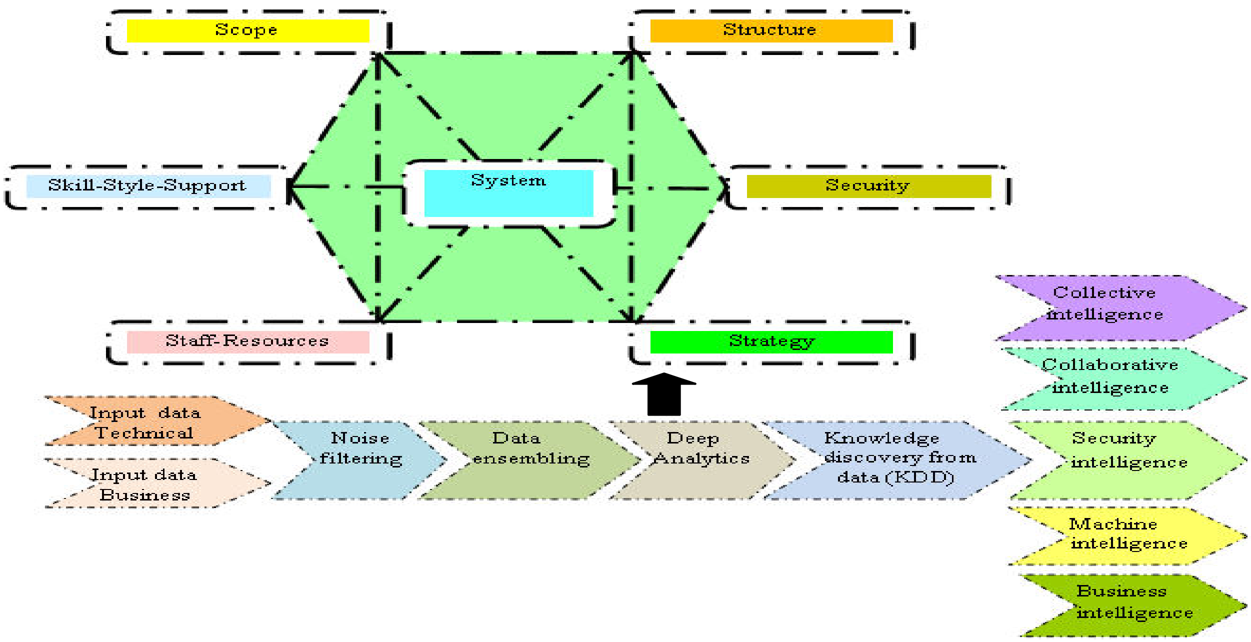
Business Analytics:

Technology for Humanity

3rd Edition, 2019

By

Sumit Chakraborty
Suryashis Chakraborty



Deep Analytics

Solar Power Electronics & Nanotechnology

Smart Electrical & Hybrid Vehicles, RailTech, DAS

Solar Computing : Self-healing Smart Grid

Information Security Intelligence Analytics: : Adative Security & DDP

Cancer : prediction & Prevention Deep Learning

Biomedical Instrumentation

Artificial Rainfall : Laser, Cloud Physics

Astronomical Hazards : Real-time Moving Target Search

Preface

Deep analytics does not only mean statistics or data mining or big data analytics, it is a complex multi-dimensional analysis through '7-S' model based on rational, logical and analytical reasoning from different perspectives such as scope, system, structure, staff-resources, skill-style-support, security and strategy. This book presents a deep analytics model through a consistent and systematic approach and highlights its utility and application for reasoning ten technology innovations today: (1) solar power electronics & Nanotechnology, (2) Electrical and hybrid vehicles : smart batteries , (3) RailTech: DAS, security & safety, (4) Emerging digital technology, (5) Solar computing : Self-healing mechanism for a smart grid, (6) Information Security Intelligence (ISI) Analytics : Adaptive security and dynamic data protection for IIOT, SCADA & ICS (7) Cancer prediction & prevention mechanism: deep learning, (8) Biomedical instrumentation, (9) Artificial rainfall & cloud physics and (10) Real-time moving target search for astronomical hazards.

The reality is that every stakeholder is impacted by the challenges and opportunities of innovation ecosystems today. The concept of deep analytics is still relatively new; it has now emerged as a powerful tool for business analytics and a real world theme in the modern global economy. The target audience of this book includes academic and research community, corporate leaders, policy makers, administrators and governments, entrepreneurs, investors, engineers, producers and directors interested in production of documentary films, news and TV serials. We are excited to share the ideas of deep analytics with you. We hope that you will find them really value adding and useful and will share with your communities. It is a rational and interesting option to teach deep analytics in various academic programmes of various Business Management programmes (e.g. Technology Management, Information Technology, Information Systems, Management Information Systems (MIS), Strategic Management and Analytics for BBA, MBA, PGDM, PGDBM) and also Electrical and Electronics Engineering (e.g. B.Tech, M.Tech, B.E.E., M.E., Ph.D.).

This e-book is the summary of electronic version of 3rd edition dated 15 August'2019; Price: $250 (per copy). This book contains information obtained from authentic sources; sincere efforts have been made to publish reliable data and information.

Thanks and regards.

Sumit Chakraborty, Fellow (IIM Calcutta), Bachelor of Electrical Engineering (JU)
Suryashis Chakraborty
Business Analytics Research Lab, India
15.08.2019

Content

CHAPTER 1 : DEEP ANALYTICS - TECHNOLOGY for HUMANITY

1. INTRODUCTION : DEEP ANALYTICS

Figure 1.1 : **Deep Analytics**

Deep analytics is an intelligent, complex, hybrid, multi-phased and multi-dimensional data analysis system. The basic steps of computation are data sourcing, data filtering / preprocessing, data ensembling, data analysis and knowledge discovery from data. The authorized data analysts select an optimal set of input variables, features and dimensions (e.g. scope, system, structure, security, strategy, staff-resources, skill-style-support) correctly being free from malicious attacks (e.g. false data injection, shilling); input data is sourced through authenticated channels accordingly. The sourced data is filtered, preprocessed (e.g. bagging, boosting, cross validation) and ensembled. It is rational to adopt an optimal mix of quantitative (e.g. regression, prediction, sequence, association, classification and clustering algorithms) and qualitative (e.g. case based reasoning, perception, process mapping, SWOT, CSF and value chain analysis) methods for multi-dimensional analysis. The analysts define intelligent training and testing strategies in terms of selection of correct soft computing tools, network architecture – no. of layers and nodes; training algorithm, learning rate, no. of training rounds, cross validation and stopping criteria;. The hidden knowledge is discovered from data in terms of collective, collaborative, machine, security and business intelligence. The analysts audit fairness and correctness of computation and also reliability, consistency, rationality, transparency and accountability of the analytics.

