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Original paper

Knowledge exchange and adoption to enable safer post-disaster self-recovery

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Abstract Despite extensive knowledge on disaster risk reduction and knowledge transfer studies since the 1970s in management and classroom situations, the adoption of knowledge to reconstruct more hazard-resistant housing after a natural disaster is still rare in self-recovery processes. Approximately 85% of the disaster affected populations recover without humanitarian or governmental shelter assistance. Hazard-resistant construction guidelines are infrequently applied, and new insights from scientific research rarely lead to changes in policy and practice. As a result, disaster affected populations remain vulnerable in case of recurring disasters. The focus of this study is to understand where and why the exchange of knowledge and adoption of knowledge fails in the self-recovery process. The literature presents causes for the rejection of knowledge as the lack of institutional structures and communicating science, and proposes to engage both ends of the producer-user spectrum in a dialogue to negotiate a consensual view of what is feasible and desirable. Currently, governmental and humanitarian organisations involved in recovery aid have difficulty designing communicative interactions effectively in communities using and diffusing hazard-resistant construction guidelines. To reach and support the 85% in self-recovery processes, there is a need to develop an adequate understanding of how knowledge exchange and adoption in such interactions can be more effective. To address this challenge, we propose an analytical framework to evaluate knowledge transfer interventions in self-recovery processes. Current knowledge interactions in post-disaster recovery are examined and critically analysed using existing knowledge exchange literature. The framework intends to highlight barriers and failure mechanisms that may hamper the knowledge adoption. This analysis provides proposals based on logic to overcome these obstacles; lifting barriers, strengthening trust, matching need and knowledge and reducing risk of adoption failure. The value of these proposals needs to be verified in field research. In line with the proposals a second framework is proposed, that enables the analysis of knowledge exchange interventions, as knowledge exchange is essential for adoption.

Key words Knowledge exchange; Science-policy gap; Self-recovery; Knowledge adoption; Disaster risk reduction; Community resilience.

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1. INTRODUCTION

Natural hazards are affecting increasingly large populations (Dominey-Howes 2015). In contrast to what might be expected, worldwide less than 15% of the affected population receives shelter assistance after a disaster by humanitarian organisations (Parrack *et al.* 2014). This leaves the majority, the remaining 85%, to improvise their own shelter, without humanitarian or governmental shelter assistance (Parrack *et al.* 2014).

In this rather unexplored phenomenon of self-recovery processes, although essential for community resilience, the provided hazard-resistant construction guidelines are generally little applied and poorly communicated (Opdyke *et al.* 2016). Developing more effective (knowledge providing) interventions is crucial to the efficacy of the use of disaster relief resources and to a sustainable housing solution for the people affected. In this article, interventions are considered more effective when they lead to an increase of the hazard-resistance of reconstructed housing due to an effective knowledge exchange (process) in which interaction between actors leads to adopting and adapting provided technical knowledge to the local context

This requires a better understanding of existing communication and interaction between the various actors involved to identify barriers and failure mechanisms in knowledge adoption in self-recovery processes. Therefore, in this article an analytical framework based on knowledge transfer is developed and applied to identify existing barriers and failures. This identification allows to formulate proposals for the design of more effective interventions applying knowledge exchange principles, for which a new analytical framework is then proposed.

2. EXPLORING THE LACK OF ADOPTION IN SELF-RECOVERY PROCESSES

Gap between science policy and practice

Numerous researchers studied the gap between science, policy and practice in disaster risk reduction. Studied is the role of different stakeholders (Abedin and Shaw 2015, Izumi 2018), different networks (Islam and Walkerden 2017), and the role of different types of knowledge (Shaw *et al.* 2018; Spiekermann *et al.* 2015) and communication strategies (Nakamura *et al.* 2017).

With reference to the gap between science, policy and practice, Spiekermann, Kienberger and Norton (2015), identified knowledge challenges and factors hindering the use of knowledge in disaster risk reduction. They introduced a model to analytically identify barriers in practice that systematically lead to fragmentation of knowledge shown in Figure 1.

Regularly, indigenous knowledge is disregarded by scientists while local actors are little aware of scientific knowledge (Spiekermann *et al.* 2015). Therefore, on the one hand, scientific research findings of Disaster Risk Reduction (DRR) rarely find their way to local decision-makers. On the other hand, local, tacit and personal knowledge are common areas of ignorance in knowledge by scientists and NGOs, although of significant importance in decision-making (Spiekermann *et al.* 2015; Polanyi 1966).
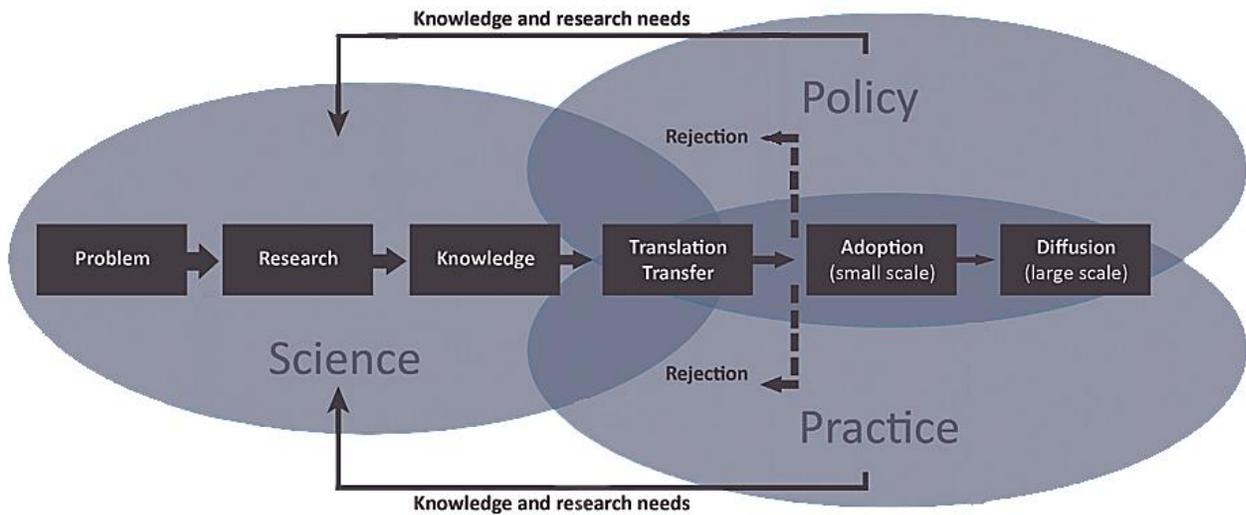
Figure 1. The rejection of scientific knowledge through transfer simplified from Spiekermann et al.(2015)

