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THE ROLE OF LEARNING IN CONSTRUCTION TECHNOLOGY TRANSFER: A 'SCOT' PERSPECTIVE

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Technology transfer (TT) has been given increasing importance since the formulation of the international code of conduct for technology transfer by the UNCTAD in 1985, and has become a preferred medium to bridge development gaps between developed and developing countries. Concomitantly, international joint ventures (IJVs) have been put forward as vehicles for change in the belief that contractors in developing countries can position themselves to receive technology from their developed counterparts. So far, TT has been studied through a variety of theoretical lenses. However, predominantly, the perspectives taken have assumed a linear process, viewing technology merely as an object, and effectively disregarding the multiple interactions involved in TT. In this paper, we argue that such perspectives only provide partial explanations of what construction technology entails, and how it is transferred between organisations. A counter-argument is put forward to view TT as a process of socio-technical interactions that is reliant on learning. Adopting the theoretical lens of the Social Construction of Technology (SCOT), we show how the SCOT framework allows for examining the socio-technical interactions between human actors and construction technology in TT. Specifically, we use the SCOT constructs of 'interpretative flexibility' and, 'closure and stabilisation' to reveal how learning is an integral process within the socio-technical interactions, which plays a critical role in TT between contractors in IJVs. Conclusions are drawn, highlighting the importance of studying TT as a system of socio-technical interactions on a construction project, in order to understand how learning plays a role in the process.

Keywords: developing countries, international joint ventures, learning, social construction of technology, technology transfer

INTRODUCTION

Contractors in developing countries lack in technology needed to undertake the usually large and complex construction infrastructure projects that are vital for their countries' development (Devapriya and Ganesan 2002; UNCTAD 2014). These infrastructure projects include hospitals, highways, dams, harbours, airports, water processing facilities, power plants and, oil and gas processing plants. Through international tendering, contractors from developed countries are able to compete for, and win most of these projects, because they have the requisite technology (Osabutey *et al.*, 2014). This contributes to the creation of a vicious cycle of technology gaps between contractors in developing countries and their counterparts from developed countries. The persistence of this cycle further promotes an unhealthy dependence by

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developing countries on foreign contractors to deliver their key infrastructure projects (Ofori 1994).

As part of global effort to narrow technology gaps between developed and developing countries, the United Nations Conference on Trade and Development (UNCTAD) introduced Technology Transfer (TT) as an alternative to foreign direct investment in 1985. Essentially, the UNCTAD suggests that TT should be arranged according to the levels of economic development, infrastructure gaps and technological deficits between developed and developing countries (UNCTAD 2014). The United Nations further suggested international joint ventures (IJVs) as potentially effective channels for TT into developing countries (*ibid.*). IJVs are, indeed, reportedly the most preferred medium for the transfer of construction technology into developing countries (Ofori 1994; Wahab *et al.*, 2012b; Chrysostome *et al.*, 2013; Osabutey *et al.*, 2014). The contractors there are less advanced, hence IJVs provide an enabling environment for close assistance, which is vital for them to learn in the process of TT (Manimala and Thomas 2013; UNCTAD 2014).

Notwithstanding the strong arguments for why TT into developing countries should be achievable through IJVs, there are ample examples of where this has not turned out to be the case. For example, the World Bank undertook a number of construction projects (e.g. roads, drainage and water treatment plants) in developing countries from the early 1980s to the late 1990s, mainly through IJVs (Haug 1991; Ayittey 2002; Estache 2005). One of the main intentions behind the formation of IJVs, was to facilitate TT. This ambition was, however, largely unrealised (Haug 1991; Devapriya and Ganesan 2002; Estache 2005). In recent times, countries like Ghana, Nigeria, Tanzania and South Africa have attempted to improve their local contractors through TT, by forming IJVs with foreign contractors to undertake construction projects. These attempts are based on the intention of having some technology transferred to their local contractors as they work with foreign contractors on the projects (Rwelamila and Mkandawire 2013; Osabutey *et al.*, 2014). However, many of such TT attempts are reported to have failed.

The failure of TT attempts into developing countries is, at least partly, a result of an erroneous assumption that foreign contractors transfer technology to local contractors once they merely work together on a project; and that local contractors already possess the capabilities and skills that will enable them to receive technology from foreign contractors. Furthermore, it can be argued that early attempts of TT were generally based on a narrow consideration of the concept of technology and the process of TT itself. With construction technology commonly linked to tangible artefacts, tools, equipment or machinery, the related assumption is that TT is a linear process of transferor-transferee relations; merely passing on machinery between the parties (Ofori 1994; Abbott *et al.*, 2007; Rwelamila and Mkandawire 2013). Considering construction technology and its transfer in this mechanistic view neglects the series of socio-technical interactions involved in the transfer process between the IJV contractors (*cf.* Williams and Edge 1996; Manimala and Thomas 2013).

