Literature review on the Diffusion of Innovations and Best Practice for Technology Transfer

Health Analysis & Information For Action (HAIFA)

Steven Kelly

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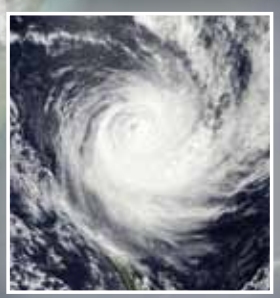

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1. Introduction

This literature review aims to inform the development of a process to extend the Health Analysis and Information for Action (HAIFA) resource system. As such, the review has a shared focus on the theoretical underpinnings of successful adoption of new innovations, as well as a practical focus on potential processes for managing the diffusion of the tool through appropriate user groups.

As this review will demonstrate, there is no shortage of literature on "technology transfer" or associated processes of innovation diffusion. As Wejnert (2002) notes, since the publication of Ryan and Gross's (1943) work on the diffusion of the use of hybrid seed corn, widely considered the touchstone publication for the field, some 4,000 publications across a range of innovations were published. However, as also highlighted by Wejnert, this literature is one where disciplinary focus is pronounced and where individual context plays a key role in the conceptualisation and theorisation of the innovation diffusion process.

The review has been structured to investigate in turn three broadly inter-related aspects of the technology transfer process: theory, method and implementation[1]. While the review was originally intended to develop an understanding of technology transfer "best practice", the consistent challenges to such unproblematic assumptions about the linear transfer of technology and knowledge from "source" to "user" (see, for example, Smith and Kelly 2008) suggest that such an attempt would not serve the current state of the literature well. Instead, this review attempts to characterise these challenges to the traditional model of technology transfer, and in doing so suggest a range of possibilities for promoting the uptake of the HAIFA tool amongst targeted communities of interest.

1.1 An outline of the HAIFA project

The Health Analysis and Information for Action (HAIFA) resource system is a 'proof of concept' designed to provide end-users (professional communities of interest in the local government, health and environment sectors) with scientifically robust methods, tools and information to help develop appropriate responses and adaptive strategies that can increase human health resilience to the infectious disease consequences of climate variation and change.

Having secured three years funding from the Foundation for Research, Science and Technology (FRST), the project builds New Zealand research capacity in environmental change and human health. The project aims to provide central, regional and local authorities with information to help formulate and plan the implementation of responses and adaptive strategies to build human health resilience for infectious diseases related to climate change.

'Information for action' is a term commonly used within the data management and health informatics professions. It concerns the importance that data and information gathered and collated in a public health surveillance setting is utilised to inform and support meaningful, practical action. A social science component of the HAIFA project has aimed to explore questions of how the data might be used by professionals themselves, and how it might be utilised by others to support policy planning and coordinated response to a particular issue. Namely to identify the capacity, assumptions and barriers that exist for coordinated adaptive planning between the health and environment sectors, and to better understand two key capacity areas for adaptation responsiveness – 'social capital' and 'information and communication'.

Several phases of enquiry were undertaken:

1. In-depth interviews with the District Health Boards, local and central government, and key stakeholders in a rural area.
2. Development of a vulnerability assessment tool with those involved in managing drinking water.
3. A literature review from the climate change field to unpack the concepts of 'social capital' and 'information and communication' (as well as issues of scale, timing, and coordination mechanisms).

[1] This structure follows that proposed by Miller ***et al.*** (2010) in seeking to demonstrate the possibilities for greater integration of the different research traditions associated with vulnerability and resilience. It is hoped that this approach will move beyond a review of available literature on innovation diffusion to suggest potential methods and implementation strategies.

This three-year body of work was subsequently extended by a further one year of funding from the Ministry of Science and Innovation to build upon the work completed in the originally funded programme. In particular, this extension to the original HAIFA project was "designed to generate value through knowledge and data mining of project outputs" as well as "disseminate and validate project findings by peer review". In addition, this fourth year of funding included further complimentary project outputs such as the report here in. This report aims to providing a review of the literature relevant to understanding "technology transfer", to extend New Zealand's knowledge and capacity in technology transfer for climate change adaptation planning.

1.2 Structure of the review

The review has been structured to develop an understanding of the diverse literature that constitutes the processes associated with "technology transfer" and how this is related to the literatures that encompass the diffusion of innovations. As a first step, the review sets out to define how terms including technology transfer, technology extension, and diffusion of innovation have come to be used in a variety of inter-related contexts. In doing so, this section clarifies both the topic and scope of this review in an attempt to ensure its relevance to an assessment of best practice for ensuring the adoption of a new technology such as the HAIFA tool.

This clarification of the scope and intent of the review is followed by a review of the diffusion of innovation literature as it exists across a range of disciplinary traditions. In particular, this review focuses on the development of the diffusion of innovation concept, outlines a range of other conceptualisations of the diffusion process, before looking specifically at shift in the technology transfer from linear transfer mechanisms to more participatory approaches. The review then connects with work done elsewhere in the HAIFA programme to address a range of literatures specifically related to communicating climate change knowledge.