Knowledge exchange includes a knowledge transfer from policy to science and from practice to science, providing a better-informed development of scientific knowledge, and potentially enabling a higher application of hazard-resistant construction principles in practice, in order to obtain more successful adoptions in practice. Success of adoption is defined by whether hazard-resistant construction principles are to a large extend applied in self-recovery. Figure 1 indicates the current situation where scientific knowledge is rejected before it is adopted and diffused in practice and policy. The model in Figure 1 is explained with a number of causes for the gap from which a few are related to the interaction; *(1) the lack of designing knowledge, (2) the lack of communicating science, (3) the lack of appreciating the cultural context.* Most important in their analysis for our article is the indicated research need to investigate how to design knowledge and facilitate knowledge exchange. To be exact, they propose to facilitate *"engagement of both ends of the producer spectrum in a dialogue to negotiate a consensual view of what is feasible and desirable"* to enable an effective adoption in practice. They highlight that there is currently a lack of research on the role of communication to enable adoption in those situations.

Knowledge exchange

Often indigenous knowledge is disregarded by NGOs and scientists while local actors have little awareness of scientific knowledge, leading to uninformed decision making (Spiekermann *et al.* 2015). No actor possesses the complete knowledge, and therefore, existing knowledge needs a holistic interpretation to be used more adequately (Hayek 1945; Edgar and Schofield 2001; Shi *et al.* 2012). So, knowledge cannot be regarded as a universal or shared truth but rather as a model for reality based on the bits of knowledge that are revealed (Stehr 2009).

Knowledge exchange, as opposed to one-way transfer, is a two-way negotiative sequence of knowledge transfer between actors and leads to a better agreement of ideas and therefore a stronger

adoption of knowledge within communities (Fazey *et al.* 2014). Knowledge exchange considers information, experience and skills from all actors involved, and is considered more appropriate in these self-recovery situations since local assets are considered (Moser 1998). In knowledge exchange the limitations recognized by the actors, that are supposed to apply knowledge, are taken seriously and form the basis for the development of new design solutions. In knowledge exchange the actors develop knowledge together that is suitable for the situation it is meant to be applied in.

In the management of organizations, effective knowledge exchange is broadly recognized as a key to success and increasingly elaborate on (Pruzak 2009). Through knowledge exchange organizations are in theory likely to be more innovative, efficient and successful on the marketplace (Argote 2012; Grant 1996; Inkpen 1998; Levin and Cross 2004). Though, management related literature already acknowledges the difficult challenge of knowledge exchange in practice (Levin and Cross 2004; Szulanski, 1996; Argote *et al*. 2000). Although heavily discussed in organization management (Levin and Cross 2004; Goh 2002; Rai 2011; Al-Adaileh and Al-Atawi 2011; Bartol and Srivastava 2002), in the field of humanitarian aid and in specific post-disaster recovery the role of knowledge exchange is relatively unexplored. In addition, the facets of knowledge are seldom comprehended or distinguished in a context of disaster risk reduction. Nevertheless, a few academic studies recognize the potential benefits of effective knowledge exchange for disaster risk reduction and post-disaster recovery and have addressed different aspects that hinder the application in practice (Spiekermann *et al.* 2015; Weichselgartner and Pigeon 2015; Thanurjan and Seneviratne 2009; Abedin and Shaw 2015). The value of knowledge exchange in post-disaster recovery lies in the ability of a community to learn from previous disasters and apply new skills to protect themselves.

Humanitarian interventions and knowledge exchange

Although comprehensive research is lacking in this area, evidence suggests that most post disaster NGO programmes do not have a lasting effect on community resilience, (Spiekermann *et al.* 2015). The humanitarian organisation CRS has found, through a limited pilot study in different countries, indications for five determinants of behaviour that significantly influence the adoption of hazard-resistant construction principles by non-beneficiaries (Turnbull *et al.* (2015) 2015). These determinants found are; cues for action, access, perceived risk, perceived positive consequences and perceived self-efficacy. In this article we deepen this knowledge by studying knowledge-based interventions.

The authors have not found any in-depth descriptive study into self-recovery processes that confirms these determinants solely for hazard-resistant construction principles. Further, no study has been found analysing the existing local knowledge networks and how they can be optimized for self-recovery. Little is documented about the knowledge needs of local actors in their disaster recovery, and their knowledge and opinions are under-represented in global decision-making during the disaster recovery (ARUP International Development 2012; Gaillard and Mercer 2013). A higher priority needs to be given to the design of interactions as part of a learning system that encourages the adoption of hazard-resistant construction principles (Twigg 2004). Therefore, both technical and social expertise need to be combined.

Self-recovery and knowledge exchange

This paper proposes to focus on knowledge exchange in communities who self-recover after

disaster. Self-recovery is inevitable in many post disaster situations (Parrack *et al.* 2014) and can be beneficial in a number of ways. It creates autonomy of the end-user in the design and building process and the liberty of expression of local identity (Harris 2003). It enables the preservation of tradition at a local level which is important in post-disaster recovery (Alexander 1989). Community-led construction activities contribute to higher psychological recovery of disaster survivors than in projects with involvement of external parties (Leon *et al.* 2009; Kennedy *et al.* 2008).

