Technology Management Practices of CTOs in Emerging Economy India

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Abstract—Emerging economies have mostly been dependent on developed economies for advanced technology and industry practices. In India, a developing country, many initiatives are taken to catch up with fast pacing technological development. Industries respond with development of new C-level positions of technology leaders like CTO, CIO and CDO amongst others, each focusing on their practices in technology management domain. In the era of the fourth industrial revolution, technology leaders are attempting to enhance efficiency and cater to business opportunities of the vast market of India.

We observe that the change in role of the CTOs using the NLP-based technique to understand the gap between academician's knowledge and practitioner's view. The findings suggest that role of technology leaders is evolving and gaining importance in the top management team. It is also found that technology management practices vary as per the need of organizations.

I. INTRODUCTION

Emerging economies have mostly been dependent on developed economies for advanced technology and leading industry practices. Developed nations have constantly been selling or transferring technologies to developing nations like India in different sectors like defense, railways, hardware, telecom and automotive. In India, initiatives like the current government's international marketing strategy "Make in India" [1] are a call to action to business leaders and have invited potential partners and stakeholders around the world. Such initiative underpins on layers of collaborative efforts. Even much before this initiative, Indian government liberalized its economy in 1991 seeking reforms against the severe balance of payment crisis [2]. Such initiatives have driven market forces and private players to get involved in businesses and connect with international players.

Technology being one of the key drivers for economic growth and characterized as changing at increasing speed, industry is responding with the set of next practices in technology management domain. Technology leaders or Chief Technology Officers (CTOs - Head of technology management practices in an organization) attempt to cater business opportunities to create value for all stakeholders. One such previous study examines the impact of technology and innovation on organizations especially SMEs [3]. To understand the impact of technology and innovation across all types of organization we try to explore the focus and scope of their CTOs.

In our ongoing research, we observe that the evolution of the role of CTO by looking at their profiles to understand the gap between academician's knowledge and practitioner's view.

This gap is quantified and the appropriate mechanism is suggested to fill it. The primary intention of this research paper is to systemically identify and discuss the nature of the changing role of CTOs by drawing particular attention to the trends, typical characteristics, and complexities associated with their role. The study is important as there is a paucity of literature in emerging economy context and NLP-based technique on web-based text data. This paper has six sections. Next section presents a literature review on emerging economies, technology management practices and CTOs. Section 3 is the research methodology chosen for the study. Section 4 describes data collection and analysis. The final section discusses the findings and future research direction.

II. LITERATURE REVIEW

A. Emerging economies in Interconnected World

The interconnected world, which can be assumed as a cluster of virtually connected entities, requires strategic networking or collaboration among entities for co-creation of values by utilizing network resources and dynamic capabilities. This helps achieve economies of specialization and knowledge spillovers which result in higher efficiency, productivity and innovative activities [4]. Emerging economies like India and China are pushing towards developing indigenous technologies and keeping pace with developed countries. Emerging economies have drawn the attention of many authors. Chan & Daim [5] reviewed the technology transfer issue in china from technology management literature to suggest policy implications. Similarly, they discuss India's foresight program and its strong emphasis in catching up with the developed world through economic development [6].

B. Technology Management Practices

Effective technology management requires the integration of technical, marketing, human resource and financial functions. In addition, it is essential for strategic and operational processes to be integrated [7]. Cetindamar et al. have categorized various technology management activities under 11 groups. They are technology utilization, knowledge management, technology acquisition, R&D management, technology integration, technology protection (license/patent purchasing), technology transfer, technology planning & forecasting, technology strategy, technology assessment, and technology commercialization & marketing [8]. They have emphasized the need to understand technology management as a dynamic capability to capture and create value from continuously changing nature of environmental opportunity [9].

C. CTO – dynamic leader for value creation

CTO being head of technology management practices [10] in an organization is increasingly accepted position in most of the technology-driven organizations. Understanding the evolving role of CTO gives the proxy to understand Technology Management practices.