Deep analysis (e.g. in memory analytics) can process precisely targeted, complex and fast queries on large (e.g. petabytes and exabytes) data sets of real-time and near real-time systems. For example, deep learning is an advanced machine learning technique where artificial neural networks (e.g. CNN) can learn effectively from large amount of data like human brain learn from experience by performing a task repeatedly and gradually improves the outcome of learning. Deep analytics follows a systematic, streamlined and structured process that can extract, organize and analyze large amounts of data in a form being acceptable, useful and beneficial for an entity (e.g. individual human agent, organization or BI information system). It is basically a specific type of distributed computing across a number of server or nodes to speed up the analysis process. Generally, shallow analytics use the concept of means, standard deviation, variance, probability, proportions, pie charts, bar charts and tabs to analyze small data set. Deep analytics analyze large data sets based on the concepts of data visualization, descriptive and prescriptive statistics, predictive modeling, machine learning, multilevel modeling, data reduction, multivariate analysis, regression analysis, logistic regression analysis, text analysis and data wrangling. Deep analytics is often coupled with business intelligence applications which perform query based search on large data, analyze, extract information from data sets hosted on a complex and distributed architecture and convert that information into specialized data visualization outcome such as reports, charts and graphs. In this book, deep analytics has been applied for technology management system (TMS).

Technological innovations are practical implementation of creative novel ideas into new products or services or processes. Innovations may be initiated in many forms from various sources such as firms, academic institutions, research laboratories, government and private enterprises and individual agents. There are different types of innovations from the perspectives of scope, strength, weakness, opportunities, threats and demands from the producers, service providers, users, service consumers and regulators.

Innovation funnel is a critical issue in technology management; innovation process is often perceived like a funnel with many potential ideas passing through the wide end of a funnel but very few become successful, profitable, economically and technically feasible products or services through the development process [24]. Deep analytics is an intelligent method and consulting tool that is essential for effective management of top technological innovations today [Figure 1.1]. It is basically an integrated framework which is a perfect combination or fit of seven dimensions. Many technological innovation projects fail due to the inability of the project managers to recognize the importance of the fit and their tendency to concentrate only on a few of these factors and ignore the others. These seven factors must be integrated, coordinated and synchronized for the diffusion of top technological innovations globally [16,53].

Deep Analytics Mechanism [DAM]

****

Agents: Single or a group of data analysts;

System : Technology Management System /* Technology for humanity*/

Moves:

- Adopt a hybrid approach : quantitative ⊕ qualitative;
- Optional choices :
    - Collaborative analytics /* agents : multiple data analysts*/
    - Big data
    - Predictive modelling

Objectives: Evaluate an emerging technology for innovation, adoption and diffusion;

Constraints: Availability of authenticated and correct data, time, effort, cost;

Input: Technical data (D_t), Business data (D_b); /* Entity : An emerging technology for humanity*/

Procedure:

- Source data (D_t, D_b);
- Filter data;
- Ensemble data;

- Analyze data → select choice
  - Choice 1: qualitative analysis (Perception , Case based reasoning, SWOT, TLC);
  - Choice 2: quantitative analysis (Prediction, Simulation);
  - Choice 3 : Hybrid (quantitative ⊕ qualitative);
- Multi-dimensional analysis → KDD (S_1, S_2, S_3, S_4, S_5, S_6,S_7); /* S_1: Technology scope, S_2: System, S_3 : Structure, S_4: Technology security, S_5: Strategy, S_6: Staff-resources, S_7: Skill-style-support; KDD: Knowledge discovery from data */

Revelation principle:

- Define information disclosure policy → preserve privacy of strategic data.
- Verify authentication, authorization and correct identification in data sourcing.
- Audit fairness, correctness, reliability, consistency and rationality of analytic computation.

Payment function : Compare a set of technologies based on cost benefit analysis.
Output: Technology intelligence (collective, collaborative, security, machine, business);

****

Deep analytics is essential to understand the nature of a technological innovation and identify the gaps between as-is and to-be capabilities in a systematic and compelling way. It reasons seven dimensions under three major categories: (a) Requirements engineering schema: scope [S_1]; (b) Technology schema : system [S_2], structure [S_3], security [S_4] and (c) Technology management schema : strategy [S_5], staff-resources [S_6] and skill-style-support [S_7] [Figure 1.1]. This chapter analyzes each dimension briefly and reasons nine cases of top technology innovations today in chapters [2-10] applying the tool of deep analytics. The basic building blocks of our research methodology include critical reviews of existing works on technology management and case based reasoning. We have reviewed various works on technology management [1-33,53]. We have collected the data of nine cases from various technical papers and secondary sources. Chapter 11 concludes the work.

a. RESEARCH METHODOLOGY AND OPEN AGENDA

The basic objective of this book is to explore a set of fundamental questions on technology management:

- **Scope : What is technology swing? What is the scope of a technology innovation?**
- **System: What are the basic schema and dominant design of a system associated with a technology innovation?**
- **Structure: What are the basic elements of the system architecture associated with a technology innovation? How to represent the structure correctly and transparently through multi-dimensional simulated modeling such as digital twins?**
- **Security: What do you mean by technology_security? How to verify the security intelligence of a system associated with a technology innovation?**
- **Strategy:**
  - **What are the strategic moves of technology innovation, adoption and diffusion?**
  - **What is the outcome of technology life-cycle analysis?**
  - **How to compare an emerging technology with the existing old technologies through SWOT analysis?**
  - **What are the technology spillover effects?**
  - **What are the blind spots and critical success factors?**
- **Staff - resources: How to exercise ERP and SCM in a technology innovation project? What should be the talent management strategy?**
- **Skill-style-support:**
  - **What are the skills, leadership style and support demanded by a technological innovation? How to manage technology innovation projects efficiently through resource and time constrained, stochastic, adaptive multi-objective and multimode project scheduling algorithms?**
  - **What should be the shared vision, common goals and communication protocols?**

- **How to ensure a perfect fit among '7-S' elements?**
- **What type of organization structure is essential for various types of technology innovations?**

We have adopted two approaches to develop '7-S' model of deep analytics for technological innovation management. The first approach is learning-before-doing. We have reviewed relevant literature on technology management and have defined an initial framework of the deep analytics. We have reviewed on top emerging technologies today from the technical reports of Gartner, IEEE, MIT and other sources. We have observed that today, technology management demands a rational balanced approach for the benefits and sustainabilities of the humanity globally. There is too much focus on information and communication technology; but less focus on other critical domains such as biomedical and electrical engineering, nanotechnology, earth and space science.
Next, we have selected ten potential strategic technologies for humanity. which have significant impact on our society globally. The most of these technologies are at emergence phase of TLC; the others are passing through growth phase. As a part of learning-by-doing approach; we have analyzed these nine cases using '7-S' model and have backtracked to redefine the initial framework of deep analytics. We have found out several open research agendas: (a) Should We consider any additional elements for the proposed deep analytics which can streamline the evolution and diffusions of various technological innovations effectively? For instance the deep analytics may be 10-S model instead of 7-S in figure 1.1. (b) Is it practically manageable to consider too many elements simultaneously? Should we consider resources instead of staff – resources? Should we decompose sixth element into skill, style and support separately? Should we position the element 'system' centrally or 'strategy' in figure 1.1? (c) There are ${}^{7}C_{2}$ links (such as S1-S7, S2-S7,S3-S7,S4-S7, S5-S7, S6-S7....) among 7-S elements of the deep analytics; what are the implications of these links on complex technological innovations? There may be other various types of links considering ${}^{7}C_{3}$,${}^{7}C_{4}$,${}^{7}C_{5}$ and ${}^{7}C_{6}$ combinations (S1-S2-S3, S4-S5-S6-S7 ....). (d) How do these elements of deep analytics impact technological innovation in terms of technology trajectory, spillover, dominant design and organizational learning process? (e) How to foster creativity, problem solving capability, learning rate, generalizability, convergence and stopping criteria in organizational learning? What are the major constraints and barriers against nine cases of technological innovations? There are several open issues of debate on the concept of deep analytics. It is an interesting observation from this book that we are living in 21st century today; but we could not reach the point of saturation at present; extensive R&D efforts are still pending for the sustainability of human civilization in the coming future.

