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Leadership development: Towards a more systematic approach in technology management

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ABSTRACT

Technology leadership research pays little attention to leadership differences across organizational levels. Research at the upper echelons is particularly sparse despite the importance of strategy in technology management. The "leadership pipeline", with its specification of six levels of organizational leadership, the leadership challenges at each, and the appropriate leadership preparation for each, can be adapted to technology management to provide an integrated, systematic, approach to technology leadership development and practice. A review of technology management research reveals shortcomings which could be remedied through the application of a pipeline approach. Future research should focus more on reliably differentiating the hierarchical levels of technology management, particularly at the middle management and executive levels. From there, the differing demands at each and the requisite capabilities for meeting them can be determined. This would facilitate the development of more effective leadership preparation for technology mangers as they transition from level to level, to their career benefit and for the competitiveness of their organizations.

1. Introduction

Leadership is an important concern for researchers in the technology management field (Edler, Meyer-Krahmer, & Reger, 2002; Gritzo, Fusfeld, & Carpenter, 2017; Rifkin, Fineman, & Ruhnke, 1999; Tschirky, 2004). Evidence indicates that many technology executives are not effectively leading the strategic mobilization of technology in the competitive positioning of their firms (Uttal, Kantrow, Linden, & Stock, 1992). For example, Edler et al. (2002) found that only 45% of the firms in their sample perceived the Chief Technology Officer (CTO) to be playing a significant role in setting business unit strategy and only 55 perceived the CTO as significantly involved in setting corporate strategy. Zehner (1998) found that, among CEOs in Fortune 1000 companies, only 3% had backgrounds in R & D. Rifkin et al. (1999) concluded that the identification and development of technology managers for all levels is "troublesome" for most companies and suggests that a more systematic approach be taken, as do Uttal et al. (1992). Gritzo et al. (2017), in a very large sample across diverse organizations, found that R & D managers at all levels were rated as less effective leaders than non-R & D managers. R & D executives were examined separately and they, too, were rated as less effective than their non-R & D counterparts.

Stevens and Swogger (2009a, 2009b) describe a successful systematic approach to selecting, training, and coaching technical leaders, and others, at Dow Chemical. In summary, these papers suggest that technology leadership at all levels needs to be improved and that part of the solution is to take a more systematic approach to the development of technical people for leadership.

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Ensuring a steady supply of effective leaders for all levels (not just the top) and in all functions of the organization (not just in technology management) is a significant challenge for most organizations (Charan, Drotter, & Noel, 2011; Drotter, 2011; Freedman, 1998; Groves, 2007). Charan et al. observe that a common problem is that leader selection and development is fragmented across levels and functions so that a steady stream of capable leaders is not available for open positions when they occur. There is no integrated, comprehensive system of leadership development, no leadership pipeline, which ensures that people are selected and developed over the period of their careers to move through progressively more challenging levels of leadership, for the benefit of themselves and their organizations. The research by O'Conner and her colleagues (e.g. O'Connor & Euchner, 2017) affirms that levels of management can be meaningfully distinguished in the technology/innovation management context and those distinctions contribute importantly to our understanding of how to innovate radically and effectively. Firms, such as GE, which have developed effective leadership pipelines, can have enduring success in the marketplace (Groves, 2007).

It is a premise of this paper that the fragmentation of technology leader development is a significant impediment to the effective mobilization of technology in many organizations and a more systematic, comprehensive approach should be taken which includes the differentiation of demands at different levels of the hierarchy (DeChurch, Hiller, Murase, Doty, & Salas, 2010). The leadership pipeline (Charan et al., 2011) is based on many years of practical experience in leadership development and provides such an approach. This paper will review the research on technology leadership at the levels of the organization identified by the pipeline model. It will show that technology leadership development is wanting in several respects and goes on to suggest research directions to remedy this. The outline of this paper is as follows. In the second section, the empirical research showing different leadership challenges at different levels of the organization will be reviewed, supporting a fundamental assumption of this paper. In the third part, the levels of leadership in the pipeline model (Charan et al., 2011) will be described. Fourth, research on technology management will be mapped onto the pipeline levels. Correspondences and anomalies will be revealed. The fifth section proposes future research directions and the sixth draws conclusions.

2. Different leadership challenges at different levels of the organization

The leadership pipeline (Charan et al., 2011; Drotter, 2011) assumes that different levels of management require different leadership skills and this section reviews the research which supports that assumption. Most of the evidence comes from non-technical settings. Katz (1955) did founding conceptual work proposing three broad management levels; executive, middle, and supervisory. Jacobs and Jaques (1987) called these “domains” and proposed seven sub-divisions of the three principal levels, and some other researchers posit more than three principal levels. In brief, top executives include the CEO and those who report directly to the CEO. Supervisors are those who manage people who do not manage others. Middle management includes all the levels between supervisors and executives. In large firms, the middle can include several levels which may differ significantly. The three levels of management differ in their responsibilities, functional activities, time spans of responsibility horizons, and primary skill requirements (Kaiser, Craig, Overfield, & Yarborough, 2011) as shown in Table 1, where each cell is an abbreviated version of what Kaiser et al. (2011) included in the corresponding cells in their table.

In Table 1, the second column, “Responsibilities”, describes the parts of the organization that managers at each level are responsible for. These parallel the levels in the leadership pipeline (Charan et al., 2011) as will be shown below. The third column, “Functional Activities”, shows the nature of the activities managers are responsible for at each level. The nature of these activities follows from the organizational responsibilities shown in the second column. The fourth column, “Time Span”, indicates the time horizon of the matters for which the manager is responsible. The higher the level in the hierarchy, the longer the time span. The fifth column, “Primary Skills”, indicates the most critical skills for effectiveness at each hierarchical level. The three skills shown in Table 1; conceptual, inter-personal and technical; were originally proposed by Katz (1955) and more recent work has expanded the list (e.g. Mumford, Campion, & Morgenson, 2007).

