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Introducing Technology for Development

Mohammed Muttayem Mahi Khan

Record Assistant, Government Degree College Husnabad, Dist. Siddipet Pin: 505467, Telangana State, India
Cell: +91 8341298597
Email: *mahikhan00713[at]gmail.com*

Abstract: ***The introduction of technology for development from the Engineering Management and Sustainability perspectives each present a piece of the puzzle. However, to have a complete picture of this issue, a discussion that builds upon the common ground of these disciplines and others will be presented below. To the point, it is important to understand what is meant by development and why it is important and understanding the development will bring the notion of introducing technology for development into a more holistic perspective. The remainder is an exploration into the ideas of development as freedom, the capability approach, and technology as capability expansion.***

Keywords: Entrepreneur, Development, Engineering management, Sustainability, Revolutions, Effectuation centric, Discovery centric, Causation centric and Tactic centric, Empowerment, Geographical.

1. Introduction

According to the United Nations Sustainable Development Goals (2015), the ratio of people living on less than $1.25 per day in a developing region is 1: 5. This occurs despite the existence of technology that can greatly improve the lives of those living in the developing world. However, the issue is much more complicated than a country simply giving advanced technology to those that would benefit from its use. As such, this paper seeks to address the considerations of successfully introducing a technology for development from the perspectives of engineering management and sustainability.

The introduction of technology begins with the entrepreneur.

According to Oakley (2007), a major mechanism for change in the free market system is entrepreneurial action. To make the case, entrepreneurs are not encumbered by the inertia caused by heavy investments in the status quo (Oakley, 2007). Having this kind of mobility gives the entrepreneur the opportunity to break into the market with a competitive alternative (Oakley, 2007). From a different angle, major facilitation of this mobility comes from government influence, from funding research and development, to being aware of technological monopolies, and nurturing the right environments for entrepreneurs to thrive (Oakley, 2007). Further, "it is a characteristic of many of the most radical technological revolutions that they often emerge on the boundary between technological disciplines" (Oakley, 2007, p.13). Sebastiao (2011) agrees with this assessment in his assertion that, when confronted with a high degree of uncertainty, an entrepreneur will rely on who and what is known, a concept known as effectuation (Sebastiao, 2011, p.87). Armed with knowledge and social contacts, the entrepreneur can make a radical and often disruptive idea work.

The phrase, 'disruptive technology', refers to the "manner in which radical new technological improvements occur" (Oakley, 2007, p.10). At first glance, disruptive technology might seem like something that is counterproductive. However, according to Oakley (2007), the reality of the situation is that the long term effects of such disruptions are simply inevitable progress. For example, the industrial revolution was a time of unprecedented technological advancement. This in turn "triggered changes in industrial location, and concentrated the population into major industrial cities, " resulting in long term economic growth, (Oakley, 2007, p.10). For Oakley (2007), the apparent negative connotations of disruptive technologies are linked to the inherent uncertainty that comes from unexpected events. However, if a disruptive technology is to succeed, then it must first have an impetus.

Khavul & Bruton (2012) exhort the entrepreneur to consider local customers, networks and business ecosystems. One way of addressing poverty reduction is for mature economies to make sacrifices for the benefit of developing countries (Khavul & Bruton, 2012, p.285). However, a counterargument is that it is unrealistic for mature economies to make this sacrifice (Khavul & Bruton, 2012, p.285). "Today, those working in developing countries call for the introduction of appropriate technologies that use local skills and capabilities and available resources in an environmentally sustainable manner" (Khavul & Bruton, 2012, p.290). It is clear that if a new technology is to be successful, special consideration for those that will be impacted by the technology is essential.

Alone, technology cannot solve the wicked problems of the world. However, when the savvy entrepreneur gives special consideration for the local systemic environment that the new technology affects, the resultant disruption will ultimately have a positive impact. It is through the actions of entrepreneurs and the influence of government that the status of developing countries will improve. With special attention to local customers, networks and business ecosystems appropriate technologies can be developed to achieve the desired improvement. It is through the lenses of engineering management and sustainability that the introduction of technology for development come into focus.

