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ANALYZING RELATIONSHIPS AMONG SUCCESS VARIABLES OF CONSTRUCTION PARTNERING USING STRUCTURAL EQUATION MODELING: A CASE STUDY OF TAIWAN'S CONSTRUCTION INDUSTRY

Wei Tong Chen[1], Tung-Tsan Chen[2], Chun Sheng Lu[3], Shu-Shun Liu[4]

[1, 4]*Dept. of Construction Engineering, National Yunlin University of Science & Technology, Yunlin 640, Taiwan*
[2]*Dept. of Civil Engineering and Engineering Management, National Quemoy University, Kinmen 892, Taiwan*
[3]*Graduate School of Engineering Science & Technology, National Yunlin University of Science & Technology, Yunlin 640, Taiwan*
E-mails: [1]chenwt@yuntech.edu.tw (corresponding author); [2]tungtsan@nqu.edu.tw; [3]lu9116213@yahoo.com.tw; [4]ssliu@yuntech.edu.tw

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Abstract. This study explored the success variables (SVs) in construction partnering and the relationships among the SVs using structural equation modeling (SEM). Research results show that four successful factors (collaborative team culture, long-term quality perspective, consistent objectives, and resource sharing) have a significant influence on the success of construction partnering. Of the four factors, collaborative team culture and consistent objectives have the highest correlation. Collaborative team culture and long-term quality perspective have the lowest correlation. Additionally, good cultural fit has the most influence on characterizing collaborative team culture, commitment to continuous improvement has the highest influence in characterizing long-term quality perspective, clear understanding has the highest influence in characterizing consistent objectives, and availability of resource has the highest influence in characterizing resource sharing. The proposed SEM framework provides information which enables the users to control individual SV by considering their relationships with other SVs.

Keywords: success variable, construction partnering, construction industry, factor analysis, structural equation modeling.

1. Introduction

Success in construction projects is dependent on the effective organization of multiple, specialized teams, each of which brings its own ability, experience, knowledge and skill towards completing the joint project, but which also bring their own objectives, goals and management styles, which may not be entirely complimentary. Failure to tightly coordinate communication between these teams can result in schedule delays, cost overruns and poor final results, exposing project participants to potential legal and financial repercussions (Thompson, Sanders 1998; Cheng, Li 2002). Over the past few decades, increased competition, expectations, globalization and regulation have transformed the construction industry, and firms have responded by seeking alternative management methods to allow them to rapidly and flexibly respond to construction problems and manage risk.

Numerous studies have yielded several definitions of partnering, such as W. T. Chen and T.-T. Chen (2007), Bennett and Jayes (1998), Crowley and Karim (1995) and Yeung *et al.* (2007a). Nyström (2005) even proposed a new method to define the concept of partnering in a flexible and structured way. He concluded that there are two necessary components in partnering – *trust* and *mutual understanding* – and other components can be added to form a specific variant of partnering. However, the definition developed by the Construction Industry Institute (CII) in the United States is the most widely cited one. CII defines partnering as "a long-term commitment between two or more organizations is important for achieving specific business objectives by maximizing the resources of each participant. Accordingly, it is necessary to replace traditional relationships with a shared culture without regard to organizational boundaries. Such a new relationship is based on trust, dedication to common goals, and an understanding of individual expectations and values".

The fundamental principles of partnering, namely trust, commitment, communication, respect, and equality, include appropriate consideration of the interests of all parties at every level (CII 1991; Cowan *et al.* 1992; Uher 1999; Li *et al.* 2000), and aim to build "trust" among the parties involved in a contract. Such trust helps avoid problems with the project that recently have tended to lead to litigation (Moore *et al.* 1992; Wong *et al.* 2005). Partnering is a way to quickly, efficiently and inexpensively achieve these goals (Wilson *et al.* 1995). Additional advantages of partnering include reduced risks, cooperative problem solving, increased competitive advantage, increased asset security, the opening of new markets, and the enhancement of productivity (Chan *et al.* 2004; W. T. Chen, T.-T. Chen 2007; Yeung *et al.* 2007b). In Taiwan's construction industry, a constant lack of trust and verification of information has characterized the working relationship between owners, designers, contractors and materials providers. Owners continually seek the lowest cost contractors (Chen *et al.* 2010). In response to perceived exploitation by owners, contractors (professionals) gradually become less loyal and less trustworthy. Therefore, the practice of construction partnering between owners and contractors is steadily growing.

Researchers and practitioners have proposed various success factors to facilitate construction partnering. Chan *et al.* (2006) identified 10 critical success factors (CSFs) of partnering projects among the private, public and infrastructure sectors in six cited projects in Hong Kong. The top three CSFs are "mutual trust amongst the project participants", "early implementation of partnering process" and "commitment to win-win attitude". "Regular monitoring of partnering process" was the least important CSF amongst the six partnering projects. They concluded that the level of mutual trust and the level of commitment to a win–win attitude are the most critical factors to partnering success. Cheng and Li (2002) used two surveys (a simple rating method and the analytic hierarchy process) to produce empirical evidence for highlighting the relationships between the construction CSFs and individual partnering process stages, namely: formation, application, and completion/reactivation. The study reaffirms that there are critical common factors affecting the whole partnering process and various CSFs influencing particular process stages. Specifically, the four critical common factors are: top management support, open communication, effective coordination, and mutual trust. Cheng *et al.* (2000) developed a framework to identify the CSFs for construction parties implementing partnering arrangements. The CSFs identified in the framework are effective communication, conflict resolution, adequate resources, management support, mutual trust, long-term commitment, coordination, and creativity. The framework highlights the influence of contextual characteristics and management skills on partnering success. However, incentivization scheme has recently been found to be another factor of partnering success. Chan *et al.* (2008) analyzes the rationale behind the successful development of partnering culture based on a case study of the infrastructure sector of Hong Kong. According to their results, they recommended that partnering together with target cost contracts, such as incentive agreement, greatly assists in the achievement of construction excellence and can provide a workable model for enhancing overall project performance in electrical and mechanical projects.

