An era of Appropriate Technology: Evolutions, oversights and opportunities

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ABSTRACT: *As we develop practical, innovative and sustainable technology solutions for resource-constrained settings, what can we learn from the Appropriate Technology (AT) movement? Based on a review of academic literature over the past 35 years, this article identifies, and chronologically maps, the defining tenets and metrics of success advocated by scholars. The literature has gradually evolved from general musings into concrete lessons learned, while the definitions of "success" have transitioned from laboratory success into practical application and long-term usefulness. Nonetheless, juxtaposing this scholastic history with actual projects reveals three major gaps in AT philosophy related to a lack of (1) bilateral knowledge exchange, (2) emphasis on venture scalability, and (3) integration of implementation strategy through the project lifecycle. This article argues that rethinking and repositioning AT with a human-centric narrative emphasising sustainability and scalability is imperative in order to revitalise and accelerate the AT movement and to achieve the large-scale impact it was expected to deliver.*

KEYWORDS: Appropriate Technology, scalability, implementation, indigenous knowledge.

1 INTRODUCTION

Appropriate technologies (ATs) refer to simple, typically labour-intensive and local-manufactured, technology solutions that aim to improve the lives and livelihoods of people in resource-constrained environments. The AT movement was founded by Dr. Ernst Schumacher and started to gain popularity in the 1970s as an alternative to foreign aid. Appropriate Technology scholars and advocates argue that such aid can be more disruptive than beneficial to developing countries because it fosters dependency and takes vital business away from local entrepreneurs. Driven by this foundational philosophy, the movement has grown to encompass a host of approaches to designing and implementing simple technology solutions. Yet despite the movement's longevity, the scale of most AT ventures still pales in comparison to the size of worldwide struggles with hunger, poverty and health (United Nations, 2013). Additionally, an examination of the academic literature and praxis indicates that the definition of Appropriate Technology, and its bounds of "appropriateness," have diffused to accommodate developments in globalisation, shifting macroeconomic and political environments, and changing user preferences (Steenkamp et al, 2003; Upadhyay, 2003; Baker & Edmonds, 2004; Estime, 2005; Ferrantino, 2009; Law, 2011). While this evolution is certainly important and warranted, it has compromised the clarity of valid means and ends that provide inspiration and guidance to new AT ventures.

Against this backdrop of a long but disjointed and relatively low-impact history (Polak, 2010), the question emerges: what exactly constitutes Appropriate Technology in current times? How have its tenets and definitions of success evolved over the decades? Is the AT movement a success? Is it still relevant today and into the future? These questions are especially important now as universities, corporations, governments and non-profits emphasise technology solutions for addressing developing world challenges: the true mission that the AT movement always had (Bowonder, 1979; Atarah, 1990; Leary, 2001; Amiolemen et al, 2012). This article delves into the academic literature related to Appropriate Technology from 1978 to 2013. It provides a comprehensive review of how the core tenets and definitions of success promoted in literature have evolved over time, and endeavours to identify gaps that have prevented the movement from achieving its full potential. These insights can inform and inspire the next generation of technology ventures and ensure that they create truly sustainable and scalable value for developing communities.

2 EVOLUTION OF THE TENETS OF APPROPRIATE TECHNOLOGY

2.1 Thirty five years of literature

Since the term Appropriate Technology was coined, many academics have theorised about the core tenets that make Appropriate Technology successful and beneficial to all stakeholders. Forty three academic articles fitting this description were selected to examine the development and evolution of the core tenets of Appropriate Technology. Although these articles represent a small sample of all Appropriate Technology literature, they were selected from a wide variety of journals, time periods, authors, media, and perspectives. Further, each decade's sample was selected to reflect the quantity and diversity of AT scholarship in the timeframe (hence the increase in sample size over the decades). Tenets were extracted from this sample by thorough read-throughs of each article. Notes on themes and quotes were compiled and articulated into a comprehensive list of tenets. The frequency that these tenets occurred in literature was also captured, taking note of authors' names.

The selected articles show that over time, Appropriate Technology tenets have evolved from exogenous research and general musings to lessons learned from experience. This phenomenon can be observed, in part, simply by examining the titles of different articles over time. In the 1970s and 1980s, when the Appropriate Technology movement was just beginning, titles suggest a broad overview, such as Bowonder's "Appropriate Technology for Developing Countries: Some Issues" in 1979, and Sorensen's "Which Technologies Are Appropriate for Developing Countries?" of the same year. More recently, titles have begun to express more precise concepts and contexts. Examples include the 2011 piece entitled "Urban energy transition and technology adoption: The case of Tigrai Northern Ethiopia". The content of these articles reflect the specificity of their titles. This is not to say that articles on theory and exogenous research are no longer written – discussions on the meaning and potential of Appropriate Technology persist, such as in Ja-young's (2012) "Technology serves the needs of developing countries".

In order to advance the AT movement, new AT ventures must be able to glean generalisable ideas from the complexities, failures, and successes of one specific location and technology and apply them to others. There is no standardised answer to this, but a common approach is to examine several relevant case studies and theorise overarching trends that can be combined into a practical framework. This section examines the chronology of the tenets that comprise such frameworks, and explain their dependence on project context.