2. Definitions, clarifications and scope

As Bozeman (2000, 627) wryly notes: "In the study of technology transfer, the neophyte and the veteran researcher are easily distinguished. The neophyte is the one who is not confused". This assessment is based on three key difficulties associated with the study of the technology transfer process;

> *"First, putting a boundary on "the technology" is not so easy. Second, outlining the technology transfer process is virtually impossible because there are so many concurrent processes. Third, measuring the impacts of transferred technology challenges scholars and evaluators, requiring them to reach deep down into their research kit bag"* (Bozeman 2000, 627)

Bozeman goes on to suggest that the third of these challenges is due to the fact that the impacts of technology transfer are "usually numerous and they are almost always difficult to separate from other parts of organisation life", making the measurement of transfer effectiveness "daunting" (Bozeman 2000, 627).

In light of these challenges, it is important that as a first step in attempting to develop an understanding of the literatures associated with technology transfer, that we attempt to define, or at least clarify exactly what it is we are talking about when we use the term "technology transfer". Bozeman goes on to cite Roessner (2000) who notes that the term 'technology transfer'

> *"has been used to describe and analyze an astonishingly wide range of organizational and institutional interactions involving some form of technology-related exchange. 'Sources' of technology have included private firms, government agencies, government laboratories, universities, nonprofit research organizations, and even entire nations; 'users' have included schools, police and fire departments, small businesses, legislatures, cities, states and nations..."* (cited in Bozeman 2000, 629).

Such a range of interactions seems daunting enough, however, the context in which Bozeman is making these observations encompasses but a small and specific definition of technology transfer. Specifically, these observations refer directly to a conceptualisation of technology transfer which is concerned principally with the transfer of research from publically funded science institutions to private users.

This conceptualisation of technology transfer is associated with the development and proliferation of research commercialisation offices of Universities, which have experienced a period of rapid expansion following what is known as the Bayh-Dole Act and subsequent technology transfer legislation in the United States (Green ***et al.*** 2009; Karlson, 2010). As such, it is associated principally with the intellectual property rights which might accrue to institutions which develop novel technologies and are able to patent and market them. The Journal of Technology Transfer, the official journal of the Technology Transfer Society demonstrates this focus emphasising the "management practices and strategies for technology transfer" as well as exploring "the external environment that affects these practices and strategies, including public policy developments, regulatory and legal issues, and global trends"[2].

For many researchers (across a range of disciplines), professionals and policy makers, the term is considered a "cover-all" for the process by which knowledge or technologies are transferred from their developers to another population to either use or further develop. This context is expressed in the context of climate change, where Working Group III of the IPCC, in a publication which looks specifically at issues for technology transfer, define it as "a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, non-governmental organisations (NGOs) and research/education institutions" (IPCC 2000, 3). However, while the context for this set of processes is for the transfer of technologies between nations states, whether developed, developing or in transition, they also note that their conceptualisation includes "the process of learning to understand, utilise and replicate the technology, including the capacity to choose it and adapt it to the local conditions and integrate it with indigenous technologies" (IPCC 2000, 3).

[2] http://www.springer.com/business+%26+management/journal/10961

Within this specific national "technology transfer" literature the mechanisms of transfer themselves are generally formulated as either some form of national system, for example National Systems of Innovation (NSI), legislation for promoting science commercialisation, or some form of "transaction' to improve the distribution of technology through structural means (e.g., Official Development Assistance or foreign direct investment, see IPCC 2000). Both the stages of transfer in this example as well as the potential barriers to successful transfer are as a result both related to the political and economic context in which such transfer takes place and are not entirely relevant for this review, while some of the approaches used to confront challenges (the use of participatory approaches for example) do have relevance.

Within this literature review, which seeks to establish what constitutes best practice in the "transfer" of the HAIFA 'technology' to its intended (and non-intended) users, we by necessity engage with the broader understanding of technology transfer identified above. In doing so, this review regards the "technology" as both a functional tool and a set of knowledge that exists within the HAIFA tool (Bozeman 2000) and attempts to engage with the broad literature associated with "technological change" and the diffusion of innovations in addition to a literature that more explicitly focuses on the planned dissemination of knowledge through a community of use and users.

3. Understanding the "Diffusion of Innovations" Literature

As outlined above, the theory and practice of technology transfer are intimately related to theories of innovation adoption. As Wejnert (2002, 297, following Rogers, 1995) notes:

> *"Diffusion of innovations refers to the spread of abstract ideas and concepts, technical information, and actual practices within a social system, where the spread denotes flow or movement from a source to an adopter, typically via communication and influence"*

An understanding of the range of factors that influence innovation provides valuable insight into what constitutes best practice in transferring scientific knowledge into practice.

The study of diffusion has been traced back to the work of French sociologist Gabriel Tarde (1903), whose *The Laws of Imitation* incorporates a number of key concepts deployed within the study of the diffusion of innovations (Rogers and Singhal 1996). Green ***et al.*** (2009) suggest that Tarde's work was complemented by that of Gustave Le Bon's Collective Behaviour Theory as outlined in *The Crowd: A Study of the Popular Mind* published in 1895. However, for most researchers, this work is overlooked in tracing the history of innovation diffusion research in favour of work by rural sociologists.