The requisite skills for each level of management have been the subject of several studies. Katz (1955) proposed that although each skill is particularly critical at one level (as shown in Table 1), all are required to some degree at all levels. Mumford et al. (2007) examined four skills; business, strategic, interpersonal and cognitive; and found that the importance of all four increases with increasing hierarchical level and that the order of importance was the same at all levels, in ascending order of importance; business, strategic, inter-personal and cognitive. De Meuse, Dai, and Wu (2011), measuring a wide range of competencies, also found that most increased in importance across the ascending levels of hierarchy. Only one competency, technical learning, showed a consistent decline in importance across ascending levels. Kaiser and Craig (2011) examined several manager characteristics across the hierarchy

Table 1
Managerial work at three organizational levels.
After Kaiser et al. (2011).

Managerial level	Responsibilities	Functional activities	Time span	Primary skills
Top (*Executive*)	Performance of an enterprise or a group of businesses	Creation of strategy, structure, systems, culture	10 or more years	Conceptual
Middle (*Middle Management*)	Performance of multiple functional units or a division	Translate strategy into operational goals, allocate resources	2 to 5 years	Interpersonal
Bottom (*Supervisory*)	Performance of a small team within a single function	Manage operations	Less than 2 years	Technical

and found that only one positively predicted effectiveness at all three levels, learning agility. It was a stronger predictor for executives than for middle and supervisory managers. Executive effectiveness was more strongly associated with empowering leadership than with directive leadership, while middle manager effectiveness was more closely associated with directive than empowering. Neither kind of leadership significantly predicted supervisory effectiveness. Brousseau, Driver, Hourihan, and Larsson (2006) researched the decision-making style of mangers at five levels from supervisor to executive and found, for example, that the decisive style declined from supervisor to executive while the flexible style rose. Day and Harrison (2007) showed that individual and relational leadership identities dominated among individual contributors and first-level supervisors while collective identities were more predominant at the general manager level and above. Natali (2014) found significant differences in the personalities, cognitive abilities, experiences and behavioural competences of managers across the three levels. These studies of skill, leadership and other characteristic differences across levels, some associated with effectiveness, show patterns which it would be useful to verify in technology management.

A few studies have investigated technology management skills at different levels. Waldman and Atwater (1994) researched the effects of transformational leadership on project effectiveness. Transformational leadership by project managers had no effect on project outcomes but did have a positive effect for higher level managers. Huber (2013) found that the higher the job position the more important external networks are for effectiveness. Mumford (2000) reviewed the research on innovation management and prescribed strategies for fostering innovation in four different management contexts, managing the individual, small groups, the organization, and the environment. His advice for individuals and small groups may apply at all levels. His advice on how to engage people across the organization and manage the environment is probably most relevant to middle and top managers.

These studies of management roles and skills at different organizational levels have confined themselves to the three-level model, with one exception, and have shown different requirements at different levels. However, the three-level model has not shown itself to be very applicable to practical concerns such as leader selection, training and career planning. Other models of management levels based on more levels have proven to be more useful although not as much rigorous empirical research has been done to validate them. One such model is the Leadership Pipeline (Charan et al., 2011; Drotter, 2011) and some supportive empirical research has appeared (Dai, Tang, & de Meuse, 2011; Kaiser & Craig, 2004, 2011).

3. The leadership pipeline: six levels of management

The “Leadership Pipeline” (Charan et al., 2011; Drotter, 2011) is a model of management levels which has been developed from practice and provides a more granular analysis than the three-level models. It posits six levels of management (Table 2) which are defined in ways which lend themselves well to the practical issues of selection, training and career progress. These six levels parallel the three level models. The leadership pipeline shows promise as a guide for improving technology and other kinds of leadership and management given its finer distinctions across levels, particularly in middle management.

Table 2
Pipeline levels and representative management challenges.
(After Charan et al. (2011).)

Level 6: Enterprise Manager	
Deliver consistent results, top and bottom-line; Set enterprise direction; Shape the soft side of the enterprise	
Maintain an edge in execution; Manage in a global context	
TRANSITION 6	
Level 5: Group Manager	**Level 5a: Enterprise Functional Manager**
Select and develop competent business managers	Apply enterprise perspective to the function
Critique (not make) strategy of the businesses	Envision needed changes to the function and lead their implementation
Connect business & corporate objectives	
Appreciate multiple different businesses	
TRANSITION 5	
Level 4: Business Manager	**Level 4a: Group Functional Manager**
Appreciate many more & more diverse considerations	Integrate functional strategies from the group's businesses into a coherent group strategy
Appreciate sustainability of the business, income & costs	Solicit funds to support that strategy
Deal with much higher visibility, inside and out	Provides group executives with business-based critiques of functional strategies and results
	Manage multiple reporting relationships
TRANSITION 4	
Level 3: Functional Manager	
Appreciate the “business perspective” and strategy Appreciate that function exists to support the organization	
Appreciate function's role in context of many functions; Communicate through multiple organizational layers	
TRANSITION 3	
Level 2: Managing Managers	
Select & train capable first line managers; Hold first line managers accountable for their work	
Deploy resources among units; Manage the boundaries between units	
TRANSITION 2	
Level 1: Managing Others	
Define and assign work to be done; Enable/guide direct reports in their work	
Build positive social networks to facilitate work	
TRANSITION 1	
Managing Self	
Manage own work performance; Get results through own professional proficiency; Follow procedures and goals	

Table 3
Pipeline levels in technology management.