Self-recovery is here defined as the shelter repair or housing reconstruction process in which members of a disaster-affected population take full responsibility, independently from humanitarian or governmental physical shelter assistance. Even though directly after a disaster it is often required to turn to external aid for immediate relief, in self-recovery the affected population decides how their homes are rebuilt or repaired, whether they build the shelter themselves or procure local labour to do so. Local organisations, governmental institutions and NGOs may provide purely (building) materials or tools. Self-recovery does not include projects and processes in which external parties select the beneficiaries and/or beneficiaries provide manual labour to rebuild homes under instruction of other persons leading the project (Parrack 2017).

Included in the definition of self-recovery are processes in which local organisations, governmental institutions or NGO's try to assist with knowledge to build back safer. However, currently, knowledge assistance is rarely provided for or even considered in any strategy to support self-recovery (Parrack 2017).

There is a lack of validated data to compare guided shelter projects with self-recovery processes which enables to identify and prioritize specific hurdles (Parrack *et al.* 2014). Currently, interventions based on hazard-resistant construction guidelines are applied by NGOs without having a profound understanding of the construction knowledge needs in self-recovery. Therefore, aid organisations are searching for tools and methods to efficiently support self-built initiatives (Saunders 2004).

The evidence on how knowledge is transferred in shelter self-recovery is open to debate. An evidence synthesis commissioned by the Humanitarian Evidence Programme on the effectiveness and efficacy of interventions supporting shelter self-recovery following humanitarian crises concluded '*There are unclear findings about the effects of humanitarian interventions on... knowledge of safer construction techniques*' (Maynard *et al.* 2017, p62). The evidence identified by this study consisted of only a small number of papers, eleven in total, demonstrating the need for more research in this area.

A better understanding of the processes of knowledge exchange in self recovery would have significant impact on post disaster self recovery outcomes, including the safety of the reconstructed dwellings.

3. ANALYTICAL FRAMEWORK FOR KNOWLEDGE TRANSFER

Knowledge transfer framework

There is a variety of frameworks related to knowledge transfer but only few models consider knowledge exchange (Al-Adaileh and Al-Atawi 2011; Liyanage *et al.* 2009; Graham *et al.* 2006). Although the models that consider knowledge exchange indicate several general process steps to

enable adoption, clear recommendations that are applicable in disaster risk reduction are lacking (Field *et al.* 2014). Next to that, very few analysis models for knowledge transfer are used in practice by the policy makers or practitioners. Though, Weichselgartner and Marandino (2012) and Spiekermann *et al.* (2015) already attempted to clarify if and how knowledge has an influence on different disaster phases with the Disaster-Knowledge-Matrix (Spiekermann *et al.* 2015) and the information flow model (Spiekermann *et al.* 2015). These evaluation models focus on what data, information, knowledge or wisdom is used, misused, disregarded or lacking in the transfer of knowledge between actors. However, the model is multi-interpretable for practitioners when it comes to distinguishing data, information, knowledge and wisdom in practice and leads to little specified outcomes. Next to that, not all emergency phases as defined by Spiekermann *et al.* (2015) are relevant to combine in practice. In this article we are for example only interested in the recovery phase. Besides that, the existing models do not evaluate the indicators used to map the effectiveness of knowledge exchange. Next to that, only few models also discuss the adoption, application or uptake of knowledge as a success criterion for effectiveness (Graham *et al.* 2006; Liyanage *et al.* 2009; Tromp and Bots 2016).

In this article we have chosen to adapt a model from Tromp and Bots (2016) presenting a framework for knowledge transfer and adoption for one sender and one receiver. Their framework brings to the fore possible barriers and failure mechanisms which could limit the effectiveness of knowledge transfer and adoption. That framework is in this article adapted to an analytical framework of knowledge transfer between multiple actors in post-disaster self-recovery processes. The framework of Tromp and Bots (2016) is not necessarily the most appropriate model as it excludes for example resource-based barriers. However, the model can be used to dissect possible failure mechanisms and barriers in our context prior to field research and help to design interventions through a list of proposals for more effective adoption (cf. Chapter 4).

The adapted framework allows analysis of current interventions based on one-directional knowledge transfer and relies on a collaboration model that distinguishes three types of actors: technical experts, end-users and local constructors. In the situation of self-recovery, end-users and local constructors are responsible for the reconstruction processes, and might adopt expertise to build back safer as provided by the technical experts. In self-recovery processes end-user and constructor are sometimes the same person. These three types of actors have the following characteristics:

- **Expert:** The technical expert is an actor from outside the community, knowledgeable on how to construct hazard-resistant houses. The proposals for interventions in Chapter 4 are based on the control we could have on this technical expert.

- **Constructor:** The constructor is an actor from within the direct area of the community, to a certain extend knowledgeable on how to construct a house with local construction techniques, sometimes based on own experience. The constructor is likely to be consulted or hired by end-users in the reconstruction process, and therefore considered essential in the adoption process.

- **User:** The end-user is an actor of the affected family who will live in the house, knowledgeable on the family's preferred spatial preferences, financial limitations and priorities.

Focus in this analytical framework (Fig.2) lies on the knowledge (K) transfer from Expert to User and to Constructor.