Using the Delphi survey technique, Yeung *et al.* (2007b) developed a model to objectively measure the performance of partnering projects in Hong Kong based on a consolidated Key Performance Indicators' conceptual framework. A composite Partnering Performance Index for Hong Kong's partnering projects can provide an all around assessment of partnering performance. The index can be used to measure, evaluate and improve the performance of partnering projects to strive for construction excellence. Additionally, Yeung *et al.* (2008) established quantitative indicators (QIs) and quantitative ranges (QRs) for each KPI's for Hong Kong's construction projects. The identified QIs and QRs could be used to evaluate objectively different partnering projects on a common basis and then help to set a benchmark for measuring the performance level of partnering projects. QIs and QRs can be applied to measure, evaluate and improve the existing performance of their partnering projects to strive for construction excellence. In summary, previous research in this field has identified various success factors of construction partnering. However, the relationships among these success factors of construction partnering remain unclear.

Defining a construction partner as an owner or professional participant in a jointly-managed construction project, this type of partnership was present in Taiwan's construction industry over 20 years ago, but was obscured by poorly defined contracts. With Taiwan's economic development, globalization, and privatization of public enterprises, over the past ten or so years, public and private construction partnerships have come to be defined as cooperation between construction management partners, with owners and contractors emerging as the primary advocates for partnership. However, the state has no clear policy for implementing such partnerships, thus making it difficult to accurately count the number of projects implemented under such partnerships. Jointly-managed construction projects began over 20 years ago in Taiwan with a model promoted by the private sector, and has developed up through the most recent decade as a public-private construction industry partnership defined in the spirit of cooperation on jointly-managed construction projects. The aim of this study is to explore the SVs in construction partnering in Taiwan and the relationships among these identified SVs.

2. Questionnaire development and distribution

2.1. Questionnaire development

This empirical study obtained raw data using a questionnaire survey. The questionnaire used a Likert-type scale from 1 (extremely unimportant) to 5 (extremely important). The original questionnaire included 22 structural questions representing 22 nominated SVs in construction partnership. Respondents contributed their opinions on the importance of construction partnering. Reliability testing was conducted to examine measurement accuracy and also to ensure that characteristics and variables were accurately measured. The measurements were combined with the forecast number of characteristics to represent the correct measurements.

As seen in Table 1, 22 nominated SVs were collected based on the framework for developing construction partnerships proposed by Li *et al.* (2001), the behavioral aspects of construction partnerships by Cheung *et al.* (2003), insights on co-operation in construction projects from Cheung *et al.* (2003) and Li *et al.* (2001), and insights on project management, project objectives and success factors (Chan *et al.* 2004; Belout, Gauvreau 2004; Atkinson 1999; Chua *et al.* 1999).

Table 1. The 22 nominated SVs in construction partnership

Success Variables	Survey Result	
	Means	Ranking
SV1 Mutual trust	4.32	6
SV2 Effective communication	4.63	1
SV3 Commitment from senior management	4.25	8
SV4 Clear understanding	4.24	9
SV5 Acting consistent with objectives	4.37	3
SV6 Dedicated team	4.03	17
SV7 Flexibility to change	4.07	14
SV8 Commitment to quality	4.33	5
SV9 Commitment to continuous improvement	4.16	12
SV10 Long-term perspective	3.92	18
SV11 Total cost perspective	4.20	10
SV12 Formation at design stage	4.05	16
SV13 Good cultural fit	3.80	19
SV14 Company wide acceptance	4.08	13
SV15 Technical expertise	4.39	2
SV16 Financial security	4.29	7
SV17 Questioning attitudes	4.35	4
SV18 Availability of resources	4.06	15
SV19 Equal power/empowerment	4.18	11
SV20 Contract administration capabilities	3.31	20
SV21 Ability to obtain business	3.15	22
SV22 Adapt owner changes	3.22	21

The study questionnaire was validated through a pilot test and distributed to forty-two experienced construction industry professionals who were asked to complete the questionnaire and comment on its readability, comprehensiveness and precision. The pilot test (questionnaire) was distributed to forty-two experienced construction industry professionals including 12 project owners, 10 practitioners of design firms, 10 contractors, and 10 academic professionals. Table 2 shows the background of the 42 professionals including years of working experience, current position and specialties. Highly equipped with popularity and recognition in the construction industry, the 42 professionals were requested to complete the questionnaire and comment on its readability, comprehensiveness and precision. Thirty-four completed questionnaires were collected and Cronbach's α determined for each factor, returning a reliability value of 0.904, which indicates a high degree of reliability (Gay 1996). Referring to Table 1, there is a huge gap (0.49/5.0 = 12.89%) between 19th-ranked SV13 and 20th-ranked SV20 in terms of variable average value. Therefore, it was decided that any variable with an average value below 3.8 would be deleted. The corrected scale contained 19 SVs, reduced from 22 SVs. Three variables which were deleted include *Contract administration capabilities* (3.31), *Ability to obtain business* (3.15) and *Adapt owner changes* (3.22).