Pipeline levels	Examples in technology management
6. Enterprise Manager	CEO of the Enterprise
5a. Enterprise Functional Manager	Chief Technology Officer V.P. Technology
5. Group Manager	V.P. Marine Businesses
4a. Group Functional Manager	V.P. Material Technologies
4. Business Manager	CEO of a single business firm General Manager in a multi-business firm
3. Functional Manager	Director of R & D Manager of Research, Chief Technology Officer in a single business firm
2. Manager of Managers	Managers of larger projects and departments
1. Manager of Others	Managers of small technical departments Leaders of small teams and projects
Managing Self	Scientists, engineers, other professionals, support staff

In the pipeline, a manager's rise to the top of the organization is more or less an orderly progression through successive levels of management. At each level new challenges are encountered requiring new skills and perspectives. The pipeline addresses the challenges associated with each transition requiring the manager to discontinue behaviours that were effective in the past but are not in the new role, continue behaviours that have been effective and continue to be so, and acquire new behaviours for new challenges. Since these challenges are predictable by level, the selection and training of leaders with the potential to handle them is possible as a practical matter. The six levels of management are preceded by a stage of self-management. These will now be described and corresponding levels of technology management noted and summarized in Table 3. These correspondences do not hold in all organizations because different firms use titles in different ways, but they do provide a general alignment of the pipeline with technology management. **Managing Self.** In this role people have no formally assigned management duties. In the technology context, this includes engineers, scientists, other professionals, and support staff who do not carry significant management responsibilities. **Level 1: Managing Others**. This role is usually called supervisory or first-level management and involves managing people who do not themselves have any management responsibilities. In technology management, we find this with the leaders of small teams, projects and technical departments. **Level 2: Managing Managers**. This is the management of Level 1 managers. In technology management, it is found with the managers of larger projects and departments. In large organizations there may be multiple levels of managing managers before one reaches the next transition in the pipeline which is to Level 3, the functional manager. **Level 3: Functional Manager.** This involves managing a whole organizational function such as marketing, human resources or technology. In technology management the function manager covers all the technology activities of a business and reports directly to the CEO/general manager. Sample titles include Chief Technology Manager (CTO), Vice-President of Technology and Vice President of R & D. **Level 4: Business Manager.** At this level the manager has profit and loss responsibility for a business and manages the diverse functional managers of the business. If the firm is a single business, the business manager is the CEO of the firm and together with the functional managers constitutes the TMT of the firm. If the firm is a multi-business enterprise, business managers may be called general managers rather than CEOs. Level 4 is the first level at which the rising technical manager steps out of the technical environment and assumes responsibility for non-technical matters. Although Level 4 managers are not necessarily from the technology function they have the responsibility to ensure that technology works in a synergistic way with the other functions to achieve the strategic goals of the business. **Level 5: Group Manager.** If the firm is a multi-business enterprise the next step up is often to Group Manager. This position is found when there are too many businesses in the enterprise for the Enterprise CEO to manage directly so group managers are appointed, each to manage several related businesses at the enterprise level. The role of the group manager does not seem to have been addressed in technology management research although it seems likely that they would have some responsibility for ensuring that technology is included in group strategy. **Level 6: Enterprise Manager.** This is the top level in the pipeline and the incumbent is responsible for the enterprise as a whole and is usually called the CEO. There is some research on the role of the CEO in technology management and it will be discussed below. The CEO is ultimately responsible for technology strategy and management in the enterprise as a whole. In addition to these six positions which define the core of the pipeline, two other functional positions are included in the model. They are at the group and enterprise levels. **Level 4a: Group Functional Manager.** This is a functional manager who reports to a group manager and is responsible for a particular function across the businesses in the group. This manager works with the Level 3 functional managers in the businesses and the Level 5 group manager to coordinate and strategically optimize the function within the group. The Level 4: Business Manager and the Level 4a: Group Functional Manager are taken to be at the same level in the pipeline and present alternative promotion routes from Level 3. **Level 5a: Enterprise Functional Manager.** This position reports directly to the enterprise CEO and oversees a particular function for the enterprise as a whole, liaising with the group functional managers and business functional managers to ensure a coordinated and strategically focused management of the function at the enterprise level. The Level 5: Group Manager and the Level 5a: Enterprise Functional Manager are at the same level in the pipeline and represent alternative promotion routes from Level 4. The Level 5 positions report directly to the enterprise CEO and together with the CEO constitute the TMT of the enterprise. Menz (2012) describes two kinds of executives (group and functional) in the enterprise TMT. An example is seen at IBM where the enterprise c-suite includes

functional vice-presidents of human resources and of research, among others; as well as group managers for business groups such as "Software and Cloud Solutions Group". In technology management this position is usually given titles such as CTO; Vice-President, Technology; or Vice-President, R & D.

4. Technology management and the levels of the leadership pipeline

Now that the essentials of the leadership pipeline have been introduced a review of research on the management of technology within that framework can proceed. The research does not fit into the pipeline precisely because researchers have not framed their studies that way. However, there are some direct alignments and in other cases satisfactory approximations are found.

