

AN EXAMINATION OF TACIT KNOWLEDGE NETWORKS IN A COLOMBIAN CONSTRUCTION PROJECT: COMMUNITIES OF PRACTICE AND PROJECT CULTURE

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Project-based organisations are effective vehicles for knowledge transfer potentially benefiting all project actors. In the case of construction companies, operatives nourish their knowledge through experience across different organisations that are dedicated to the same activity, as well as involvement in technical training. Furthermore, members of a project group will determine how the culture of the project is perceived. The study sought to examine the network of principal cause-effect interactions between the members of a Colombian construction project focussing on the nature and characteristics of knowledge exchange between site operative. The research project dealt with interactions and socialisation activities and the way in which these activities supported the development of operative skills. Social network analysis (SNA) was used to observe the communities of practice (COP) and their influence on operatives. Some networks function through the transmission of explicit knowledge to operatives that is later transformed into tacit knowledge (TK). Other networks provide working environments where TK is developed and practiced with other members. The SNA method demonstrates that COPs not only influence operatives, they also influence co-workers within the project and facilitate other, less central operative actors, to acquire TK.

Keywords: communities of practice, culture, project-based organisations, social network analysis, tacit knowledge.

INTRODUCTION

The construction industry is characterised by its project based environment. Consequently, the industry is constantly integrating into project teams a wide variety of individuals who come from different backgrounds and technical expertise. Some of them have attended relevant courses, whereas some others have become experts through work experience. A high involvement of temporary staff is always present.

Even though individual project actors only participate in a project for a short period of time, it is extremely important they are qualified to deliver the work requested (Winch, 2002).

It is interesting to understand how operatives relate to each other within a project team, and how they acquire their tacit knowledge (TK), which is believed to be influenced by other individuals who are able to transmit the knowledge required.

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Consequently communities of practice (COP) can be seen as groups of people who share a concern, set of problems or passion about a topic. During these interactions, individuals are able to exchange different points of view, while learning (Wenger *et al.*, 2002). In this research a method was developed to facilitate the studying of actor knowledge networks through a case study of a Colombian Construction Company, Alfa Co Ltda (ACL).

Aims and Objectives of the Research

This study describes how site operatives share knowledge and skills in their everyday work in a project-based project. Through this investigation the following research objectives were set:

- Identification of the COP that influence the operatives' TK acquisition.
- Determination of how COP helps operatives to acquire tacit knowledge.
- Definition of how strong the influence of each COP is on the operatives' performance.

The research hypothesis related the acquisition of TK to the existence of project actor networks providing stability, identity, and personal satisfaction, as well as opportunities to engage and interconnect with other members.

Theoretical Concepts and Relation to the Research

The concept of practice connotes doing, within a historical and social context giving meaning to what is being done. It highlights the social and negotiated character of both the explicit and tacit in everybody's lives (Chaiklin and Lave, 2006). As a result COP arise as a group of individuals who offer stability and provide an identity where members can connect across geographical and organisational boundaries, focusing on expertise and professional development. Therefore, the knowledge of experts turns out to be an accumulation of experiences relying more on a living process, rather than a static body of information (Chaiklin and Lave, 2006). Hence COP become part of the living storehouse where this knowledge can be developed and spread as TK.

There are two kinds of knowledge, explicit knowledge (EK) and tacit knowledge (TK). The first one consists of the knowledge which can be easily expressed in words and numbers and shared in the form of data. This kind of knowledge can be transmitted to individuals formally and systematically (Nonaka and Teece, 2001). EK is also rational and objective; it is orientated towards a context-free theory (Nonaka and Takeuchi, 1995).

The learning process and skills shared with others need to be internalised – reformed, enriched and translated to fit the organisation's self image and identity. To understand the nature of knowledge and how it should be created, it is important to recognise that both TK and EK complement each other and therefore are essential when enabling knowledge creation (Nonaka and Teece, 2001).

In the construction industry, operatives work together either by pairs or teams. Therefore, coordination between those groups should exist, since creation within the construction works relies on the interaction and communication between each of these parties, leaving no room for isolated works. Thus, work organised on a craft basis provides a work environment which allows social integration and learning (Applebaum, 1981).

As a result, construction industry relies upon relationships. Since this industry works by projects, construction workers function as independent units. Each individual seeks

employment and makes his/her own arrangements according to his/her personal networks and contacts. Given that a new labour force is assembled for each project, operatives are constantly negotiating with employers to get new contracts and become part of their future workforce (Applebaum, 1981). As a result networking becomes a very important strategy which contributes to the worker's intellectual and personal growth.