This transfer encounters various barriers (B) and failure mechanism (F) in its success to enable adoption (A), and is more effective when knowledge receiver (User or Constructor) trusts (T) the sender (Expert) as being benevolent and competent. Decision to adopt depends on the knowledge need (N) and the grounds(G) of those needs. Success of adoption is defined by whether hazard-resistant construction principles are to a large extend applied in self-recovery.
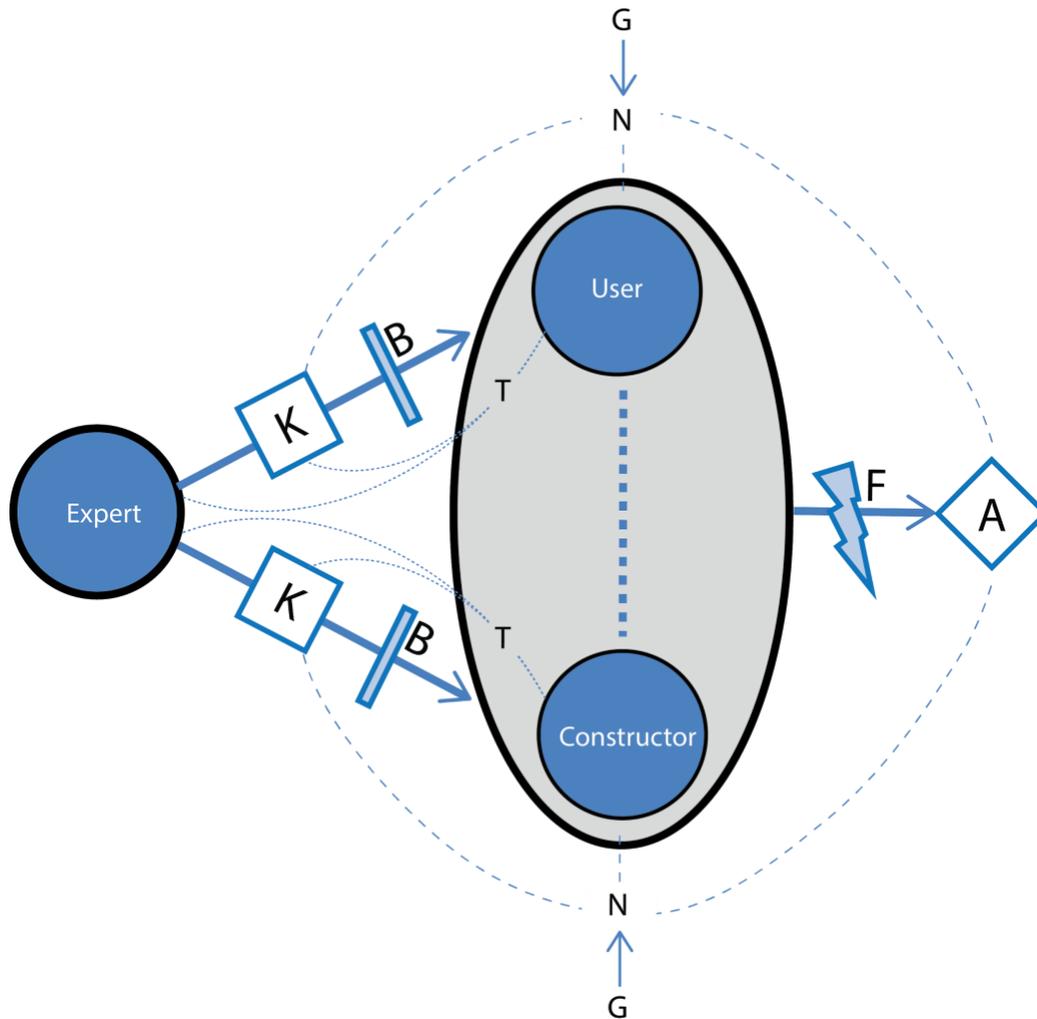

Figure 2. Analytical framework for knowledge transfer, for the adoption of hazard-resistant construction principles in post-disaster self-recovery adapted from Tromp and Bots (2016).

Clarification of the knowledge transfer framework

1) The model does not define *how* knowledge exchange is taking place. The model does not provide direct input for the exchange method and no assumptions are made about the nature of K.

2) In this framework a clear distinction between the three types of actors is proposed for a precise analysis of current barriers and failures for adoption. It does not restrict a particular actor to fulfil the role of only one type of actor.

3) This framework in used here only to consider the interaction between the expert and the constructor and the expert and the user. The interaction between user and constructor is not considered in here.

Based on the preconditions of Tromp and Bots' model (2016) there are some preconditions to be taken into considerations in the use of this framework:

1. Preconditions of knowledge transfer:

(P1)   Expert must have knowledge (K) that is relevant to the other actors.

(P2)   Expert needs to be willing to share knowledge (K).

    a) Expert must trust User and Constructor (Levin and Cross 2004, Connelly and Kelloway 2003, Davenport and Prusak 1998, Podolny and Baron 1997).

2. Preconditions of knowledge adoption (A):

    b) User and Constructor must have a particular knowledge need (N) related to hazard-resistant construction.

    c) Knowledge (K) fills at least partially the knowledge need (N), but was not earlier accessible to the actors responsible for the labour in the housing construction.

    d) User and Constructor find at least some part of the received knowledge (K) trustworthy.

Knowledge (K)

● From Expert to Constructor: hazard-resistant construction knowledge

● From Expert to User: awareness of constructive risk after disaster

Needs (N) and Grounds (G)

The effectiveness of adoption is influenced by the need for construction knowledge of User or Constructor and the grounds on which these needs are based. Barriers can occur when daily needs of households have priority over the need to construct a hazard-resistant house (e.g. obtaining enough food and clean water for the family, saving money for education, making a boat for fishing, having access to sanitation, acquiring legal land to build on)

Barriers and failure mechanisms

The effectiveness of knowledge transfer is hindered by barriers such as; cognitive barriers between the actors (B1), or resource related barriers (B2) (Tromp and Bots 2016). Failure mechanisms that hinder adoption are; incompatibility with current practice (F1), incorrect use of knowledge (F2), diffidence by other actors disqualifying the before trusted knowledge (F3), lack of diffusion because of non-receptivity (F4) (Tromp and Bots 2016). This is elaborated in Chapter 4.

4.   PROPOSALS FOR INTERACTION DESIGN

In this article we present various proposals for designing an intervention that aims to provide knowledge with a high chance of adoption, to local low-income groups for safer self-recovery after a disaster. These proposals are in tune with the presented intervention model of chapter 3 (Fig. 2) in which the expert (E) introduces new knowledge into the local community.