4.1. Level 1 - Managing Others: first line management in technology contexts

In technology settings managers at Level 1are typically leaders of small projects, teams or technical departments. They lead technical professionals, technical support workers and some non-technical professionals and support staff. Reviews of R & D leadership by Elkins and Keller (2003), Farris and Cordero (2002), Mumford (2000), and Mumford, Scott, Gaddis, and Strange (2002) find that most of the empirical work examines this most junior level. One consistent theme is that, because of their closeness to technical specialists, Level 1 managers must have a firm grasp of technology as well as other skills including leadership and management. Elkins and Keller (2003) organized a number of studies on leadership in R & D using the concept of leadership roles. The evidence suggests that when leaders effectively take such roles as planner or team builder their teams are more effective. Thamhain and Wilemon (1987) offered recommendations for technical team leaders around the themes of communication, commitment, team image, decision making, team-building and cultivating support for the team among senior managers.

Cross-functional teams are common in technology management, particularly when expedited action is critical and the challenges are complex and multi-faceted (Souder, 1988; Workman, 1995). Junior level technology managers often lead them and must resolve the conflicts that arise from diversity. Workman (1995) empirically demonstrated deep-seated differences in the perceptions of marketers and technical people. Souder (1988) provided guidelines to junior technical managers for effectively leading cross-functional teams.

Virtual teams are becoming more common as firms increasingly disperse their technical work geographically, often internationally, and often in partnerships. Barczak and McDonough (2003) address the issues of multi-national virtual teams. They say the challenges of leading global teams arise from a number of sources and recommend face-to-face meetings at the beginning of a team initiative to foster the development of trust, the clarification of roles and responsibilities and to allow the "natural" formation of team dynamics. Effective leadership can be maintained through a close monitoring of communications and regular progress meetings.

Leading projects is a common role for technical first line managers. Although much of the research on project management concerns methods for organizing projects, good leadership is also critical. Pinto and Kharbanda (1995) outline differences between project leadership and the leadership of technical functional departments. Projects are more structured, cross-functional, focused and depend more upon improvisation and so require different leadership approaches.

Fostering creativity and innovation is another expectation of Level 1 technical managers. Mumford (2000) surveyed the research on fostering innovation not confining his attention to just technical contexts. He suggested practices for fostering creativity such as allowing individuals discretion in organizing their work. Elkins and Keller (2003), in their review of the research, stressed the creation of an innovation climate by building a sense of community, providing personalized recognition and other methods. Brainstorming is one commonly used tool for stimulating creativity and Thompson (2003) has provided guidelines for leading brainstorming activities after identifying four threats to team creativity. In summary, the research on fostering innovation in organizations provides many suggestions for effective practice and many are within the purview of Level 1 technical mangers. The essence of much of the advice is to do less management and more leadership if you want creativity to emerge.

Transformational leadership among Level 1 technical managers has also been researched (Berson & Linton, 2005; Keller, 1992). Berson and Linton found that transformational leadership is a better predictor of project success and employee satisfaction than transactional. Keller found that both transactional and transformational predicted project success in both research and development teams, but transformational was a better predictor for research teams and transactional was a better predictor for development teams. It seems that Level 1 technical leaders should vary their leadership depending on the tasks being led.

Boundary spanning in technical project teams has been researched by Ancona and Caldwell (1992) who organized the activities into four categories: scout, ambassador, sentry and guard; which they describe in detail. They found that most boundary spanning is performed by team leaders rather than team members.

Networking is another important skill for Level 1 technical managers (Norling, 1996; Ransley, 1995). Development and maintenance of a network both inside and outside the organization should be a priority for all junior managers, as well as middle and senior. Ransley presents a checklist of tips for effective networking which covers attitude, planning, developing networks, how to meet people, and common courtesy.

The characteristics of the individual contributors who must be managed by first level technology managers have also been researched. Perry, Hunter, and Currall (2016) examined organizational and professional commitment among scientists and engineers and found relationships with organizational productivity. Bobadilla and Gilbert (2015) found that conflicts among the technical, market and managerial logics among knowledge workers are problematic and proposes management tools to allay the negative effects of them. Politics in new product development teams can have positive and negative effects on communications and therefore on collaboration and NPD success (Kyriazis, Massey, Couchman, & Johnson, 2015).

In addition to this work on the tasks of Level 1 technology managers, there is work on the transition from individual contributor to Level 1 (Badawy, 1995; Howard, 2003; Maurer & London, 2015; Medcof, 1985). Some of the challenges involved in that transition are the need to spend more time dealing with people rather than working alone on technical issues; grappling with complex issues for which there is no clear-cut answer; making decisions with incomplete information; mastering accounting, labour relations, marketing and other business disciplines and knowledge; shifting loyalty from the profession to the firm and adjusting personal relationships with former peers, according to Medcof. Howard found in his sample that the three biggest challenges were perceived to be (1) balancing the many more responsibilities, tasks and priorities which go with the management role; (2) relationship changes with former peers and others, and (3) delegating work that must be entrusted with others. This work on transition issues can provide the beginning point for developing supports for technical people moving into the first level of management, as recommended by the pipeline.

The research on Level 1 managers is the most advanced in the technology management field from the perspective of the pipeline. It includes a considerable body of research on the tasks of Level 1 technology managers (Elkins & Keller, 2003; Mumford, 2000; Natali, 2014) and on the transition from individual contributor to Level 1 (Badawy, 1995; Howard, 2003; Maurer & London, 2015; Medcof, 1985). The research on Level 1 technology managers is typically done on samples of Level 1 managers, but it is not always clear what applies to Level 1 only, and what applies to other levels as well. For, example managing cross-functional and virtual teams occurs at several levels. Similarities and differences in these tasks at different levels have not been explored. Research might also clarify which tasks are found only at Level 1. The pipeline provides a coherent structure in which these transition issues can be researched and theory built.