Networks of people play an important role in the context of projects, since they provide connections through which communication channels are created to establish a sense of mutual understanding. Consequently, project networks provide the creation of social ties which enables them to reconfigure according to the diverse set of circumstances that the project may encounter. Furthermore, firms operate and interact within a network of other firms. Sometimes they collaborate and work together, such as being part of the supply chain, while under other circumstances they can be competitors (Pryke and Smyth, 2006).

The Context of Study

In Colombia, the National Petroleum Enterprise – ECOPETROL – is responsible for the hydrocarbons' exploration, extraction, production, transportation and marketing. The majority of projects are carried out as joint ventures between ECOPETROL and foreign contractors. The Occidental Petroleum Corporation and British Petroleum Company are two of the biggest companies which are present in the sector (Ecopetrol, 2008). Civil works firms play an important role in the petroleum industry, since they are in charge of building pipelines and polyducts able to transport petroleum together with its derivatives, which in turn communicate production systems with the large consumption centres and maritime terminals (Ecopetrol, 2008).

ACL is one of the contractors that works within the petroleum industry on a project based environment. It was founded eight years ago and as a civil engineering contractor and is dedicated to (<http://www.alfacoltda.com>):

- Providing different services to the private and public sector of the petroleum industry.
- Developing civil and geotechnical works.
- Providing equipment, construction of civil, electromechanical and pipeline works.
- Commercialising and installing geosynthetic membranes.

Apart from the permanent staff, there is a high proportion of temporary staff that takes part in projects. The number required varies according to the project specifications and requirements.

Case Study - ACL's Project

One of ACL's projects was chosen as a case study for this research. It consisted of civil works for the construction of oil process pipelines, at a station which belonged to an operation division of Ecopetrol. It also embraced the creation of multiple entrance pipelines and storage tanks with capacity of 10,000 to 30,000 barrels. The project objective was to provide an optimal oil storage coming from the different oil fields so it could then be transported through multiple entrance pipelines to the local refineries and exportation ports.

The project activities were mainly divided into civil works and mechanic works. Civil works were divided into excavation and concrete works, whereas the mechanic works were divided into the prefabrication and assembly of metallic supports for oil process

pipelines. Operatives with different skills and TK were required to perform the main activities described above.

Project Team and Identification of Actors

The project team consisted of administrative and operative staff; totalling 55 members. The construction and project director was in charge of managing the whole project. He coordinated different engineers such as the quality, health and safety and resident ones. They managed different operative staff related to their own tasks and specific responsibilities. Operative staff comprised heavy equipment operators, welders, painters, sandblaster operators and assistant operators. All staff was continuously working together, since all the activities were taking place at overlapping stages.

All these individuals were actors of interest to the Social Network Analysis (SNA). As these individuals were constantly interacting with their environment at different levels, a number of interesting COP which were believed to influence operatives' acquisition of TK in different ways are attractive to analyse. Two main groups were identified; pier organisations which are companies dedicated to the same activities as ACL, and learning institutions which are technical institutions where operatives attend welding, painting and general craft courses. The following table shows the COP which interacted in some way or another with the project operatives and which were included in the SNA:

Table 1.1 COP involved in SNA

Pier Organisations	Learning Institutions
Conequipos	National Learning Centre SENA
Konidol	Technical and Industrial Institute Don Bosco
Colserpetrol	Welding Institute West - Arco
Maco	
Montecz	

Questionnaire

As Wegner states, human beings nature is to interact with each other and their world around learning from these relationships in a constant process (Wegner, 1998). Having identified COP as groups of people who share a concern, a set of problems or a passion about a subject, questions were formulated in a way that helped understand if COP in fact interacted and influenced operatives in their acquisition of TK. Through the analysis of the results obtained from this questionnaire, ideas about how operatives worked, discussed, relied on, obtained information from, were generated, thus validating the hypothesis. The following were the set of relationships asked to each of the actors in order to pursue and confirm the hypothesis.