Greenhalgh ***et al.*** (2004), in their systematic review of the diffusion of innovations literature in relation to service organisations, eschew the linkages with the early work of Tarde and Le Bon entirely in favour of identifying 13 principal research areas (Greenhalgh ***et al.*** 2004, 587-8). Of these, they identify four as "early diffusion research": rural sociology, medical sociology, communication studies and marketing, in which "robust empirical findings" are balanced by a number "theoretical limitations" based on a series of erroneous assumptions. They go on to identify studies in development studies, health promotion, and evidence-based medicine, as fields which grew out of, or broke away from these early literatures, before identifying a range of organisation and management literatures which reflected a realisation that previous studies had focused on the individual at the expense of understanding innovativeness within organisations.

While this review draws on a broad range of these literatures, those most commonly referred to relate to the rural sociology literature, communication studies, health promotion and certain of the organisational management literatures relevant to the diffusion of innovation within organisations. This bias reflects both the expertise and background of the author and the context (i.e. the dissemination of the HAIFA tool), which the review hopes to inform.

Wolfe (1994) identifies a range of staged models of the diffusion process. While the numbers of stages in these models can vary, there is considerable overlap and Rogers (1995) five-stage model is the most frequently cited (Nutley ***et al.*** 2002, 11). The five stage of this model are:

1. *Knowledge – the individual (or decision-making unit) is exposed to the innovation's existence and gains some understanding of how it functions.*
2. *Persuasion – the individual (or unit) forms a favourable or unfavourable attitude toward the innovation. This may involve, for example, a matching of the innovation to a perceived problem, and some kind of appraisal of the costs and benefits of adoption.*
3 *Decision – the individual (or unit) engages in activities that lead to a choice to adopt or reject the innovation. This may include interaction with forces of support or opposition that influences the process.*
4. *Implementation – the individual (or unit) puts an innovation into use.*
5. *Confirmation – the individual (or unit) seeks reinforcement for an innovation-decision already made, but may reverse this decision if exposed to conflicting messages about the innovation.*

This model, or variations on it, is widely considered to represent the standard model of technology transfer. However, as Nutley ***et al.*** (2002, 11) note, some authors extend the model to "include considerations of the routinization of the innovation (so that its adoption no longer seems innovative) and issues of infusion (when the innovation is applied to its full potential)"[3].

Nutley ***et al.*** (2002) argue that passage through the stages of the adoption process are influenced by "prior conditions (such as previous practice and innovativeness) and mediated by characteristics of the decision-making unit, the perceived characteristics of the innovation, the communication channels involved, and the role of change agents and opinion leaders in promoting an innovation". We consider these factor in turn in the remainder of this Section, although not in the order that Nutley ***et al.*** (2002) suggest.

3.1 Characteristics of Innovations

Where Wejnert (2002, 299) argues that "most analyses of diffusion have emphasised actors and their perceptions of innovations", Greenhalgh ***et al.*** (2004, 594) note that "A very extensive evidence base from sociology (including medical sociology) supports the notion of key attributes of innovations (as perceived by prospective adopters), which explain much of the variance in innovations' adoption rates". These perceived attributes of innovations are central to understanding the adoption of innovations by a given population.

Rogers (1995) again provides an authoritative account of the range of innovation characteristics which may impact on the diffusion process, including relative advantage, compatibility, complexity, trialability, observability and reinvention (see Greenhalgh ***et al.*** 2004 and Nutley ***et al.*** 2002 for summaries).

Relative advantage – Innovations that have a clear advantage over either the idea it supersedes or competing innovations, either in terms of being effective, or cost-effective (Nutley *et al.* 2002). Greenhalgh ***et al.*** (2004, following Rogers (1995)) suggest that relative advantage is a *sine qua non* for adoption, in that potential adopters are unlikely to evaluate the innovation further if it is absent. They go on to suggest that nevertheless, the presence of relative advantage is not in itself always enough to motivate adoption and that even "so-called evidence-based innovation undergo a lengthy period of negotiation among potential adopters, in which their meaning is discussed, contested and reframed" (Greenhalgh ***et al.*** 2004).

Compatibility – Where innovations are compatible with intended adopters' values, norms, and perceived needs they are likely to be more readily adopted. (Greenhalgh *et al.* 2004, following Aubert and Hamel 2001; Denis *et al.* 2002; Ferlie ***et al.*** 2001; Foy *et al.* 2002 and Rogers 1995). The identification of values and norms as impacting on compatibility ensures that this characteristic can have a significant impact on the adoption decision.

Complexity – An innovation which is perceived as easy to use is more likely to be adopted.

Trialability – New ideas that can be trialled before adoption are more likely to be taken up (Nutley ***et al.*** 2002). Greenhalgh ***et al.*** (2004, following Plsek 2003 and Rogers 1995) note that experimentation can be encouraged through the provision of "trialability space". Such trialability, when coupled with increased ability to reject an innovation, also makes

Observability – The level of observability the degree to which the use and benefits of the innovation are visible to others, and therefore act as a further stimulus to uptake by others.