4.2. Level 2 - Managing Managers: “middle” management in technology contexts

In the leadership pipeline, the term “managing managers” is applied specifically to those who manage first line managers. This creates ambiguity since managers above Level 2 also manage managers. Further, the research on middle managers of technology does not, for the most part, distinguish among the levels of middle management specified in the pipeline. Consequently, the review here will not distinguish among middle management levels except in the case of the Chief Technology Officer (CTO) who has been singled out for differentiating research.

The leadership of multiple teams is often undertaken by middle managers (Kraut, Pedigo, McKenna, & Dunnette, 2005). Harris and Lambert (1998) identified a number of effective practices. The middle manager needs to ensure that team roles and responsibilities are clarified and that work on areas of overlap is coordinated effectively. Given differences in team cultures, different leadership approaches may be needed with different teams. Kelley, O'Connor, Neck, and Peters (2011) did an interview study of practices for selecting and managing project leaders. On the management side, they concluded that the management role should include a carefully tuned balance of autonomy and accountability with concurrent hands-on/hands-off involvement. Penalties for the failure of innovations should be reduced and innovation efforts more recognized. Designing team structures can also fall to middle managers and Clark and Wheelwright (1988) have provided options on a spectrum running from lightweight team structure to heavyweight team structure.

The study of champions of innovation in technology settings and elsewhere shows the critical role that middle managers can play in connecting technology to the marketplace through multi-functional, ground-breaking initiatives (Howell & Higgins, 1990a, 1990b; Howell & Boies, 2004; Markham, 2000; Shim & Lee, 2001). It is middle managers (level unspecified) who usually become champions rather than first line or TMT managers. Middle managers with significant experience in the firm have the organizational knowledge, contacts and influence necessary to bring large projects to fruition if they also have strong leadership qualities. In related work, which is also not level specific and is not confined only to technology managers, Floyd and Wooldridge (1992, 2000) explored the ways middle managers influence senior managers. The research shows that middle managers are called upon to provide reports evaluating or proposing future strategic directions and they influence the strategic direction of a firm by deciding what to include in reports and how to present them. Middle managers can also engage in informal persuasive discussions with senior managers. Research on issue selling by middle managers done by Dutton and her colleagues (Dutton, Ashford, O'Neill, & Lawrence, 2001) addresses similar themes. They interviewed managers on tactics such as how to present an issue, how it is packaged with other issues to give it more credibility, and how to recruit allies in the selling activities.

The leading of open innovation activities (Chesbrough, 2003) often falls to middle managers. Outsourcing is common in technology work and Schick (2006) proposes that it requires some leadership and management skills not found with in-house activity because of the dynamics of working with teams from more than one organization. Alliances usually have broader mandates than outsourcing, may involve multiple partners, and involve more complex relationship issues (MacAvoy, 1997). Strategic alliances are usually managed and lead by middle managers. According to MacAvoy, the leadership challenges of alliances are extraordinarily high because of the high levels of uncertainty.

This completes the review of research on technology middle management. It is presented here under the heading of “Level 2: Manager of Managers”, the lowest level of middle management in the pipeline, although much of what is presented may well apply to other levels of middle management and perhaps to Level 1 management as well. There appears to be no research in the technology context on the transition from Level 1 management to Level 2. The leadership pipeline would recommend that future research be clearer about the differences between tasks at different levels of middle management.

4.3. Level 3 – Functional Manager and Level 5a – Enterprise Functional Manager: CTO

Functional managers are responsible for parts of businesses such as marketing, human resources, manufacturing and technology. As shown in Table 2, the pipeline suggests that organizations may have functional managers at three different levels; Level 3: [Business] Functional Manager; Level 4: Group Functional Manager; and Level 5a: Enterprise Functional Manager; depending on how they have organized themselves. In technology management, CTO is a common title for a functional manager although other titles such as the Vice-President of Research are also common. Originally, CTO research was centred on the highest-ranking technology executive in large complex firms who report directly to the Enterprise CEO (Adler & Ferdows, 1990). This is the Level 5a: Enterprise Functional Manager. However, it is not clear now that firms and researchers have confined the term CTO to that level. Some firms use the term CTO at Level 5a, others at Level 3, and some probably at both. It is not clear and it makes it difficult to disentangle the research results. In some firms, there are CTOs at Level 4a: Group Functional Manager (Hartley, 2011; Smith, 2011). Given these ambiguities, the term CTO will be used somewhat ambiguously here to refer primarily to the 5a CTO and perhaps to the other levels as well. Uttal et al. (1992) address the responsibilities of Level 5a CTOs suggesting there are three broad leadership roles for the position. **Functional leadership** is of the technology function itself, making sure it meets budget, timeline and effectiveness requirements. **Strategic leadership** ensures that there is a technology strategy and it is appropriately represented in, and aligned with, corporate strategy. **Supra-functional leadership** involves the CTO in the formulation and execution of enterprise-level strategy. The CTO has cross-functional work to do in all three roles (Adler & Ferdows, 1990; Cetindamar & Pala, 2011; Herstatt, Tietze, Nagahira, & Probert, 2007; Van der Hoven, Probert, Phaal, & Goffin, 2012, Industrial Research Institute, 1998, Rifkin et al., 1999, Smith, 2003). In the functional role, the CTO focuses mainly on the technology function but since that function should collaborate with other functions, customers and others outside the organization, the CTO needs to oversee the significant amounts of cross-functional and cross-organizational work being managed by subordinate managers. The CTO's own direct cross-functional work will take place mainly in the strategic and supra-functional roles. The CTO's strategic leadership role aligns technology strategy with firm strategy and, depending on the stance of the CEO, it may be a prime responsibility of the CTO to lead TMT discussions on the organization's technology strategy and its relationship to business or enterprise strategy. In the supra-functional role, as a member in good standing of the executive team, the CTO takes on a variety of tasks which involve the leadership of senior managers and executives from across the organization. A CTO with a background in just technology management may not be well prepared for the complex cross-functional work required in the TMT and may not contribute effectively (Uttal et al., 1992). Lack of contribution may constrain credibility and influence in the TMT and limit the ability to promote the technology agenda at the senior level, to the detriment of the firm and the CTO's own career. The building of an influence base in the organization and beyond is an important task for a fully functioning CTO (Medcof, 2008).