In this paper, we first present technology from a social constructionist perspective, and show how its transfer in construction can be seen as a system of socio-technical interactions between contractors in IJVs. We then go on to argue that learning is an intrinsic component within the social shaping of technology and socio-technical interactions, and that it plays a critical role in the process of TT. We begin by setting out technology from a social construction position, against traditional views. TT is

then presented as system of socio-technical interactions with learning as a critical component for its success. The social construction of technology (SCOT) is then presented as a theoretical framework to be used in exploring the complexities of TT under IJV arrangements. The SCOT constructs of 'interpretative flexibility' and 'closure and stabilisation' are used to present learning as a key to successful TT.

Technology and Technology Transfer

What is technology?

Providing a single definition for 'technology' is difficult owing to its extensive application in different areas (Wahab *et al.*, 2012a). Its root word 'techne', means to bring forth the essence of a thing in its true form; meaning that technology goes beyond tangible products or artefacts. In the extreme, technology is considered as a means to drive reality. It encompasses a way of thinking and a style of practice that goes beyond the physical to something intuitive (cf. Heidegger 1977). Hence, technology should not be conceptualised distinctively as an artefact or process only, detached from the social interactions related to its development (Williams and Edge 1996; Elle *et al.*, 2010).

Early definitions of technology can be broadly grouped under: product, process and management technology. Recent literature categorises technology as 'hard'/'explicit' or 'soft'/'tacit', with definitions characterized by key elements such as: knowledge, physical artefacts, systems and processes, and managerial expertise (Wahab *et al.*, 2012a). Related to this, technology is generally considered to comprise four closely linked components: knowledge; technique; products and the organization involved. 'Knowledge' refers to the explicit facts and embedded experiences associated with technology, and is as such an intrinsic component of technology. 'Technique' refers to the practical methods, skills and processes deployed in conjunction with knowledge and physical 'products' towards realising a desired outcome. The 'organisation' is the immediate context which hosts the interactions between the other three components of technology (Gorman 2002; Ismail *et al.*, 2009). One widely held perspective portrays technology distinctively as either an artefact/product, or a set of rules and patterns of actions (Wahab *et al.*, 2012a). Such compartmentalised views effectively disregard the complexity of the social construction and socio-technical interactions in what constitutes technology (Williams and Edge 1996) and subsequently, its transfer. This, in turn, leads to a limited representation of the composition of technology, and also constrains the extent to which the complexities involved in its transfer can be explored.

A handful of recent studies on construction technology have argued for a more comprehensive approach in conceptualising technology, and its uptake between organisations (Harty 2005; Ismail *et al.*, 2009; Schweber and Harty 2010; Boyd *et al.*, 2015). Technology in this sense is viewed as being socially constructed. It is developed through a series of interactions, leading to modifications and alterations in the technology, and the various actors involved in a context. It is a composition of explicit (e.g. machinery, plant and equipment, tools and devices) and tacit components (e.g., knowledge, intuitive ideas, experience and skills) that are developed through series of interactions with human actors, and shaped towards a desired outcome (see Pinch and Bijker 1984). From this view, these components of a technology are inseparable. They are all in a constant relationship through series of actors' negotiations, influencing and modifying each other (Williams and Edge 1996). Hence, technology is socially constructed through a series of socio-technical

interactions. It is, as such, not socially neutral. Rather it is a product of socio-technical interactions and social shaping in a specific context (Williams and Edge 1996; Elle *et al.*, 2010). Based on the above, we consider 'Technology' as comprising: tangible and intangible components, as well as systems or processes that interact with human actors towards an intended, specific output. This composition varies across contexts, and undergoes series of modifications as it is developed and moved from one place to another, to be re-developed and re-shaped socially through a series of interactions.

Technology transfer

There are many definitions of technology transfer owing to the different meanings ascribed to technology (Wahab *et al.*, 2012a; Manimala and Thomas 2013). Generally, definitions emphasise that TT is neither merely handing over documented information, nor a simplistic sale of machinery to a transferee. It is a collaborative process that requires a sustained, close relationship between the parties involved over a period (Wahab *et al.*, 2012b; Manimala and Thomas 2013; UNCTAD 2014). Here we position 'Technology Transfer' as a deliberate process through which technology is moved from one party to another through series of interactions, within a specific channel towards an intended outcome.