2. SCOPE

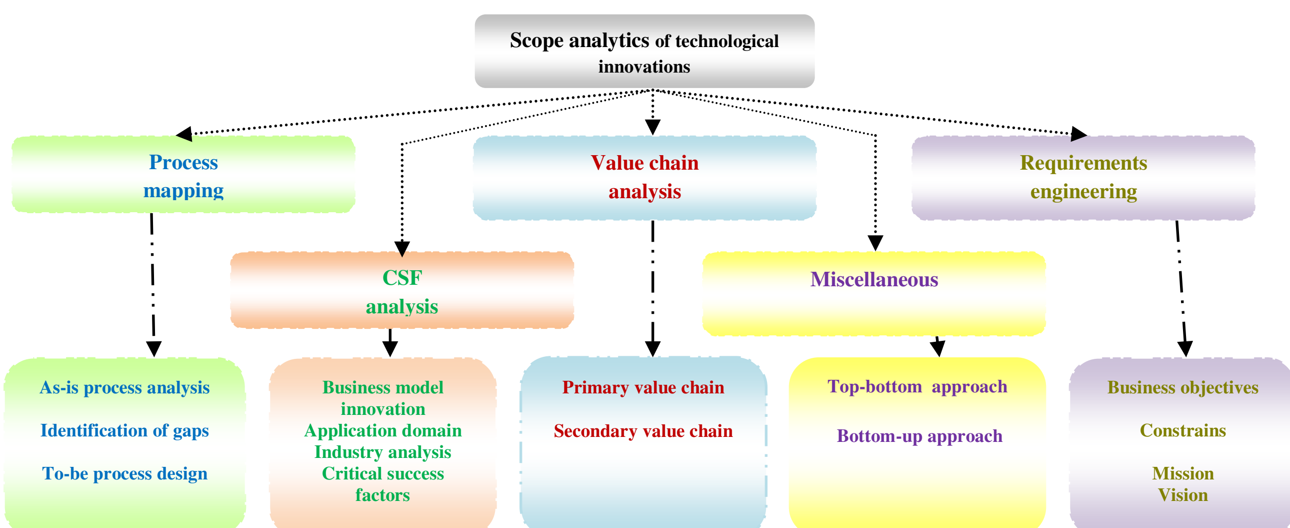


Figure 1.2 : Scope analytics

Technological innovation is basically associated with new product development and new process innovation, act and initiatives of launching new devices, methods or materials for commercial and practical applications. It is one of the most critical competitive drivers in many industries such as information and communication technologies, high technology manufacturing and life-science. Deep analytics explores miscellaneous issues of top technological innovations today such as dynamics of innovation, innovation strategy and implementation process; the impact of globalization of markets and advanced information and communication technologies, computer sided design, computer aided manufacturing, flexible manufacturing system, economic feasibility, economies of scale and short production run; technology life cycle, technology diffusion; social, environmental and economic effects, negative effects of technological changes; R&D fund allocation strategy; pace, advantages and disadvantages of innovation, critical success factors, causes of failure; cost optimization and differentiation. Technological innovations are essential to create new business models. But, many innovation projects fail to make profit due to various reasons such as scope creep or ill-defined scope analysis.

The first element of deep analytics is scope [Figure 1.2]. The scope of a technology innovation project should be explored through various scientific and systematic methods such as process mapping, critical success factors (CSF) analysis, value chain analysis, analysis of business objectives, constraints, mission and vision and top-down and bottom-up approaches. Process mapping analyzes a set of critical issues: what is as-is process? How to identify gaps of as-is process? How to innovate to-be process? What are the inputs, outputs, mechanism and constraint for each task associated with a business process? How to configure process flow diagram? The basic objective of CSF analysis is to identify a set of critical success factors through business model innovation, application domain and industry analysis.

The scope of a technology innovation project is explored based on CSFs. The basic objectives of value chain analysis is to find out a set of critical parameters: what is value; it may be product differentiation, cost leadership or improved quality of services? How to define value in a technology innovation? What are the activities associated with primary and secondary value chain? Primary activities add value to a product and service directly such as manufacturing and supply chain management; secondary value chain activities (e.g. HR, Maintenance) support primary value chain activities. Top bottom approach analyzes business plans and goals of a firm, defines the basic needs of a system and explores the scope of technology innovation projects. On the other side, bottom up approach analyze as–is system, identifies gaps and explores the basic needs or scope of a project.

The scope of a technological innovation should be explored through industry analysis and also external environment and various stakeholders associated with the value chain. In this connection, Porter's six force model is useful to assess the bargaining power of the customers and suppliers, role of compliments, threats of new entrants and substitutes and competition. The internal environment should be accessed through SWOT analysis, identification of core competencies and rigidities, dynamic capabilities, potential strength and opportunities of sustainable competitive advantages. The scope should be also explored in terms of strategic intent, vision, mission and goals from different perspectives such as process innovation, organization learning, financial performance and customer satisfaction.

The scope of technological innovations may be analyzed from the perspectives of product or process innovation, radical or incremental, architectural or component and competence enhancing or destroying innovation. Product innovations occur in the outputs of a firm as new products or services. Process innovations try to improve the efficiency of business or manufacturing process such as increase of yield or decrease of rejection rate. Component or modular innovation changes one or more components of a product. Architectural innovation changes the overall design of a system or the way the components of a system interact with each other. Radical innovation is new and different from prior solutions. Incremental innovation makes a slight change of existing product or process.

We have explored a set of innovative concepts such as technology for humanity, cancer genomics, separating chromosomes, DNA computing, large scale cheap solar electricity and photovoltaics technology, solid state batteries, synthetic cells, next generation predictive, collaborative and pervasive analytics, big data analytics, adaptive security and dynamic data protection, smart transformers, applied AI and machine learning, deep learning, assisted transportation, Internet of Things (IoT), cloud computing and cloud streaming, Internet of bodies, Blockchain and distributed ledger technology, homomorphic encryption, crash-proof code, social indexing, gestural interfaces, social credit algorithms, advanced smart material and devices, activity security protection, virtual reality, chatbots, automated voice spam prevention, serverless computing, edge computing, real-time ray tracing, digital twins, tablets and mobile devices in enterprise management, innovative mobile applications and interfaces for a multichannel future, human computer interface, context aware computing and social media, enterprise app stores and marketplaces, in-memory computing, extreme low energy servers and strategic global sourcing.

