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Correlation between intellectual capital and business performance of construction industry – an empirical study in Taiwan

Ding-jyun Lin\textsuperscript{a}, Wen-der Yu\textsuperscript{b}, Chih-ming Wu\textsuperscript{c} and Tao-ming Cheng\textsuperscript{d}

\textsuperscript{a}Comprehensive Planning Division, Ministry of Finance, Taipei, Taiwan (R.O.C.); \textsuperscript{b}Department of Construction Engineering, Chaoyang University of Technology, Taichung, Taiwan (R.O.C.); \textsuperscript{c}Department of Construction Management, Xiamen University of Technology, Xiamen, Fujian, People’s Republic of China (P.R.C.); \textsuperscript{d}Department of Construction Engineering, Chaoyang University of Technology, Taichung, Taiwan (R.O.C.)

ABSTRACT
Researchers have sought to determine the correlation between intellectual capital and business performance to enable corporations to shape policy decisions that benefit business performance in the past two decades. Previous works have focused on information technology and biotechnology industries rather than on the construction industry. This research aims at developing a construction industry intellectual capital valuation model for managers of construction-related firms to make better decisions in managing intellectual capitals. An empirical study was conducted on the application of the proposed intellectual capital valuation model to four representative firms from the construction industry listed in Taiwan’s stock market. It is found from the results of the empirical study that the business performance of construction industry relies highly on intellectual capital. As a result, the managers of construction-related firms should emphasize more on accumulation of the intellectual assets in order to improve their business performance. Moreover, the empirical results also show that the traditionally conceived ‘capital- and labour-intensive’ construction industry is actually highly intellectually capitalized, with the average values of the MV/BV and Tobin’s $q$ values significantly greater than 1.0 similar to that in the high-tech industries.

KEYWORDS
Intellectual capital evaluation; business performance; construction industry; time series analysis

Introduction

In an era of global competition and a knowledge economy, the key factors determining national and corporate competitive success are no longer traditional natural resources and capital, but rather the creation and utilization of new knowledge. Former researchers (Duquette & Stowe 1993; Örnek & Ayas 2015) have indicated that the ultimate goal of any business organization is the creation of profits and the improvement of organizational performance. The firm’s business performance reflects its relative success of operational management and becomes a focus of corporate attention (Örnek & Ayas 2015). Understanding the correlation between intellectual capital and business performance is critical, while aiming to sustain in a competitive environment, not only for industries and corporations but also for a nation (Herciu & Ogren 2015).

The concept of ‘intellectual capital’ was first proposed and defined by Galbraith (1969) as the use of intellectual capacity rather than the inherent possession of knowledge and intelligence. The intellectual capital resulting from value creation explains the discrepancy between book value and market value of a firm (Lataș & Walasek 2016; Roos et al. 1997). Stewart (1997a) refers intellectual capital to the sum of knowledge and abilities possessed by each employee and team capable of providing a company with competitive advantages. Intellectual assets are intangible, in contrast to tangible assets. Such a perspective is currently widely accepted in management science. However, how a corporation employs intellectual capital in a competitive environment and exerts a leveraging effect to provide the corporation with continual business opportunities and benefits remains an important question to be answered. Chu et al. (2008) evaluated the impact of intellectual capital on company business performance in Taiwan’s electronics industry and confirmed that intellectual capital plays an important role. They also indicated that corporate market value far exceeds the value expressed through traditional accounting methods, and believed that the industry should develop evaluation indicators to assist internal and external decision-makers in effectively measuring organizational intellectual capital and formulating correct decisions. Thus, how to measure the value of
corporate intellectual capital and its impact on business performance is an issue attracting increasing attention from both academia and industry.

Although the importance of intellectual capital to many industries and knowledge-based corporations in the era of a knowledge economy has become evident, the research of intellectual capital and its impacts in the construction industry have rarely found. Chang and Wang (2005) examined the sustainable competitiveness of Taiwan’s construction industry from the perspective of intellectual capital and found that further development of the construction industry must address issues of intellectual capital; however, they did not address the correlation between intellectual capital evaluations and business performance. Yu et al. (2009) found that although knowledge management (KM) has gradually gained importance in the construction industry, evaluation of KM on a firm’s business performance has lagged behind primarily because of the lack of an effective evaluation method. Tserng et al. (2009) compared and summarized evaluation models for the construction industry from the perspective of corporate evaluation, but did not tackle the issues of intellectual capital evaluation and business performance. It is found from literature reviews that there has not yet an intellectual capital valuation model for construction industry. Without such a model, appropriate decisions are difficult to make for the managers of construction-related firms in managing intellectual assets and thus the long-term competitiveness of firm, or even a country, could be declined (Herciu & Ogrean 2015; Örnek & Ayas 2015).

