

# Team Relationship and Knowledge Management in Construction Projects in Thailand Part 1: Network Relationship Analysis Using UCINET Software

## ความสัมพันธ์ในขณะทำงานและการจัดการความรู้ของโครงการก่อสร้างในประเทศไทย

### ภาคที่ 1: การวิเคราะห์ความสัมพันธ์แบบเครือข่ายด้วยโปรแกรม UCINET

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#### Abstract

Problematic relationship within fragmented team structures and inefficient multi-stage project development processes are the two major issues that affect project development performance in the construction industry. The problems are particularly apparent in Thailand's developing economy. This paper focuses on the study of relationship among construction project team members at the pre-design appraisal development stage as the first step to improve the competitiveness of project development in Thailand's construction industry.

Recently completed large commercial residential projects in Bangkok's central business district were used as case studies. For the field research, semi-structured interviews were conducted with a selection of client organisations and key project members using a standardised questionnaire to collect relevant quantitative and qualitative data. UCINET, the social network analysis software, was implemented to analyse quantitative data to reveal the relationship characteristics.

The transformed aggregate scores of strength and satisfaction of relationship, as well as some of the project network characteristics like low network density (0.2045 out of 1.000) in selected case study projects, did not appear to be very accommodating to the creation of good relationship. Other network characteristics, including high reciprocity (68.75%), above average reachability (8 out of 11), relatively short (1.405) average geodesic distance and small degree centralisation (27% out degree and 37% in degree) suggested a close relationship among key project members. Moreover, supportive personal and subgroup characteristics such as low to average (1 to 6 out of 11) out and in degree centrality and a high clustering coefficients (0.725 out of 1.000) were considered as the key factors to achieving effective knowledge creation and transfer. This will be explored further in part 2 of this research.

## บทคัดย่อ

ความสัมพันธ์ที่ไม่ต่อเนื่องในคณะทำงาน อันประกอบไปด้วยผู้มีความรู้ความชำนาญจากหลากหลายสาขา และกระบวนการพัฒนาโครงการที่ประกอบไปด้วยขั้นตอนที่ซับซ้อน เป็นสองสาเหตุสำคัญที่ก่อให้เกิดความด้อยประสิทธิภาพในอุตสาหกรรมก่อสร้าง ปัญหาดังกล่าวยิ่งเด่นชัดมากขึ้นในประเทศไทยที่มีการเปลี่ยนแปลงอย่างรวดเร็วตามวัฏจักรของวงจรเศรษฐกิจ บทความวิจัยชิ้นนี้นำเสนอผลการศึกษาความสัมพันธ์ในคณะทำงานพัฒนาโครงการ ในช่วงการกำหนดเนื้อหาโครงการก่อนการออกแบบ อันจะเป็นบันไดขั้นแรกที่จะนำไปสู่การเพิ่มขีดความสามารถในการแข่งขันของอุตสาหกรรมก่อสร้างของประเทศไทย

อาคารพักอาศัยขนาดใหญ่ที่พัฒนาขึ้นในเชิงพาณิชย์ ที่เพิ่งก่อสร้างเสร็จในย่านธุรกิจใจกลางกรุงเทพมหานคร จะใช้เป็นที่ศึกษา เพื่อเก็บข้อมูลเกี่ยวกับความสัมพันธ์ดังกล่าวทั้งในเชิงคุณภาพและในเชิงปริมาณ ผ่านการสัมภาษณ์ตัวแทนของเจ้าของโครงการและผู้เชี่ยวชาญในการออกแบบก่อสร้างอาคาร โดยใช้ชุดคำถามมาตรฐานที่ออกแบบมาโดยเฉพาะ ข้อมูลเชิงปริมาณที่เก็บรวบรวมได้ จะนำไปวิเคราะห์ด้วยโปรแกรม UCINET เพื่อแสดงความสัมพันธ์แบบเครือข่ายทางสังคม (social network) ในด้านต่าง ๆ