2. Topic Overview

a) Engineering Management

Although Engineering Management (EM) is a well developed field that's been around since the '60's, there is no uniform definition (Lannes, 2001).

Some writers would use a narrow definition of “engineering management, ” confining it to the direct supervision of engineers or of engineering functions. . . Others would add an activity we might consider the “engineering of management” - the application of quantitative methods and techniques to the practice of management (often called “management science”), (Babcock, 1996, pg.14).

Lannes (2001) makes the case that EM is the phase in an engineer's career path that represents the transition from the reduction approach to problem solving to the management of problem solving. When comparing an engineering manager to other managers, EM requires the management of both technical and broad (e. g. marketing or top management) functions in a high - technology enterprise (Babcock, 1996). With regard to the introduction of technology, having this kind of management capability is essential to the entrepreneur.

According to Sitoh & Yu (2014), entrepreneurs utilize two approaches that coexist during the various phases in new product development: effectuation and causation. The logic behind effectuation is “to the extent we can control the future, we do not need to predict it” (Sitoh & Yu, 2014). While the logic of causation is “to the extent we can predict the future, we can control it” (Sitoh & Yu, 2014). The two approaches appear to be contradictory, yet, Sitoh & Yu argue that the approaches are coexisting, generic decision - making mechanisms that change in configuration during the process of creating the product. In Sitoh & Yu’s framework, there are two stages that separate business models from tactics.

The two stages of the competitive process of Sitoh & Yu’s framework are defined by a strategic business model and the respective tactics. “A business model is the result of strategic choices about policies, assets and governance, and its consequences are associated with these choices” (Sitoh & Yu, 2014). Tactics are the activities that implement strategy and lead to competitive advantages when growth is driven internally (Sitoh & Yu, 2014). During the first stage, the firm makes strategic decisions to select a business model it intends to utilize (Sitoh & Yu, 2014). In the second stage, the firm selects tactics based on choices that are guided by the business model selected (Sitoh & Yu, 2014). Moving forward with the selected business model and tactics, the proper decision - making configurations can be utilized.

With respect to business model and tactics, causation and effectuation can have one of four decision - making configurations: effectuation centric, discovery centric, causation centric and tactic centric (Sitoh & Yu, 2014). The four decision - making configurations correspond to the specific development phase (Sitoh & Yu, 2014). During the conceptualization phase the configuration is effectuation centric, where effectuation is dominant for both business model and tactics (Sitoh & Yu, 2014). During the prototyping phase the configuration is discovery centric, where effectuation is dominant for the business model, but causation is dominant for tactics (Sitoh & Yu, 2014). During the production phase the configuration is causation centric, where causation is dominant for both the business model and tactics (Sitoh & Yu, 2014). During the marketing phase the configuration is tactics centric, where causation is dominant for the business model but effectuation is dominant for tactics (Sitoh & Yu, 2014). When applied to the introduction of disruptive technology, proper implementation of the competitive process results in a significant competitive advantage within an established organization.

During the 1980’s, the Software Engineering Institute (SEI) conducted a study to determine the capabilities of software contractor's which led to the Capability Maturity Model (CMM) (Khraiwesh, 2015). Later, various organization from industry, government and SEI joined together to develop an integrated form of CMM formally known as Capability Maturity Model Integration (CMMI) (Khraiwesh, 2015). Now, the United States Department of Defense and other parts of the government use CMMI as a relatively complete framework to reduce risk within organizations (Khraiwesh, 2015). According to Khraiwesh (2015), two kinds of materials are included in the CMMI model:

1. Materials to evaluate the contents of processes; specifically, information that is essential for managerial activities and technical support activities; 2. Materials which help improve process performance; specifically, information that is used to increase the capability in organizations.

Through the process of adopting CMMI, we try to attain the following objectives: 1 - to improve project management capability; 2 - to enhance product quality; 3 - to increase productivity and [keep] cost down; 4 - to improve the capability of estimating the project budget and schedule; 5 - to increase customer satisfaction (Khraiwesh, 2015, pg.105).