Table 1.2 Questionnaire

<p>1. Which nature of information do you send to each of the actors (the most)?</p> <p>1= Instruction 2= Advice 3= Information 4= Discussion</p> <p>3. To do your job well who must you depend on?</p> <p>1= Depend on the actor 0= Do not depend on the actor</p> <p>5. To do your job well who must you depend on?</p> <p>1= Depend on the actor 0= Do not depend on the actor</p>	<p>2. Which nature of information do you receive from each of the actors (the most)?</p> <p>1= Instruction 2= Advice 3= Information 4= Discussion</p> <p>4. To do their job well who generally depends on you?</p> <p>1= Actor who depends on you 0= Actor who does not depends on you</p> <p>6. To do their job well who generally depends on you?</p> <p>1= Actor who depends on you 0= Actor who does not depends on you</p>
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The information of attributes show in the following table was used as support of the results obtained from the network analysis. It involved the identification of actors by gender, role within the network and team - as which organisation they belonged to-. Teams 2 to 6 include peer companies of ACL, while organisations 7 to 9 are teaching institutions. Note that the management, engineer and instructor role have been identified as circle due to their mentor role played in the case study.

Table 1.3 Attributes

Gender	Role	Team
1 Male	1 Management	1 Alfa Co
2 Female	2 Engineer	2 Conequipos
	3 Supervisor	3 Konidol
	4 Technical Assistant	4 Colserpetrol
	5 Driver	5 Maco
	6 Secretary	6 Montecz
	7 Equipment Operator	7 SENA
	8 Welder	8 Don Bosco
	9 Sandblaster Paintor	9 West Arco
	10 Operator	
	11 Helper	
	12 Instructor	

Data Collection

The data and information of the project was collected directly at the project site. During this process, 55 actors were asked to answer the questionnaire designed. Different reactions were observed, since there were actors who were very interested in

the survey and others who were not. Nevertheless once getting enrolled in the process, all 55 actors contributed by answering and replying to the questionnaire. During the survey, clusters were identified regarding their own tasks at the project, as well as influential actors.

Additionally 8 COP were contacted and asked to answer about their relation to the actors involved in the ACL project through the same questionnaire designed. The data gathered was then used as an input for the SNA software - UCINET to obtain graphic illustrations which gave a good number of networks to analyse.

Results

The following networks present the most significant results obtained from the questionnaire. These networks provide demonstrations of centrality, ego analysis as well as reciprocal ties, confirming the different relationships found in different relational flows.

Discussion Flow Network

This network shows how discussion flows within the network, that is including all of the 55 actors of the project and the additional 8 COP. COP are involved and play important degrees of centrality amongst the network. Conequipos, Maco and Sena are the most central COP which seem to offer discussion spaces to a wide variety of operatives. Nevertheless there is a central actor who seems to have the most reciprocal tie relation with his peers. P. A. Murcia which is an operator, discusses with other actors such as technical assistants, supervisors, operator's assistants, equipment operators, sandblaster painters and COP. J. M. Restrepo is another actor which has a good level of centrality. He is also involved by reciprocal ties with other actors such as COP, operators, equipment operators, sandblaster painters, operator's assistant and supervisors. Both actors claimed to learn very different points of view from this interaction.

Information Flow Network

The information flow network shows a good number of reciprocal ties between all the set of actors identified. E. Carvajal which is the secretary of the project is the most central actor, since she is the one in charge of dealing with most of the paperwork that flows in the project. Nevertheless this kind of information does not influence operatives to acquire TK or improve their performance at work in a direct way.

Apart from E. Carvajal, most of the actors in the network appear to have similar levels of importance. The Sena institute is the most significant actor who discusses with other COP and operatives such as equipment operators, sandblaster painters, operators and supervisors. Sena institute was sensed as the most structured and helping COP. It offers open spaces for discussion with its members, where a good amount of information flows in both directions; this characteristic is clearly reflected in the network.

Instruction Flow Network

This network shows a greater proportion of non-reciprocal ties compared to the reciprocal ones, that is expressing which pair of actors have agreed when answering the same set of questions (Pryke, 2005). This characteristic could be present due to a misunderstanding of the concept of instruction. It is possible that while one actor is giving an instruction the receiver might be accepting it as information or advice. Nevertheless COP seem to have a better level of importance in this network,

especially Konidol, Sena and Don Bosco. They seem to influence a wide variety of operatives when giving instructions.

Furthermore contrary to what it is believed in a project environment, operatives seem to have much more importance than managers and supervisors when giving instructions to other actors. Such is the case of P.A. Murcia an operator, J.A. Garcia and V.I Moya, both equipment operators. This is possible since these actors are continuously interacting with other members moving and locating material, hence indicating operatives when to stop and continue with their duties. On the other hand, L.C. Herrera, the health and safety engineer seems to be very central, this is explained due to the fact that he is continuously instructing operatives how to work safely on a regular basis.