ผลการศึกษาพบว่า ความแข็งแกร่งและความพึงพอใจในความสัมพันธ์ ตลอดจนลักษณะของความสัมพันธ์พื้นฐาน อาทิเช่น ระดับของ network density ที่ต่ำ (0.2045 out of 1.000) ไม่ได้มีส่วนสนับสนุนให้เกิดความสัมพันธ์แบบเครือข่ายที่ดีมากนัก อย่างไรก็ตาม ความสัมพันธ์แบบเครือข่ายในลักษณะเฉพาะ ได้แก่ reciprocity ที่อยู่ในระดับสูง (68.75%) ตลอดจน reachability ในระดับปานกลาง (8 out of 11) หรือ average geodesic distance ที่สั้น (1.405) และ degree centralisation ที่มีขนาดเล็ก (27% out degree and 37% in degree) ซึ่งชี้ให้เห็นถึงความสัมพันธ์ที่ใกล้ชิดในคณะทำงาน ยิ่งไปกว่านั้น ความสัมพันธ์ที่ดีในกลุ่มขนาดเล็ก ที่เห็นได้จากระดับของ out and in degree centrality ที่มีน้อยจนถึงปานกลาง (1 to 6 out of 11) และ clustering coefficients ระดับสูง (0.725 out of 1.000) ยังเอื้อให้การสร้างสรรค์และส่งผ่านความรู้เป็นไปอย่างมีประสิทธิภาพ ซึ่งประเด็นของการบริหารจัดการความรู้ จะได้นำเสนอต่อไปในภาคที่ 2 ของบทความวิจัย

## Keywords

Construction Industry (อุตสาหกรรมก่อสร้าง)

Project Development Performance (ประสิทธิภาพของการพัฒนาโครงการ)

Network Relationship Characteristics (ลักษณะเฉพาะของความสัมพันธ์แบบเครือข่าย)

Knowledge Management (การบริหารจัดการความรู้)

## 1. Context and Rationale

The construction industry transforms raw materials and engages a range of production factors such as labour, land and capital to create the built environment, and is regarded as a significant economic sector. However, its poor and underwhelming performance to meet client requirements on time and budget has always been recognised. Studies in the UK identified two underlying causes. The first, identified in the Egan Report (Department of Trade and Industry, 1998), is the fragmented industry structure. Typically, a construction development project involves at least seven groups of agents or stakeholders, namely clients, architects, quantity surveyors, clerks of works, technical consultants, contractors and subcontractors (Chappell and Willis, 1992). The project development process is also supported by a wide range of professional and research organisations, such as the planning authority, legal advisors, financiers and higher education institutions. Low barriers to entry (Porter, 1980) in a highly competitive environ-

ment create a ‘fallacy of centrality’ (Westrum, 1982 cited in Weick 1995) where each project member concentrates mostly on their own assigned remit. Moreover, psychological adequacy (Hosking and Morley, 1991) makes them strongly protect and promote their personal values and interests.

The second cause is the linear multi-stage project-based development process (Sexton and Barrett 2003). The eleven successive sequences identified by the Royal Institute of British Architects (RIBA) Plan of Work (Table 1) illustrate this well. It can be seen that the early inception stage, where crucial decisions are made on the appraisal development, usually affects performance in the subsequent design, construction and operation stages. It is the limited project life span that causes learning difficulties. As the team is quickly dissolved once the project is completed, the structure does not support the effective transfer of knowledge from experience. This constant state of disruption makes it hard for project members to learn and update new knowledge from retrospective reviews (Morris and Loch, 2002).

**Table 1.** RIBA Plan of Work.

	Work Stages	Activities	Key stakeholders
<b>Preparation</b>	A	Appraisal	Client and building professional team
	B	Design Brief	Client
<b>Design</b>	C	Concept	Building professional’s team
	D	Design Development	Building professional’s team
	E	Technical Design	Building professional’s team
<b>Pre-Construction</b>	F	Production Information	Building professional’s team
	G	Tender Documentation	Client and building professional team
	H	Tender Action	Contractor
<b>Construction</b>	J	Mobilisation	Contractor
	K	Construction to Practical Completion	Contractor and subcontractor
<b>Use</b>	L	Post Practical Completion	Client and contractor

Source: Based on RIBA’s Outline Plan of Work (2007)

