCES

[1] Berisha-Namani, M. and Ramadani, A. 2009. The Role of Information Technology in Small and Medium Sized Enterprises in Kosovo. Fulbright Academy Conference.

[2] Firat, A. K., Woon, W. L., and Madnick, S. 2008. Technological forecasting–A review. Composite Information Systems Laboratory (CISL), Massachusetts Institute of Technology.

[3] Prakash Sai L. Technology Management. Indian Institute of Technology Madras.

[4] Yonghee Cho, "Investigating the Merge of Exploratory and Normative Technology Forecasting Methods," 2013 Proceedings of PICMET '13: Technology Management for Emerging Technologies, pp. 2083-2092.

[5] Forecasting the Take-up of Mobile Broadband Services. White paper. Available at tellabs.com .

[6] Scenarios for the Future of Technology and International Development, Report, The Rockefeller Foundation and Global Business Network, May 2010

[7] Armstrong, J. S. 2001. Standards and Practices for Forecasting. Principles of Forecasting: A Handbook for Researchers and Practitioners, J. Scott Armstrong (ed.): Norwell, MA: Kluwer Academic Publishers.

[8] Bunn, D. W. and Salo, A. A. 1993. Forecasting with scenarios. European Journal of Operational Research, 68, 291-303.

[9] Vanston, L. K. and Hodges, R. L. 2004. Technology forecasting for telecommunications. Telektronikk, 4, 32-41.

[10] Van den Ende, J. and Dolfsma, W. 2005. Technology push, demand pull and the shaping of technological paradigms - Patterns in the development of computing technology. Erasmus Universiteit Rotterdam.

[11] Ware, W. H. 1966. Future computer technology and its impact. The RAND Corporation, California.

[12] Bergner, K., Deifel, B., Jacobi, C., Kellerer, W., Rausch, A., Sabbah, A., Schatz, B., Sihling, M., Vilbig, A., and Vogel, S. The Future of Information Technology –an interdisciplinary, scenario-based approach.

[13] Duch, W. Future Trends in Computational Intelligence from the 2012 perspective.

[14] ICT 2020_4 Scenario Stories Hidden Assumptions and Future Challenges, Ministry of Economic Affairs The Hague, 2010.

[15] Myers, B., Hudson, S. E. and Pausch, R. Past, Present and Future of User Interface Software Tools.

[16] Leva, T. Scenario Analysis on Future Internet. Master's Thesis, Helsinki University of Technology.

[17] Elders, I. M., Ault, G. W., Galloway, S., and McDonald, J. R. 2005. Identification of Long-term Scenarios of Electricity Network Development. In Proceedings of the International Conference on Future Power Systems, IEEE.

[18] Laivuori, T. The diffusion of disruptive innovation (tablet) on the media industry and emerging new business opportunities. Master's thesis, Department of Management and International Business, Aalto University.

[19] Menck, N., Weidig, C., and Aurich, J. C. 2014. Approach for predicting production scenarios focused on cross impact analysis. Procedia CIRP, 17, 493–498.

[20] Kishita, Y., Nakamura, Y., Kegasa, A., Hisazumi, Y., Hori, T., Fukushige, S., and Umeda, Y. 2014. Scenario

Analysis of the Diffusion of Fuel Cells in the Residential Sector. Procedia CIRP, 15, 294–299

[21] Farber, D. and Lakhtakia, A. Scenario Planning and Nanotechnological Futures.

[22] Lindqvist, K. 2007. Scenario Analysis of the Mobile Voice Market. Master Thesis, Department of Electrical and Communications Engineering, Helsinki University of Technology.

[23] Bohm, M., Leimeister, S., Riedl, C., and Krcmar, H. Cloud Computing and Computing Evolution. TUM, Germany.

[24] Schon, D. 1967. Technology and Social Change, Delacorte.

[25] Chau, P. Y. K. and Tam, K. Y. 2000. Organizational adoption of open systems: a technology-push, need-pull perspective. Information & Management, 37, 229-239.

[26] Mowery, D. and Rosenberg, N. 1979. The Influence of Market Demand upon Innovation: A Critical Review of Some Recent Empirical Studies. Research Policy, 8, 103-153.

[27] Chidamber, S. R. and Kon, H. B. 1993. A Research Retrospective of Innovation Inception and Success: The Technology-Push Demand-Pull Question. Massachusetts Institute of Technology.

[28] Herstatt, C. and Lettl, C. 2000. Management of technology push development projects.

[29] Rothwell, R. 1994. Towards the fifth-generation innovation process. International Marketing Review, 11, 7-31.

[30] Chen, K., Jarboe, K., and Wolfe, J. 1981. Long-Range Scenario Construction for Technology Assessment. Technological Forecasting And Social Change, 20, 27-40.

[31] Bishop, P., Hines, A., and Collins, T. 2007. The current state of scenario development: an overview of techniques. Emerald Group Publishing Limited, 9 (1), 5-25.

[32] Mietzner, D. and Reger, G. 2004. Scenario Approaches – History, Differences, Advantages and Disadvantages. In EU-US Seminar: New Technology Foresight, Forecasting & Assessment Methods-Seville.

[33] Atkinson, R. D. and Stewart, L. A. 2013. Benefits of Information and Communications Technology. Information Technology & Innovation Foundation.

[34] Lee, K. R. Impacts of Information Technology on Society in the new Century.