Ego Discussion Companies and Institutions Networks

The objective of these networks was to observe and evaluate how peer companies and institutions behaved amongst the ACL's project actors. These networks definitely give more information about reciprocal ties. They also indicate more interaction between COP and operatives. It is interesting to see that different operatives are involved in discussions and that COP themselves also interact. From discussions with COP, this group of operatives stated they are exchanging valuable information which is helping them to improve their performances at their current work.

Ego Rely on Companies and Institutions Network

As it was the case with the previous set of networks, these networks show strong reciprocal ties between members of the project and COP. COP themselves rely on each other when benchmarking for future projects and works. As an example, they exchange knowledge in terms of technology, techniques and manual labour. Furthermore, operatives seem to strongly rely on the entire COP identified, showing the important role they are currently playing in these networks. This behaviour can be seen as an indicator of influence to the operatives' acquisition of TK, since most of the operatives who declared having any connection to these COP are actually relying on them to do their current work.

CONCLUSIONS

The development of this research was focused on elaborating a research method robust enough to help the research question evolve, and find the right tools to obtain an accurate result. A theoretical framework was defined which linked tacit knowledge, communities of practice, culture of construction workers, and social network analysis, which linked the context of study to the research question.

The study found non expected actors to play very central roles towards other actors in the networks. This is the case of equipment operators, technical assistants, operators and welders. This result shows that actors do not really need a high status in the project structure in order to help other members. With enough expertise they are able to transmit their TK and help other members to perform better.

Operatives agreed to rely on COP when having doubts about their jobs, which make COP ego-centred networks who interact and nourish operatives knowledge by correcting and suggesting current practices. It can be stated that evidently the COP identified actually influenced operatives to acquire TK and become more skilful in their practice. Nevertheless other actors which are part of the project showed to influence more in other operatives. It can be concluded that even though COP play an important role in the operatives acquisition of TK, members of the project itself which

are continuously interacting, socialising and combining their knowledge have a very high impact on operatives acquisition of TK.

SNA definitely provided a great opportunity to understand the different network characteristics in terms of the actors' positions and influences. It showed interesting points of centrality giving rise to different measures of set of actors to the networks provided. The analysis of the discussion and reliance networks clearly showed a social structural environment which is constantly allowing leverage creation of TK. All networks demonstrated that the key to nourish knowledge is to interact on an ongoing basis through the expansion and cultivation of expertise among its members.

Survey Remarks

It was found that the project environment was clearly appreciated during the survey. Attitudes of cooperation and mutual engagement were perceived amongst its members, such as sharing of information, relying on operatives when solving day to day problems, discussing of current situations, and concern about aspirations and needs towards the future. All these situations clearly demonstrated one of the qualities of COP. Through these actions, and even without noticing, operatives are creating a COP which offers stability and provides an identity when connecting across skill boundaries, while focusing on expertise when facing and sharing similar situations.

Furthermore, during the same process cognitive and technical elements of TK were identified. Operatives were seen as transmitting their knowledge and expertise by generating informal learning processes such as analogies, metaphors, storytelling, and simple conversations when explaining their way of working to other colleagues. It was observed that these explanations helped apprentices to define their working environment by perceptions, perspectives and beliefs shaped with the help of their mentors. This kind of information within the project culture and the operative's own knowledge, abilities and skills, definitely helped shape the cognitive level of TK. In many cases operatives agreed to have acquired their knowledge thanks to their colleagues information and help.

Limitations

The results obtained from this study have been based on one case study. Therefore the conclusions drawn from the SNA only represent a very small sample of operatives interacting in the construction sector of the petroleum industry. This study then has given some idea of how this sector behaves and interacts. If this study was developed in the future, it would be a good idea to include the SNA interactions across organisations represented by all the operatives who are part of them.

Lessons learned

There is awareness that the SNA was based on simple questions, which was a requirement when evaluating 63 different actors. Nevertheless perceptions play a very important role and after looking at the results obtained, for future and complementary studies, it would be useful to use a set of semi-structured interviews with some of the actors which may appear to be central and important within a given network.

To understand the nature of knowledge and how it should be created, it is important to recognise that both TK and EK complement each other and therefore are essential when enabling knowledge creation. Nevertheless the SNA was based on questions believed to pursue and analyse TK's acquisition. It is recommended that for a further study, questions focused on pursuing the EK's acquisition should be elaborated in order to integrate and demonstrate how the knowledge conversion interacts and coexists.

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