Table 2. Background of the 42 professionals

Roles	Yrs. of Working Experience	Position	Working Attributes and Specialties
1	2	3	4
Project owner 01	35	GM	Business planning, corporation management
02	21	GM	Corporation management, business coordination
03	35	GM	Corporation management
04	28	Deputy GM	Business development, corporation management
05	30	AM	Land development, business coordination
06	27	AM	Construction and Management
07	20	VM	Marketing and sales, business coordination
08	32	Manager	Project management
09	28	President	Corporation management
10	16	VM	Marketing and sales, business coordination
11	31	President	Business planning, corporation management
12	28	President	Corporation management, business coordination
Designer 01	26	Deputy GM	Design, business coordination
02	30	GM	Planning and design, business coordination
03	20	Architect	Planning and design, supervision
04	33	Architect	Planning and design
05	30	Architect	Planning and design
06	35	Architect	Planning and design
07	32	Architect	Design review, business coordination
08	28	Architect	Planning and design, supervision
09	30	Manager	Design review, business coordination
10	34	PE (structural engineering)	Structural design, supervision
Contractor 01	29	GM	Corporation and construction management
02	22	Deputy GM	Project and construction management
03	25	GM	Corporation and construction management
04	21	Manager	Project and construction management
05	25	PE (civil engineering)	Project and construction management
06	20	Manager	Project and construction management
07	10	PE (structural engineering)	Project and construction management

End of Table 2

1	2	3	4
08	17	Manager	Project and construction management
09	20	Vice Manager	Project and construction management
10	31	Manager	Project and construction management
Academic expert 01	31	AP	Transportation Engineering
02	26	AP & Dept. head	Transportation engineering
03	18	AP & Director	Architectural engineering
04	12	AP & Dept. Chair	Architectural engineering
05	18	Professor & Dept. Chair	Civil engineering management
06	15	AP	Civil engineering management
07	8	Assistant Professor	Civil engineering management
08	20	Professor	Construction engineering management
09	16	AP	Construction engineering management
10	25	Professor	Construction engineering management

Note: GM: General Manager; VM: Vice Manager; AM: Assistant Manager; PE: Profession Engineer; AP: Associate Professor

2.2. Questionnaire distribution

The survey was distributed to construction industry practitioners in Taiwan. The research subjects were drawn based on the three considerations: (1) different project attributes (high-tech/non-high-tech) and scales (large/small) may result in different aspects for evaluation; (2) most high-tech construction projects in Taiwan are large-scale; (3) most non-high tech projects could be classified as large-scale and small-scale projects. Consequently, respondents were found in high-tech large construction projects (HLCP), non-high-tech large construction projects (NLCP), and non-high-tech small construction projects (NSCP). High-tech construction projects are large projects requiring highly-interfaced integration, such as the Taiwan High Speed Rail project. Non-high-tech construction projects do not require high-interface integration (e.g., roadway construction). Three hundred and thirty questionnaires were distributed via mail, e-mail, fax, telephone and personal delivery, with 221 retrieved (67% response rate). As seen in Table 3, 50 responses came from HLCPs, 125 from NLCPs, and 46 from NSCPs. Broken down by profession, the sample included 39 (17.6%) government employees, 32 (14.5%) project owners. 63 (28.5) design professionals and 87 (39.4%) construction firms. The respondent group was made up of highly-experienced professionals, with nearly 75% having over 5 years of experience in the industry. Although construction professionals are not necessarily knowledgeable in partnering practices, they still are more conversant on the subject than those with less construction experience.

Table 3. Analysis of the sampling group

Sampling group	HLCP	NLCP	NSCP	Total	%
Government employee	3	22	14	39	17.6
Project owner	14	16	2	32	14.5
Design firm	4	39	20	63	28.5
Construction firm	29	48	10	87	39.4
Total	50	125	46	221	100.00

Note: HLCP stands for hi-tech large construction projects; NLCP stands for non-hi-tech large construction projects; NSCP stands for non-hi-tech small construction projects

2.3. Correlation analysis of SV

Based on the survey results, correlation analysis using Pearson's correlation coefficient was conducted and discussed as follows. Pearson's correlation coefficient is a statistical tool used to determine the degree and direction of relatedness between two variables. Possible values of the correlation coefficient range from –1.00 to +1.00, and the closer the number is to an absolute value of 1.00, the greater the degree of relationship. Table 4 shows the correlation among all examined variables executed by SPSS.

The Bartlett test of sphericity for the survey is 1613.353, and the associated significance level is 0.000, indicating that the population correlation matrix is not an identity matrix (Norusis 2001). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is 0.900, which is significantly greater than 0.5 and thus is considered highly acceptable. The results of tests show the sample data is appropriate for FA. Referring to Table 4, the relationships with high-correlation coefficients (greater than 0.5) were as follows: SV6 (dedicated team) with SV7 (flexibility to change), SV7 (flexibility to change) with SV18 (availability of resources), SV8 (commitment to quality) with SV9 (commitment to continuous improvement), SV9 (commitment to continuous improvement) with SV17 (questioning attitudes), SV12 (formation at design stage) with SV13 (good cultural fit), SV13 (good cultural fit) with SV14 (company wide acceptance), SV18 (availability of resources) with SV19 (equal power/empowerment).