Adopting CMMI would not only improve the performance of an organization but clearly show to others that the organization is capable of achieving what it sets out to do.

According to Obal (2013) the concept of interorganizational trust gives incumbent organizations the competitive advantage they need to out perform new entrants regarding disruptive technology. However, success of disruptive technology is generally attributed to new entrants to the market due to the flexibility and opportunistic nature of new firms (Obal, 2013). Obal asserts that innovation comes with inherent risk and uncertainty. Furthermore, firms that manufactured or sold products from the previous generation of products, i. e. incumbents are encumbered by organizational inertia (Obal, 2013). However, “large, pre - established distribution systems become a point of competitive advantage for incumbents” (Obal, 2013). The resulting interorganizational trust reduces opportunism and promotes cooperation giving the incumbent the competitive advantage (Morgan & Hunt, 1994).

Obal presents a number of hypotheses that explain the influence of interorganizational trust on the adoption of disruptive technologies. Perceived usefulness, perceived ease of use, perceived value and financial stability are the factors that influence the intention to adopt a new technology (Obal, 2013). Financial stability plays a significant role which aligns with the theory that financially sound firms will be more likely to adopt new technology. Perceived ease of use and perceived value influence perceived usefulness, which is the strongest determinant of intention to adopt (Obal, 2013). The factors of interorganizational trust play a significant role in the adoption of disruptive technology that come with significant risk.

To mitigate risk, a development from NASA, known as Technology Readiness Levels (TRLs), can be used as a general metric of technology advancement for the management of technology (Altunok & Cakmak, 2010). “Technology readiness assessment (TRA) is a consequential process to select the best technologies meeting the system requirements by examining maturity of the technology” (Altunok & Cakmak, 2010). Before system development can begin technology must be tested in a relevant environment and achieve the threshold measurements to meet requirements (Altunok & Cakmak, 2010). There are four stages of technology maturity: incubation, growth, maturity and decline, described by the technology S curve (Altunok & Cakmak, 2010). Once a technology is deemed to be of significant use then the technology transition process can begin.

According to Wagner & Ngai (2014), technology has a crucial role in fulfilling the promise of sustainable development. Wagner & Ngai add that technologies for sustainable development requires radical and incremental innovations. Radical innovations are needed to improve the environmental and social performance of goods or production processes while not altering consumer benefits (Wagner & Ngai, 2014). Utility and incremental (product - and process - related) innovations are needed for existing production and consumption systems due to path dependencies which can cause temporal lock - in and inertia (Wagner & Ngai, 2014). The next section of this paper will discuss technology in the context of sustainability in greater detail.

b) Sustainability

The generally accepted definition of sustainability comes from the the Brundtland report “Our Common Future”, published by the United Nations’ World Commission on Environmental and Development in 1987. Sustainable development is that which “meets the needs of the present without compromising the ability of future generations to meet their needs” (World Commission for Environment and Development, 1987). The approach received a boost during the United Nations’ conference on Environmental Development in Rio de Janeiro in 1992, where many global leaders agreed to support the initiative (Dresner, 2002). Since then, sustainable development has been a highly debated topic, with many arguing that it is an irreconcilable goal (Robinson, 2004). Although there is much contention surrounding sustainable development, it continues to hold an important and influential position within current business practices and policy (Wyness & Klapper, 2015).

Sianipar et. al (2013) suggest a methodology for developing appropriate technology (AT). The idea emerged around four decades ago with limited success (Sianipar et. al, 2013). “Due to the close relationship between AT and community empowerment ideas, considerations were incorporated to construct a strong basic approach of the new methodology” (Sianipar et. al, 2013). The methodology is based on three axioms: recognition, correspondence and operation (Sianipar et. al, 2013).

Further, the methodology consists of four stages: analyzing, concepting, designing, and assessing with several steps in each stage (Sianipar et. al, 2013). The desired result is that engineers become facilitators that help the locals of the developing country design and implement their own technologies that are relevant and needed, i. e. appropriate technology.