2.2 The diversity of AT tenets

As shown in Figures 1a-1c, each article suggests a different set of core principles of Appropriate Technology. (These figures lists the number of references to each tenet per decade and colour codes relative to the total number of articles analysed in each decade.) Whether an article offers a case study or a theoretical approach – or some of both – they all typically attempt to explain the reasons AT solutions succeed or fail. In order to extrapolate broadly applicable information from these articles, the reasons for success or failure tend to become guidelines or "tenets" to consider for future projects. After thorough analysis of the 43 articles, these tenets were characterised and organised into the common groups displayed in Figures 1a-1c. Some authors explicitly propose tenets based on their own conclusions, while others offer more implicit definitions open to the readers' interpretations. Similar tenets are repeatedly noted throughout the history of the AT movement, suggesting that the concept of Appropriate Technology has not changed drastically since its inception. Twenty out of forty three articles emphasise the importance of local context or site-specific research. Comparatively, only six out of forty three articles agree that traditional skills and indigenous knowledge are two of the most important aspects of Appropriate Technology. Thus over the course of the movement, the need to fit the local context appears three times more often than the need to utilise traditional local skills. Even within the decade, there is no general consensus on a framework with core tenets.

Given these different concentrations, a general, overarching list of AT core tenets cannot completely determine the course of any given project. There is no one framework or finite set of tenets to reach success; everything reverts to the context and goals of a venture. In other words, the tenets promoted throughout AT history apply differently to each venture, and the future of the movement must be more flexible and not depend on just a single archetype. However, although there is no single framework through which all AT ventures should be *undertaken*, the literature shows some evolution on how to generally *evaluate* their success. This is an important insight, because without uniformly applicable tenets, the objective progression and evaluation of ventures becomes one of the few potential uniting characteristics of the future AT movement.

3 METRICS OF SUCCESS FOR APPROPRIATE TECHNOLOGY

3.1 The value of evaluation

While "appropriateness" has been established as context-dependent, standardising the metrics for

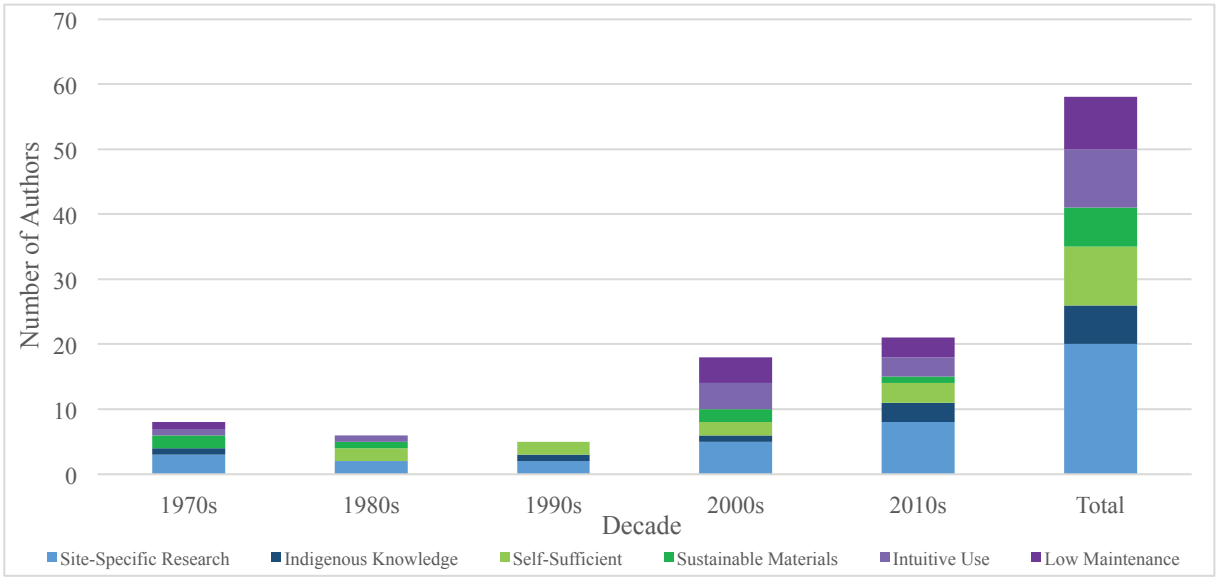

Figure 1a: Appropriate Technology design tenets in thirty five years of literature.