This completes the review of research on the role of functional mangers of technology. There is some research on 5a CTOs but the degree to which it does or does not apply to Levels 3 and 4a and/or is based on samples which include Levels 3 and/or 4a is unclear. Although the reviewed findings might plausibly apply to all, the pipeline cautions that there are probably important differences among the three. Future research should make the distinction between the three levels of functional management which the pipeline proposes, clarify their differences, develop a corresponding understanding of the management and leadership skills needed in each, the challenges of transitioning into and out of these roles, and integrate that understanding into a general leadership pipeline model for technology management.

4.4. Level 4 – Business Manager and Level 6 – Enterprise Manager: the CEO

What the CTO needs to do to get the CEO on side with the technology agenda, and how to get the CTO included substantively in firm strategy setting (e.g. Smith, 2003; Uttal et al., 1992), have been the focus of much of the research on the CEO in technology management. The research is more about the CTO's role than the CEO's. The most common theme Much of the research on the CEO in technology management address is how to build credibility and trust with the CEO (Landau, 1992; Medcof, 2008; O'Neill, 1992; Robb, 1994; Uttal et al., 1992; Zhen, Xuan, & Jing, 2012). The CEO is treated as a powerful being who makes decisions that can help or hurt the technology agenda but little is said about the nature of the CEO's work in this respect. The research is unclear about whether it is about the CEO of a single-business firm (Level 4) or about the CEO of a multi-business enterprise (Level 6).

Tschirky (2004) directly addresses the CEO's role in technology management and lists important roles for the CEO. These include; (1) Ensure that technology and innovation values are expressed in vision, mission and policy statements, (2) Ensure that the vital link between technology and innovation strategy and company culture is properly managed, and (3) Equip top management decision bodies with appropriate technology competencies. In related work, Ollila and Ystrom (2017) investigated the roles of senior managers in open innovation collaborations in technology intensive firms. They found that the roles of facilitator, tactician and sensegiver are important to the success of collaborations. Nguyen and Aoyama (2014) showed that there are management practices that can be implemented by executives which can foster a corporate culture conducive to more efficient technology transfer. Kouaib and Jarboui (2016) showed that CEOs who cut R & D expenditures can be distinguished by those who do not on the basis of CEO overconfidence, tenure, age, and education.

Some technology management research, while not focused directly on the CEO, is suggestive of the responsibilities of the position but it has not been systematically integrated. For example, a prominent theme in technology management research is that technology strategy should be integrated with firm strategy (Roberts, 2004; Tschirky, 2004). Although the focus is not on the CEO it is clear that, ultimately, it is the role of the CEO to make sure this happens. Research has been done on the R & D budget as part of strategy (Tubbs, 2007); the strategic management of intellectual assets (Reitzig, 2007; Tao, Daniele, Hummel, Goldheim, & Slowinski, 2005); the role

of the TMT in fostering innovation throughout the organization (Roberts, 2004; Tschirky, 2004; Zien & Buckler, 1997) and the fostering of effective cross-functional activity in the firm (Song, Kawakami, & Stringfellow, 2010; Tao et al., 2005; Tschirky, 2004). Kouaib and Jarboui (2016) found that a number of CEO characteristics influence the cutting of R & D expenditures to achieve earnings benchmarks. This work implies the responsibility of the CEO to oversee these activities and their integrated inclusion in firm strategy. Anand and Gomez-Mejia (2014) found that TMTs in high technology firms have different information seeking behaviours than those in low technology. This implies interventions by the CEOs of high technology firms. This general CEO research might be a starting point for developing a clearer and more systematic understanding of the role of the CEO in technology management.

In related work, the composition of the TMT has been shown to influence technology management. Variations in the profiles of TMT members influence the proportion of the budget allocated to R & D (Baysinger, Kosnik, & Turk, 1991; Dallenbach, McCarthy, & Schoenecker, 1999; Kor, 2006) and the kind and level of innovations pursued (Huffman & Hegarty, 1993; Meyer & Dean, 1990; Papadakas & Bourantas, 1998). These studies suggest that the management of the TMT is another facet of the CEO's role in technology management.

This completes the review of the research on the role of the CEO in technology management. Tschirky (2004) and Ollila and Ystrom (2017) are the only studies found which directly address the question. Research on other facets of technology management implies roles for the CEO but these need to be systematized. No work on the transition from functional manager to CEO was found. The pipeline recommends that a clear understanding of the CEO's role in technology management be developed, including a distinction between the business and enterprise-level roles, and that the implications for transitioning into and out of the roles be researched.

5. Research implications

This review of technology management research and its parsing into the levels of the leadership pipeline (Charan et al., 2011) is intended to be a first step towards applying the ideals of the pipeline to technology management at all levels of the organization. An integrated, comprehensive system of leadership development would ensure that technology is effectively deployed in the context of firm strategy. It would ensure that well prepared leaders are available to move into vacant positions in a timely way wherever they are needed. This review has shown that, in broad terms, the challenges and role expectations of technology leaders vary by level. It has also shown that the amount of research done varies considerably by level and the field of technology management has some way to go before the ideals of the pipeline are approached.