Reinvention – The ability to adapt, refine or modify an innovation to suit the specific use needs of adopters will allow it to be adopted more easily. While

In addition to these "standard attributes", Greenhalgh ***et al.*** (2004, 597) add a range of attributes which help "explain the adoption and assimilation of complex innovations in organisations":

> *Fuzzy boundaries – Complex innovations in service organizations can be conceptualized as having a "hard core" (the irreducible elements of the innovation itself) and a "soft periphery". (the organizational structures and systems required for the full implementation of the innovation); the adaptiveness of the "soft periphery" is a key attribute of the innovation.*

[3] This aspect highlights what has been termed the "implementation line" in the development and use of technology and will be discussed in a later section (see Bozeman 2009).

Risk – If the innovation carries a high degree of uncertainty of outcome that the individual perceives as personally risky, it is less likely to be adopted.

Task issues – If the innovation is relevant to the performance of the intended user's work and if it improves task performance, it will be adopted more easily.

Knowledge required to use it – If the knowledge required for the innovation's use can be codified and transferred from one context to another, it will adopted more easily.

Augmentation/support – If a technology is supplied as an "augmented product" (e.g. with customization, training, and a help desk), it will be assimilated more easily. (Greenhalgh *et al.* 2004, 597-598).

Many of these attributes speak specifically to the HAIFA tool. In particular, the concept of "fuzzy boundaries" seems apt for a tool which has been conceived both as a functional "hard core" of the innovation, and a set of knowledge which may be adapted for use in a number of settings.

Likewise the issue of risk, particularly as it is framed in relation to uncertainty has specific relevance for innovations which seek to improve adaptation to climate change, a set of processes characterised by an "uncertainty explosion" (see Baker ***et al.*** 2012 and Adger and Vincent 2005). The remaining attributes (task issues, knowledge required to use it, and augmentation/support) are also relevant, particularly from the perspective of the assertion that it is "extremely unlikely for any adaptive work to be undertaken in light of climate change alone" but rather is likely to occur as part of exiting initiatives or programmes of work (see Smit and Wandel 2006, 285).

Wejnert (2002) adds a further layer to these attributes, highlighting that whereas most literature has focused on actor perceptions of innovation attributes, there also exists a literature in which these attributes are afforded agency in and of themselves. She highlights the differential impact of whether an innovation is characterised by public versus private consequences, and the different methods by which innovations can be channelled as a result. She also notes the impact of costs (both direct and indirect) versus benefits as an innovation attribute and notes that these "often inhibit adoption, especially when costs exceed an actor's resource potential" (Weijnert 2002, 302).

Despite the abundance of attributes identified as impacting on the adoption of an innovation, as Greenhalgh ***et al.*** (2004, 598) note, "the attributes are neither stable features of the innovation nor sure determinants of their adoption or assimilation. Rather it is the interaction among the innovation, the intended adopter(s), and a particular context that determines the adoption rate". Such a statement behoves us then to consider initially the characteristics of these intended adopters and the context of the adoption rate, in addition to how information is communicated within these contexts.

3.2 Characteristics of Innovators

Within the standard model of technology transfer in agriculture, the characteristics of innovators was traditionally given a prominent, indeed explanatory role in understanding the diffusion of innovations. The early consensus, established by the mid-20th century, held that the spread of an innovation was due largely to the psychological characteristics and personality traits of adopters. As Smith ***et al.*** (2008) note, this belief was reinforced by the repeated identification of "Bell" and "S" shaped curves in mapping the diffusion of an innovation through a population. Adopter categories based on personality characteristics were defined and fitted to these statistical distributions, in the process introducing a vocabulary of early adopters and laggards which "highlighted the inherent assumption that change was "good" and that the responsibility and capacity to change resided firmly with the respondents..." (Smith ***et al.*** 2008, following Jones, 1967). However, as Smith ***et al.*** (2008, 3) note:

"The capacity to match personality traits and characteristics with a statistical distribution, on hindsight at least, resulted in the assumption that a causal relationship had been established, and is a useful cautionary tale that statistics don't equal science and that a statistical correlation is not necessarily evidence of a casual relationship".

Despite this, there remains a range of adopter attributes which are considered important in understanding the adoption decisions of individuals.

Greenhalgh ***et al.*** (2004, 599-600) outline seven key aspects of adopters and their interaction with the adoption process, including general psychological antecedents as outlined above, context specific psychological antecedents, the meaning an innovation has for a potential adopter, the context within which the adoption decision takes place, and concerns of adopters across the preadoption, early use and established use phase. In doing so, they explicitly distance their account from the judgemental and inadequate language of "laggards" and "early adopters" to highlight how innovators

> *"seek innovations, experiment with them, find (or fail to find) meaning in them, develop feelings (positive or negative) about them, challenge them, worry about them, complain about them, "work around" them, gain experience with them, modify them to fit particular tasks, and try to improve or redesign them – often through dialogue with other users"* (Greenhalgh ***et al.*** 2004, 598).