In Thailand's developing economy, problems originating from the industry's structure and project development processes are unique due to the differences in social and economic context. As recognised by Toor and Ogunlana (2008), there are managerial problems, especially at the project design and delivery stages, resulting from a lack of resources, planning and scheduling deficiencies, design delays, poor contractor management, shortage of labour, change of orders and contractors' financial difficulties. The roles of certain key stakeholders, such as quantity surveyors and clerk of works, are not prominent. Relationship and communications among project participants are ineffective, especially in smaller sized organisations (Vorasubin and Chareonngam, 2007). At the same time, the widely used traditional contracting procurement approaches do not adequately recognise knowledge management. It is, therefore, difficult for the construction industry in Thailand to effectively procure and use new knowledge to cope with increasingly complex user requirements such as building refurbishment and redevelopment.

In order to create further innovations to improve construction project development performance, two main solutions are proposed: the improvement of relationship within the fragmented structure of the industry, and more effective knowledge creation and transfer in the linear multi-stage project-based development context. In this paper, relationship among construction project team members at the pre-design appraisal development stage will be explored as the first step to improving the competitiveness of Thailand's construction industry.

## 2. Network Relationship

According to Veludo et al. (2006), relationship can be seen in four unique contexts. In *organisational context*, the relationship is created in a formal setting. At the same time, organisation members

are also temporarily engaged with others in a task such as a construction project in *relational context*. People in the same trade such as architectural practice can also develop relationship in *spatial context* as members of professional organisations like the Association of Siamese Architects (ASA). Relationship in the fourth *network context* deserves special attention. Unlike linear relationship in other contexts, network relationship can be out of sequential order. The boundaries of membership in an extensive social structure known as Wenger's (1998) Communities of Practice (CoP) cannot be clearly identified. Moreover, the current study of complex network relationship in construction project development is not extensive, unlike the study of task-driven time-related relationship, involving various approaches including statistical analysis, critical path analysis and process mapping (Pryke and Smyth, 2006). Previous research on relationship such as Pryke (2004) and Davis and Walker (2009) paid little attention to relationship among building professionals at the pre-design stage (Smith et al., 2001). As a result, decisions made on the direction of development, including project parameters and contents (Markus, 1997, cited in Ryd and Friestedt, 2007) as well as 80% of the final project costs (Winner et al., 1988, as cited in Fruchter and Demian, 2005) based on the limited scope of relationship study at the pre-design stage are not sufficiently critical to create a successful project.

It is therefore necessary to investigate the weaknesses and strengths of relationship among the identified key players at the appraisal stage of project development in the Thai context. Combined with the study of the knowledge creation and management processes within the key players' organisations, a strategic conceptual framework to strengthen relationship, improve knowledge transfer and enhance management can then be developed and tested.

### 3. Research Methodology

Deductive explanatory research is used to study dependent and independent variables that influence network relationship among key project members. A quantitative approach was adopted to measure the existence, strength and satisfaction of relationship on a 5-point Likert scale. UCINET computer software was used to analyze this quantitative data to further reveal the extensive characteristics of network relationship at project level, namely *network size, density, reciprocity, reachability, geodesic distance* and *network centralisation*. At the same time, the characteristics of individual project members within a network were also captured in *out and in degree centrality* and *clustering coefficients*. Subgroup characteristics were also measured in terms of *cliques, ego network* and *brokerage*. Points and lines were also used to represent people and their respective relationship in a network diagram.

The research method involved selecting multiple case studies to explore these issues in a fast changing and dynamic context. A number of criteria were used to find appropriate examples (Table 2). Firstly, the selected samples of large-scale commercial residential development in Bangkok's central

business district (CBD) had to be developed by well established property companies with well-kept records of past projects after the original team had dispersed. Secondly, the preferred cases engaged a large number of building professionals and organisations to create substantial network relationship that are worth studying. Thirdly, the projects had to be recently completed so that the memory of the project was still relatively fresh in the minds of former project members. Willingness to participate in the study was also an important factor.