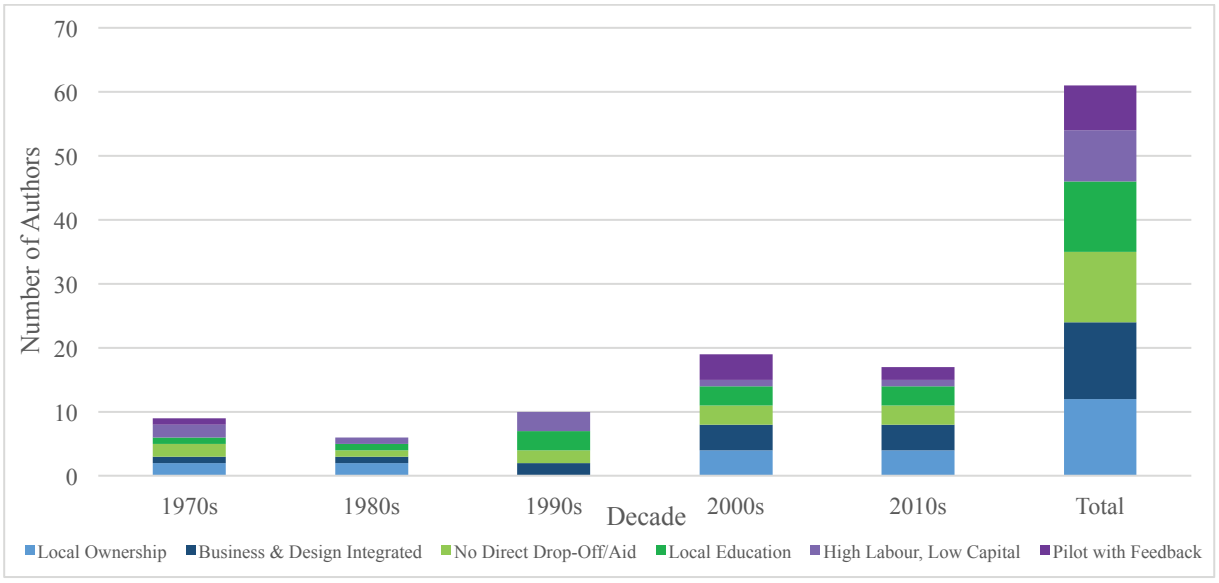

Figure 1b: Appropriate Technology business and implementation tenets in thirty five years of literature.

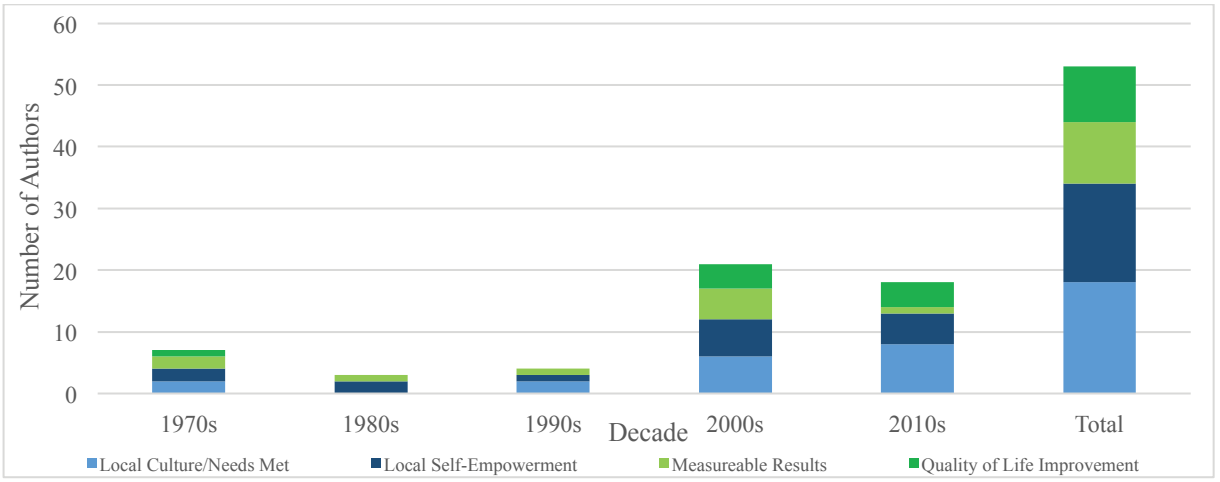

Figure 1c: Appropriate Technology tenets on goals and outcomes in thirty five years of literature.

evaluating ventures can help guide the AT movement and assemble insights from prior successes and failures. Assessing specific project goals with well-aligned evaluation metrics can inform all aspects of the project and advance it towards the desired economic, social and environmental bottomlines (Sulewski et al, 2012). While the Appropriate Technology literature recognises the importance of evaluation and uses the word "success" universally, the definition of success varies considerably. Laboratory success indicates that a technology is capable of producing desired results when tested in a controlled, isolated environment. Application or implementation success, on the other hand, means that those capabilities can actually be harnessed in the situations for which they are intended. Other authors argue that these two accomplishments are not true success unless the technology endures ("long-term success"). This view gained particular support in the 2000s (Murphy, 2000; Dimpl, 2003; Upadhyay, 2003; Estime, 2005; Sawaya, 2005; Harvey & Reed, 2006; Donaldson, 2009). Finally, some scholars note that even if the venture itself is a failure, some good may still come out of all the hard work put into the project. Several authors from the turn of the millennium onwards have argued that success can also include contribution to the body of knowledge, regardless of a venture's outcome (Dimpl, 2003; Estime, 2005; Sawaya, 2005; Dennis, 2009; Wyckoff, 2010; Egbe, 2012; Wyche, 2012).