In academic literature, there are very few studies related to CTO. A quick search with keyword "Chief Technology officer" leads us to around 40 articles. Figure 1 shows year wise publications of academic articles related to CTO. The literature on CTO is available since 1988. The major themes emerging out from the literature on CTO are CTO's role and responsibility, corporate structures, technology management, credibility, strategic technology planning, technology transition points and leveraging technology. Reflecting on the literature on CTOs it is found that "Companies began adding Chief Technology Officers (CTO) to the executive ranks in the 1980s because technology decisions were becoming an integral part of many strategic decisions and future plans". A CTO is a top executive who provides business decisions involving technology. The CTO position called for a technologist or scientist who could translate technological capabilities into strategic business decisions [11].

In recent time, the CTO position has become significant at the executive tables of corporations around the world. From tech-centric startups to the U.S. government (which appointed its first CTO in 2009), more organizations are finding that the position is integral to organizational success [12].
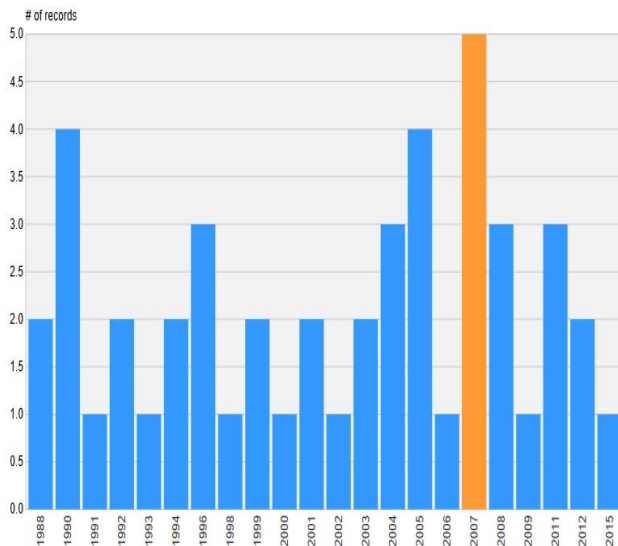

Fig. 1.   year wise publications of academic articles on CTO

Medcof has suggested following classification (in table 1) of Mintzberg's ten management roles for CEO or sub-CEOs as internally oriented (leader, disseminator, resource allocator) and externally oriented (figurehead, monitor, liaison, spokesperson, entrepreneur, disturbance handler, negotiator). Externally oriented roles are also called expeditionary roles which deal with interaction with outside people [13] and such roles prevalent among technology leaders today's sixth

generation of R&D management. CTO falls under a sub-CEO or senior management position in an organization [14].

TABLE I.   CLASSIFICATION OF MANAGEMENT ROLES AND RELATED RESPONSIBILITIES

Internally Oriented Roles	Externally Oriented Roles
Leader: Is responsible for the motivation and activation of subordinates, and for staffing.	**Figurehead:** As symbolic head of the organization performs a number of routine duties of a legal or social nature.
Disseminator: Transmits information from outsiders or from subordinates to members of the organization; some information factual, some involving interpretation and integration of diverse value propositions of organizational influencers	**Monitor:** Seeks and receives a wide variety of special information (much of it current) to develop a thorough understanding of organization and environment. Emerges as a nerve center of internal and external information of the organization
	Liaison: Maintains a self-developed network of outside contacts and informants who provide favors and information
Resource Allocator: Responsible for the allocation of organizational resources of all kinds, making or approving all major decisions	**Spokesperson:** Transmits information to outsiders on organizational plans, policies, actions, results, etc.; serves as an expert on the organization's industry
	Entrepreneur: Searches the organization and its environment for opportunities and initiates "improvement projects" to bring about change; supervises design of certain projects as well
	Disturbance Handler: Responsible for corrective action when organization faces important, unexpected disturbances
	Negotiator: Responsible for representing the organization at major negotiations

Following Uttal et al. [15] Medcof has identified three different types of leadership roles of CTO and mapped respective responsibilities [16] [17]: Functional (managing daily activities of subordinates), Strategic (aligning department's strategy aligned with organizational strategy) and Supra-functional (helps in building sustainable competitive advantage as part of the top management strategic planning team and as a leader of the innovation process). The supra-functional role is for leaders who have innumerable tasks to perform and is for CEO and sub-CEO employees. CTO in this role ensures that technology is kept into consideration in taking all kinds of strategic decisions in the organization. Hence, CTO plays a role in developing an organizational strategy.