Semi-structured interviews based on a standardised questionnaire made it possible to study any particular issue in depth from the primary sources. The first two stages of a three-stage plan were designed to collect relationship information data from selected project members. At stage 1, executives representing five Thai property development public companies (plc) that owned and developed ten large and successful recent commercial residential projects were interviewed from July to September 2007. To protect their privacy, Case S1, Case R, Case S2, Case L and Case A were used as coded names to represent the companies. For the same reason, abbreviations were used to replace the real names of selected projects. As seen in Table 3,

**Table 2.** Information on selected construction projects.

Client s	Selected projects	Number of units	No. of floors x building	Project value (m Baht)	Project timeline
S1	OTL	302	20	906	2004-2006
	PMR	Serviced apt: 138	28	1,546	2003-2005
		Condo: 358	30		
R	LKS	165	36	1,600	2003-2005
	LGN	75	14	1,545	2004-2006
S2	YKT	79	8	354	2003-2005
	SKV10	118	8x2	630	2004-2006
L	SUB	155	8x3	N/A	2003-2005
	NTW	294	8x5	N/A	2003-08/2005
A	BKK	580	26x1 & 27x1	2,500	2004-2007
	ADRS	224	24x1	1,000	2005-2008

**Table 3.** Summary of interview participants at stage 2 identified by roles, organisations and projects.

Role at appraisal development stage	Organisation	Number of people interviewed	Projects
Planning authority	BMA	1	All large scale projects
Architect	WBT	1	LKS
	SJA	1	LGN
	ATP	1	YKT
	PT	1	SKV10
	PLN	1	SUB
	HNT	1	NTW
	REP	1	BKK and ADRS
Interior designer	0	0	-
Landscape designer	0	0	-
Structural engineer	ATC	1	YKT
	RKV	1	SUB/NWT
	CWT	1	LGD
	MH	1	LKS
	GMT	1	BKK and ADRS
M&E engineer	ECLS	1	LGD
	VG	1	YKT
	PAS	1	BKK and ADRS
Project manager	S2	1	YKT and SKV10
	A	1	BKK and ADRS
Legal consultant	ANO	1	LKS and LGN
Client executive	S1	2	OTL and PMR
	R	1	LKS and LGN
	S2	1	YKT and SKV10
	L	1	SUB and NTW
	A	2	BKK and ADRS
User	0	0	-
Investment and financial consultant	0	0	-
Professional organisation	0	0	-

they were OTL, PMR, LKS, LGN, YKT, SKV10, SUB, NTW, BKK and ADRS. The interviews aimed to reveal the existence, strength and satisfaction of relationship with other members at the appraisal development stage. As a result of snowball sampling, 21 key project members identified by clients at stage 1

were interviewed at stage 2 in July and August 2008. Stage 3 was designed to collect information on knowledge management practices in key project member organisations that will be analysed and presented in part 2.

#### 4. Findings of Relationship in Selected Projects

##### 4.1 Existence of Relationship

Based on research participants' responses (0 = no relationship and 1 = established relationship), the high transformed aggregate scores<sup>1</sup> of the relationship in Table 4 (3.636 to 4.091 out of 5) suggested noticeable links among most of the key project members at the pre-design appraisal development stage under the widely adopted construction management procurement system. The lack of contributions from other key members, such as interior and landscape designers who usually join the team at the later stage, or quantity surveyors whose significant role at construction stage is generally performed by the project manager, accounted for the proportionately reduced scores. Partnering or long cultivated two-way collaborations had also been contractually established between clients, architects and engineering consultants in a series of projects developed by Case A. From time to time, new collaborations were established with specialists as strategic partners, such as property developers in different market segments or legal consultants, like in Case R. Non-contractual relationship among project members was also prominent. Project management representatives specifically

assigned by Case L and the Building Control Division in the Public Work Department of the Bangkok Metropolitan Authority (BMA) have established strong relationship that is the basis of the project's success. However, relationship between clients and users was indirect, since the information required to create programmes for speculative commercial projects was generally derived from the clients' databases. Support from professional organisations, higher education and research institutions were marginal and infrequent.