3.2 The evolution of "success" in literature

A qualitative analysis of the same 43 articles from Section 2 determined how each author proposed to measure success in present and future projects. The results of this analysis are shown in Figure 2. Many articles offered primary and secondary means, which are noted with and without parentheses, respectively. Articles in the 1980s and earlier tend to criticise a past system, stating that there seemed to be no specific metrics in place ("Evaluation Emphasized" in Figure 2) and arguing that at the time success was taken for granted. Proposals for future analytical methods are presented with critiques of the status quo. The specificity and substantiveness of these suggestions tend to increase as the years progress, with some later articles providing concrete procedures for assessment. For instance, the African Network for Solar Energy (ANSOLE) sets specific milestones toward facilitating the spread of knowledge such as instituting a student exchange program and developing several research centres throughout Africa (Egbe, 2012). The aforementioned narrower focus of many articles from the 2000s and later presents an opportunity for detailed project-specific metrics. Again, while this is useful for similar projects, this evolution jeopardises the applicability and relevancy of the AT movement in the broader context of addressing the struggles of developing countries. The question then becomes how to harness the benefits of concrete assessment procedures while generalising them to future AT endeavours.

3.3 A history of clear ambitions and vague measurements

At the beginning of the AT movement, definitions of success focused heavily on the technology rather than the value created for people. Laboratory achievement

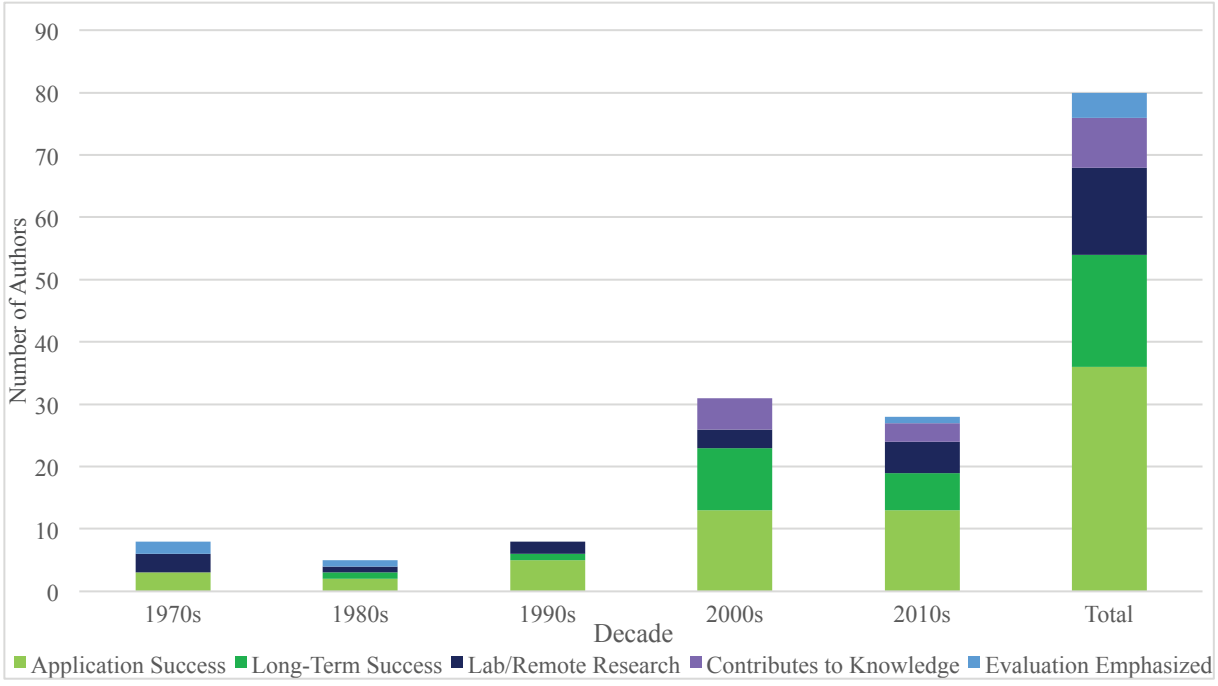

Figure 2: Appropriate Technology success metrics from literature.

alone was believed to show the full potential of a venture. Successful implementation and longevity were assumed to follow technological realisation ("Lab/Remote Research" in Figure 2). While it is important for a technology to pass lab tests before it is applied in the field, focusing on laboratory success neglects the final location, culture, and users. Even where the importance of users is explored, attempts to express their contribution to the venture are vague at best. Figure 2 shows that over time, literature begins to focus on application success as an important indicator of the appropriateness and overall achievement of a venture. However, as a whole, metrics used to gauge success are still vague and disjointed.

Though ambitions of success have evolved towards application and long-term results, the exact measurement of these goals remains inexplicit in most of AT's scholarly discourse. For instance, Bowonder (1979) criticised that, "in many situations, institutions connected with the specific aspect of a need, mainly project its aspirations *[sic]* as societies' own aspirations" (56). The ambition of supporting community goals continues in current scholarship, such as an article highlighting that projects should provide for the needs of the people, rather than the organisation (Ja-young, 2012). While this is an admirable goal, the author does not offer any recommendations on how to implement and monitor whether the product meets the users' needs. If anything, the proposed metric of success is cost-effectiveness, which is still addressed in technology design rather than user experience. An emphasis on affordability, usability, or return on investment (ROI) would have helped define success from the users' perspective rather than the technology's perspective. This is a trend in the literature as a whole – while many articles suggest user-centrality, methods actually achieving this focus are typically either limited to exogenous research prior to implementation, or are not explicitly stated at all.