3. SYSTEM

The second element of deep analytics is system [Figure 1.3]. A system is a complex grouping of interrelated parts i.e. machines and agents; it can be decomposed into a set of interacting sub-systems. A system may have single or multiple objectives; it is designed to achieve overall objectives in the best possible way. It is possible to analyze a system from the perspectives of system state, complexity, model, environment, system dynamics, cause effect analysis, feedback loop, physical and information flows and policy decisions [35-41]**.** A system may be open or closed loop. A hard system has clearly defined objectives, decision making procedures and quantitative measures of performance. It is hard to define the objectives and qualitative measures of performance and make decisions for a soft system. The state of a system at a specific time is a set of relevant properties of the system. The complexity of a system can be analyzed in terms of number of interacting elements, number of linear and nonlinear dynamic relationships among the elements, number of goals or objectives and number of ways the system interacts with its environment. A model is an abstraction of real system. A model is isolated from its environment through model boundaries. A model may be static or dynamic, linear or non-linear based on functional relationship among various variables in a model.

Figure 1.3 : System analytics

A complex system can be analyzed from the perspectives of different branches of engineering and technology such as information and communication technology, electrical and electronics, mechanical, civil, chemical, metallurgical, biotechnology, genetic engineering, pharmacy and others. IT system can be analyzed in terms of computing, communication or networking, data, application and security schema and also application integration (EAI). An electrical system may have various subsystems such as power system, renewable energy, photonics, system control, power electronics, machines, measurement &

instrumentation, illumination and high voltage engineering. A complex system may be associated with various domains of earth science such as space science, water, wind and solar power.

The basic objectives of system analytics are to analyze complex, dynamic, non-linear and linear interactions in various types of systems and design new structures and policies to improve the behavior of a system. A system is associated with a problem oriented model; the basic building blocks of system dynamics are cause effects analysis, positive and negative feedback loops and physical and information flows. The basic functions of system analytics include defining a problem and model boundary, building model, testing and validation of a model, model analysis, evaluation of policy alternatives and recommendation of most viable R&D policy related to technological innovations [42].

4. STRUCTURE

The third element of deep analytics is structure i.e. the backbone of a system associated with a specific technological innovation [Figure 1.4]. What are the basic elements of the system architecture associated with a technology innovation? It has two critical viewpoints: system architecture and organization structure. The first one considers technological aspects of the system architecture in terms of topology, smart grid and various components of industrial control system such as SCADA, Expert system, DCS, PCS, SIS, BAS and EMS. The topology of a system should be analyzed in terms of nodes, connectivity, type of connections such as P2P or multipoint, layers, interfaces between layers and organization of layers.

For example, OSI model is a layered framework for the design of communication networks of information systems. It has seven layers from bottom to top : physical, data link, network, transport, session, presentation and application layers. A data communication system has five basic components such as message, sender, receiver, transmission medium and protocol. On the basis of nodes and links, the physical topology of a communication network can be classified into four categories such as mesh, ring, star and bus. The second viewpoint is organization structure – what type of structure is suitable for specific technological innovation; it may be functional, divisional, matrix or network structure. Is there any link between technology and organization structure? It depends on the characteristics of business model.

Another view of structure should be explored in terms of organization structure, size of a firm, economies of scale in R&D, access to complementary resources such as capital and market, governance mechanisms and organizational learning. There are various types of organization structure such as divisional and networked models. The efficiency and creativity of innovation model is closely associated with different types of structural dimensions such as formalization, standardization, centralization, decentralization and loosely coupled networks within and between firms. Global firms should consider several critical factors such as knowledge, resources and technological diffusion to conduct R&D activities.