Hart [18], CTO in a technology company, shared his experience on evolving role of CTO. He claims that the role of CTO has grown to become more of a true C-level executive and CTO must value shareholder value while making technological decisions and use of IT to gain strategic advantage for the company. Furthermore, he suggested that the role will continue to evolve as the line between external and internal technology continues to blur. Also, CTO's role is to champion innovative ideas and ensure employees become innovators.

The role of CTO depends on where his/her organization is operating, what market structure exists and what position his/her organization seeks to achieve. As CTO's role is evolving and being more dynamic to cater environmental changes, he/she can contribute in a better way [19]. Hoven et

al. have identified dynamic leadership role of CTO varying as per anticipated and/or unanticipated changes [20].

III. METHODOLOGY

In order to assess the body of literature on technology strategy, CTO and dynamic capabilities, an information search was made on popular databases (e.g. Google Scholar, web of science, Research Gate, Academic.edu, Knimbus, Scopus, PubMed, EBSCO, Proquest, Emerald-insight, Science-direct etc.) together covering the majority of the literature in management of technology domain. The objective of the study is to capture various aspects of CTO literature.

The keywords (or, a combination of keywords) used for the search were CTO, Chief technology officer, definitions, process, theories, underlying mechanisms and intervening factors. As per the objective of our study, all the published studies specifically dealing with CTO from the period 1988 to 2016 were selected. In general, we covered important studies role of CTO to grab an understanding of the phenomena and to find out the lacunas in the extant literature.

Natural language processing (NLP) is a computer-based technique to analyze data comprehensible to humans. NLP is used to extract phrases and from profiles of CTO. For this purpose VantagePoint's NLP algorithm is used. This process is a form of content analysis that has roots in the pre-electronic information processing era but has blossomed with the availability of electronic datasets and analytical software. One examines patterns in term usage to infer emphases in given domains. The process is also termed as KDD (Knowledge Discovery in Databases) [21]. It's combination of established and relatively new bibliometrics and text mining techniques. Using this concept, Porter & Zhang has proposed a framework for extracting intelligence from a set of text documents [22].

We processed the data in following way: firstly we did Fuzzy matching to select similar words with respect to name of organization, persons, British and American spellings etc. Secondly we did term (phrase/keyword) cleanup/removal of noise by basic clean up macros (removal of stop words, punctuation terms etc.). Thirdly we did term consolidation by manual grouping, stemming and PCA (principal component analysis). The inductive process allows data speak without predetermined identification of target terms or information. Instead, we used a purposive process that focuses on particular terms based on external criteria to search the target text fields for the occurrence of theory-guided terms and adjacent content. Finally, we requested experts for further validation.

IV. DATA & ANALYSIS

We considered using text data from LinkedIn profiles of CTOs for the required analysis. The LinkedIn profile is a source of data that provides almost complete information about CTO's role, responsibilities, authorities, background, all of which has been written, shared and updated by the same individual. LinkedIn, a secondary source of data is a professional social networking website. From LinkedIn profiles, only that portion of details is extracted which mention about the duration of the CTO. This type of data collection

from online sources is much in use for understanding the changing nature of consumers' needs, insights, perceptions, and thoughts of individuals etc. Capturing data from such online sources saves time and provides a bigger reach of the sample under study. This kind of studies is usually termed as Netnography or online or virtual ethnography. The choice of selecting this method of data collection depends on the availability of respondents on the online platform and their views, thoughts or descriptions related to research questions. To triangulate the findings of the present study subsequent stage is to conduct an in-depth interview of CTOs to collect primary data and this is ongoing.