3.4 The search for a comprehensive view of success

The success of Appropriate Technology is ultimately dependent on the success of the user. After all, isn't that the goal of all AT? Given that the appropriateness to the user is determined by local factors such as culture, economy and geography, it's clear that the most direct way to monitor this goal is by emphasising user-focused and user-defined metrics of success. Some literature expresses that the implementation of Appropriate Technology must be actively monitored (Gebreegziabher et al, 2011; Heriba et al, 2011), while others blur the line between tenet and metric by emphasising measureable results to be a key issue to consider in creating a venture ("Measureable Results" in Figure 1c). Many authors focus heavily on the application of a technology in context (e.g. "Site-Specific Research" in Figure 1a) or over the long-term ("Long Term Success" in Figure 2), albeit with or without directly referring to users.

The only near-universal assertion comes in the later decades of the AT movement, when many authors agree (implicitly or explicitly) that just because an Appropriate Technology is developed, does not mean it will be successfully adopted. Researching the users and the location prior to implementation is important, but it is not enough, particularly considering the unpredictable and chaotic nature of developing countries. Even tedious preparation cannot, by itself, account for the success of a venture. Despite this concurrence, there is comparatively little scholastic agreement on what to do about it.

This incomplete understanding of what makes a venture successful, combined with the necessary lack of a singular tenet-based framework for starting ventures, has left the AT movement in an identity crisis. Noted social entrepreneurs have even called it "dead", and understandably so, given its low impact, particularly relative to the enormous scale of the problems it attempts to address (Polak, 2010). For instance, as of 2010, 925 million people still do not have enough to eat, and 1.7 billion people still lack access to clean water, all compounded by the fact that 1.4 billion people in developing countries live on $1.25 a day or less (The Hunger Project, 2012). In comparison, the scale of most ventures in AT history is minuscule. In order to move forward, the AT movement must comprehensively address the barriers it faces to reaching more people in need. The movement can have relevance far into the future if AT scholars and entrepreneurs can unite to created scaled-up ventures that better match the scope of today's global problems. In other words, in order to address global needs on a tangible level, we need a consistent and meaningful approach to Appropriate Technology.

4 A POTENTIAL FUTURE FOR APPROPRIATE TECHNOLOGY

4.1 The challenge of relevancy

The review of Appropriate Technology literature has illustrated a number of facets in the evolution of this decades-long movement. At its core, there's widespread support for site-specific research and culturally-appropriate designs. Additionally, the focus of success has shifted away from purely laboratory results to incorporating the importance of in-context application. The field now benefits from practical case studies alongside the hypothetical musings. Nonetheless, the formation of a united and cohesive paradigm for AT remains elusive. There is little consensus among authors about what issues to focus on, or approaches to target, in the future. This disjointedness leaves several gaps that must be filled

for the AT movement to remain relevant and viable going forward.

4.2 Foci for the future

The Appropriate Technology movement's relevance will depend on its ability to offer comprehensive design and evaluation processes that converge on "appropriate" solutions to major problems while allowing for a variety of venture goals. This is only possible if the variety of current ambitions and tenets offered in the literature can be directly supported by specific approaches to venture development. For instance, even articles promoting a tenet as fundamental as focusing on user needs generally fails to note any mechanism by which to do so. Based on the previous analysis, we present three foci that have been discussed as tenets (Figures 1a, 1b, and 1c again, respectively) but not comprehensively integrated into Appropriate Technology development and assessment processes. These are (1) the continual exchange of technology and knowledge between local populations and external Appropriate Technology developers, (2) the direct integration of scalability objectives into ventures and products, and (3) the importance of implementation strategy considerations throughout venture development. These foci will each be presented in the context of current challenges, with emphasis on how successful ventures define success in terms of net impact on communities. The first of these new concentrations is the need for genuine bilateral interchanges between local users and AT organisations. In particular, we present this as a method of implementing the literature-supported tenets of site research, cultural applicability, local ownership, and community empowerment.

5 BILATERAL EXCHANGE OF KNOWLEDGE & TECHNOLOGY

5.1 The relevance of exchange ecosystems

Currently, Appropriate Technology literature as a whole exhibits a disparity between the understood importance of user context and the overlooked corollary of indigenous knowledge. Failure to understand *and incorporate* traditional knowledge of unknown origin has been the downfall of many Appropriate Technology ventures (Mehta et al, 2013). For example, one sector that has an understandably difficult job adapting to the local practices is biomedical equipment used in hospitals. Currently, "drop-off" donations dominate this field in developing countries, where 95% of devices in public hospitals are imported (Malkin, 2007). 70% of those are unused due to incorrect maintenance or operation (World Health Organisation, 2000). Eleven of the 43 articles studied in this paper note the limitations of such donation-based approaches ("No Direct Drop-off/Aid" in Figure 1b), but neither articles nor ventures report much success with alternatives from the industrialised world. The most common alternative today is for AT ventures to essentially take the Western technology and modify it, primarily by removing features in an effort to reduce cost, with little regard for indigenous perspectives and skills (World Health Organisation, 2013). Unfortunately, these modifications do not address infrastructure, supply chain, climate, and training issues – even those well-noted in literature – and thus they have largely failed.