The obtained correlation coefficients have certain implications. For example, the higher occurrence of "commitment to quality" implies a higher occurrence of "commitment to continuous improvement". The higher correlations among SVs (Table 4) also demonstrated that correlations among SVs are complicated and require further investigation. The implications provide limited information to users because the correlation coefficient indicates only a simple relationship between two variables. Users cannot gain a holistic perception of most key variables of project partnering. Therefore, correlation coefficient analysis alone in this case cannot provide an acceptable result for distinguishing the relationships among SVs of construction partnering.

Table 4. Correlation matrix showing correlations among the SV for partnering

SVs	SV1	SV2	SV3	SV4	SV5	SV6	SV7	SV8	SV9	SV10	SV11	SV12	SV13	SV14	SV15	SV16	SV17	SV18	SV19
SV1	1.000																		
SV2	0.183	1.000																	
SV3	0.280	0.270	1.000																
SV4	0.288	0.330	0.347	1.000															
SV5	0.317	0.311	0.255	0.460	1.000														
SV6	0.339	0.229	0.198	0.426	0.410	1.000													
SV7	0.267	0.348	0.264	0.418	0.306	0.546	1.000												
SV8	0.182	0.210	0.177	0.288	0.321	0.343	0.323	1.000											
SV9	0.139	0.214	0.274	0.371	0.345	0.375	0.402	0.720	1.000										
SV10	0.300	0.263	0.210	0.420	0.331	0.423	0.412	0.437	0.499	1.000									
SV11	0.190	0.207	0.268	0.174	0.295	0.187	0.283	0.175	0.240	0.266	1.000								
SV12	0.122	0.232	0.166	0.331	0.264	0.371	0.304	0.353	0.434	0.402	0.195	1.000							
SV13	0.300	0.190	0.224	0.422	0.330	0.489	0.473	0.332	0.391	0.499	0.165	0.576	1.000						
SV14	0.191	0.185	0.202	0.354	0.372	0.456	0.423	0.225	0.345	0.386	0.254	0.474	0.564	1.000					
SV15	0.221	0.319	0.232	0.390	0.378	0.415	0.348	0.322	0.388	0.358	0.158	0.237	0.328	0.341	1.000				
SV16	0.193	0.284	0.352	0.284	0.360	0.254	0.334	0.309	0.351	0.319	0.424	0.239	0.310	0.366	0.432	1.000			
SV17	0.197	0.261	0.255	0.450	0.459	0.395	0.390	0.477	0.522	0.471	0.254	0.293	0.416	0.302	0.459	0.458	1.000		
SV18	0.318	0.279	0.304	0.362	0.300	0.390	0.512	0.310	0.360	0.414	0.398	0.267	0.386	0.457	0.314	0.367	0.445	1.000	
SV19	0.186	0.312	0.319	0.368	0.325	0.289	0.383	0.247	0.432	0.404	0.314	0.294	0.327	0.397	0.351	0.399	0.393	0.522	1.000

Note: Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy = 0.900; Bartlett test of sphericity =1613.353;
Degree of freedom = 171; Significance = 0.000

2.4. Success variables extraction

Factor analysis identifies clusters of related variables and can thus be used to generate a comprehensible framework (Norusis 2001) using a data matrix produced from individual cases or respondents. Factor analysis commonly uses principal component analysis which generates linear combinations of variables or factors to explain variance in the data. Since the goal of FA is inclusive clustering of initial variables, a variable load exceeding 0.5 (rounded) on the factor was considered acceptable variable and left unmodified.

Factor analysis was applied here to explore the underlying constructs of the 19 SVs for construction partnering using principal component analysis and varimax rotation. SPSS was used to automatically generate a matrix along with the FA. Via the rule of eigenvalue greater than one, the four-Factor solution was considered the most appropriate. Table 4 shows that the Cronbach's α values for all four SFs exceed 0.7, which is the threshold of acceptability. Meanwhile, the cumulative criteria explanation value is 56.58%, meaning that the four SFs can explain 56.58% of the variances in the SVs. Table 5 lists the SFs and their associated SVs. Every SF is named according to its associated SVs. Among the four extracted SFs, six of the SVs loaded on *Collaborative team culture*, three of the SVs loaded on *Long-term quality perspective*, five of the SVs loaded on *Consistent objectives* and five of the SVs loaded on *Resource sharing*. The four SFs were seen as the Latent variables (ηi) for performing SEM.

Collaborative team culture refers to partnerships in which team members are free to challenge the assumptions of the others, thus making the group process transparent and encouraging individuals to question their own assumptions (Lewis 1990). *Long-term quality perspectives* indicate the willingness of the respective teams to continuously manage unanticipated problems (Bresnen, Marshall 2000). Teams which have a greater commitment to a project are less likely to exhibit opportunistic behavior, and are more likely to give priority to achieving long-term goals as opposed to short-term expedients (Mohr, Spekman 1994). *Consistent objectives* are the individual strategic goals of the respective project members which can converge to act in concert to achieve joint goals. This is critical in that ambiguous goals and poor coordination are the leading causes of partnership failure (Lynch 1990). However, when effectively managed, partnerships can raise competitiveness and expand operational capabilities, and provide a venue in which firms are incentivized to share technologies, experience, information, knowledge, and skills (CII 1991).