Level 1: Managing Others is the most researched level as shown in several reviews; Elkins and Keller (2003), Farris and Cordero (2002), Mumford (2000), and Mumford et al. (2002). These focus on the tasks required of Level 1 technology managers. The work of Badawy (1995), Howard (2003), Maurer and London (2015) and Medcof (1985) focuses on the transition from individual contributor to Level 1. This research should be organized in the context of the pipeline if it is to be applied practically to the support of managers making the transition. That organizing would probably trigger more research. The degree to which the findings for Level 1 do and do not apply to higher levels is also an open question.

Level 2: Managing Managers, which was expanded here to include multiple levels of middle managers, has a significant body of research although not nearly as much as for Level 1. No research into the challenges of the transition from Level 1 to Level 2, or to higher levels of middle management, was found except for the case of the CTO. This research will be helpful to those applying the pipeline to technology management but it has a significant shortcoming in that it does not distinguish the different levels of middle management, distinctions which the pipeline argues are important. These level distinctions should receive more attention in future research.

Levels 3, 4a and 5a, functional managers, have been primarily researched with a focus on Level 5a: The Enterprise Functional Manager (CTO), but there is ambiguity because distinctions among the three levels have not been made conceptually or empirically. There is a significant amount of work on the roles of the CTO, and some on the preparations necessary to assume them. An important research challenge will be to clarify the roles of CTOs at different levels and develop leadership preparations for each of them.

Levels 4, 5 and 6; business, group and enterprise managers; are the levels with the most significant shortcomings in technology management research. Senior leadership is important for the strategic mobilization of technology and it requires serious research attention. This shortcoming is manifest in several ways. There are only a small number of papers which mention the CEO or other senior managers as part of technology management, apart from the CTO. There seems to be no technology management research on Level 5: Group Manager. The research on the CEO fails to distinguish between CEOs at Levels 4 and 6, as does the research on TMTs. There is no research on the challenges of transitioning between these different levels of technology management, although there is on transitions at this level for mangers in general.

The lack of research on the top levels of technology management is an issue to be addressed on a priority basis. It is as if, in the minds of researchers, there is no technology management outside the technology function, i.e. above the CTO. The leadership pipeline does not stop at functional management and shows that managers above the functional level carry a heavy responsibility for the success of the function, particularly in strategy setting and in cultivating the right organizational culture. Even the research on CTOs gives most of its attention to managing and advocating for the technology function.

In addressing the dearth of level-differentiating research on technology management, the question of leadership is important. If leadership requirements change from level to level a pipeline should specify and train for the optimal leadership approach at each

level. Kaiser and Craig (2011) found that executive effectiveness is negatively associated with directive leadership, positively related to empowering leadership and not related to supportive leadership. Middle manager effectiveness is positively related to directive and supportive leadership but negatively related to empowering leadership. Supervisor effectiveness is not related to directive or empowering leadership and is negatively related to supportive leadership. Waldman and Atwater (1994) found that transformational leadership by project managers was not correlated with effectiveness but for higher level managers involved with the project it had a positive relationship. There is no clear conclusion which spans both these studies but the following proposition seems worthy of empirical test.

Proposition 1. *In technology management, executives will be more effective with empowering leadership, middle managers will be more effective with directive and/or supportive leadership and supervisors will be most effective if they avoid supportive leadership.*

This proposition addresses only three levels of management. If it is tested empirically, the researchers should classify mangers with the six levels of the pipeline and look for patterns across them. Answers to questions such as, "At what level of middle management do directive and supportive leadership start to be effective?" can be explored. The data on supervisory leadership provides no clear suggestions about how technology supervisors should lead and further research is called for.

Another approach to research on the pipeline and technology management is to focus on competencies at different hierarchical levels. As described above, there is already some empirical and conceptual work on this for management in general (De Meuse et al., 2011; Kaiser & Craig, 2004; Katz, 1955; Mumford et al., 2007) which may inform research on technology management. Table 1, based on Kaiser et al. (2011), could provide a starting point for this. The fifth column in Table 1, "Primary Skills", indicates the most critical skills for effectiveness at each level using the trilogy of skills proposed by Katz (1955); conceptual, inter-personal and technical. Although one skill is the most critical at each level, all are required to some degree at all levels (Katz, 1955). There have been several other studies of the important skills at each level. Mumford et al. (2007) examined four skills; conceptual, inter-personal, strategic and business. All increased in importance with increasing hierarchical level; and their order of importance was the same at all levels. De Meuse et al. (2011), measured several competencies and found that most increased in importance across ascending levels of hierarchy, consistent with Mumford et al. Only one competency, technical learning, showed a consistent decline in importance across ascending levels. Kaiser and Craig (2011) examined several manager characteristics and found that only one positively predicted effectiveness at all levels, learning agility. These studies show some patterns which it would be useful to verify in the technology management context using the hierarchical levels of the pipeline.

Proposition 2. *In technology management, the following four management skills have the same order of importance at all organizational levels, that order being, from most to least important; cognitive, interpersonal, strategic and business.*

Proposition 3. *In technology management, the importance of cognitive, interpersonal, strategic and business skills increases with ascending organizational level.*

De Meuse et al. (2011) found that technical expertise decreased in importance with increasing hierarchical level, supporting Katz's (1955) earlier finding. This does not contradict earlier studies showing that technical expertise is the most important determinant of effectiveness of technology management supervisors (Mumford et al., 2002). As an aside, this may partially explain why no leadership style has been found to be positively associated with supervisor effectiveness in technology management. The following proposition should be tested across all levels of the pipeline.