Based on the abovementioned demand, the current research aims at developing a construction industry intellectual capital valuation model for managers of construction-related firms to make better decisions in managing intellectual capitals. An empirical study was conducted on the application of the proposed intellectual capital valuation model in the construction industry of Taiwan. Three different evaluation methods, i.e. market value/book value (MV/BV), Tobin’s $q$, and value added intellectual coefficient (VAIC$^{TM}$) value, are used to calculate the value of intellectual capital for each selected case. Representative construction-related firms from four categories of construction industry listed in Taiwan’s stock market were selected for verification of the proposed model. Twenty-year long-term tracking data are collected for the four selected representative firms. Statistical testing methods are employed to analyze and measure the construction industry’s intellectual capital. Finally, the relationship between quantifiable intellectual capital indicators and business performance was examined to provide strategic suggestions for managers of the construction firms.

**Literature review**

**Definition and categorization of intellectual capital**

Since the concept of ‘intellectual capital’ was first proposed by Galbraith (1969), many researchers have conducted successive studies to address the related issues, e.g. Stewart (1997a), Edvinsson and Malone (1997), Ulrich (1998), Lynn (1999), Viedma Marti and do Rosario Cabrita (2012), Užienė (2015), Kohl et al. (2015), and Lataš and Walasek (2016), among others. Due to the substantially different domains covered by each study, no consensus definition of intellectual capital was reached yet. The factors and definitions of intellectual capital differ according to the development of intellectual capital from KM (Stewart 1997a), management inventory (Dzinkowski 2000), resource-based theories (Edvinsson & Malone 1997), or national competitiveness (Herciu & Ogrean 2015). Although the definitions of intellectual capital differ slightly by different scholars, most researchers agree with the categorization of intellectual capital, i.e. ‘human capital’, ‘structural capital’, and ‘customer capital’ (Dzinkowski 2000; Edvinsson & Malone 1997; Stewart 1997b; Viedma Marti & do Rosario Cabrita 2012). The three intellectual capital categories are described below.

**Human capital**

Dzinkowski (2000) believes that corporate human capital is positively correlated with competitive advantage. Human capital refers to the personal abilities, knowledge, technical skills, and experiences possessed by every employee and manager of a company. It is the economic value, experience, and knowledge held by its employees that are intangible and exhibit high fluidity and social complexity. In terms of construction industry, the human capital relates direct to the knowledge and experiences held by the engineers and staffs of the firms for performing their daily works.

**Customer capital**

Bontis et al. (1999) stated that the customer capital generated by all external parties interacting with an organization, or customer capital relationships that are established formally and informally, which represents the potential intangible assets that exist outside the organizational core. Although customer capital exists between corporations and external parties, customer capital originating from customer contributions, satisfaction, and loyalty is closely related to current and future competitiveness. A good example of the customer capital is the long-term relationship of trust established
among different consortium parties in the construction market.

**Structural capital**

Dzinkowski (2000) referred structural capital as the corporate exclusivity and key technical knowledge of intellectual property rights held by a corporation, as well as the innovation applied internally to improve efficiency and profit-making. That is, the tangible and intangible assets that cannot be taken away from the corporate by the employees leaving the organization. This type of capital exists within organizations, rather than in employees. The construction equipment or facilities owned by a construction firm may fit into this category of intellectual capital.

**Intellectual capital evaluation models**

Sveiby (2007) categorized 34 intangible asset valuation methods based on the studies conducted by Luthy (1998) and Williams (2000). Four major categories of intellectual capital evaluation models are identified based on whether monetary value was used for measurement and whether the overall organization or individual components used for measurement (Luthy 1998; Williams 2000), i.e. the market capitalization method (MCM), return-on-assets (ROA) method, direct intellectual capital method, and scorecard method. This research adopts the Market Value over Book Value Method (MV/BV) (an MCM method), Tobin’s q (also an MCM method), and the intellectual capital VAICTM method (an ROA method) for intellectual capital valuation of a construction-related firm concerning the data availability, relevant to individual organization’s performance, and using objective monetary value as measurement units. The three selected valuation methods are described as follows.

**The MV/BV valuation method**

The MV/BV valuation method was proposed by Stewart (1997a) and uses the ratio of corporate stock market capitalization to its book value to measure the intangible assets held by a corporation. When a corporation exhibits an MV/BV value greater than ‘1.0’, it implies that a corporation possesses intangible asset value.

**Tobin’s q method**

Tobin’s q method was proposed by James Tobin (1969), a Nobel Prize laureate in economics, and is defined as the ratio between the market value and asset replacement costs of a company. If the Q value is greater than ‘1.0’, then the market value is greater than the value of the company’s recorded assets. High Tobin’s q values encourage companies to invest more in capital because they are ‘worth’ more than the price they paid for them. Because the calculation of original Tobin’s q is extremely complex, Chung and Pruitt (1994) proposed a more convenient alternative method, that is ‘approximate Tobin’s q’. Empirical studies have found that this alternative method can explain up to a 96.6% degree of variation in original Tobin’s q. Thus, we employed approximate Tobin’s q as the tool to measure the value of intellectual capital.