The sample size of profiles is 101 which is more than previous studies related to CTO [23]. Out of 101 profiles, 79 are found useful for the analysis.

TABLE II.   DESCRIPTIVE ANALYSIS OF PROFILES

Attribute	Classes	Count
Size of organization	<100	15
	100-2000	35
	2000 & above	50
Location (country)	India only	78
Type of organization	Technology driven	101
Industry	Telecom	40
	Automotive	20
	IT & services	40

We divided the CTO profiles into 3 groups based on year of becoming CTO: 1988-1997, 1998-2007 and 2008-2015 to understand if there is any shift in CTO's work profile.

TABLE III.   FREQUENCY OF PROFILES IN EACH GROUP

Group of profiles	Number of selected LinkedIn profiles
1988-1997	4
1998-2007	21
2008-2015	54

NLP steps are used to process content from LinkedIn profiles for group 1998-2007 and 2008-2015. Group 1988-1997 is left out as only 4 profiles are available in this category.

TABLE IV.   PROCESSING OF LINKEDIN CTO PROFILES FROM 1998 TO 2007

SN	Steps of term clumping	Count
1	Total number of NLP phrases	612
2	Total number of phrases after clean up by various thesauri and fuzzy routines	404
3	Total number of phrases after manual clean up	219
4	Total number of phrases considered as "CTO Role"	30

We have found 30 phrases related to CTO's role in the content of 21 CTO LinkedIn profiles for group 1998-2007. The Aduna cluster map in figure 2 shows interlinkages among them based on their co-occurrence of phrases in LinkedIn profiles. For instance nodes like the phrase, project manager appears in twice: once along with the executive team and again alone. Similarly, other high frequencies (of two) are director operations, visionary technology executive, and responsible technology manager. Rest of the phrases appear just once. However, this gives limited insights due to limited sample size used for analysis and more can be interpreted by closely looking at phrases. We have found that we can further cluster these phrases of fig. 2 into three different types of leadership role (functional, strategic and supra-functional) and interpret them for our purpose.
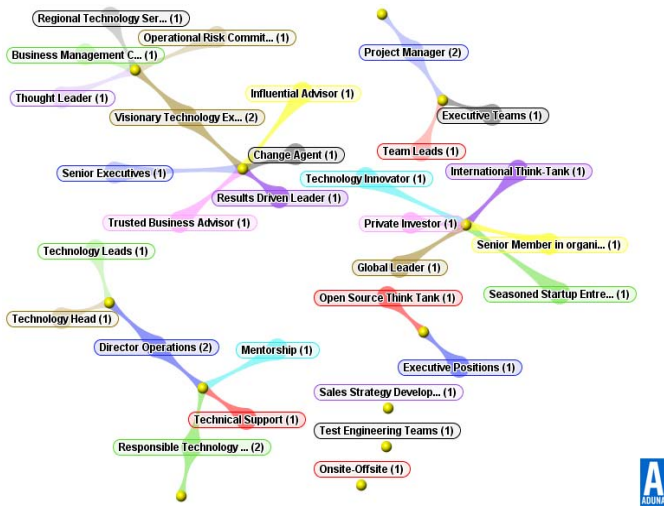

Fig. 2.   Aduna map showing 30 roles of CTO LinkedIn profiles from 1998 to 2007

From fig.2 we have found support for

1. CTO playing functional role of project manager, technology leader, technical support, innovator, part of test engineering teams etc.
2. CTO holding the strategic role of visionary technology expert, change agent, part of the risk committee, senior executive roles, business advisor, sales strategy developer etc.
3. CTO's having a supra-functional role as influential advisor, an international think-tank, mentor, investor, startup entrepreneur.

Similarly, we have processed another set of text data from 54 CTO profiles from 2008 to 2015.