The proposals we describe focus on four elements:

1. Match Need (N) with Knowledge (K)

- adapt knowledge to local knowledge need through exchange and experimentation

2. Lift transfer Barriers (B) via contextualization

- Adapt knowledge to local skills and cognitive levels through knowledge exchange
- Adapt communication to local culture
- Adapt knowledge to financial possibilities and priorities of low-income groups

3. Strengthen Trust (T) in knowledge (K) and actors

- Establish positively perceived consequences of actors on K adoption
- Provide and enhance trust in the knowledge sender

4. Reduce risk of adoption Failure (F)

- Adapt knowledge to local building culture
- Apply a community learning strategy

Description proposals of intervention design:

4.1 Match Need (N) with Knowledge (K)

- *adapt knowledge to local knowledge need through exchange and experimentation*

An important aspect of a successful knowledge transfer is the ability of the receiver to use the knowledge given (Szulanski 1996), knowledge should be applicable in the context of the receiver. And thus, when the transferred knowledge is answering a need of the receiver, transfer success increases (Lövbrand 2011, Dilling and Lemos 2011). Therefore, the expert should be informed, for example through a knowledge exchange method, of the user's or constructor's need for knowledge, in order for the expert to match knowledge to this need.

The local constructor should be facilitated to familiarise with the new knowledge by means of experimentation (Goh 2002). Trialability in order to make knowledge compatible has found to be important for adoption (Rogers 2002). For effective knowledge adoption, it is important to stimulate knowledge exchange and create an innovative atmosphere in which the provided knowledge can be discussed, and new technical solutions are welcomed for testing and experimentation (Goh 1998).

4.2 Lift transfer Barriers (B) via contextualization

Via contextualization new knowledge is made compatible with the local situation (Rogers 2002). In this case the compatibility with the cognitive barriers and resource barriers are discussed.

B1: Cognitive barriers

When knowledge is transferred from expert to user or to constructor, cognitive barriers risk preventing the knowledge uptake by the receiver. These cognitive barriers can occur when the user or constructor lack prerequisite knowledge, or the transferred knowledge does not fit their understanding of the real world, or communication is distorted due to a lack of a common lexicon and/or to interpretive differences in concepts. To lift these cognitive barriers two proposals can be formulated:

- *Adapt knowledge to local skills and cognitive levels through knowledge exchange*

Through a knowledge exchange method, the expert identifies the skills and cognitive level of user or constructor. This allows the expert to establish the construction knowledge and skills already possessed within the local understanding of the world. Through this understanding of the local actors, the expert is able to adapt accordingly the knowledge to be transferred and the knowledge transfer method. This exchange method also implies checking the success of the knowledge transfer and if necessary repeat/adapt the transfer of the missing knowledge parts.

- *Adapt communication to local culture*

The way knowledge is being communicated needs to consider the existing communication culture. In many developing countries, communicating via written documents is not the standard in local communities. In addition, reading 3-dimensional images, counting, measuring, reading and writing is in many developing countries an underdeveloped skill. Communication methods that are standard in western society, such as construction manuals, cannot be expected to be universally successful. This complicates knowledge exchange and demands adapted communication methods.

B2: Resource barriers

When foreseeing unattainable financial consequences, adoption of knowledge can be discarded. Specifically, in the case of knowledge adoption with low-income groups, this leads to the following proposal:

- *Adapt knowledge to financial possibilities and priorities of low-income groups*

In developing countries affected by a natural disaster, due to the impact of the disaster on housing and livelihood, households often have limited financial means. Often the proposed technical solutions are too expensive to apply. In addition, in their recovery process, the hazard-resistance of the house might not be a first priority. If the affected population does not have land security, it is more likely that hazard-resistant construction principles are not yet applied. The lack of affordable alternatives forces low-income groups to self-built, mostly illegal, a housing solution within the proximity of their former settlement. Permanent sites for recovery are not easily guaranteed to the newly created communities (Vestbro 2008). Because of their limited financial resources, it is difficult to make the transition from the emergency sheltering to an alternative and more permanent housing solution (Vestbro 2008). Political, social and economic influences delay and obstruct the process, and as a consequence inhabitants of these supposed temporary settlements live in a long lasting insecurity and do not build back safer (Vestbro 2008).

Therefore, knowledge adoption is often not taking place. Technical guidelines need to be translated into financially feasible and practical solutions. This implies in most cases that full hazard-resistance can only be obtained to a certain degree. The transition from unsafe to safe is

gradually taking place over years of development of the community. The knowledge experts could consider a prioritisation of guidelines in time, allowing for temporary shelters to transform into permanent settlements over a relatively long period after the disaster.

4.3 Strengthen Trust (T) in Knowledge (K) and actors

Competence-based and benevolence-based trust

Knowledge transfer is more effective when the receiver believes not to be intentionally harmed by the sender (benevolence-based trust) and the sender possesses expertise in the transferred knowledge (competence-based trust) (Levin and Cross 2004 in Tromp and Bots 2016). These trusts can be strengthened by the following proposals:

- *Establish positively perceived consequences of knowledge adoption*

Adoption only takes place when it is accepted as relevant in the recovery process by the decision makers, in this case the constructor of the building who might also be the end-user. Directly after a natural disaster, where houses have been destroyed, the relative advantages of hazard-resistant construction principles is expected to be higher than normal. Therefore, establishing perceived positive consequences for the safety guidelines are more likely to be successful when communicated in the reconstruction phase after a natural disaster. Therefore, new knowledge is more likely to be adopted, when affected population perceives positive consequences when applying this new knowledge (Rogers 2002). However, misconceptions of these actors of what is considered to be relevant knowledge for their safety, leads to the challenge of how and when to organise communication in a variety of self-recovery contexts (Hayek 1945). People do not always reach a minimal threshold of concern for their own safety (Moser and Ekstrom 2010). The trust in knowledge can be increase by making its value observable. In the case of transferring hazard-resistant construction principles, structures surviving a next disaster can really contribute to the perceived value of these techniques (Rogers 2002). Therefore, real observability and trialability of the knowledge are difficult to establish during post-disaster recovery. This requires an adequate knowledge transfer method focussing on a successful communication of these positive consequences, while monitoring its perceived understanding by the affected population.