These processes of "working on" an innovation and discussing an innovation highlight two further aspects of the innovation process, specifically the characteristics of the receiving environment and the communication channels and processes.

3.3 Characteristics of the receiving environment

The characteristics of adopters outlined above is based on understandings of the adoption of innovations by individuals. As the HAIFA tool is intended for general public distribution to enable diverse organisational access, rather than through individual decision-making units, it is important to consider the role the characteristic of organisations play in mediating the adoption process. Greenhalgh ***et al.*** (2004) argue that as much of the diffusion of innovation has focused on simple innovations, where the unit of adoption is the individual, it is important not to over generalise such findings to the diffusion of complex innovations within, in their case, service organisations. As they argue: "In such circumstances, there is almost always a formal decision-making process, an evaluation phase, or phases, and planned and sustained efforts at implementation" (Greenhalgh ***et al.*** 2004, 601).

We discuss the specific practices associated with planned dissemination of an adoption within an organisation in a later section, but it bears highlighting here that in undertaking such processes, an organisation's structure, culture and resources must all be accounted for in understanding these processes (Nutley, ***et al.*** 2002). Greenhalgh ***et al.*** (2004) highlight three critical organisation features which are implicated in the decision to adopt innovations: structural determinants of innovativeness, absorptive capacity for new knowledge, and receptive context for change.

3.4 Communication channels and communicators

In the diffusion of innovation literatures, a general distinction is made between interpersonal and mass media channels when assessing the impact of communication channels on the uptake and adoption of an innovation (Rogers, 1995). However, where mass communication has the ability to raise awareness of an innovation, it is widely recognised that "interpersonal influence through social networks... is the dominant mechanism for diffusion" (Greenhalgh ***et al.*** 2004, 601). In particular, the role of change agents and opinion leaders has been identified as an important factor in influencing technological change (see Rogers 1995).

Opinion leaders are thought to exert influence over the adoption decisions of their peers (see Rogers 1995; Greenhalgh ***et al.*** 2002). Greenhalgh ***et al.*** (2004) have highlighted the difficulties of harnessing the influence of opinion leaders, and note that where this has been planned, the results have been disappointing. They also note that the influence of opinion leaders may be monomorphic (restricted to a single innovation) or polymorphic (being influential across a range of innovations).

Change agents have been identified by Nutley ***et al.*** (2002, 12, following Rogers 1995) as being those "who work proactively to expedite and widen innovation". In the agricultural extension model, these change agents have traditionally taken the form of extension agents appointed by the state, or private providers, working as intermediaries between researchers/scientists and end users. The ability of change agents to work with both of these groups is critical to their success. Equally, it has been asserted that they work best in partnership with opinion leaders (Nutley ***et al.*** 2002, following Rogers 1995).

Within the context of organisational innovation, Greenhalgh ***et al.*** (2004, following Backer and Rogers 1998 among others) have also distinguished the role of "champions" from that of opinion leaders in providing opinion leadership. In this context, "champions" have been conceptualised as:

- Organisation mavericks
- Transformational leaders
- Organisational buffers
- Network facilitator

These different champion roles provide a range of contexts in which a champion might promote the adoption of a specific innovation.

3.5 Key criticisms of the Diffusion of Innovations approach

This section has outlined the key characteristics of the Diffusion of Innovation approach as outlined by Rogers (1995). As noted throughout this section, and reiterated through the remainder of this review, the pervasiveness of this approach throughout theoretical and practical discussion of the adoption and diffusion of innovation and knowledge through social networks indicates its utility in understanding these processes (see Greenhalgh ***et al.*** 2004). However, inevitably such pervasiveness is accompanied by equally well-established critiques which outline the limitations of this approach in explaining these same processes. These have been expressed by a number of authors as representing a range of biases (see Botha and Atkins 2004; Smith ***et al.*** 2008).

Botha and Atkins (2005) summarise many of the key criticisms of the model. They note that the theory has a pro-innovation bias, in that it assumes change to be a good thing and reflects this position in the value laden classification of later adopters as "laggards" (see also Smith ***et al.*** 2008). They also note that the model emphasises "individual blame" at the expense of a more nuanced understanding of the impact of social structures on the decision to adopt an innovation (Botha and Atkins 2005). This criticism speaks directly to observations made by Shove (1998) in relation to the utility of the technology transfer framework for understanding what is an inherently social process (see Section 5.3).

4. From extension to participation and systems: Methodological development in technology transfer

The theoretical framework for understanding the processes of innovation diffusion outlined above have at their foundation a linear conceptualisation of the process of transferring knowledge or technology from the developer to the user. Within this literature, the "adopter" is conceptualised as the recipient of the "innovation" and each has been characterised by a range of attributes which influence adoption. As Rogers (1986) argues, this conceptualisation of innovation diffusion is heavily influenced by the history of agricultural extension model, which was developed on the basis of viewing farmers as "passive recipients of information that they should uniformly adopt and apply" (Klerkx and Jansen 2010, following Leeuwis and Van den Ban 2004). Rogers (1986) refers to this model as a set of assumptions, principles, and organisational structures for diffusing research results, specifically within the context of farm audiences in the United States. He goes on to assert that this model is a "centralised" one, where a government agency was responsible for diffusing agricultural technologies.