##### 4.2 Strength of Relationship

Responses given by a limited number of research participants (1 = the least frequent contact, 5 = the most frequent contact) transformed into aggregate strength scores showed generally weak collaboration (0.144 out of 5 in project OTL to 0.955 out of 5 in projects BKK and ADRS). Information on the strength of relationship for each key project member varied. Client organisations had the strongest relationship (rated 5) between clients, project managers, the planning authority and building professionals (Table 5). The results also show weak to moderate relationship (score 2 to 3) between clients, financial consultants and project managers, as seen in Case S1 and R. Other key members such as the MH engineering firm established medium-

**Table 4.** Transformed aggregate scores of existence, strength and satisfaction of network relationship in selected projects.

Clients		S1		R		S2		L		A	
Projects		OTL	PMR	LKS	LGD	YKT	SKV10	SUB	NTW	BKK	ADRS
Aspects of relationship	Existence of relationship (out of 5)	3.636	3.636	4.091	4.091	3.636	3.636	3.636	3.636	3.636	3.636
	Strength of relationship (out of 5)	0.144	0.167	0.485	0.583	0.795	0.470	0.417	0.417	0.955	0.955
	Satisfaction of relationship (out of 5)	0.114	0.114	0.455	0.538	0.826	0.5	0.424	0.424	1	1

**Table 5.** Strength and satisfaction of relationship between clients and key project members.

Cases	In-house financial consultant		Project manager		Planning authority		Building professionals	
	Strength	Satisfaction	Strength	Satisfaction	Strength	Satisfaction	Strength	Satisfaction
<b>S1</b>	2	5	3	5	5	2	5	5
<b>R</b>	2	5	3	5	5	2	5	5
<b>S2</b>	4	3	3	3	3	2	3	3
<b>L</b>	5	4	5	4	5	4	5	4
<b>A</b>	3	4	4	4	3	2	3	4

strength connections (score 3) with regional offices, professional organisations as well as product and building technology suppliers. Moreover, most of the architects like WBT, HNT and PLN had weak relationship (score 1) with the planning authority and professional organisations that provided technical support. The strength of relationship between architects, clients and project managers ranged from medium (3) to high (5) depending on to the types of project and business management style of the clients. In design-oriented companies like SJL, HNT and PLN, the strength of relationship with others was moderate (score 3). Clients' briefs and suggestions were considered only as design guidelines. On the contrary, information sharing relationship with clients, project managers and engineers was stronger (score 5) for commercially-oriented companies like WBT, PT, ATP and REP.

#### 4.3 Satisfaction of Relationship

Based on a Likert scale where 1 = lowest satisfaction and 5 = highest satisfaction, the transformed aggregate scores of relationship strength and satisfaction were also low (from 0.114 out of 5 for project OTL to 1 out of 5 for projects BKK and ADRS) due to the limited number of research participants. However, those key project members interviewed were generally satisfied with the state of their relationship.

For example, client A-VP was fully satisfied (score 5) by the strongly established relationship with their architect, project manager, structural and M&E engineers. On the contrary, A-VP's moderate satisfaction of relationship with the planning authority (score 3) was due to problematic coordination. The rare involvement of interior and landscape designers at the early stage of appraisal development also resulted in moderate satisfaction. This was also true in projects developed in the S2 and A case studies. The moderate satisfaction scores (3) given by client S2 originated from their aspiration to achieve better communication and management. In the case of the bureaucratic planning authority, moderate satisfaction (3) originated from the slow problem solving process led by the project coordinators.

In the next section, many characteristics of network relationship among team members beyond the basic aggregate scores that influence knowledge creation, communication and sharing is revealed, using UCINET software based on the relationship existence data. The analysis is conducted at three levels: project, individual and subgroup. OTL, as a large commercial residential project recently developed by an established client (S1) with extensive experience in property development, was selected as the case study for its extensive involvement of building professionals and organisations.



## 5. Network Relationship Analysis in OTL Project Using UCINET Software

In general, most of the relationship in the OTL project, as suggested by the project manager, was reciprocal. Relationship between the client executive and building professionals, especially with architects who worked closely together, was strong. However, some members such as the user had only indirect one-way links with the client, while the planning authority had a single link with the project manager. There was no established relationship with the specialists who provided additional management skills and services, such as financial or legal consultants. Contributions from professional organisations were not widely recognized by most project members. Satisfaction of relationship between client, architect, project manager, planning authority and engineers was generally moderate (score 3).