3. SEM framework for construction partnerships

3.1. SEM framework development

SEM can describe the relationships among observed and latent variables. The data represented by observed variables can be directly measured, while those represented by latent variables cannot be directly observed, and must be expressed in frameworks that describe them in terms of observed variables. SEM implementation involves a measurement component and a structural component (Byrne 1994); the former specifies how latent variables are measured in terms of observed variables, while the latter expresses relationships among latent variables. Thus, using SEM, a latent theoretical structure can be represented by measured variables in a causal indicator framework, while simultaneously accounting for measurement errors, thus producing more accurate representations.

This study proceeded to develop and test the structural relationships between SVs of construction partnering using SEM. A basic framework was developed by incorporating the latent constructs with their corresponding measures into an initial SEM on the basis of theoretical expectations and past empirical findings. Framework improvements were performed over several iterations to arrive at a final framework specification by using a combination of modification indices (Hoyle 1995) and theoretical justifications until a final satisfactory framework was identified. Additionally, to ensure the appropriateness of factors of the identified attributes as construction partnering SVs, Cronbach's α reliability testing was applied. Cronbach's α values range from 0 to 1. Values ranging from 0.6 to 0.7 are considered sufficient, and values above 0.7 are considered reliable (Sharma 1995).

The SEM framework, consisting of a measurement component and a structural component, was built using AMOS. The measurement component determines how well exogenous variables measure latent variable constructs, while the structural component models the relationships among latent variable constructs to explicitly model direct, indirect and correlative effects. Fig. 1 displays the format of the initial SEM framework with path coefficients. For each variable, Fig. 1 shows its influence on different variables and its connection to the SF. The rectangles in Fig. 1 indicate observed (or measured) variables. Unobserved latent variable constructs appear in ellipses. The arrows in the figure indicate the direction of hypothesized influence. For example, the influence of $\eta 2$ (long-term quality perspective) is presumed to be reflected in the observed measures of the variables: SV8 (commitment to quality), SV9 (commitment to continuous improvement) and SV17 (questioning attitudes) as depicted by the directional arrows. Error terms are included for each exogenous variable indicating a latent variable construct. For example, SV8 (commitment to quality) does not perfectly describe $\eta 2$ (long-term quality perspective), and so an error term is needed to represent the error of measurement. This error term, $\varepsilon 8$, is an unobserved entity consisting of the portion of measured value of SV8 (commitment to quality) that does not reflect the influence of $\eta 2$ (long-term quality perspective). According to Fig. 1 it is obvious that the degree of partnering success is determined by the three main influence SFs, and there are several courses of influence in each SF.

3.2. SEM framework assessment

From Table 5, all SFs in the initial SEM had Cronbach's α values higher than 0.7, indicating sufficient internal

Table 5. Principal components analysis on success variables and reliability testing of initial SEM

Factors (Latent variables, ηi)	Items (Measuring variables, SV)	Factor loadings	Eigenvalues	Percentage of variance	Cumulative percentage of variance	Cronbach's α
Collaborative team culture $\eta 1$	SV6 Dedicated team	0.569	7.102	37.38	37.38	0.8326
	SV7 Flexibility to change	0.499				
	SV10 Long-term perspective	0.467				
	SV12 Formation at design stage	0.702				
	SV13 Good cultural fit	0.776				
	SV14 Company wide acceptance	0.741				
Long-term quality perspective $\eta 2$	SV8 Commitment to quality	0.831	1.375	7.24	44.62	0.8010
	SV9 Commitment to continuous improvem	0.802				
	SV17 Questioning attitudes	0.615				
Consistent objectives $\eta 3$	SV1 Mutual trust	0.677	1.208	6.36	50.98	0.7016
	SV2 Effective communication	0.487				
	SV4 Clear understanding	0.607				
	SV5 Acting consistent with objectives	0.567				
	SV15 Technical expertise	0.482				
Resource sharing $\eta 4$	SV3 Commitment from senior management	0.475	1.064	5.60	56.58	0.7432
	SV11 Total cost perspective	0.767				
	SV16 Financial security	0.643				
	SV18 Availability of resources	0.568				
	SV19 Equal power/empowerment	0.591				

Note: ηi and SVi represent success factors on partnering, latent variables, and observable variables, respectively.