A model developed by Pearce et. al. aims at enabling innovation in appropriate technology for sustainable development (Pearce et. al, 2012). The core of the Enabling Innovation (EI) system’s design is composed of four elements: innovation use by geographical location and resource availability, innovation evolution or adaptation, social networks among innovators and networks of complementary innovations or systems designs (Pearce et. al, 2012). However, this approach is not without its challenges, many of which are not technical (Pearce et. al, 2012). “Perhaps the greatest inclusive challenge to the EI system is the wide spectrum of target audiences; creating a tool that is concurrently used by faculty at MIT, a business in Switzerland, and remote villagers in the Yucatan Peninsula will require a great deal of creativity and expertise by communication specialists” (Pearce et. al, 2012). Moving forward, expanding the EI system to a broader audience would pose an even greater challenge. While this model is geared toward enabling innovation, Brown & Ulgiati provide a reference set of indices for the evaluation of ecotechnological processes and whole economies (Brown & Ulgiati, 1997).

Brown & Ulgiati (1997) address the problem of evaluating sustainability activities with the definition of several indices. Among these indices are emergy yield ratio (EYR), environmental loading ratio (ELR), emergy investment ratio (EIR) and a new index called the emergy sustainability index (ESI) (Brown & Ulgiati, 1997). “Emergy is defined as the sum of all inputs of energy directly or indirectly required by a process to provide a given product when the inputs are expressed in the same form (or type) of energy, usually solar energy” (Brown & Ulgiati, 1997). The purpose of these indices are to increase understanding of relative contributions of various alternative means of production and consumption (Brown & Ulgiati, 1997). “This approach may also shed new light on the sustainability of national economies, a question of concern to all citizens” (Brown & Ulgiati, 1997). Ideally, these emergy indices will aid the decision - making and transition process by providing quantifiable sustainable targets (Brown & Ulgiati, 1997).

Up to this point, technology has been regarded without a discussion on the nature of technology. “The mainstream interprets technology as neutral and instrumental: technology is no more than an instrument to reach a goal; it cannot be judged on its intrinsic characteristics, only on its use” (Paredis, 2010). Alternatively, technology can be viewed as an autonomous and almost uncontrollable power that fundamentally reshapes our culture (Paredis, 2010). An approach that is emerging that seems to bridge these two concepts is fostered in research regarding socio - technical sustainability transitions (Paredis, 2010). As a proponent of transitions research, Geels (2005) states that technology is heterogeneous and not just a material contraption.

Additionally, technologies only function through linkages between these heterogeneous elements (Geels 2005). Moving forward, Paredis (2010) advocates the potential of transitions research to give guidance in technology choices.

Paredis (2010) makes it a point to mention the co - evolution of society and technology as common sense in the philosophy of technology. "The more complex understanding of the intertwining of technology and society has, in the sustainable development debate, reached the design community and the socio - technical transitions community" (Paredis, 2010, pg.222). The argument is that both social determinism and technological determinism are insufficient in describing a comprehensive understanding of technology (Paredis, 2010). The debate has reached a more robust understanding of how radical changes to socio - technical systems happen and how particular insights can be useful for advancing sustainability transitions (Paredis, 2010). Though many challenges are still present, such as a political stance in defining sustainable development and the philosophical inquiry of developing a practice of 'engaged knowledge', technology itself is becoming clearer (Paredis, 2010). The interplay of the socio - technical systems provides the basis for the co - evolution of society with technology (Paredis, 2010). Further, it speaks to the means of introducing technology for development.

c) Integration

The introduction of technology for development from the Engineering Management and Sustainability perspectives each present a piece of the puzzle. However, to have a complete picture of this issue, a discussion that builds upon the common ground of these disciplines and others will be presented below. To the point, it is important to understand what is meant by development and why it is important.

Moreover, understanding development will bring the notion of introducing technology for development into a more holistic perspective. The remainder is an exploration into the ideas of development as freedom, the capability approach, and technology as capability expansion.