While the conceptualisation of the technology transfer process has its root in the centralised process described by Rogers, the extension of the process into other knowledge transfer contexts has witnessed a shift towards less centralised processes, and as such a reconceptualisation of the form of these processes. Ward ***et al.*** (2010) in their thematic analysis of the literature relating to transferring knowledge into action, identify three key knowledge transfer processes:

1. A linear process
2. A cyclical process
3. A dynamic multi-directional process

These rough distinctions in knowledge transfer processes can be seen as roughly approximating shifting understandings of the relationships between funders, researchers and end-users in the technology transfer process. In this review these processes have been equated with shifts in the theory and practice of extension as representing respectively, the standard model of technology transfer, the shift to participatory approaches, and the emergence of the idea of innovation systems within agricultural extension.

As outlined above, the standard model of technology transfer, has its roots in the rural sociology literature, in particular with the work of Ryan and Gross (1943) and the meta study of the processes of innovation diffusion by Rogers, whose *Diffusion of Innovations* is now into its fourth edition. This standard model of transfer is typically conceived as a linear flow of knowledge or information from scientists to transfer agents and on to users (Guerin 1999). As also outlined above, within this conceptualisation of the innovation process, the path to adoption of an innovation sees an individual (or social network) pass through a series of stages:

1. *Knowledge of the innovation*
2. *Persuasion of the attributes of said innovation*
3. *Decision on whether or not to adopt the innovation*
4. *Implementation of the innovation in practice*
5. *Confirmation (or rejection) of the continued use of the innovation*

The standard model outlined above has been subject to longstanding critique of its core attributes. As Smith ***et al.*** (2008) note these critiques were reflected in a shifting consensus about the linear model of technology transfer:

> *"By the early 1950s there was a broad consensus among scientists and extension officials that the process of behavioural change, in particular the process of technology transfer or "innovation diffusion" was well understood. By the mid-1970s this consensus was crumbling. Today, in the early 21st century, there is renewed questioning of our understanding and capacity to effectively promote*

technical change".

In particular, models of innovation began to make explicit the shift from a focus on "science push" to actively develop what has been termed "demand pull" (see Nutley ***et al.*** 2002).

This recognition of the goals and aspirations of end-users as informing the innovation process has been put into practice through the focus on participatory research approaches. The evolution of participatory approaches has also been conceptualised as evolving from a recognition that the challenges posed by extending sustainable agriculture have forced governments to rethink their traditional extension practices (Bruges and Smith 2008; Vanclay and Lawrence 1995).

As Hoffmann ***et al.*** (2007, 355) note in the context of agriculture, the basic idea of participatory approaches is that researchers and farmers "have different knowledge and skills, which may compliment (sic) each other and that by working together the two groups may achieve better results than by working alone". However, this assertion is in contrast to significant debate about the purpose of participatory approaches. Some authors believe that such engagements should primarily be functional and argue that: "We cannot judge farmer participatory research by any other standard than its ability to generate useful new technologies for rural people" Bentley 1994, 143). While others argue that such approaches should be viewed principally, if not solely, as a means to advance the aspirations of a community to advance their own goals (see Pain and Francis 2003; Reason and Bradbury; 2001; Stoecker 2005). The result of these discussions has been an acceptance of a continuum of participation in research projects (Pretty and Chambers 1993).

Regardless of which of these positions is more theoretically robust, Bruges and Smith (2008, 14) note that such participatory approaches are increasingly being deployed in the service of policy goals in "complex, uncertain, and contested environments where more conventional research methods have been ineffective". As a result, these approaches have been given specific attention in the context of the science-policy interface, where "participatory processes" are seen to include a vast range of engagements between "science" and the "public" (McNie 2007; Smith and Kelly 2003).

Any discussion of participatory research in the New Zealand context, must address their specific manifestations in working with Maori. In particular, Wilcox ***et al.*** (2008) identify that the recognition of different values of participants in such cross-cultural participatōry projects is of crucial importance to ensuring effective participatory engagements. In addition, and with particular relevance in relation to climate change, a consideration of how these values inform Maori conservation values is important

(Roberts ***et al.*** 1996).

5. Crossing the Implementation Line

This section takes its title from a paper by Paul Leonardi, in which he deploys the idea of the "black box" of implementation to highlight the relationship between the fields of development and use of technology. As Leonardi (2009, 294) argues, "conceptualising development as ending with a black box, and use as beginning with one, means that the implementation line – that space between development and use – becomes an important empirical and disciplinary divide".

While Leonardi's (2009) analysis highlights the interaction of these two spheres through a lens of organisational change, the concept of the black box provides a useful metaphor for highlighting a key limitation of the technology transfer literature for understanding the uptake of the HAIFA tool. That is, the suggestion that the HAIFA "technology" can be "transferred" by passing from development to use. This section, then, uses this metaphorical starting point to highlight some recent thinking on theoretical and practical approaches to crossing the implementation line with the intention of improving the use of the use of the HAIFA tool.