Achieving a genuine level of bilateral exchange with local communities can facilitate an alternative to the largely futile approach of stripping down features from products designed for Western markets. Specifically, bilateral exchange involves integrating a culture's existing resources, norms and solutions – both material (ie technology) and non-material (ie knowledge) – with additional insights from positivist science to make products both more effective and more accessible for the resource-constrained communities.

5.2 Opportunities in bilateral exchange

Some Appropriate Technology ventures have begun to develop better systems of bilateral exchange and thus better address developing contexts' infrastructure, supply, ecology, and education challenges. These ventures are built upon the previously discussed tenets in the literature of Appropriate Technology – site research, local participation/ownership, and the ideals for local relationships noted in Figure 1c. However, some ventures go a step beyond this, establishing cross-cultural interchange as a keystone and continuous process of venture development. For instance, Husk Power Systems in rural India has provided electricity to over 200,000 people via recycling bio-waste. Their venture began with technical understanding of the region's infrastructure, geography, climate and flora. However, it was the organic replication process that enabled them to reach more communities and expand their success. In particular, bilateral exchange with host communities led to an understanding of community social norms, which enabled a uniquely sustainable form of recruitment, group billing and self-regulation (Husk Power Systems, 2011).

A further use of knowledge exchange is in directly developing solutions. To date, very few of the articles studied (only 6 of 43) promoted developing technology based on the indigenous knowledge of local populations. Nonetheless, this approach of starting with traditional skills and contributing empirically derived insight has led to numerous advances across Appropriate Technology sectors. For instance, the South Centre has begun work on adapting indigenous Chinese fermentation equipment and practices into effective cardiovascular pharmaceuticals (Jusoh, 2009). When

such technological advances are combined with equitable stakeholder involvement and foresighted business and implementation plans, ventures have the potential to meet the ambitions for application and long-term success mentioned above.

5.3 Caveats of bilateral exchange

In advocating indigenous knowledge, we find it important to emphasise that bilateral exchange is not just about indigenous understandings versus Western positivist science. It's about the development of ecosystems that facilitate the continual sharing, iteration and adaptation of ideas, perspectives, and technologies across societies. Indigenous knowledge should be integrated into Appropriate Technology development, rather than being overlooked or even being appended post-design. This move in rejecting the "us" vs "them" mentality can help globalised organisations engage in true frugal engineering, rather than mere feature removal for cost-cutting. For instance, Neonuture brought new meaning to the term "indigenous knowledge" when they presented a design to replace complex imported baby incubators with an alternative made from automobile parts already found and maintained in the local communities (Thairu et al, 2013). Instead of "downgrading" a Western device, the team based their work on the target market's current culture, resources, and skills – many already adopted from the West – to develop a more Appropriate Technology.

Finally, the idea of local wisdom as previously adopted knowledge (eg automobile maintenance) brings up an opposing barrier to open exchange: imposed cultural preservation. While many Appropriate Technology efforts have been bound by external research and laboratory success without incorporating local knowledge, the opposite has also been true. On occasion, individuals have felt pressured to preserve certain aspects of their culture in particular ways that do not make sense locally. For instance, the internationally exhibited Tibetan artist Tsherin Sherpa paints to "question and provoke all of us to check and see how we are actually preserving" (Nils, 2011) – unlike some forced preservationists, he views his traditions as thriving through transformation. As the Appropriate Technology movement progresses, it will need to use open cross-cultural communication to balance what indigenous communities do, and do not, wish to preserve as their culture and technology evolves.

6 SCALABILITY & STANDARDISATION

6.1 The true tradeoffs of scalability

Another under-emphasised and under-studied tenet of Appropriate Technology is scalability. Our literature study uncovered only 6 of 43 articles that emphasised any aspect of scalability, and even those tended to focus on the importance of piloting and feedback, rather than finding pathways to scale solutions from a few individuals to millions. In contrast to the reportedly low attention it receives, we believe that many of the more popular tenets of Appropriate Technology must be understood in terms of their effect on scalability and vice versa.

Several of the well-publicised tenets of Appropriate Technology must be re-examined in order to successfully scale up and benefit larger populations. For instance, ventures looking to impact hundreds of communities must rethink their approach to understanding local needs and integrating them into the design process. Their solutions will necessarily end up less customised to the local environment than those developed through more comprehensive participation from a smaller community. There is no inherent limit to community size in scalability: take the sunflower oil press ATI developed for pan-African markets in the 1980s. Even the economies of scale created by the continent-wide target market could not lower the price past $200, while Kickstart managed to make a $30 press by concentrating less on efficiency and more on the specific needs of some communities. Kickstart's version has dominated the market, helping millions of low-income customers (Polak, 2009). Their standardised product lowered the price point at the cost of decreased efficiency and lower community-specific customisation, allowing the venture to achieve a much greater scale.