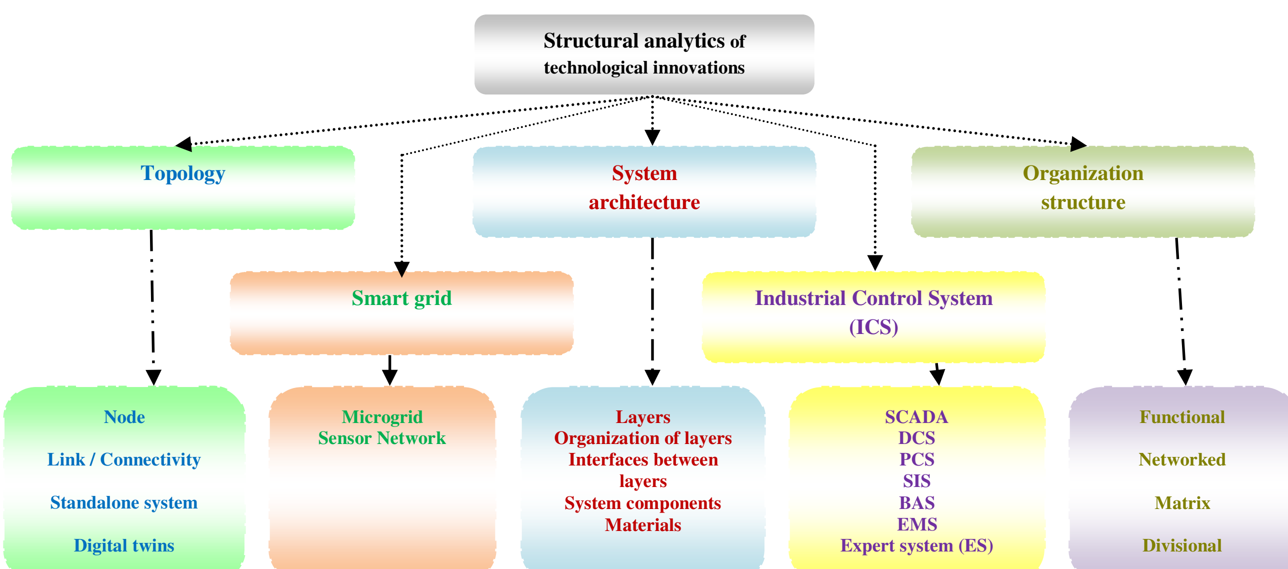


Figure 1.4: Structure analytics

How is it possible to represent the structure of a system associated with a technology innovation correctly and transparently? Digital twins may be an interesting solution; it integrates the concept of industrial IoT, AI, machine learning and software analytics to optimize the operation and maintenance of physical assets, systems and manufacturing processes. A digital twin is the digital replica of a living or non-living physical entity (e.g. physical asset, process, agent, place, system, device); it is expected to bridge and support data sharing between the physical and virtual entities. Digital twins can learn from multiple sources such as itself through sensors, historical time series data, experts and other nodes of the networking schema of the system and get updated continuously to represent real-time status, working conditions or positions.
The concept of digital twins are expected to be useful for manufacturing, energy (e.g. HVAC control systems), utilities, healthcare and automotive industries in terms of connectivity, digital traces and product life-cycle management. The concept can be used for 3D modeling to create digital companions of the physical objects i.e. an up-to-date and accurate copy of the properties and states of the objects (e.g. shape, position, gesture, status, motion) based on the data collected by the sensors attached to the system. It may be useful for the maintenance of power generation equipment such as turbines, jet engines and locomotives; monitoring, diagnostics and prognostics to optimize asset performance and utilization through root cause analysis and to overcome the challenges in system development, testing, verification and validation for automotive applications. The physical objects are virtualized and can be represented as digital twin models seamlessly and closely integrated in both physical and cyber spaces. Digital twins should represent the structure of a product innovation intelligently through various phases of the product life-cycle.
Another interesting technology for exploring innovative structure is **V-commerce** through virtual (VR), mixed (MR) and augmented reality (AR). A virtual entity may not exist physically but created by software in a digital environment. VR and AR are sophisticated, creative and powerful tools to show complex structures and offer a complete computerized digital experience by integrating AI, computer vision, graphics and automation in various applications such as manufacturing, retail, healthcare, entertainment, furniture and interior decoration.

5. SECURITY

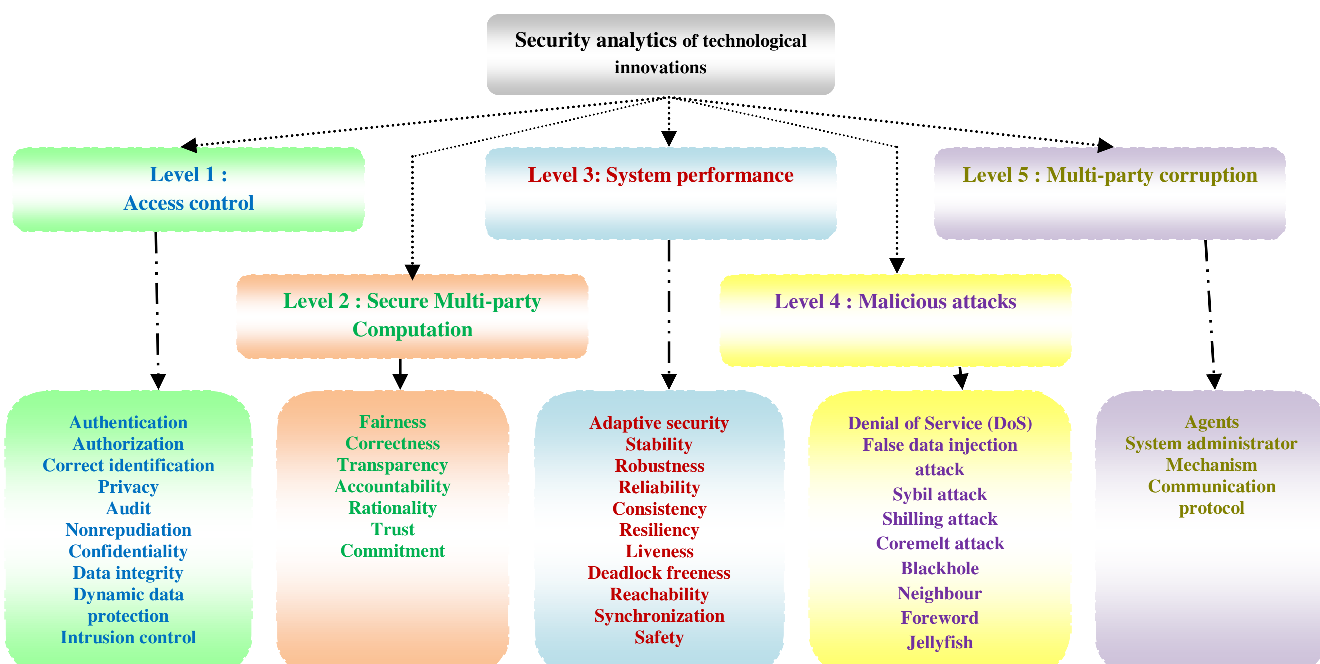


Figure 1.5 : Security analytics

The fourth element of deep analytics is security. **What do you mean by technology_ security?** A system may face various types of threats from both external and internal environments but it should be vigilant and protected through a set of security policies. An emerging technology demands the support of an adaptive security architecture so that the associated system can continuously assess and mitigate risks intelligently. Adaptive security is a critical feature of a technology that monitors the network or grid associated with a system in real time to detect any anomalies, vulnerabilities or malicious traffic congestion and. If a threat is detected, the technology should be able to mitigate the risks through a set of preventive, detective, retrospective and predictive capabilities and measures. Adaptive security analyzes the behaviors and events of a system to protect against and adapt to specific threats before the occurrence of known or unknown types of malicious attacks.

Let us explain the objectives of adaptive security architecture in depth. New threats are getting originated as an outcome of technology innovation and may cause new forms of disruptions with severe impact. Today, it is essential to deploy adaptive security architecture for the emerging technologies. The systems demand continuous monitoring and remediation; traditional 'prevent and detect' and incident response mindsets may be not sufficient to prevent a set of malicious attacks. It is required to assess as-is system administration strategies, investment and competencies; identify the gaps and deficiencies and adopt a continuous, contextual and coordinated approach.

How to verify the security intelligence of the system associated with an emerging technology? It is essential to verify security intelligence of a technological innovation collectively through rational threat analytics at five levels : L1, L2, L3, L4 and L5 (Figure 1.5).. The basic building blocks of the security element are an adversary model and an intelligent threat analytics. An adversary is a malicious agent who attacks a system or a protocol; the basic objectives are to cause disruption and malfunctioning of a secure system. The security element should be analyzed in terms of the assumptions, goals and capabilities of the adversary. It is also crucial to analyze the adversary model in terms of environment, location, network, resources, access privileges, equipments, devices, actions, results, risks, reasons and motivations of attacks and probable targets (i.e. why the adversary attacks and to obtain what data).

Let us consider the security of an information system innovation. At level L1, it is required to verify the efficiency of access control in terms of authentication, authorization, correct identification, privacy, audit, confidentiality, non-repudiation and data integrity. For any secure service, the system should ask the identity and authentication of one or more agents involved in a transaction. The agents of the same trust zone may skip authentication but it is essential for all sensitive communication across different trust boundaries.

After the identification and authentication, the system should address the issue of authorization. The system should be configured in such a way that an unauthorized agent cannot perform any task out of scope. The system should ask the credentials of the requester; validate the credentials and authorize the agents to perform a specific task as per agreed protocol. Each agent should be assigned an explicit set of access rights according to role. Privacy is another important issue; an agent can view only the information according to authorized access rights. A protocol preserves privacy if no agent learns anything more than its output; the only information that should be disclosed about other agent's inputs is what can be derived from the output itself. The agents must commit the confidentiality of data exchange associated with private communication.