TT is a process that unfolds over a period of time, comprising a series of interactions between: the transferor, the technology, the transferee, the channel/vehicle of transfer, and the context of transfer. The process can be either intra- or inter organisational, based on the direction of the transfer. It may be categorised as local or international, based on the home countries of the firms involved. The transferor is the primary entity in possession of a relatively stabilized technology desired by others, and the transferee is the entity which receives technology from the transferor. The process of TT can however be bi-directional as the transferor and transferee positions are not fixed throughout the period of interactions. The channels of transfer are the intermediary conduits, modes and agents which facilitate the transfer process, generally referred to as 'vehicles of transfer'. Popular TT channels in construction include subcontracting and joint venture arrangements (Wahab *et al.*, 2012b).

A Socio-Technical Perspective of Construction Technology and Its Transfer

Broadly, construction technology refers to any form of technology used by construction firms towards the delivery of a construction product. Generally, it consists of tacit and explicit technology, with the tacit form being most difficult to transfer. Tacit technology refers to the embedded, intangible assets of an organisation, such as skills, operational and experiential knowledge, production methods, systems and processes, and management ideas and skills. Its transfer is considered largely impossible without person-to-person interactions between transferor and transferee (Manimala and Thomas 2013). Explicit technology, on the other hand, is the tangible machinery, tools or equipment that are guided by knowledge to produce desired results (Ismail *et al.*, 2009). These two broad aspects of technology are constantly developed, modified and used on construction projects by human actors. During construction project execution, contractors employ a combination of tacit and explicit technology. These include construction plant and equipment, project techniques, construction and management processes, as well as intuitive ideas that are incorporated in a project design, and managing construction processes (Harty 2005; Ismail *et al.*, 2009).

It follows from the above that, the process of project delivery involves a series of socio-technical interactions between human actors and technology. As part of the interactions, technology is 'socially constructed' (i.e., modified by actors to suit their respective organisational and contextual requirements for effective utilisation). The interactions lead to the creation of a technological system, which is used in delivering construction products such as buildings, bridges, dams or harbours (Schweber and Harty 2010). Despite the foregoing, TT in construction has been generally conceptualised as a linear process (e.g., Ofori 1994; Abbott *et al.*, 2007). Accordingly the transferee identifies the desired technology and its owner, after which arrangements are made for its transfer. Over a trial and re-trial period, the transferee is able to make adjustments to the technology to suit their operations. This approach fails to put in perspective the inter-organisational and socio-technical interactions that take place during the transfer process, as well as the social shaping of the technology involved. Hence, the relationship between the nature of the technology being transferred, the context of the transfer and, the interactions of the actors involved (with themselves, as well the machinery, systems or processes of technology) are subsequently neglected.

Reflecting on the nature of construction technology, TT is neither the mere act of transferring proprietary documented information from one organisation to another, nor transferring a piece of hardware from one location to another. The process involves a series of socio-technical interactions between the actors and the technology involved (Wahab *et al.*, 2012b; Manimala and Thomas 2013). These interactions introduce adjustments, modifications and alterations in the organizations involved. These changes contribute to the abilities of the TT parties to receive and incorporate new technology into their organisational practices and routines. Few studies in construction research have adopted a socio-technical perspective on technology, focusing mainly on intra-organisational analysis of technology adoption (e.g. Schweber and Harty 2010, Sackey *et al.*, 2014; Boyd *et al.*, 2015), adoption of smart electricity meters in domestic buildings (Skjølsvold and Ryghaug 2015), and systems building in the use of 3D CAD technology in construction (Harty 2005). The socio-technical view in technology studies presents a coherent and inclusive approach to examine the complex realities of interactions between people, technology and organizations. It puts into perspective the co-development of the parties involved, and the modification of technology in the process of its transfer within a defined social context (Schweber and Harty 2010). This view helps to explain the series of interactions between actors in a defined context, and in turn the multiple interactions that influence technology development and uptake, or transfer (Harty 2005; Sackey *et al.*, 2014).

As TT actors shape technology within their social and organisational contexts, and are themselves modified by the technology through socio-technical interactions, there is the revision of old, and/or, development of new knowledge. This is reflective of learning (see Huber 1991; Schilling and Kluge 2009). Additionally, the processes of alteration and adjustment by TT parties in order to transfer and/or receive technology is indicative of a learning process. Thus, we argue that within the series of socio-technical interactions of TT, there is a component of learning which plays an essential role in the outcome of TT. Related to this, some studies (e.g. Manimala and Thomas 2013; Chrysostome *et al.*, 2013) have intimated that learning is a critical component in TT.

Technology Transfer and Learning

Historically, the transfer of agricultural, military and construction technology between parties involved close interpersonal relationships. These relationships allowed the parties to spend sufficient time with each other, in order to learn as part of the transfer process (Gorman 2002).