5.1 Dissemination, routinisation and adaptation

Research elsewhere in the HAIFA project has highlighted the role of organisational form and institutional readiness in determining the successful adoption of innovations (see Baker ***et al.*** 2012; Baker and Winstanley 2012). In particular, this work has identified a lack of existing practice or intent to support the promotion of information for action in relation to addressing the health-related impacts of climate change. In addition, this work has outlined the impact of institutional readiness in achieving such an orientation.

In the context of the transfer of technology literatures, and specifically, the processes of innovation diffusion, Greenhalgh ***et al.*** (2004) draw an explicit distinction between the processes of diffusion and dissemination. They argue that in the context of a planned dissemination process, the uptake of an innovation will be more likely where the program organisers:

1. Take full account of potential adopters' needs and perspectives, with particular attention to the balance of costs and benefits for them;
2. Tailor different strategies to the different demographic, structural, and cultural features of different sub-groups;
3. Use a message with appropriate style, imagery, metaphors, and so on;
4. Identify and use appropriate communication channels; and
5. Incorporate rigorous evaluation and monitoring of defined goals and milestones. (Greenhalgh ***et al.*** 2004, 603)

This list incorporates many of the key components of effective science communication, or communication generally. However, it also highlights the linear communication inherent within the technology transfer process in its standard form. However, within these dissemination principles also lie pointers for engaging with end-user to improve the adoption of an innovation. In particular, the suggestion of identifying and employing appropriate communication channels is important.

As outlined above, participatory approaches provide opportunities for engagement which allow for the dissemination principles to be given voice in a range of contexts. Preston ***et al.*** (2008, see also Measham ***et al.*** 2010 for further analysis) outline a process of climate changing vulnerability mapping used as a mechanism for stakeholder engagement with local government. In outlining their process they highlight the importance of guiding stakeholders in the interpretation of results, the challenges which arise where inconsistencies arise between assessed vulnerability and stakeholder beliefs, and the importance of transparency in addressing such challenges.

In the context of dissemination, and specifically to the tailoring the process to end-user needs, it is perhaps pertinent here to mention the process of mainstreaming. As Baker ***et al.*** (2012) have identified, the idea of mainstreaming is based on a belief that it is unlikely that adaptive work for climate change is

likely to "occur as incremental modifications to existing initiatives" (Smit and Wandel 2006, 289, see also Patterson ***et al.*** 2012; Clarke and Berry, 2012). As such, the designing of any dissemination strategy must be cognisant of the ways in which the HAIFA tool, incorporating the tool itself and the knowledge it can produce, could be put to use in the service of other goals.

5.2 Motivating practice change for climate change adaptation

The challenge of motivating behaviour change in support of adaptation and mitigation in relation to climate change has been the source of much angst among researchers and policy makers. Work elsewhere in the HAIFA project (see Baker ***et al.*** 2012) highlights how ongoing definitional issues, as well the challenge of accounting for the "uncertainty explosion" (see Adger and Vincent 2005) make the task of motivating adaptation to climate more difficult.

Gifford (2011) has articulated the idea of "dragons of inaction" to account for a range of obstacles which limit environmental behaviour change, which positions uncertainty as but one of a range of barriers associated with limited cognition. While it can be argued that the adoption of a knowledge tool such as HAIFA by local government and public health organisations may appear to avoid these individual "dragons" the evidence as expressed in work elsewhere in this project has demonstrated that even within these organisations scepticism persists and uncertainty confounds the decision-making processes in these sectors (see Baker and Winstanley 2012). As such, it seems justified to reflect here on a range of creative contributions to the field of science communication specifically for climate change.

The Centre for Research on Environmental Decisions (CRED 2009, 2) has produced a guide for scientists, journalists, educators, political aides and the interested public which aims to provide "principles derived from the social sciences concerning how to communicate effectively about a topic that is complex, confusing, uncertain, sometimes overwhelming, and often emotionally and politically loaded". They go on to note, following their own research, that for such communication to be effective it must be "actively communicated with appropriate language, metaphor and analogy; combined with narrative story-telling; made vivid through visual imagery and experiential scenarios; balanced with scientific information; and delivered by trusted messengers in group settings".

Their guide outlines an eight-stage plan for achieving such effective communication. Mirroring many of the lessons outlined through the diffusion of innovation literature, but also emphasising key tenets of successful communication practices more generally. These stages are:

1. Know your audience
2. Get your audience's attention
3. Translate scientific data into concrete evidence
4. Beware the overuse of emotional appeals
5. Address scientific and climate uncertainties
6. Tap into social identities and affiliations
7. Encourage group participation
8. Make behaviour change easier.

Taking these functional guidelines one step further, advertising firms specialising in environmental issues have proposed ways of "selling the sizzle" of climate change, rather than focusing on the potential negative (or even catastrophic) outcomes of a continued failure to develop coherent mitigation and adaptation plans (Futerra Sustainability Communications undated). Vanclay (2004: 220) has made a similar argument in relation to the promotion of land management practices to mitigate environmental degradation. In particular, such approaches emphasise that the benefits of climate change, or our adaptive strategies for climate change, must be emphasised above the focus on the negative consequences of not addressing the issue.