### 5.1 Network Relationship at Project Level

At the project level (Table 6), there were 12 key members who had at least one relationship with others in the OTL project, meaning that the network size was relatively small. OTL's network density, or the proportion of the present ties compared to all possible pairs of ties (132 ties<sup>2</sup>), was as low as 0.2045

out of a 1.000 maximum. Low density means that there is limited interaction and low participation in project development, leading in turn to poor decision making. The high level (69%) of *reciprocity*, or the proportion of project members with reciprocated ties or mutual connections to all the possible pairs, suggested that there was strong potential for knowledge transfer among project members. It was also found that project management style was one of the key influential factors affecting network density and reciprocity. Traditional project procurement within the rigid hierarchy system used by the OTL project developer created a lower network density and reciprocity compared to projects developed by A where a vice president (VP) has full authority to initiate effective collaboration and to make all final decision making. However, a VP's authoritarian style might discourage the development of effective two-way communication in the project team.

*Reachability* shows the existence of paths that can be traced from the source of information to the target, no matter how many other members are in between. A high level of reachability suggests the low division of the network into smaller subgroups. It also means a higher potential number of project members are able to connect and transfer knowledge. Of the total 11 paths of project OTL<sup>3</sup>, there were only 5 to

**Table 6.** Summaries of project OTL network characteristics at project level.

Project	Client	Transformed aggregate scores (5)		Network size (12)	Density (1.000)	Reciprocity (1.000)	Reachability (11)	Average Geodesic distance	Out degree centralisation (%)	In degree centralisation (%)
OTL	S1	Existence	3.636	12	0.2045	0.6875	8	1.405	27.273	37.190
		Strength	0.144							
		Satisfaction	0.114							

8 paths of any length that connected one key project member to others. The ability to reach other members can also be significantly influenced by the management style. For example, the number of reachable members was higher (8 to 9) with the shortened line of command in Case A's project. This was the result of the adopted procurement approach equivalent to partnering where every aspect of the project development is fully supervised by a vice president (VP) as project manager.

*Geodesic distance* is the shortest possible path for information to be effectively passed on between project members. The 1.405 average geodesic distance in project OTL reflected the likelihood that information could reach everyone through short direct links fairly quickly. Hence, knowledge transfer is likely to be more effective than a longer chain of connections involving one or two members between the source and target. *Out degree* and *in degree network centralisation* show the variance of a complete (100%) star network of a similar size that is recognised as the most centralised or the most unequal network. High levels of centralisation suggest high concentration in a network, with few smaller groups. In the OTL project, out degree centralisation was only 27.273% while in degree centralisation was 37.190%, of the ideal centralised and complete network. The low network centralisation suggested a fragmented construction development project team, with a significant impact on knowledge management as a result. Moreover, the higher score of in degree compared to out degree network centralisation showed the more distinctive role of *prominent* project members, such as building professionals with distinctive technical skills and knowledge, than *influential* project members such as the project manager.

## **5.2 Network Relationship Characteristics of Individual Project Members**

The power associated with the locations or positions of individual project members in a network is known as *out* and *in degree centrality*. Members

with a high out degree tend to be the most influential as they are the primary sources of information. On the other hand, members with a high in degree tend to be in prominent positions that others want to connect with. In the OTL project, the project manager had the highest scores (5.000) of out and in degree centrality (Table 7). This influential and prominent figure had both outward and inward connections with 5 out of the highest possible 11 other project members. The lack of out or in degree centrality for dedicated specialists like investment and legal consultants, as well as interior and landscape designers, suggested that their roles were not seen as important at this appraisal development stage. They were not at the centre of the network and could not exert even their limited influence over others.

A network with a high degree of clustering coefficients or a high average density of all actors in a network tends to be less efficient at knowledge management and transfer. The clustering coefficients in the OTL project (0.725 out of the maximum 1.000) were very high for a small and low density network. Further study of each project member's adjacent neighbourhood density or *node clustering coefficients* revealed project members who were capable of performing the most efficient information and knowledge transfer. In the OTL project, the architect, structural and M&E engineers had very high node clustering coefficients of 0.750. It means that of all the possible 10 pairs of link, 75% or 7.5 pairs were present in these project members' adjacent neighbourhood. However, too many large neighbourhoods in a network can become an obstacle to effective inter-organisational knowledge creation and transfer beyond the immediate circle.