- *Provide and enhance trust in the quality of knowledge and the knowledge sender*

Besides knowledge being best transferred to recipients with similar knowledge capacities (Goh 2002), the nature of the relationship between sender and receiver can be of great importance for the effectiveness of the knowledge transfer (Goh 2002). Rogers' and Shoemakers diffusion model (1971), for example, supports the idea that the authority of the knowledge source is of influence on the acceptance of knowledge by the receiver. Nonaka (1994) has found that hierarchical levels are found not to encourage knowledge exchange.

The availability of knowledge does not imply that it is acquired, accepted or translated into actions (Spiekermann *et al.* 2015). The acceptance of the knowledge is influenced by personal expertise and trust in the quality of the knowledge. Various studies indicate that effective transfer of knowledge into action is hindered by mistrust (Newton and Weichselgartner 2014; Moser and Ekstrom 2010; Lövbrand 2011). Trust is needed for effective knowledge exchange since it stimulates actors' motivation and willingness to share information. A fundamental variable in the cooperation between groups or individuals is the level of trust (Goh 2002). A high level of trust indicates an increased willingness to co-operate and a low level of trust leads to poor cooperation

(Goh 2002). Enabling trust and thus motivation and willingness is probably the most difficult hurdle to take (Goh 2002). Based on these statements it is clear that the perceived trustworthiness of the knowledge provider is crucial for a learning interaction.

4.4 Reduce risk of adoption Failure (F)

F1: Adoption is incompatible with current practice

Even though knowledge is understood by the receiver, adoption of this knowledge can still fail to occur because application of knowledge is not compatible with current building practice of the user and constructor. To avoid this failure the following proposal can be formulated:

● *Adapt knowledge to local building culture*

Even though construction science has a common ground in the world, construction practice varies according to the local culture: availability of materials and local habits in construction methods are key aspects for these differences (Deplazes 2006). Getting innovations in building technology into practice has proven to be difficult: if new ideas are not compatible with the local building culture problems can occur in the transition to a new building technology (Lichtenberg 2004).

Therefore, it is important for the expert to sufficiently understand the local building culture in order to adapt knowledge towards compatibility with local practice. Knowledge on the local building culture might be found through literature study, but can be gathered more accurately through knowledge exchange with the local user and constructor.

F2: Incorrect use of knowledge K

F3: Diffidence, some other actor disqualifies knowledge K and dissuades knowledge receiver from adopting K

F4: No relay, other community members are not receptive to adopt knowledge K

Three more failures of adoption of knowledge K can be identified. (F2) User or Constructor can apply knowledge K in ways for which it was not intended. Or (F3) User or Constructor interacts with some other actor who disqualifies knowledge and dissuades the User or Constructor from adopting the knowledge. The last identified failure (F4) is when knowledge needs to be taken up by the next actor in line for adoption, but this next actor is not receptive for the knowledge. To diminish the chances of these failure of adoption to occur, a community learning strategy is proposed. Here community learning leads to an understanding of knowledge by the community as a whole, but not by every member of it.

● *Apply a community learning strategy*

Currently within the structure of humanitarian and governmental organisations, engineers who have the knowledge to build back safer, play a limited role in self-recovery process in rural areas of developing countries. In addition, the scope of humanitarian assistance often does not reach the local household level. This means that the process of self-recovery often occurs outside the structure of the humanitarian and governmental organisations, and that the proposed intervention needs to be adapted for this role. Construction knowledge transfer through community learning provides a strategy which allows for such a self-recovery process outside the structures of these organizations.

Weichselgartner and Pigeon (2015) explored the value of knowledge in disaster risk reduction and emphasise the need to improve the level of knowledge understanding, learning and disaster risk. They developed a continuum of understanding, transforming facts to data to information to knowledge and finally through a process of evaluation requiring wisdom, in which the higher complexity of wisdom is best capable of reducing the disaster risks when building back.

These levels of understanding relate to a learning of the individual. But in relation to self-recovery, community learning is even more essential in the long-run. Here only a few members need to attain a high technical understanding to then advise less knowledgeable members during self-recovery This makes the community less vulnerable and supports their self-reliance. Next to a high level of construction understanding in the community, every household should develop a minimum level of understanding to assess the hazard resistance of their own house and to be better informed on their construction need when collaborating with the Constructor during recovery.

Especially preventive innovations are found by Rogers to be difficult to diffuse. Rogers (2002) describes strategies for the diffusion of preventive innovations advocating for; (1) the change of the perceived attributes of preventive innovations, (2) the use of champions for promotion, (3) the change of norms of the system regarding preventive innovations through peer support, (4) the use of entertainment-education for promotion, (5) the activation of peer networks. From these strategies, design recommendations can be distracted to support the adoption of knowledge.

This strategy deals with the risk of an (F2) incorrect use of knowledge in adoption, by having a high level of understanding of construction knowledge in the community through the Constructor. Because the Constructor already has construction expertise, the effort of reaching this high level is limited and the chance of a correct understanding high.

Because within the community the Constructor has the main authority in construction, there is less chance of another community member dissuading the Constructor from adopting the gained construction knowledge. This reduces the risk of diffidence in adopting the knowledge (F3).

Through his/her minimal construction understanding the User should sufficiently understand the disaster risks to not refute the authority and knowledge of the Constructor when building back. This reduces the risk of not adopting gained knowledge through relay causes (F4).

5. ANALYTICAL FRAMEWORK FOR KNOWLEDGE EXCHANGE

Through the examination of knowledge transfer the need of knowledge exchange is recognized. Therefore, based on the proposals described in Chapter 4 we have designed a second analytical model which enables the evaluation of interventions based on knowledge exchange instead of only knowledge transfer. We propose this analytical framework for knowledge exchange, presented in Figure 3, for further research.