TABLE V.   PROCESSING OF LINKEDIN CTO PROFILES FROM 2008 TO 2015

SN	Steps of term clumping	Count
1	Total number of NLP phrases	1414
2	Total number of phrases after clean up by various thesauri and fuzzy routines	903
3	Total number of phrases after manual clean up	423
4	Total number of phrases considered as "CTO Role"	49

49 phrases related to CTO's role are found in the content of 54 LinkedIn profiles for group 2008-2015. The Aduna cluster map in figure 3 shows interlinkages among them based on their co-occurrence of phrases in LinkedIn profiles.
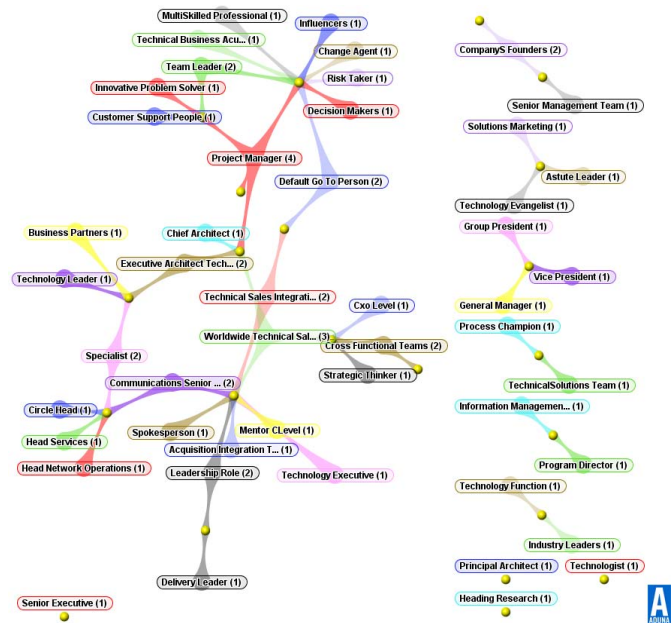

Fig. 3.   Aduna map showing 49 roles of CTO LinkedIn profiles from 2008 to 2015

From fig. 3 we have found support for

1. CTO playing functional role of project manager, technology leader, technical sales leader, customer support, technology evangelist and spokesperson, innovative problem solver, solution marketing etc.
2. CTO holding the strategic role of change agent, technical sales integration lead, strategic thinker, vice president, risk taker etc.
3. CTO's having a supra-functional role as founder of companies, business partners, CXO level executives, group president, C-level mentor, senior management team etc.

V. DISCUSSION

Based on literature review, we have created the CTO lifecycle fig. 4. It shows antecedents/drivers for CTO position in an organization which is macroeconomic context, the structure of R&D divisions and CEO's perspective on CTO. There can be alternate to CTO which are chief innovation officer[18], chief asset officer (CAO) [24], technology development manager, technology management review board (TMRB) [25]. CTO can grow in an organization from R&D head through one playing a dual role (R&D and line management) through strategic leader through the supra-functional leader. This growth is based on credibility, influence, relationship with key people and organization integration performance.
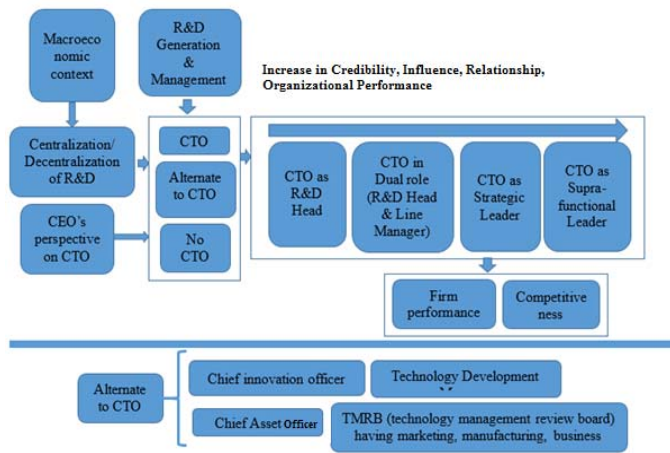
Fig. 4.   CTO Lifecycle

Fig. 5.   Evolution of CTO's role

From fig. 4 it is obvious that a CTO has strategic and operational role related to technology for the success of the organization. In current time changes in the environment are increasingly becoming faster which require CTO play his/her role with special skills and processes to support strategic decisions.