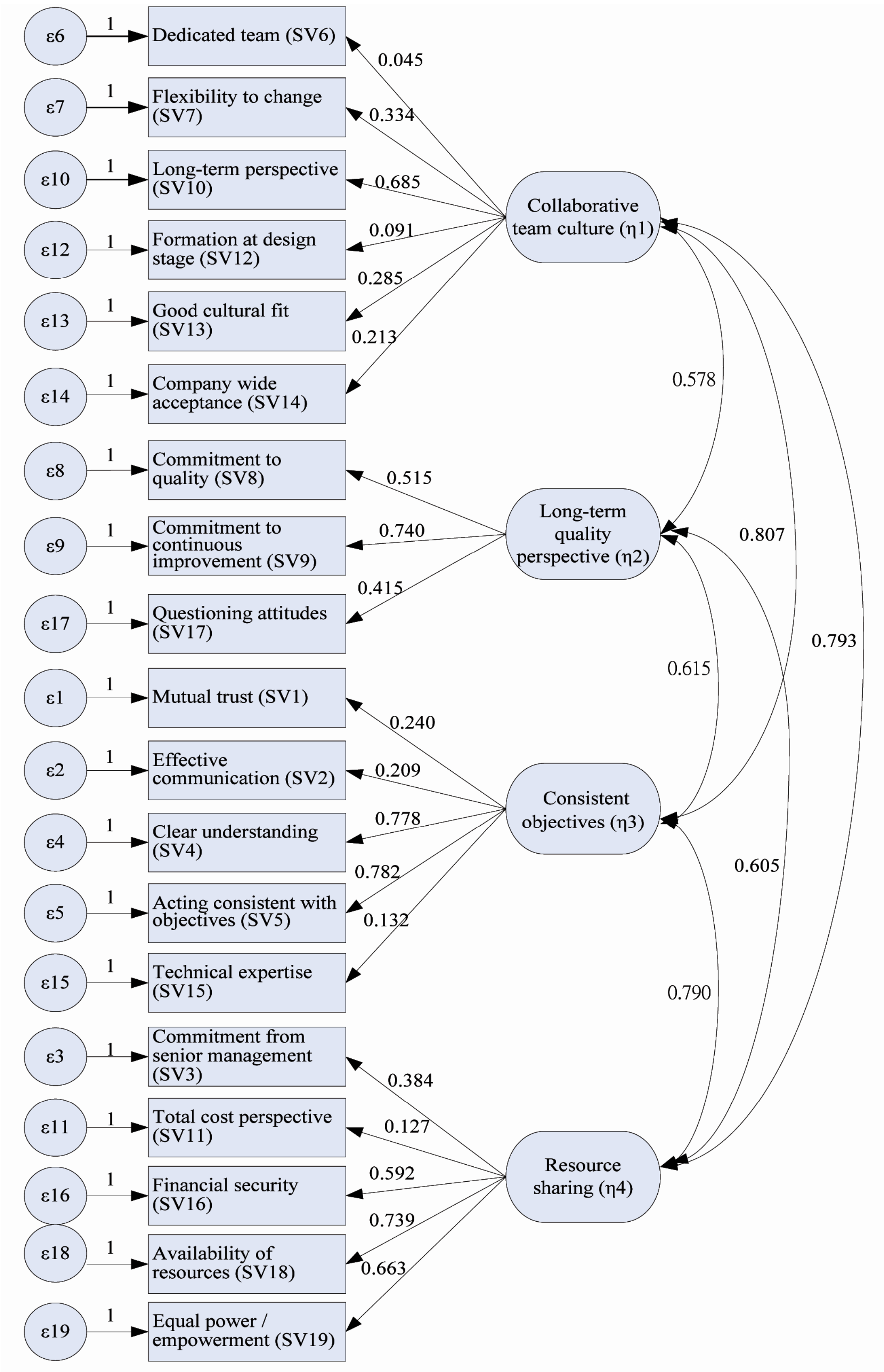

Fig. 1. Initial SEM framework with coefficients

consistency of the initial SEM. The overall fitness of the initial SEM can be assessed by employing goodness of fit (GOF) indices. Several GOF indices are available to test the fitness of the SEM. If the GOF indices of the initial SEM do not reach the recommended levels, framework refinements are required to improve overall fitness.

In this study, framework refinements were performed by two methods. First, low correlation paths and associated variables were systematically eliminated (Sarkar *et al.* 1998). The interrelationship paths were then revised or covariance error paths were added between the variables or latent factors. Both methods were needed to refine the SEM framework with reference to the modification indices provided by the AMOS. After refinement, the framework with the best performance for both GOF and the theoretical expectations (Molenaar *et al.* 2000) was selected as the final SEM framework.

Table 6 summarizes all indices and the suggested levels of GOF for initial and final SEM frameworks. Two indices of the initial SEM framework, RMSEA (= 0.056) and Noelter CN value (= 150), fail to reach the recommended levels of GOF showing the need for the refinement of the initial SEM framework. After two runs of refinement, all GOF indices of the initial SEM framework reached the recommended levels, and are therefore seen as the final version of the SEM framework. Fig. 2 shows the final SEM framework with path coefficients.

4. Results and discussion

All the path coefficients for the measurement component of the SEM framework are nonzero with a 95% confidence level. Thus, the coefficients provide meaningful implications that significant influences exist from observed variables to latent variables. As stated before, SEM involves two procedures (a measurement component and a structural component) discussed as follows.

4.1. Measurement component of developed SEM framework

Fig. 2 shows how the factors by which the latent variable collaborative team culture is measured in the SEM framework: team dedication, flexible response to change, long-term perspective, formation at the design stage, good cultural fit and widespread acceptance. Good cultural fit had the strongest influence ($\lambda = 0.724$), followed by team dedication ($\lambda = 0.701$), flexible response to change ($\lambda = 0.692$), widespread acceptance ($\lambda = 0.681$), and long-term perspective ($\lambda = 0.470$), while formation at design stage was the least influential ($\lambda = 0.397$). Conflict had a small effect of the team spirit engendered by mutual trust, effective communication, full acknowledgement and respect. These positive aspects reduce conflicts and quarrels, and establish a better working environment for the project (Stipanowich 1997).

The SEM framework measures the latent variable of long-term quality perspective according to commitment to quality, commitment to continuous improvement, questioning attitude, long-term perspective and formation at the design stage. Commitment to continuous improvement was found to have the greatest influence on long-term quality perspective ($\lambda = 0.918$) followed by commitment to quality ($\lambda = 0.785$), questioning attitudes ($\lambda = 0.321$), and long-term perspective ($\lambda = 0.279$), while formation at the design stage had the least influence ($\lambda = 0.229$), most likely due to the increased versatility and complexity of the construction industry and the evolution of required skills and procedures. Increased demand among customers for better quality and durability has also raised the importance of commitment to long-term quality, which can only be ensured through mutual commitment to continuously improve the partnering arrangement (Brensen, Marshall 2000; Cheng *et al.* 2000).