This model considers the importance of the technical expert adopting knowledge from the end-user and the constructor. That way, the expert can adapt the knowledge he or she shares in order to increase the adoption of this knowledge by the user and constructor. In the current humanitarian or governmental practice there are failure mechanisms that prevent the adoption by the expert from taking place. There is often no awareness of the need for this understanding and no time and money available in the assistance program. Experts need to be granted time to work on their understanding. The understanding process needs to be organised as part of any intervention

program in order to have a successful adoption. The knowledge exchange model already includes the recommendation to exchange knowledge, which is often not the case in practice. By including this adoption process by the expert, the knowledge exchange model provides us with a more accurate way of analysing barriers and failure mechanisms and enabling adoption in practice.
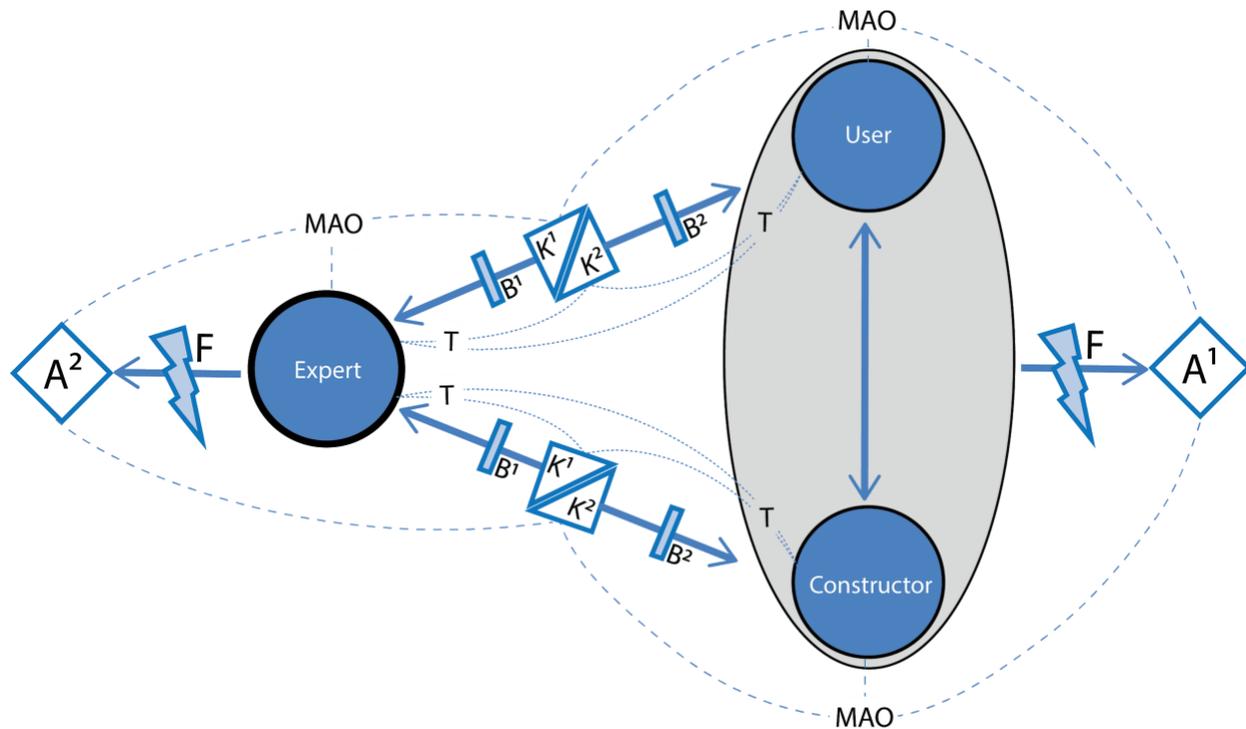

Fig. 3.   Analytical framework for knowledge exchange, for the adoption of hazard-resistant construction principles in post-disaster self-recovery adapted from Tromp and Bots (2016)

Clarification of the knowledge exchange framework in comparison with transfer framework

1) The model includes the adoption process of knowledge by the Expert and towards policy and science.

2) The model provides additional barriers in the transfer from User to Expert and from Constructor to Expert, and failure mechanisms in the adoption by the Expert.

3) The model considers motivation, ability and opportunity as the conditions for actors to consider adoption instead of needs and grounds.

4) The model includes the conditions of the motivation, ability and opportunity of the expert too.

The model considers additional trust relationships. The expert needs to trust the user and the constructor, and the knowledge provided by them.

Additional knowledge transfer

- From Constructor to Expert: practice based construction knowledge.

- From User to Expert: practice based living preferences.

Motivation, Ability and Opportunity for adoption

The Knowledge Exchange Model is a conclusion of the analysis of the Knowledge Transfer Model. This model includes Motivation, Ability and Opportunity as conditions for adoption instead of the needs and grounds that are more related to legislation. These aspects are considered more important for adoption. In the description of proposals, we have noticed that the knowledge transfer model is limited in the way Needs and Grounds are described. Where are these knowledge needs based on and how can they be measured in the field? We have searched for suitable models to improve the description of Needs and Grounds that are more appropriate for the humanitarian sector.

There is a theoretical model for behaviour, the MAO-model, which specifies the Needs and Grounds as being barriers in adoption. The MAO model describes this in terms of Motivation, Ability and Opportunity and provides clear indications on how to measure those aspects in practice (Wiggins 2004). These aspects have not been made explicit yet in the earlier proposals derived from the knowledge transfer model. Therefore, we use this MAO-model as an additional perspective to look at the process of adoption. Especially the social motivation is not sufficiently integrated yet and is an integral part of the adoption process that is essential to discuss. The model slightly alters and adds to the proposals as defined in Chapter 3. We will shortly describe the MAO model and evaluate whether the current proposals already contain MAO barriers. The knowledge exchange model together with the MAO barriers provide a theoretically sound overview of possible barriers and failure mechanisms to take into account when designing an intervention. The MAO-model is a global framework that can be used to segment actors based on the extent of barriers they experience when being introduced to a new product. In this context, the product is the knowledge to build back safer.