## **5.3 Subgroups in Network Relationship**

Project members can also be seen as part of the totally complete subgroups or *cliques* where every member possesses all possible ties. There were two cliques in project OTL with multi-membership. Clique 1 was composed of the client, architect,

**Table 7.** Summaries of individual member and subgroup network characteristics in the OTL project.

Project	Project members	Out degree centrality (11)	In degree centrality (11)	Clustering coefficients (1.000)	Number of possible pairs	Node clustering coefficients	Number of Cliques	Number of N-cliques	Ego network size	Ego network density	Brokerage	Brokerage scores (time): Liaison
OTL	1. Client	4.000	6.000	0.725	15.000	0.500	2	2	4.00	100.00	0.00	5
	2. User	1.000	0.000		0.000				1.00		0.00	0
	3. Architect	4.000	5.000		10.000	0.750			4.00	100.00	0.00	1
	4. Investment and financial consultant	0.000	0.000		0.000				0.00	0.00	0.00	0
	5. Legal consultant	0.000	0.000		0.000				0.00	0.00	0.00	0
	6. Project manager	5.000	5.000		10.000	0.600			5.00	60.00	4.00	8
	7. Planning authority	1.000	1.000		0.000				1.00		0.00	0
	8. Interior designer	0.000	0.000		0.000				0.00	0.00	0.00	0
	9. Landscape designer	0.000	0.000		0.000				0.00	0.00	0.00	0
	10. Structural engineer	4.000	5.000		10.000	0.750			4.00	100.00	0.00	1
	11. M&E engineer	4.000	5.000		10.000	0.750			4.00	100.00	0.00	1
	12. Professional org.	4.000	0.000		6.000	1.000			4.00	100.00	0.00	0

project manager, structural and M&E engineers. Clique 2 contained all the members of clique 1 except project manager and professional organisations. Most members of cliques 1 and 2 were directly connected to other adjacent members, as seen from the 100% *clique proximity*. The application of a slightly loosened rule that allows the inclusion of indirect connections, usually 2, to increase speed and scope of knowledge transfer in larger and fewer cliques created 2 *n-cliques* in the OTL project.

*Ego network* is a subgroup at the most personal level. It is a one step connection from a particular project member to others. Known as an out neighbourhood, it can be used to support effective inter-organisational knowledge transfer. In project OTL, the project manager had the largest ego network size of 5. However, the project manager’s ego network density was a moderate 60. This shows that with 60% of all the project manager’s possible pairs of

connection available, it might not be possible to support effective inter-organisational knowledge transfer.

The *brokerage* score, calculated using a tool in UCINET software, shows 4 indirectly connected pairs of links in the OTL project manager’s ego network. It shows the probability that the project manager was able to perform the role of relationship broker. The most frequent brokerage role was liaison, where the project manager is a free agent who creates 8 connections between people from two different groups.

## 6. Network Relationship Diagram

Outcomes from the analysis of network relationship, based on the existence of relationship information using UCINET software, can also be presented as a network diagram (Figure 1). In the