6.2 Opportunities of scale

The Appropriate Technology movement has numerous opportunities for rejuvenation in between the ideally customised and the disinterestedly standardised. There are several clear benefits to standardising appropriate technologies. In addition to simple economies of scale, relying on imported raw materials and mass production can lower price points and benefit more of the target market. This type of standardisation allows for greater and more cost effective quality control, which can inspire trust for imported brand names over local versions (Steenkamp et al, 2003). Such is the case with KickStart, which produces many of its devices in China (Sijali & Mwago, 2011).

An additional aspect of standardisation that is not directly represented in common AT tenets is the benefit of concentrating on a single issue. Creating single-function devices to address some of the biggest issues in developing communities as opposed to adapting multi-functional devices from Western markets, can lead to significant cost and complexity savings. For instance, Zhongxing standardised and simplified their conventional x-ray machines by creating a version that accommodated only the most common procedure, chest scans. This drastically cheaper technology has captured 50% of the Chinese market and helped millions of patients by diagnosing

issues like lung cancer (Sehgal et al, 2010). Aravind Eye Hospital is another example. It's a multi-campus ophthalmological hospital in India which has standardised operations around conducting large numbers of cataract surgeries. This model allows the hospital to help millions of patients for low or no cost while simultaneously reducing post-surgery complication rates (Venkatesh et al, 2005).

On the other side, technologies cannot be standardised past their economic usefulness. Aravind Hospital provides a good counterpoint to this: despite the standardisation on cataract surgery, they also offer customised glasses. These are produced on-site via a frugal engineering process that makes them significantly cheaper than imported lenses while still appropriate for each individual. Additionally, Aravind offers higher-end personalised frames and uses the proceeds to subsidise operations for lower income patients (Maurice, 2001). The latter example is a type of multi-segment model, in which Appropriate Technology ventures can customise certain devices (eyeglass frames) to appeal to a higher income market in order to subsidise more basic products.

Another more obvious limitation to standardisation is practical usefulness. Some appropriate technologies are simply too dependent on local conditions – climate, geology, etc – to be completely standardised. For instance, mudbrick presses may need to vary based on soil consistency and solar food dehydrators benefit from different geometries based on location and latitude. This leaves ventures looking to expand into the markets a variety of choices. The devices themselves can be customised, either by the manufacturer or by the end user, if the processes are manageable. Or the different variations (eg different angles for a dehydrator's sunlight collector) may be built into a single design, if the cost is worthwhile. In short, there are many different trade-offs that multi-market Appropriate Technology ventures must consider with regards to standardisation. The most appropriate solution needn't always be the one most fitted to a single community.

6.3 Caveats of scale

In addition to the economic and practical limits on standardisation, there are certain caveats to the benefits of standardisation for appropriate technologies. First and foremost, standardisation is usually not appropriate when the venture's end goal is not reaching the broadest market possible. For instance, specific ventures may choose to concentrate on the empowerment of local manufacturing rather than on the benefit of the end product itself. For these ventures settled on local production, standardisation is often not only unnecessary, but burdensome. This also applies to local procurement. Standardisation can be difficult and unnecessary if the product is a technology-push meant to add value to local materials.

A final exception to the advantages of standardisation is if the technology's goal is ecological sustainability or improvement. This may limit design and production in several ways. One issue is the environmental impact of long-distance shipping, which may prohibit outsourced production for these ventures. Another is if the technology requires the use of ecologically benign materials. These may be difficult to standardise between locales or even between batches, complicating adaptability and quality control. Such ventures' implementation strategies must realistically balance ecological goals against scale-up resources.

7 EMPHASIS ON THE IMPLEMENTATION PROCESS

7.1 The importance of implementation

Appropriate Technology scholars have continually migrated towards defining success in terms of long-term sustainability. However, guidance on the actual implementation, scale-up, and measurement of ventures' impact is sparse. How does one take a venture from a prototype or pilot, and turn it into a sustainable non-profit or for-profit business? These implementation efforts are plagued with obstacles pertaining to everything from design and manufacturing, to product pricing and legal hurdles, to stakeholder relations and customer interaction. Ventures that wait to address these concerns in a linear piecemeal fashion late in the development process often result in failure (Maley et al, 2013). Instead, implementation strategy must be continually integrated as the venture matures, from conceptualisation to the value proposition all the way to steady-state business operations.