The SEM framework measures the latent variable for consistent objectives by referring to clear understanding, acting consistently with objectives, technical expertise and questioning attitudes, with clear understanding exhibiting the greatest effect on consistent objectives

Table 6. Goodness of fit measurement of the SEM framework

Evaluation index	GOF	Suggested level	Initial SEM	First revised SEM	Second revised (Final) SEM
Absolute fit index	Pearson chi-square, χ^2	The least	875.683	195.425	119.431
	Degree of freedom, dof		518	84	79
	Probability, P	> 0.05	0.000	0.000	0.002
	RMR value	< 0.05	0.036	0.033	0.022
	RMSEA value	< 0.05	0.056	0.078	0.048
	GFI value	> 0.9	0.811	0.897	0.936
Relative fit index	NFI value	> 0.9	0.747	0.861	0.915
	IFI value	> 0.9	0.879	0.915	0.969
	CFI value	> 0.9	0.877	0.914	0.969
Parsimonious fit index	NCI value	< 3	1.691	2.326	1.512
	PNFI value	> 0.5	0.690	0.688	0.688
	PCFI value	> 0.5	0.810	0.731	0.729
	Hoelter CN value	≥ 200	150	132	205
Cross-validation	Akaike AIC value	The least	1029.683	276.425	201.431
	ECVI value	The least	4.680	1.216	0.916

Note: The first revised SEM deleted four SVs including mutual trust (SV1), effective communication (SV2); commitment from senior management (SV3), and total cost perspective (SV11)

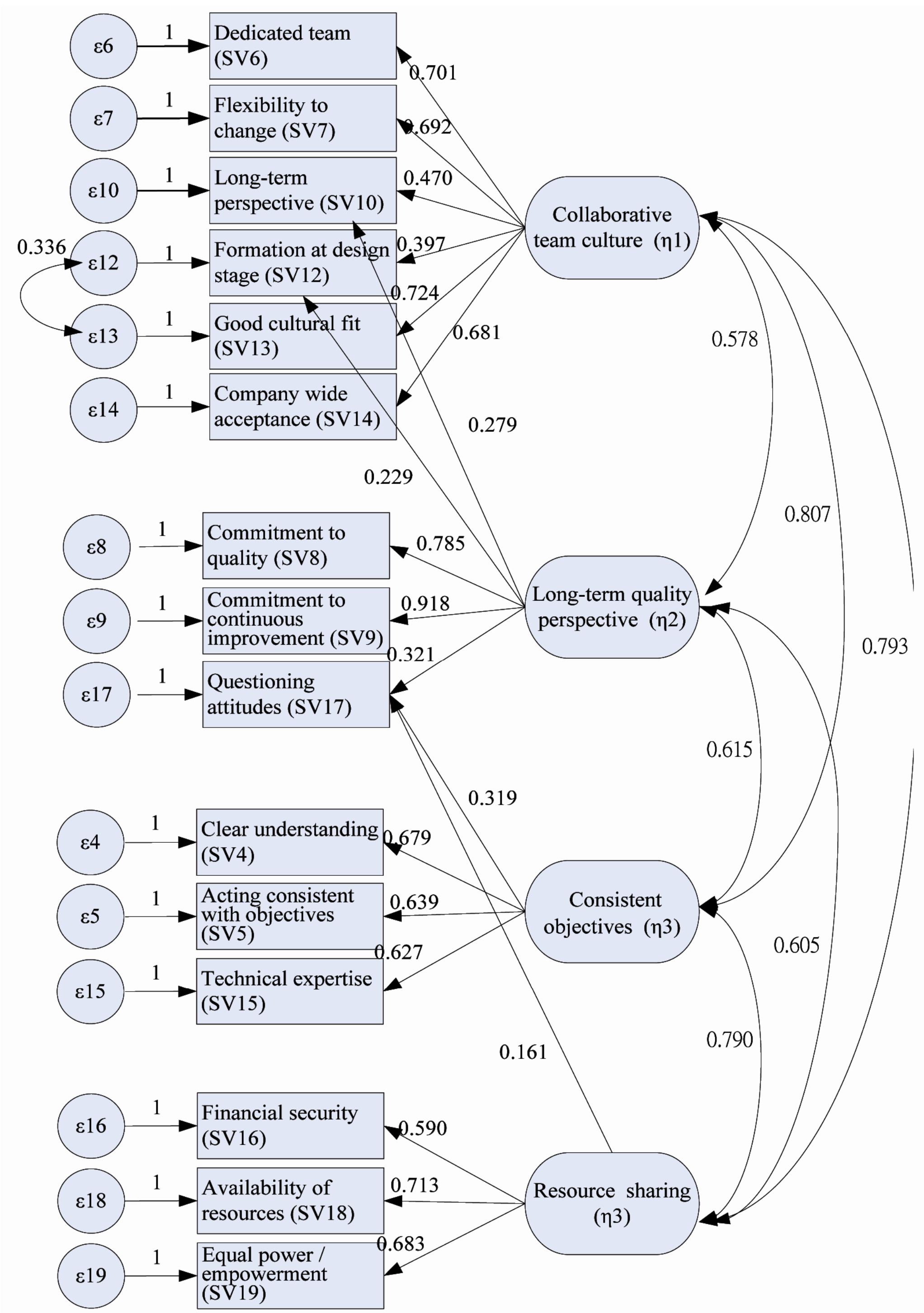

Fig. 2. Final SEM framework with coefficients

($\lambda = 0.679$), followed by acting consistently with objectives ($\lambda = 0.639$) and technical expertise ($\lambda = 0.627$), while questioning attitudes exhibited the least influence ($\lambda = 0.319$). Collective objectives, actions and ideas form the basis for cooperation between partners and, aside from professional knowledge and effective communication, to achieve project objectives efficiently, partners need to have a clear understanding of the project and the team members' respective strengths (Black *et al.* 2000).