The MAO-model is derived from limitations form the earlier work of Rogers (1962). Rogers, professor of rural sociology, provides theory on the adoption of preventive and innovative knowledge and distinguishes categories of adopters: innovators, early adopters, early majority, late majority, laggards. He also gives recommendations to facilitate the adoption and the diffusion of innovations in practice (Rogers 1962). One of his recommendations is to use highly respected individuals with a social network for the adoption and that way create a desire for the innovation. Another recommendation given is to provide benefits for the early adopters. Rogers has found 5 stages in the diffusion process; (1) knowledge, (2) persuasion, (3) decision, (4) implementation, (5) confirmation. His research is the basis for a large area of adoption and diffusion research. However, his work is little specific about the social theories that support this knowledge and does not enable the classification of groups in empirical studies.

The model assumes that people experience three types of barriers to a specific extend that determine the probability of adoption of a new product. These barriers are (Wiggins 2004):

- The motivation, defined as the desire to act

- The ability, defined as having the skills or proficiency to act.

- The opportunity, defined as the absence of environmental barriers to action.

Motivation

The motivation is about what is pushing action forward or backward and results from the activation of beliefs about participation, including positive and negative associations with the activity (Stokmans 2005). This can be personal internal physiological, social or physical needs or barriers that positively or negatively influence the desire to act. These needs or barriers depend on positive or negative characteristics of the utility product or attributes of characteristics of the products. For example, it includes the benefits the product might have in one's own experience. This depends on personal beliefs, one's self-image, and social motivations such as self-efficacy. In the proposals this is discussed under; strengthening trust and matching need and knowledge, and under failure mechanism F3 and F4.

Ability

The ability is about having the skills or proficiency to act (Stokmans 2005). The ability consists of the capacity and resources one has to adopt the knowledge. The ability can be affected by time, financial resources, physical capacities and mental resources (Stokmans 2005). In the proposals, this is mainly discussed under the barriers that need to be lifted; the cognitive barriers and resource barriers.

Opportunity

The opportunity is about the absence of environmental barriers to act (Stokmans 2005). This defines the right critical moment for behaviour to take place. The barrier of opportunity consists of context related aspects. In this research we use the 4P's from the marketing to specify this barrier; price, place, product and promotion. In this context we translate the 4P's in; (1) the price of the knowledge and the materials that need to be used, (2) the place in which the knowledge can be used, (3) the availability of the knowledge and the material to apply the knowledge, (4) the promotion and awareness of the knowledge. In the proposals this is discussed under; reducing the risk of adoption failure and specifically under F1.

By measuring these aspects in practice, the affected population can be grouped based on motivation, ability and opportunity. If they have a high score for all three aspects the probability of knowledge adoption is high. This is the case for the group of innovators and early adopters. If one or more aspects are not high enough, approaches need to be defined to increase these aspects. Based on the characteristics of the group a suitable method to communicate knowledge can be distinguished.

The MAO-model does not explicitly discuss aspects that are related to the knowledge exchange methods but addresses conditional aspects for successful exchange. These aspects need to be taken into account in field research as they potentially are key in the adoption process. The MAO-model provides an extra layer of identification of barriers in practice and is more explicit than the Needs and Grounds explained by Tromp and Bots. Therefore, to enable a more complete understanding of the adoption process in the field research, as the exact value of barriers is still unknown, it makes sense to add MAO as an additional lens to explain and structure findings.

In the field we propose to use the provided knowledge exchange model that includes the barriers and failure mechanisms defined in the MAO-model.

The barriers described are theoretically sound, but what is the most important barrier? Therefore, all barriers discussed in this article need to be further developed. Field research is needed to decide provide evidence on which of the recommendations is vital for successful adoption. The consequences of these barriers need to be analysed in a number of case studies and

should provide us with evidence-based hypothesis. Therefore, it is recommended to take a the broad scope of barriers discussed in this paper as a basis for field research to gather evidence.

6. DISCUSSION AND CONCLUSIONS

The study presented in this article, investigates the lack of adoption by self-recovering low-income groups of hazard-resistant construction principles after a natural disaster. We have found that in general when humanitarian or governmental organisations provide technical training in post-disaster recovery, most of these interventions are based on knowledge transfer and not exchange methods. By developing a framework to analyse interventions based on knowledge transfer, we identified various barriers and failure mechanism that prevent knowledge from being adopted.

This analytical framework for knowledge transfer maps the interaction of technical expert, local end-user and local constructor, as an abstraction of the various roles involved in self-recovery. This framework brings to the fore various proposals for the design of a knowledge providing intervention with high effectiveness for adoption. These proposals consists of: (1) adapt knowledge to local need through exchange, (2) adapt knowledge to local skills and cognitive levels via contextualization, (3) adapt communication to local culture, (4) adapt knowledge to financial possibilities and priorities of low-income groups, (5) establish positively perceived consequences of knowledge adoption, (6) provide and enhance trust in the knowledge sender, (7) adapt knowledge to local building culture, (8) apply a community learning strategy.

We want to highlight that not all proposals are equally essential for adoption and might vary based on the context. The exact importance of these proposals needs to be measured and compared through a variety of interventions in a variety of contexts. However, this study brings to the fore the importance of providing knowledge exchange methods in post-disaster intervention design for the success of knowledge adoption with self-recovery groups.

The analysis of the interactions between the various actors (Expert, User and Constructor) in self-recovery processes with interventions based on knowledge exchange, requires an adapted framework. This analytical framework for knowledge exchange is more complex and involves barriers and failure mechanisms for the Expert's adoption of knowledge from the user or constructor. We have developed a framework to analyse this exchange process and expect to discover additional recommendations for the design of interventions based on knowledge exchange methods.

The proposed knowledge exchange model has replaced Needs (N) and Grounds (G) with the behaviour model of Motivation-Ability and Opportunity (MAO). The interpretations have overlap but MAO provides a more complete understanding of factors important for the success of knowledge adoption. In this model, Motivation is the desire to act, Ability is having the skills or proficiency to act, and Opportunity is the absence of environmental barriers to action. Further investigations are required to test the proposed framework and develop a broader scale of barriers to overcome. In conclusion, this article is a first step in defining design recommendations for knowledge exchange interventions that contribute to the adoption of hazard-resistant construction principles in self-recovery processes after a natural disaster.

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