7.2 Need for research into practical implementation strategies

Challenges to developing and implementing a technology scale-up strategy come in many forms, from monetary and personnel issues to deciding venture lifecycle and scope. For example, the last section touched on a multi-segment business model used by Aravind Eye Hospital – selling more expensive glasses to subsidise cataract surgeries. This is also a viable scale-up model for ventures like affordable greenhouses. In the latter case, it can be very difficult to convince a low-income target market to make a major capital purchase, even if they can theoretically afford it. Beginning by selling (often more expensive) models to higher-income buyers can achieve many scale-up goals. First, it establishes a level of trust in the community that helps mitigate the risk-adverse nature of lower-income buyers. Second, it provides demonstration units, potentially strategically placed for real-life advertising. Third, it serves as an opportunity to

scale-up manufacturing and distribution operations, which can be much more difficult with lower-profit sales. And finally, the extra profit can be used to subsidise initial lower-income buyers as well as compensate for any product or personnel training issues during initial launch. This practice of selling to both low and higher-income buyers need not continue once the venture has achieved its steady-state scale and engaged its target market (though it can, as Aravind did). This is just one of countless potential business strategies to take the fruits of the research, the AT product, to the multitudes who can benefit from it. Further research and practice into this phenomenon can lead to a more rigorous definition of business implementation strategy, just as this article's literature study documents the evolution of technology tenets and success metrics. The same opportunity holds true for many personnel and stakeholder challenges to venture implementation.

Another opportunity for growth in Appropriate Technology is a more complete understanding of stakeholder engagement. The biggest challenges that face fledgling Appropriate Technology ventures are not technological at all, but have to do with establishing trust and equity amongst vested parties. Some research has already begun on the subject (Mehta & Bilén, 2011), and further discussion would help establish a number of best practices for engaging communities and retaining local venture champions. For instance, several global "FailFaires" have facilitated dialogue on why specific ventures failed. In 2011, the senior manager of Kenya's National Democratic Institute explained that their 2007 crowd-sourced method of election monitoring failed due to lack of local involvement limiting early adopter enthusiasm (Heatwole, 2011). Another 2011 device, a low-cost instant water tester, struggled with UNICEF incubation because it sought champions within UNICEF's logistics section rather than its sanitation section (Vota, 2012). Helping more Appropriate Technology ventures recruit the right local champions will help lead to more successful implementation efforts that benefit more communities.

7.3 Caveats for implementation

As with the other opportunities for the future of AT explained in this article, this implementation strategy advice comes with a variety of caveats. For instance, even when considering this incomplete list of challenges, one must be careful not to view implementation in a vacuum. The steps taken during this phase of the venture lifecycle affect all of the following phases. This applies to the business' goals as well as to its steady-state operational and organisational model. First, if a venture is focused on ecological benefit and sustainability, implementation measures must balance these goals with scale-up just as the steady-state business must (as discussed in the standardisation section). Second, ventures must ensure they are scaling up to a sustainable steady-state model. For instance, it may be easier to begin production of water purifiers in-country, but scaling-up local operations may not be an economically or ecologically viable way of reaching the target market.

Additionally, this discussion should not be taken to mean that scale-up can only occur at the start of a venture. Similar strategies can be employed throughout the ventures lifecycle to reach other disadvantaged communities. In fact, none of the concerns of implementation entirely fade away when a business reaches steady state (Maley et al, 2013). Stakeholders always seek equity, and target markets always have specific economic and trust needs. A sound implementation strategy can be transformative for an Appropriate Technology venture across its entire lifecycle.

8 CONCLUSION

Academic literature fails to provide a clear framework for Appropriate Technology that can inform the conceptualisation, development, implementation and evaluation of such projects. Scholars have continually emphasised the importance of local context and meeting local needs, while gradually evolving from general theories into concrete experience-based evidence. The definitions of "success" have transitioned from laboratory practice into practical application and long-term usefulness. Despite these general trends though, the diversity of goals within the movement has led to a disjointed account of the core tenets and evaluation methods for AT ventures. Further, the lack of specific procedures often makes achieving venture ambitions a haphazard exercise. Though converging on a singular framework for creating AT would unnecessarily limit innovation and addressable needs, the lack of any united paradigm has put the future of the AT movement in jeopardy.

The vague and disjointed nature of AT's scholarly discussions has led proven technology innovators and social entrepreneurs to declare the movement defunct. For instance, Paul Polak (2010), in his "The Death of Appropriate Technology" article, sees the movement as a failed effort by "well-intentioned tinkerers" that is only slowly being reborn as the domain of hard-nosed, market-centric entrepreneurs. This is certainly a reasonable delineation, but we must not confuse the separation of these two traditions by dismissing thirty-five years of scholarship. Moreover, this divorce alone cannot fill the numerous gaps between theoretical ambition and practical realisation that have plagued AT literature for decades.

In this article, we have explored the relevance of the AT movement (whether in its original form or Polak's renewed cohort) in light of the evolutions and oversights of the last thirty five years. In particular,

we've presented three areas for future concentration that we believe could strengthen a united AT paradigm. First, Husk Power Systems and Neonuture illustrate that developing genuine bilateral exchange ecosystems with local communities can help ventures incorporate indigenous knowledge, accomplish frugal engineering, and avoid the "us" versus "them" perspective in design. Second, the low-cost Kickstart oil press, single-function Zhongxing chest x-ray, and multi-campus Aravind Eye Hospital demonstrate that large-scale impact is achievable – particularly if ventures are willing to listen to their customers and make practical trade-offs. Finally, the low-cost greenhouse example and "FailFaire " stories serve as indications of how to integrate implementation planning throughout a venture's lifecycle. It is our hope that further scholarly discourse in these three areas will lead to the emergence of concrete processes and pathways to help AT ventures create, deliver, and assess value created for resource-constrained communities.

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