CTO position was introduced in mid-1980 when many R&D heads were named CTO and they mostly focused on R&D management work. However, during 1988-1997 few authors prescribed for greater and diversified role for CTO, the position of CTO was created to compete and link technology strategy with corporate strategy and in this period CTO performed dual role by getting line job to showcase as well as to get business insight, few pieces of evidence show strategic nature of CTO role in aligning technology strategy with business strategy.

In next decade 1998-2007, CTOs attempted to gain more power in an organization by having a strong personal relationship with various stakeholders and acting like business experts. Many new applications, packages, and solutions were planned with emerging technologies. CTO is considered as a responsible technology leader and got a place in business management committee.

In recent time 2008-2015 new developments like open innovation, radical innovation and changing context are redefining core purpose of the CTO position. CTOs are also part of investment decisions and work for company's business mission. Hence we understand that CTO position is getting more credible and finding a place in top management team focusing on shaping corporate strategy.

Based on analysis of LinkedIn data we have tried to compare decade wise shift in the role of CTO in fig. 5. New emerging concepts are taken to understand the shift. This means that CTO still has a partial functional role along with strategic role compared to purely functional role earlier.
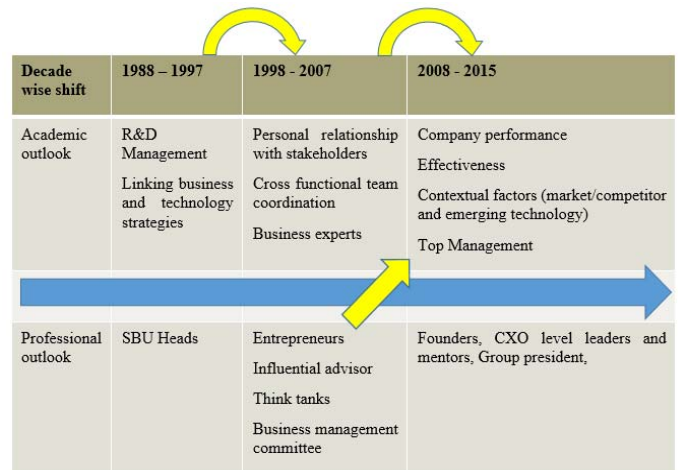
Fig. 5 shows academic and professional outlooks about CTO (from journal articles and LinkedIn profiles respectively) in terms of representative themes which are found by using NLP analysis. Academic outlook shows that various researchers have focused on these concepts (what we have categorized after reviewing the CTO literature). Professional outlook is set of concepts found in the LinkedIn profiles. In this fig. only new emerging concepts (decade wise) are illustrated for clarity. This indicates that CTO role has been constantly evolving from merely functional role to strategic and supra-functional roles organization where the effectiveness of CTO and contextual factors for organizational strategy are being considered for company performance which is in line with the findings of Uttal and Medcof.

VI.   CONCLUSION AND FUTURE DIRECTIONS

In line with the demands of the industrial revolution IV, this study provides following implications for practitioners

1. Organizations who look forward to having long-term growth plan should seriously look into creating CTO position or function.

2. CTO's role is becoming more or less at par with CEO with respect to participation in organizational strategy and his/her importance is growing. However, CEO is the ultimate authority.

3. CTO's role is polymorphous as it changes as per the need of organization as a response to technology transition points in a business environment which is highly dynamic.

It also directs towards the new avenue of research for simplifying CTO's dynamic job of strategic importance. We suggest one such direction as development a support system to address complexity and uncertainty in CTO's function.

The CTO's responsibilities and authorities were not exhaustively analyzed. The results of the present study may lack validity across sectors as only three sectors (telecom, IT services and automotive) have been considered. Sample size should also be increased to enhance the generalizability of the findings.

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