Privacy is the primary concern of the revelation principle of an information system; the issue of secure private communication can be addressed through the concept of cryptography, digital signature, signcryption and secure multiparty computation. The fundamental objectives of cryptography are to provide confidentiality, data integrity, authentication and non-repudiation. Cryptography ensures privacy and secrecy of information through encryption methods. Data integrity ensures that data is protected from unauthorized modifications or false data injection attack. The system should provide public verifiability so that anyone can verify the integrity of the data. Redundancy of data is a critical issue which is resulted through replication across the writers.

Traditionally, cryptographic solutions are focused to ensure information security and privacy. But there are other different types of security concerns. At level L2, it is required to verify the efficiency of secure multiparty computation associated with a technological innovation in terms of fairness, robustness, correctness, transparency, accountability, trust and commitment. A protocol ensures correctness if the sending agent broadcasts correct data and each recipient receives the same correct data in time without any change and modification done by any malicious agent. Fairness is associated with the commitment, honesty and rational reasoning on payment function, trust and quality of service. Fairness ensures that something will or will not occur infinitely often under certain conditions. The recipients expect fairness in private communication according to their demand plan, objectives and constraints. The sending agent expects fairness from the recipients in terms of true feedback and commitment on confidentiality of data. As per traditional definition of fairness of secure multi-party computation, either all parties learn the output or none. The system must ensure the accountability and responsibility of the agents in access control, data integrity and non-repudiation. In fact, accountability is also associated with collective intelligence. Transparency is associated with communication protocols, revelation principle and automated system verification procedures. For example, a mechanism should clearly state its goal to define a policy. There exist an inherent tension between transparency and privacy. A fully transparent system allows anyone to view any data without any provision of privacy. On the other side, a fully private system provides no transparency. Privacy can be achieved using cryptographic techniques at increased cost of computation and communication. Is it possible to trade-off privacy vs. transparency? Is it possible to provide public verifiability of its overall state without disclosing information about the state of each entity? Public Verifiability allows anyone to verify the correctness of the state of the system.

Next, it is required to verify the system performance at level L3 in terms of stability, robustness, reliability, consistency, resiliency, liveness, deadlock freeness, reachability, synchronization and safety. The performance of a system and quality of service is expected to be consistent and reliable. Reachability ensures that some particular state or situation can be reached. Safety indicates that under certain conditions, an event never occurs. Safety is a critical requirement of any system whether it may be mechanical, electrical, electronics, information technology, civil, chemical, metallurgical or instrumentation engineering. Liveness ensures that under certain conditions an event will ultimately occur. Deadlock freeness indicates that a system can never be in a state in which no progress is possible; this indicates the correctness of a real-time dynamic system. Another important issue is robustness of a system. The delivery of the output should be guaranteed and the adversary should not be able to threaten a denial of service attack against a protocol.

At level L4, it is required to assess the risks of various types of malicious attacks by adversaries on a system such as Denial of Service (DoS), false data injection attack, sybil attack, shilling attack, coremelt attack (or network traffic congestion), blackhole, neighbor, node deletion, rushing and jellyfish attacks. At level L5, it is required to assess the risks of various types of corruptions such as agents (e.g. sending agent, receiving agents), system administrator, communication protocol and payment function of a mechanism associated with a technological innovation.

For example, prevention and detection are traditional approaches to the security of a system. In today's world of expanding threats and risks, real-time system monitoring is essential to predict new threats and automate routine responses and practices. The system should not only rely on traditional prevent-and-detect perimeter defense strategies and rule based security but should adopt cloud based solutions and open application programming interfaces also. Advanced analytics is the basic building block of next generation security protection which should be to manage an enormous volume, velocity and variety of data through AI and machine learning techniques. Intelligent analytics are expected to detect anomalous patterns by comparing with the normal profile and the activities of the users, peer groups and other entities such as devices, applications and smart networks and trigger alarms by sensing single or multiple attacks on the system. The security element must overcome the barriers among security, application development and operations teams and be integrated deeply into system architecture.

Next, it is essential to develop effective ways to move towards adaptive security architecture. The mechanism should surfaces anomalies and adjusts individualized security controls proactively in near real-time to protect the critical data of a system. Adaptive Security with dynamic data protection is expected to offer many benefits over traditional security platforms depending on the size of the system and complexity of networking schema – real time monitoring of events, users and network traffic; autonomous and dynamic resolutions; prioritization and filtering of security breaches; reduction of attack surface and impact or damage of a threat and reduction of resolution time. The emerging technology is expected to adapt to the needs of a system irrespective of the size of network, nature of operation or exposure of threats. It can assess the requirements of security with greater accuracy through a set of intelligent policies and procedures and can ensure better understanding of strength, weakness, opportunities and threats of the security architecture.