The SEM framework measures the resource sharing latent variable by reference to financial security, availability of resources, equal power/empowerment and questioning attitudes. Availability of resources had the strongest effect on resource sharing ($\lambda = 0.713$), followed by equal power/empowerment ($\lambda = 0.683$) and financial security ($\lambda = 0.590$), while questioning attitudes had the smallest effect ($\lambda = 0.161$). Failure to instill win-win attitudes among the project teams could disrupt the project flow, and reduce the effective use of resources including equipment, financing, staff, materials, and information (Ellison, Miller 1995; Brooke, Litwin 1997).

4.2. Structural component of developed SEM framework

The initial research framework suggests the four latent variables (collaborative team culture, long-term quality perspective, consistent objectives, and resource sharing) are connected in a linear relationship, with the strongest correlation between collaborative team culture and consistent objectives (ψ = 0.807), followed by collaborative team culture and resource sharing (ψ = 0.793), consistent objectives and resource sharing (ψ = 0.790), long-term quality and consistent objectives (ψ = 0.615) and long-term quality perspective and consistent objectives (ψ = 0.605), while the weakest correlation was between collaborative team culture and long-term quality perspective (ψ = 0.578). This implies that the four SFs all exert a considerable influence on the success of construction partnering, thus supporting the hypotheses presented above.

This paper examines the ability of the structural components of the four latent variables to fit the data sample. The correlations found among the four latent variables range between 0.578 and 0.807, which suggests a high degree of relationships, according to Bryman and Cramer (1990). Additional discriminant validity testing also suggest a 95% probability for the four latent variables of partnering, showing them to be statistically independent (Jöreskog, Sörbom 2002).

Additionally, according to Fig. 2, there is no indirect influence from individual SV. Since these four SFs strongly affect one another, these four SFs and their framework applications must be deeply probed to achieve successful project results via partnering. Therefore, the SEM framework provides a meaningful map with path coefficients for describing and quantifying the influences of different variables on successful construction partnering. This kind of information cannot be provided by previous studies (Chan *et al.* 2006; Cheng, Li 2002; Cheng *et al.* 2000), and is useful for describing correlations among SVs of construction partnering. Users can control individual variables by considering their relationships with other variables.

5. Conclusions and recommendations

This study explored SVs of construction partnering. Factor analysis was used to identify 19 SVs which were classified into four SFs (collaborative team culture, long-term quality perspective, consistent objectives, and resource sharing). The SEM was then used to analyze the relationships among these identified SVs and SFs. The proposed SEM framework not only provides meaningful information that was not provided by previous studies, but also enables the users to control individual SV by considering their relationships with other SVs.

Research results show that four SFs have a significant influence on the success of construction partnering. Among the four SFs, collaborative team culture and consistent objectives have the highest correlation. Collaborative team culture and long-term quality perspective have the lowest correlation. Additionally, good cultural fit has the most influence in characterizing collaborative team culture, commitment to continuous improvement has the highest influence in characterizing long-term quality perspective, clear understanding has the highest influence in characterizing consistent objectives, and availability of resources has the highest influence in characterizing resource sharing. These four SFs and their framework application must be deeply probed to achieve successful project results via partnering. This type of constructive information can facilitate construction partnering among project participants. Participants can manage construction partnering by considering the size of the coefficient, examining the individual intention for construction partnering and determining the relationship between those and other factors.

The study is only concerned with the construction partnering in Taiwan. Further investigation in different countries/areas is necessary due to the localized nature of the construction industry. Additionally, utilizing case studies in partnership to extend the research findings would be beneficial since the findings could be implemented and incorporated in today's construction projects to explore how the SVs are important for the construction projects. Future research should use multi-train confirmatory factor analysis to investigate partnerships in different populations, and explore whether the proposed measurement scales can be applied to the attributes of special projects such as Design-Build and BOT.

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Wei Tong CHEN. Doctor, Professor and Chairman. Dept. of Construction Engineering, National Yunlin University of Science and Technology. His major research interests include property management, scheduling and planning, performance evaluation, and value management.

Tung-Tsan CHEN. Doctor, Associate Professor. Dept. of Civil Engineering and Engineering Management, National Quemoy University. His major research interests include property management, scheduling and planning, project management.

Chun Sheng LU. Doctor, School of Engineering Science and Technology, National Yunlin University of Science and Technology. His main research interests include construction safety and public projects management. Mr. Lu was the division chief of Public Works Department, Chia-yi City Government, Taiwan.

Shu-Shun LIU. Doctor, Associate Professor, Dept. of Construction Engineering, National Yunlin University of Science and Technology. His major research interests include property management, optimization applications on construction management, scheduling and planning, and construction E-Business.