5.3 Beyond technology transfer

While the literatures relating to the transfer of technology from developers to users has over the last fifty years increasingly emphasised the importance of understanding these processes as representing part of the process of meaning creation around specific technologies and their relation to the lived experience of users, this same literature has struggled to dispel the 'ghosts' of deterministic practice change (Smith *et al.* 2008). In particular, Smith ***et al.*** (2008) highlight the continued use of terminology which emphasises the pro-innovation bias, both in the continued use of the term "technology transfer", but also with the continued reference to terminology which suggests that "failure" to adopt or change behaviour reflects universal behavioural characteristics.

Elizabeth Shove, in her work on practice change relating to energy-efficient building technologies has argued persuasively for the abandonment both of the terminology of technology transfer, and in the process challenges the twin pillars of the approach: "technical potential" and "social barriers" to adoption. Shove (1998) argues that the linear model of technology transfer assumes that this "technical potential", that is the potential benefits which might accrue from the adoption of a technology by a population, is in turn confounded by a range of social obstacles or barriers which limit the achievement of this potential. She notes that in the linear model of technology transfer the transfer of knowledge from research to practice is hastened by technology transfer processes which increase adoption, before noting:

> *But what if knowledge does not translate into action in this way... and what if actors creatively and selectively scavenge for ideas that promise to improve their lot – whatever that lot might be* (Shove 1998, following Bruno 1991).

However, while such a wholesale rejection of the terminology of technology transfer and in the process its structural components may seem attractive at first glance, Smith ***et al.*** (2008: 5) note that in agriculture at least, the framework provides a "relatively simple framework that allows easy evaluation of "success"", and one that arguably works. When combined with the structural components of the research system as outlined by Shove (1998), it would seem the model in some form will be with us for a while yet.

Avoiding the area of technology transfer specifically, a range of research within the social sciences has sought to mobilise research capacity to improve understandings of the ways in which solutions to societal problems can be approached through disciplines whose focus is society. In the United Kingdom, the Academy of Social Sciences and the British Psychological Society, in a series of papers "Making the Case for the Social Sciences", have highlighted a range of work which is doing just that in relation to climate change and environmental issues. In addition, the National Climate Change Adaptation Research Facility has produced an adaptation research plan which outlines an agenda for understanding the social, economic and institutional dimensions of climate change. This work emphasises both the contribution that the social sciences can make to addressing the impacts of climate change and highlights the paucity of work currently occurring in this space.

6. Summary

This review has reviewed literatures associated with the theory and practice of technology transfer. While the review originally set out to document best practice technology transfer for the dissemination of the HAIFA tool, the literature on technology transfer is not one which lends itself easily to the development of such a document. Specifically, the literatures that address technology transfer, innovation diffusion and extension have contributed to and drawn on a range of disciplinary work on the uptake of technological development and the processes of technological change. This wide disciplinary focus makes distilling a set of best practice guidelines somewhat ambitious.

Nonetheless, this review has achieved three important outcomes for developing a strategy for the dissemination of the HAIFA tool through communities of end-users. The first is an account of the diffusion of innovation literature. This account is largely informed by the studies within the discipline of rural sociology, which is widely cited as the well-spring for innovation diffusion study. In particular the work of Everett Rogers, which has in turn informed cross-disciplinary studies of diffusion (Greenhalgh ***et al.*** 2004). This component of the review highlighted the roles which the characteristics of the innovation, characteristics of innovators, communication channels, and characteristics of the receiving environment play in the diffusion of innovations. Identifying how the combination of these factors may interact in the dissemination of the HAIFA tool among distinct communities of end-users should be a priority in developing a communication strategy.

Second, the review has highlighted the shift from models of technological change which emphasised the linear transfer of knowledge from developers to users. In particular, the review mapped the shift from linear "extension" to the use of a range of participatory approaches to improve the development and uptake of innovations. While the HAIFA project has incorporated elements of such approaches in its research design, there is a need to ensure that the relationships developed through this process are built on in the development of a dissemination strategy for the tool. In particular, it is essential that such a strategy allows adequate space for end-users to contribute to the development of a framework in which the tool might add value to their work.

Finally, the review has highlighted a range of recent developments in the social sciences in communicating science in the context of climate change adaptation. This includes identifying the specific factors which influence the success of a planned dissemination of an innovation, including the likelihood that such an process in relation to the HAIFA tool may need to look to "mainstream" the tool in existing decision-making processes. In addition, the review highlighted recent examples of end-user engagements which aimed to use technologies to inform adaptation planning in relation to climate change. The review also reflected on Shove's (1998) questioning of the utility of the language of technology transfer in structuring research programmes.

While these contributions to planning the dissemination of the HAIFA tool may fall short of the stated intention of this review to define best practice technology transfer they nonetheless highlight the key characteristics of successful dissemination. In doing so, the review highlights where effort should be expended in the communication of the research programmes results with end-users and the identification of how the tool might be used, or reinvented within the context of use, to inform decision-making in relation to managing the public health risks associated with climate change.

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