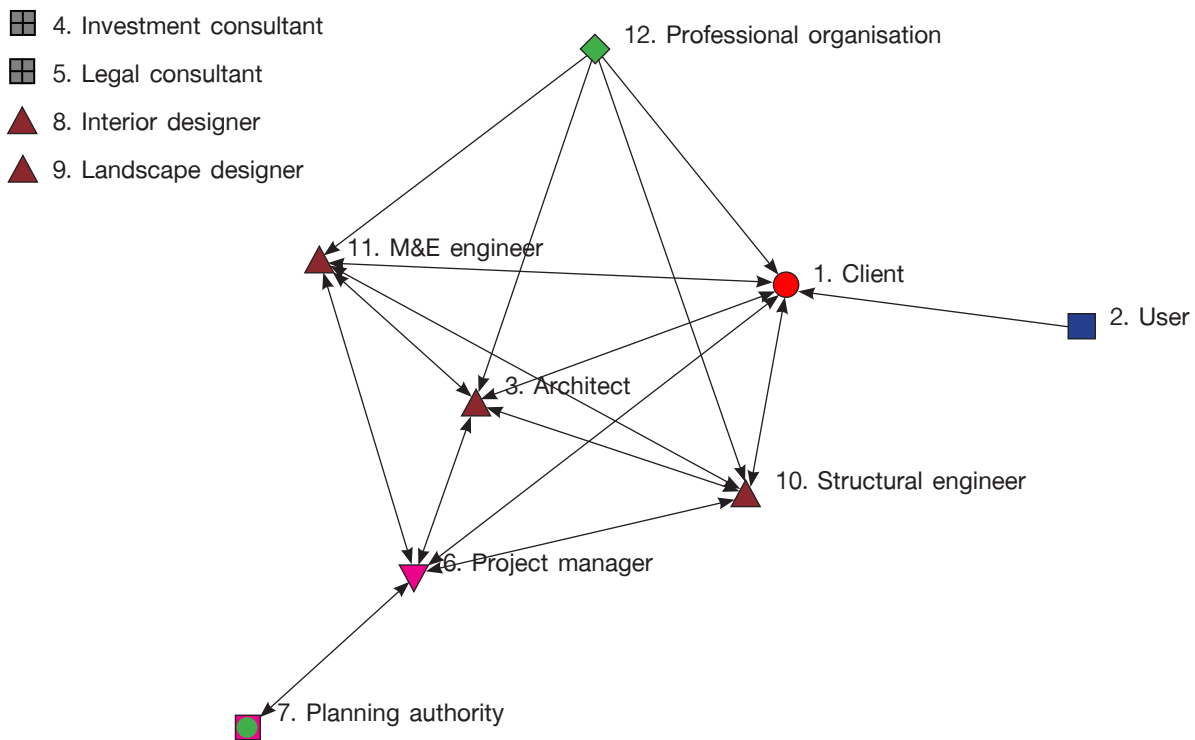


Figure 1. Project OTL network diagram.

OTL project, the client (●), building professionals including the architect and engineers (▲) as well as the project manager (▼) were at the centre of the most connections since they were the sources of information needed for project appraisal development. Other specialists also had significant roles in the network. The planning authority (■) only traded information with the project manager. The professional organisation (◆) and user (■), with the outward directed arrows, can also be regarded as influential members who provided support to others. Two-headed arrows linked some prominent members whose distinctive capabilities attracted others' attention, while information could also freely flow out from these influential members. Investment and legal consultants (■), interior and landscape designers (▲) were left without attached lines because they had no established relationship.

## 7. Conclusion

The relationship between project members certainly has significant implications on the efficiency of knowledge creation and inter-organisational knowledge transfer and management. Even though there were a number of key members including clients, architects and engineers significantly involved in appraisal development, including the most influential and prominent project manager, some other specialists such as investment and legal consultants, interior and landscape designers as well as research organisations and professional representatives were not included at all. These fundamental weaknesses were recognised as low network density in UCINET terminology. However, low to moderate strength and satisfaction of relationship, as well as other network characteristics such as moderate degree of reachability, high level of reciprocity and a

relatively short geodesic distance, reflected the tendency to achieve close and effective relationship. Numeric and graphic Information regarding the current relationship within Thailand's construction project team can then be used to plan systematic improvement.

The key point in the forthcoming part 2 of this research is the extensive study of current knowledge

creation and management practice in the same group of selected key project members' organisations, identified in the literature as another solution to improve construction project development performance. The article in the later sections will also propose a three-stage framework to improve both network relationship and knowledge management.

## Notes

<sup>1</sup> Raw data compared to the maximum score and transformed to the full score of 5

<sup>2</sup> This figure was calculated from the equation  $k*(k-1)$  where  $k$  = number of project member. For this example,  $12*(12-1) = 12*11 = 132$

<sup>3</sup> It was calculated from  $(k-1)$  where  $k$  = number of project member and relationship with oneself does not count.

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