The process of TT as a series of socio-technical interactions leads to inter and intra organisational modifications and adjustments to systems, processes and procedures. These changes influence organisational arrangements and operations. Learning is the process through which organisations are able to cope with the discontinuities and disruptions that are encountered as a result of alterations and modifications experienced through socio-technical interactions during the process of TT. It emerges out of necessity for the organizations involved to adjust to expected changes as a result of transferring and/or receiving new technology (cf. Manimala and Thomas 2013). The process of learning in TT is influenced by: the nature and composition of the technology (higher complexity demands stronger learning interactions); the process of technology transfer; the vehicle of transfer; the objectives and motives of the parties; the learning environment within and between the parties; and the learning capabilities of the actors (Gorman 2002; Wahab *et al.*, 2012b). Within the series of interactions, alterations and modifications, processes that can be considered to reflect learning (see Huber 1991; Schilling and Kluge 2009; Manimala and Thomas 2013) on the part of the actors can be traced through an analysis of the TT process using the social construction of technology (SCOT) theoretical constructs of 'interpretative flexibility', and 'closure and stabilisation'.

The Social Construction of Technology

The social construction of technology (SCOT) was first put forward by Pinch and Bijker (1984). SCOT presents “a coherent and inclusive approach for interrogating the complex realities of interactions between people, technology and institutions in empirical settings” (Schweber and Harty 2010: 673). The theoretical framework describes the development, uptake and adoption of technology within a context as a continuous process of evolution, and a continuous cycle of alternation of variations and selection (Pinch and Bijker 1984).

SCOT is based on a set of assumptions. First, technology is socially constructed, and does not comprise of only artefacts, products or machinery. It is developed through a system of interactions between human and non-human elements within a social context to achieve an intended outcome. It comprises physical artefacts, organisations, knowledge, and legislative frameworks. Second, a technological system is developed through interactions between the components of a social context being: the technology, the environment, the organisation(s) and the human actors. Finally, technology, its transfer, social context, and the actors are not considered as different components of a technological system governed by different rules. They are all considered as a single unit, operating and influencing each other through series of interactions and negotiations towards a desired outcome (Pinch and Bijker 1984).

Core constructs

SCOT is made up of four major constructs: Relevant Social Groups (RSGs), Interpretative Flexibility, Stabilization or Closure and, the Wider Context. Relevant social groups (RSGs) refer to the parties who influence the nature of a technology, i.e. an individual, organisation or, group(s) of individuals; whether organised or not. In influencing technology, they also concurrently undergo alterations. The relevance of

a group is primarily linked to the extent to which the technology involved is important to them. Direct and indirect RSGs vary per the technology and the context. For every technology, the RSGs may have a set of shared and/or conflicting meanings, forming different 'technological frames'. A technological frame is the sum of understandings of all the RSGs for a particular technology; comprising goals, problems, guiding principles, operation procedures, and artefacts (see Elle *et al.*, 2010). Differences in technological frames lead to conflicting views among RSGs. This creates strata between groups with different technological frames on the explicit and/or tacit aspects of a technology. The differences in technological frames between RSGs reflect the complexity of technology, hence depicting its 'interpretative flexibility'. The conflict between technological frames is because technology can be designed in several ways, and is thus likely to be understood from different perspectives by RSGs. Additionally, the development of technology encounters conflicting opinions among RSGs, because they do not share the same, or similar expectations of the functions of technology owing to their different backgrounds (Pinch and Bijker 1984).

In achieving closure and stabilisation, steps are taken by the RSGs to merge the different perspectives by way of exchange of explicit information and tacit experiences. This allows the RSGs to relate to the technology from a common set of technological frames. When this has been achieved, there will not be any need for further modifications of that technology among the actors in a given context. However, attaining this level is not absolute. Technology is considered to have reached a level of closure and stabilisation according to the RSGs involved. All the socio-technical interactions in the development and transfer of technology do not take place in a vacuum; the wider context is the environment within which technological development and transfer takes place (Pinch and Bijker 1984). This may be an organisational or inter-organisational, industrial or sectorial, national or international setting within which all the interactions take place.