Proposition 4. *In technology management, technical expertise is very important at the supervisory level but declines in importance with successively higher management levels.*

Learning agility has recently come into focus as an important trait for leaders (De Meuse, Dai, Swisher, Eichinger, & Lombardo, 2012; Kaiser, 2010; Yukl & Mahsud, 2010). Learning agility is defined as, "the willingness and ability to learn from experience and subsequently apply that learning to perform successfully under new or first-time conditions" (Lombardo & Eichinger, 2000). Learning agility would also be important for making the transitions as a manager transitions up through successive levels of the pipeline with their attendant, new challenges. Kaiser and Craig (2011) found that learning agility correlates with leadership effectiveness at all levels but most strongly at the executive level. Technology management usually takes place in highly competitive organizations which must compete through constant innovation under high uncertainty, so learning agility seems particularly important in the technology management context.

Proposition 5. *In technology management, learning agility is associated with effectiveness at all pipeline levels and increases in importance with ascending levels.*

The fourth column in Table 1, "Time Span", indicates the time horizon for the work of each level of management and although it is not a managerial competency its presence in the table is worth noting. Table 1 shows that, the higher the level in the organization, the longer the time horizon of responsibilities. This relationship was also described by Jacobs and Jaques (1987). Drotter (2011) provides time spans for all six levels of the pipeline consistent with this pattern. The following proposition extends this relationship to technology management.

Proposition 6. *In technology management, positions successively higher in the pipeline have successively longer time spans of responsibility and discretion.*

Six propositions have now been stated and they propose relationships between ascending pipeline levels and several variables.

Although confirmation of the propositions should be the first order of business in research testing them, the data should be carefully examined for other patterns given that these would be first steps in the exploration of the pipeline and technology management. It will be important to ensure that the levels of the pipeline can be reliably distinguished empirically and to look for discontinuities across levels. For example, at what level is it advisable for a middle manager to stop using directive leadership and start using empowerment? Patterns which are unique to technology management may be found.

This review has noted weaknesses in current technology management research and suggests directions for future research, but there have been limitations in its approach. Bailyn (1991) describes four common career paths which are open to R & D professionals. They are; (1) to move through increasing levels of technical excellence, (2) move into management and move up the management hierarchy, (3) move from project to project taking on ever more significant project leadership roles, and (4) technical transfer, moving with a project through its stages of development by moving out of R & D to other departments as needed and perhaps eventually finding promotion in one of the other departments. The leadership pipeline applies most clearly to the management promotion route and maybe to promotions following from technical transfer moves. Research into the other career routes should be pursued, for example, Holzle's (2010) work on project management careers. Such research might suggest significant additions to the pipeline model to account for these other technology career opportunities. A related limitation is that the pipeline and similar models cover the levels of management but do not include the role of the board in technology management. There is already some research on boards and innovation and technology management (e.g. Deschamps & Nelson, 2014; Robeson & O'Connor, 2013) and work in this line, in conjunction with that on technology management, should provide a more complete understanding of technology and competitive advantage. Another limitation is that the leadership pipeline (Charan et al., 2011), being based primarily upon apparently successful organizational practice, does not have a significant theoretical base, unlike some of the other models of managerial levels (e.g. Jacobs & Jaques, 1987; Mumford et al., 2007). The development of a sound theoretical foundation for the pipeline and for its application to technology management would strengthen its power of explanation and its credibility as a guide to research. A third limitation has to do with the pre-stage to the management pipeline levels, the stage of self-management. It has not been addressed here, not because it is not important, but because the scope of a single paper is insufficient to do it justice. Research on self-management for people in technical settings should be pursued. This paper has found the pipeline useful for identifying issues for research and there are implications for practice. However, the pipeline is a generic model based on the study of a variety of organizations. Since each organization is unique, we would not expect the pipeline to apply unmodified to all of them nor to all issues in the management of technology. Such inconsistencies are expected and can be addressed through on-going research and application.

6. Conclusions

This paper has reviewed the research on technology leadership at all levels of management with the intention of assessing the degree to which the pipeline approach has been applied to technology leadership development. It has found a significant body of research on technology management which has furthered our theoretical and practical understanding but has found little evidence of comprehensive, systematic differentiation of technology management at different levels and consequent implications for leadership development. This prognosis suggests that, if the issues around technology leadership and management referenced at the beginning of this paper are to be resolved through more comprehensive and systematic leadership development programs, future research should include some guidance from the pipeline approach. Most importantly, studies of technology management and leadership should be careful to clarify the level of management being addressed from both a theoretical and methodological point of view. This will contribute to the development of a systematic understanding of the challenges at the different levels of management and the similarities and differences among them. This is a prerequisite to the development of an organization-wide system that prepares managers for those levels as they anticipate moving into them and once they have taken them up. A challenge in this approach will be to develop reliable methodologies for differentiating the levels of management. Some of the considerations that will be involved in this effort have been noted. The difficulties will be overcome only through continued research and conceptualization around level-based differentiation. The development of a level-by-level description of management roles and challenges will also facilitate the application of more theory to this area of study. Theoretical models have been developed to explain management at different levels (e.g. Jacobs & Jaques, 1987; Mumford et al., 2007). Level differentiating research, guided by these theories as well as the practical solutions evolving in management development; promise a rich advancement of our understanding of technology management.

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