Sen (2006) conceives development as freedom. He describes freedom as both the primary objective and the principle means of development (Sen, 2006). The primary objective, according to Sen (2006), is a normative claim which includes the understanding that the assessment of development must not be separate from the lives that people can lead and the real freedoms that can be enjoyed. Sen promotes the idea that the nature of our ends is the "capacious freedoms that we have reason to seek, " (Sen, 2006, pg.160). He identifies five categories of freedom: economic empowerment, political freedom, social opportunities, protective security and transparency guarantees (Sen, 2006). Having these kinds of freedoms described by Sen impacts the lives and capabilities of those that experience them.

Regarding this issue, Sen (2006) examines the connection between political and civil rights and the prevention of major disasters. There is evidence that governments respond to political pressure and the exercise of political rights, such as voting, criticizing, and protesting, can have a real effect (Sen, 2006).

The role of democracy in preventing famines has received attention precisely in this context, including the fact that India has not had a real famine since independence (despite continued endemic undernourishment and often precarious food situation), whereas China had the largest famine in recorded history during 1958 - 61, when the ill - calculated public policies that led to the disaster were continued by the government without any substantial emendation for three years, while nearly 30 million people died (Sen, 2006, pg.163).

Sen (2006) looks at democracy as more than just a system of elections, and recognizes it as a system of public reasoning. Further, public reasoning can play a robustly constructive role in bringing about changes in policies and priorities to advance substantive freedoms (Sen, 2006).

Oosterlaken (2009) describes capabilities as the things that people are effectively able to do and be, or the freedoms that people have in order to enjoy valuable functionings. The capability approach, pioneered by economist and philosopher

Amartya Sen and the philosopher Martha Nussbaum, evaluates justice, equality and development (Oosterlaken, 2009). The approach argues that capability should be the focus of the evaluation, not income, resources, primary goods, utility or preference satisfaction (Oosterlaken, 2009). From the capability approach, a strong connection to technology and engineering products is easy to make (Oosterlaken, 2009).

Oosterlaken (2009) describes technology as capability expansion. Even technology as basic as the wheel have had profound effects on the capabilities of humans to transport heavy loads (Oosterlaken, 2009).

Take a bicycle. Having a bike gives a person the ability to move about

in a certain way that he may not be able to do without the bike. So the transportation characteristic of the bike gives the person the capability of moving in a certain way. That capability may give the person utility or happiness if he seeks such movement or finds it pleasurable. So there is, as it were, a sequence from a commodity (in this case, a bike), to characteristics (in this case, transportation), to capability to function (in this case, the ability to move), to utility (in this case, pleasure from moving) (Sen, 1983, pg.153).

Oosterlaken (2009) builds upon this idea to add the significance of the details of design. Her argument begins with the design of technology incorporating moral values, in what is known as "value - sensitive design" (Oosterlaken, 2009). "A similar perspective may thus be just what is needed if we want to introduce new technologies in developing countries in such a way that it does benefit the poor by expanding their human capabilities, " (Oosterlaken, 2009, pg.96). From this, Oosterlaken posits that a "capability sensitive design" is the direction of responsible innovation for the benefit of the global poor (Oosterlaken, 2009). Utilizing this approach in design would increase the ability of technology to expand capabilities.

The purpose of this endeavour was to address that which is necessary to successfully introduce technology for development. The overall argument is that the entrepreneur, before all else, must choose a technology that is not only sufficiently mature, but is also appropriate to be introduced. To complement the chosen technology, a robust framework that strategically promotes the improvement of capabilities, such as CMMI and EI, must be tailored to the systemic environment. Using established metrics to monitor and control projects and evaluate sustainable activities, progress can be closely followed to make changes as needed. Finally, one of the most vitally important concepts to consider is trust. Technology does not stand alone, it is part of the socio - technical system and depends on people to make it useful. If development is freedom, and capabilities are freedoms that people have in order to enjoy living, then the introduction of technology that expands the capacious freedoms of a people will be successful.

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