6. STRATEGY

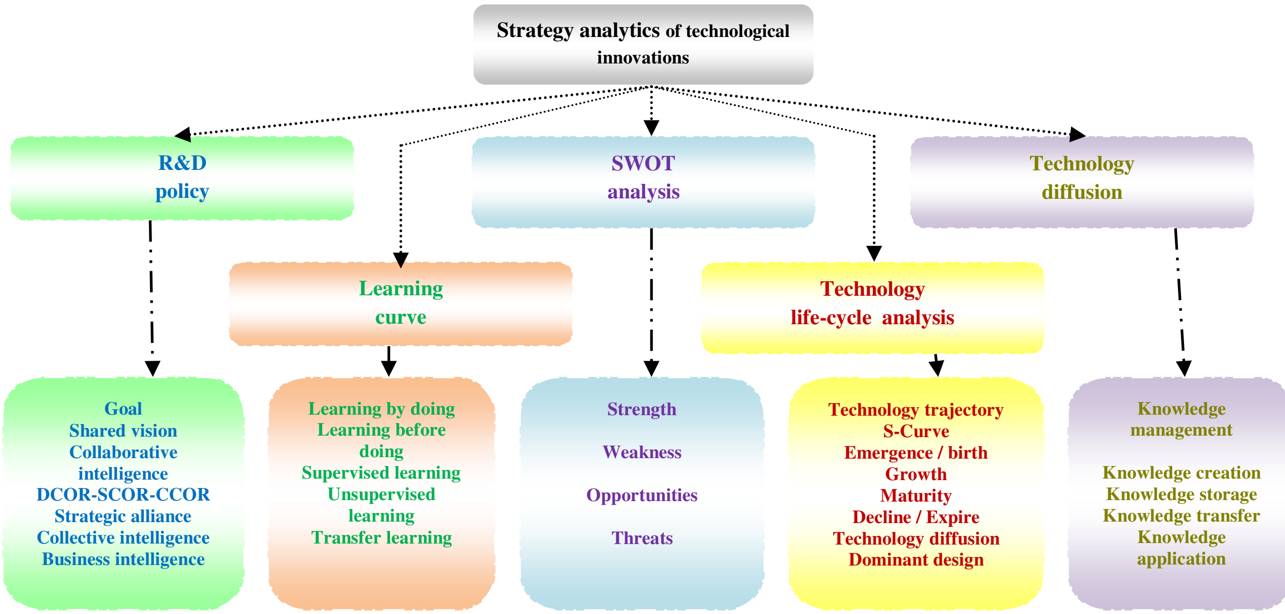


Figure 1.6: Strategy analytics

The fifth element of deep analytics is strategy [Figure 1.6]. This element can be analyzed from different dimensions such as R&D policy, learning curve, SWOT analysis, technology life-cycle analysis and knowledge management strategy. An intelligent R&D policy should be defined in terms of shared vision, goal, strategic alliance, collaborative, collective and business intelligence. Top technological innovations are closely associated with various strategies of organization learning and knowledge management, more specifically creation, storage, transfer and intelligent application of knowledge. It is essential to analyze strength, weakness, opportunities, threats, technological trajectories, technology diffusion and dominant design of top innovations today. Diffusion is the movement of molecules from high density zone to low density zone of a solution. Can an emerging technology diffuse in the same way globally? What is the pressure acting on technology diffusion? Is the external pressure natural or artificial? Another analogy is osmosis where the molecules move from low density zone to high density zone through a barrier? Can the emerging technology spread and move from low to high density zone smoothly like osmosis or reverse osmosis?

Technological innovation is closely associated with R&D policy and organizational learning strategies in new product development and process innovation. There are various strategies of learning such as learning-by-doing and learning-before-doing [6,7]. Learning by doing is effective in semi-conductor manufacturing and bio-technology sectors which demand low level of theoretical and practical knowledge. On the other side, learning-before-doing is possible through various methods such as prototype testing, computer simulations, pilot production run and laboratory experiments. It is effective in chemical and metallurgical engineering where deep practical and theoretical knowledge can be achieved through laboratory experiments that model future commercial production experience.

Let us explore the role of deep analytics on technological innovation. It is interesting to analyze the impact of different learning strategies and timing of technology transfer on product development performance, process re-engineering and R&D cost of top technological innovations. It is important to compare the effectiveness of various types of learning strategies in terms of cost, quality and time. It is also critical to analyze the relationship between process innovation and learning curve in terms of dynamic cost reduction and improvements in yield. In case of learning-by-doing, it is possible to acquire knowledge of new process development in specific production environment. But, some knowledge may be lost when a new process is transferred to commercial production environment. It is also interesting to analyze the impact of dedicated process development facilities, geographic proximity between R&D lab and production plant and the duplication of equipment between development and production facilities on practical implementation, speed and effectiveness of top technological innovations. It is essential to identify the critical success factors (e.g. resource allocation, ERP and SCM strategies) that influence the rate of learning and superior performance.

6.1 SWOT Analysis

Strength (High efficiency)	**Opportunities (Growth, Profit)**
Weakness (High Cost)	**Threats (Environmental pollution)**

Figure 1.7 : SWOT Analysis

It is rational to evaluate strength, weakness, opportunities and threats of a technological innovation [Figure 1.7]. There may be major and minor strengths and weaknesses. Strength indicates positive aspects, benefits and advantages of a strategic option. Weakness indicates negative aspects, limitations and disadvantages of that option. Opportunities indicate the areas of growth of market and industries from the perspective of profit. Threats are the risks or challenges posed by an unfavorable trend causing deterioration of profit or revenue and losses.

6.2 Technological life-cycle analysis

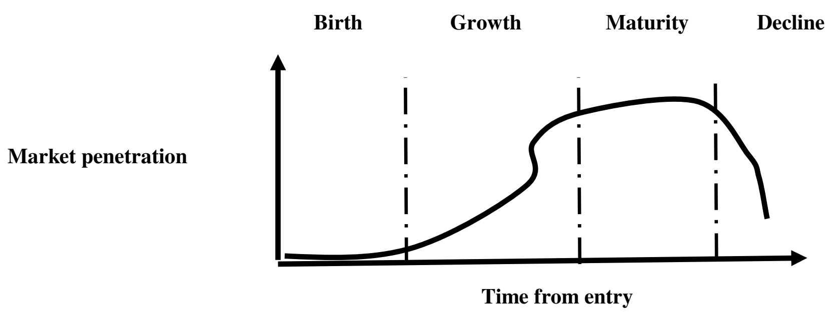


Figure 1.8 : Technology life–cycle analysis

Deep analytics evaluate and explores top technological innovations in terms of technology life-cycle, technology trajectory, S-curve, technology diffusion and dominant design. No element in this universe exists eternally. Similarly, each technology emerges, grows to some level of maturity and then declines and eventually expires [16, Figure 1.8]. It is essential to evaluate the status of each technological innovation through TLC analysis. Some technologies may have relatively long technology life-cycle; others never reach a maturity stage. Emergence of new technologies follows a complex nonlinear process. It is hard to understand how the technology life-cycle interacts with other technologies, systems, cultures, enterprise activities and impacts on society. All technologies evolve from their parents at birth or emergence phase; they interact with each other to form complex technological ecologies. The parents add their technological DNA which interacts to form the new development. A new technological development must be nurtured; many technologies perish before they are embedded in their environments. Next phase is growth; if a technology survives its early phases, it adapts and forwards to its intended environment with the emergence of competitors. This is a question of struggle for existence and survival for the fittest. Next phase is a stable maturity state with a set of incremental changes. At some point, all technologies reach a point of unstable maturity i.e. a strategic inflection point. The final stage is decline and phase out or expire; all technologies eventually decline and are phased out or expire at a substantial cost. TLC may have other different types of phases such as acquisition, utilization, and phase-out and disposal; preparation or initiation, implementation and operation; organization, directive, delegation, coordinate, collaborative, and dissolution; acquisition; emergence, diffusion, development, and maturity.

Let us consider the analysis of the performance of a new technology vs. effort; it is basically an S-curve. Initially, it is difficult and costly to improve the performance of a new technology. The performance begins to improve with better understanding of the fundamental principles and system architecture. Finally, the technology approaches its inherent limits with diminishing returns. Next, let us analyze the adoption of a new technology over time which is also an S curve. Initially, a new technology is costly for the adopters due to various uncertainties and risks. Gradually, this new technology is adopted by large segments of the market due to reduced cost and risks. Gradually, the diffusion of new technology slows with the saturation of market or due to the threats imposed by other new technologies.

The rate of improvement of a new technology is often faster than the rate of market demand over time; the market share increases with high performance. Technological change follows a cyclical pattern. The evolution of a technology passes through a phase of turbulence and uncertainty; various stakeholders of a supply chain explore different competing design options of the new technology and a dominant design emerges alongwih a consensus and convergence of structure. Then, the producers try to improve the efficiency and design of products based on stable benchmark of the industry. The dominant design considers an optimal set of most advanced technological features which meet the demand of the customer, supply and design chain in the best possible way.