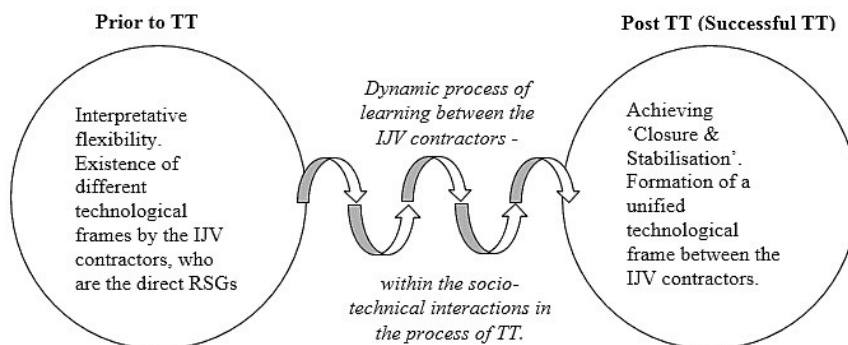
Technology Transfer through a 'Scot' Lens

The relevant social groups (RSGs) are made up of individuals from the local and foreign IJV contractors involved in construction TT. Prior to the transfer of technology, the interpretative flexibility of the technology is revealed in the conflicting understandings among the actors involved. The understanding of the contractors about what the technology stands for, how it can be used on a construction project, and its potential effect on their internal and external operations vary. The conflicting perspectives become pronounced in the face of contextual differences between developed and developing countries, as the actors have different levels of exposure to prevailing technology. Towards a successful TT, the IJV contractors need to resolve the conflicts in understandings surrounding the technology at hand; and by this achieve some closure and stabilisation. This is by means of series of interactions, leading to alterations and modifications in the actors and the technology. The processes of change and adjustments are made possible through learning processes that are developed and utilized during the process of TT, illustrated in figure 1.

The process of transferring and/or receiving technology through socio-technical interactions by TT parties is inseparable from the processes of alterations in technological frames. During TT, the technology undergoes phases of alternation and variation (see Pinch and Bijker 1984) as part of being received by the transferee. Concurrently, the RSGs also undergo some changes during the socio-technical interactions with the technology. These modifications in the actors and the

technology lead to changes in technological frames, as well as the development of a 'stabilized' iteration of that technology respectively, as part of the TT.

Figure 1: From 'interpretative flexibility' to 'closure and stabilisation' through learning



Wider context of IJV arrangement in a developing country's construction industry.

All of these contribute to achieving some level of 'closure and stabilisation', partial or absolute, for the technology (see Skjølsvold and Ryghaug 2015). The actors involved would have eliminated their conflicting understandings to an extent, and TT would have been achieved (see figure 1 above). Overall, the inter-organisational IJV arrangement and the construction industry play the role of the wider context for the socio-technical interactions, as well as contribute to the social shaping of technology as illustrated in figure 1 above.

In order to explain the process of TT as series of socio-technical interactions between IJV contractors on a construction project through SCOT, we argue that, it is imperative to identify: Who make up the RSGs involved in the development and transfer of technology? Which aspects of the technology are considered important by the parties? How do the RSGs ascribe different meanings to the technology in question? What purpose is the technology in question addressing from the perspectives of the RSGs? What processes do the RSGs go through in order to adjust to the alterations and modifications as a result of receiving technology? How are the RSGs able to negotiate series of meanings throughout TT, as part of achieving some closure and stabilisation for the technology, in order to achieve satisfactory transfer of technology?

Exploring these questions will help explain how the parties involved in TT negotiate meanings, and adjust to modifications amidst series of interactions. The answers will also shed light on how technology is altered to suit the interests of the actors during TT. All of these will contribute to providing a more comprehensive explanation for TT on a construction project, given the multiple actors involved from diverse backgrounds. This contrasts traditional views where technology is usually fixed, and TT is a linear arrangement.

Concluding Remarks

Technology transfer has been studied from compartmentalised perspectives over the years, neglecting the socio-technical interactions that take place. This has failed to capture the co-development of technology and the actors involved, alongside the multiple interactions. In this paper, we have, therefore, put forward an alternative view of TT. We have argued that technology and its transfer should be viewed as a

process of socio-technical interactions between actors, the technology and the context. This allows for the complexities in the process of TT to be explored, putting the socio-technical interactions into perspective. As part of the socio-technical interactions in TT, learning has been presented as one of the key processes which plays a vital role towards a successful transfer of technology. We have also demonstrated that the theoretical framework of SCOT can be used to explain the interactions between actors, technology and organisations in TT under IJV an arrangement. Within these interactions, we have explained that the processes of learning in TT can be identified, using the SCOT constructs of 'interpretative flexibility' and, 'closure and stabilisation'.

We put across an argument for a rethink about the approach to studying TT in construction. This will open up the complexities entailed in the process, and put the socio-technical interactions involved in perspective. Additionally, it will help provide additional explanation of TT between contractor IJVs in developing countries. Relatedly, this may offer useful insight to developing countries who are attempting to improve their local construction industries through TT.

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