Technology trajectory is the path that a technology takes through its time and life-cycle from the perspectives of rate of performance improvement, rate of diffusion or rate of adoption in the market. It is really interesting to analyze the impact of various factors and patterns of technology trajectories of top innovations today. How to manage evolution of technological innovation? The nature of innovation shifts markedly after a dominant design emerges. The pace of performance improvement utilizing a particular technological approach is expected to follow an S-curve pattern. The evolution of innovation is determined by intersecting trajectories of performance demanded in the market vs. performance supplied by technologies. Technology diffusion indicates how new technologies spread through a population of potential adopters. It is controlled by characteristics of innovation, characteristics of social environment and characteristics of the adopters such as innovators, early adopters, early majority, late majority and laggards.

7. STAFF-RESOURCES

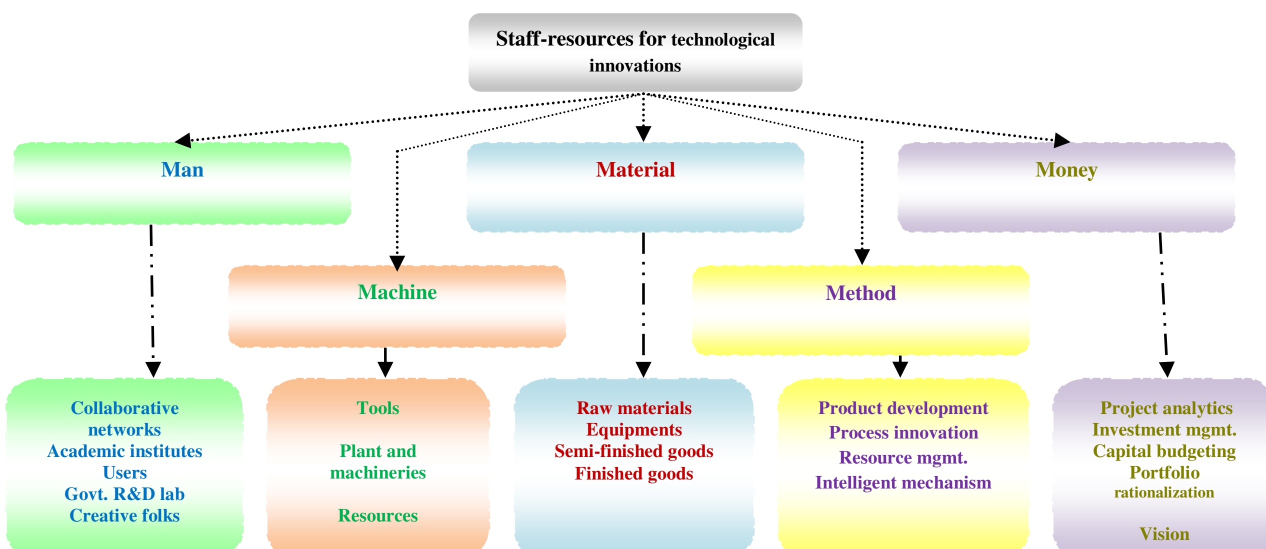


Figure 1.9 : Staff-resources analytics

Figure 1.9 outlines the sixth element of deep analytics i.e. staff-resources in terms of 5M – man, machine, material, method and money [23,54]. ‘Man’ analyzes various aspects of human capital management of technological innovations such as talent acquisition and retention strategy, training, payment function, compensation, reward, incentive and performance evaluation. ‘Machine’ analyzes the basic aspects of tools and automated / semi-automated / manual machines; ‘material’ analyzes planning of raw materials, equipments, semi-finished and finished goods. 'Method' explores various aspects of process innovation, intelligent mechanism and procedure. Finally, 'money' highlights optimal fund allocation for R&D, rational investment analytics, intelligent project analytics and portfolio rationalization.

It is crucial to analyze dynamics of technological innovation in terms of sources of innovation and roles of individuals, firms, organizations, government and collaborative networks; various resources required for effective technological evolution and diffusion such as 5M i.e. man, machine, material, method and money; dominant design factors, effects of timing and mode of entry. Innovation demands the commitment of creative people. Creativity is the underlying process for technological innovation which promotes new ideas through intellectual abilities, thinking style, knowledge, personality, motivation, commitment and interaction with environment.

Individual inventors may contribute through their inventive and entrepreneurial traits, skills and knowledge in multiple domains and highly curious argumentative mindset. Some users or customers or clients or private nonprofit organizations may innovate new products or services based on their own needs. Many firms set up excellent R&D lab and also collaborative networks with customers, suppliers, academic institutes, competitors, government laboratories and nonprofit organizations. Many universities define sound research mission and vision and contribute through publication of research papers. Government also plays an active role in R&D either directly or indirectly or through collaboration networks and start-ups (e.g. science parks and incubators).

A complex technological innovation often needs collaborative intelligence to manage the gap between demand and supply of a specific set of capabilities, skills and resources [29]. It is possible to control cost, speed and competencies of technological innovations through efficient sharing mechanisms. It is rational to share the cost and risks of new innovations through creation, storage, transfer and application of knowledge among the partners of the innovation ecosystem. There are different modes of collaboration such as strategic alliance, joint ventures, technology licensing, outsourcing and collective research organizations. Collaborative networks are other sources of innovation. Collaboration is facilitated by geographical proximity, regional technology clusters and technology spillovers. Technological spillover results from the spread of knowledge across organizational or regional boundaries; it occurs when the benefits from R&D activities of a firm spill over to other firms [34]. But, it may be hard to control the development of product and process innovation protecting IP of proprietary technologies. The critical success factors of collaborative networks may be the right selection of innovation partners having strategic and resource fit, transparent and flexible monitoring and governance process so that the innovation partners understand their rights and obligations. .

Technological innovation demands the motivation and commitment of creative people. For example, the evolution of electronics and communication technology has been possible because of the involvement of the creative and efficient engineers and scientists in related domains. Most of top technology innovations are not trivial problems; need useful and novel support of creative, skilled, experienced and knowledgeable talent. Creative talent can look at the problems in unconventional ways; can generate new ideas and articulate shared vision through their intellectual abilities, knowledge, novel thinking style, personality, motivation, confidence, commitment and group dynamics. The impact of knowledge on creativity is double-edged. Lack of knowledge is a major constraint to the original contribution in a technological innovation. But, extensive knowledge may be biased and trapped in existing logic and paradigms. It is difficult to conclude that moderate knowledge is adequate for creativity. A creative person is expected to have confidence in own capabilities, tolerance for ambiguity, interest in solving problems and willingness to overcome obstacles by taking reasonable risks. A cooperative and collaborative environment must recognize and reward creative talent in time. Organizational creativity is associated with several critical factors such as human capital management, talent acquisition and retention policy, complex and tacit knowledge management strategy, organization structure, corporate culture, routines, performance evaluation, compensation, reward and incentive policy, social processes and contextual factors.

7.1 Resource Allocation Analytics

When the capacity of a firm is more than the total demand of a set of technological innovation projects, the resource manager may like to allocate the required resources such as fund or capital to each project using suitable resource allocation model. However, when the capacity is less than total demand, the resource manager would have to find the combination of projects, which would fit the resource allocation model and