**Intellectual capital value added intellectual coefficient (VAICTM)**

The intellectual capital VAICTM was proposed by Pulic (2000) to provide managers, stockholders, and other stakeholders (e.g. creditors) with a tool for analysing a corporate’s value. The calculation process and component factors of VAICTM are defined in Equation (1) and detailed below.

\[
VAICTM = CEE + HCE + SCE, \tag{1}
\]

where CEE is the coefficient for ‘Capital Employed Efficiency’ and is defined in Equation (2); HCE is the coefficient for ‘Human Capital Efficiency’ and is defined in Equation (3); SCE is the coefficient for ‘Structural Capital Efficiency’ and is defined in Equation (4). The summation of the three capital efficiencies implies the overall intellectual capital of the firm.

\[
CEE = \frac{VA}{CE}, \tag{2}
\]

where VA stands for ‘value added’ = ‘depreciation + dividends + business taxes + retained earnings + wage costs’; CE stands for ‘capital employed’ and is defined as the net asset value. CEE indicates how efficient a construction corporate utilizes her current capital (i.e. cash) in creating the firm’s value.

\[
HCE = \frac{VA}{HC}, \tag{3}
\]

where VA is defined as that of Equation (2); HC stands for ‘human capital’ and is defined as the total wage costs of a construction corporate.

\[
SCE = \frac{SC}{VA}, \tag{4}
\]

where VA is defined as that of Equation (2); SC stands for ‘structure capital’ and is defined in Equation (5).

\[
SC = VA - HC, \tag{5}
\]
where $VA$ is defined as that of Equation (2); $HC$ is human capital and is defined as that of Equation (3).

**Intellectual capital valuation factors**

Edvinsson and Malone (1997) argued that most of the 111 indicators employed by Skandia Navigator involve internal company information and are not available for academic researchers. It is difficult to acquire the values of the required performance indicators (Edvinsson & Malone 1997). Recent studies have gradually reduced the number of performance indicators (valuation factors) to improve their feasibility in practical use. Chu et al. (2008) identified 24 financial indicators for intellectual capital valuation. Their work found that due to the high correlation between valuation factors, collinearity problems should be avoided during regression analysis. Based on their previous study, Chu et al. (2010) categorized the 24 variables into nine key valuation factors using factor analysis and employed stepwise regression to identify the most important factors under various evaluation criteria. The nine key valuation factors include: ‘profitability’, ‘employee productivity’, ‘costs incurred’, ‘R&D investment’, ‘solvency’, ‘total company assets’, ‘revenue growth’, ‘resource allocation’, and ‘management expenditure’ (Chu et al. 2010). In view of its simplicity and feasibility for construction industry, this study adopts the nine-category factors proposed by Chu et al. (2010) as the preliminary model for valuation of the intellectual capital of construction-related firms.

**Establishing a construction industry intellectual capital valuation model**

**Definition of model variables**

**Dependent variables (intellectual capital indexes)**

In the proposed intellectual capital valuation model, the values of the three indexes – MV/BV, Tobin’s $q$, and $VAIC^TM$ – are the intellectual capitals to be derived and are regarded as the dependent variables. The construction industry possesses unique characteristics that differ significantly from those of traditional manufacturing industries. Thus, we should verify whether intellectual capital influences the construction industry’s business performance and whether the nine valuation factors adopted from Chu et al. (2010) can be utilized to measure their impacts on business performance for the construction industry.

**Independent variables (valuation factors)**

To conduct data analysis in this study, single performance indicators were used as proxy variables for independent variables (valuation factors) that exhibited the same attributes based on the nine key valuation factors identified by Chu et al. (2010). The nine key factors that correspond to the proxy factors are described in the following.

**Profitability.** The ‘return on equity (ROE)’ is employed as the proxy factor for profitability; since ROE is a variable that directly combines the primary financial structure, operating efficiency, and profitability indicators of a firm, it indicates profitability. Furthermore, a construction corporate that exhibits high profitability also exhibits a high degree of solvency.

**Employee productivity.** The employee productivity relates to performance indicators such as assets per employee, net profit per employee, and revenue per employee (RPE). For this study, we used ‘RPE’ as the proxy variable for measuring employee productivity of a construction corporate. Measurements that show a decline in employee productivity often signal a decrease in the quality of a construction corporate’s human capital.

**Costs and expenditures.** Costs incurred refer to the specific and necessary expenditures required by each individual operating unit and organization to maintain normal operations. For this study, we employed ‘the ratio of management costs to net operating income (EXP)’ to measure the costs incurred factor. This variable was used to determine whether management costs and employee wages of a construction corporate have reached the optimal ratio to facilitate higher earnings and the efficient use of total assets.

**R&D investment.** R&D investment is an important indicator for evaluating the intellectual capital of a construction corporate. The ‘R&D cost ratio (the ratio of R&D costs to total assets, RD)’ is used to measure R&D investment factors and reflect the corporate’s R&D investments.

**Solvency.** Corporate solvency refers to a construction corporate’s ability to use assets for repaying long-term and short-term debts. Solvency can refer to the capability of a construction corporate to repay debts with cash. For this study, we employed ‘the current ratio (CR)’ to measure the solvency factor. It can be used to determine whether a construction corporate has been repaying short-term debts to avoid insufficient working capital (current assets minus current debts) or cash flow problems.
**Company assets.** The company assets are the company’s economic resources that can be measured with monetary units. For this study, we employed ‘fixed assets turnover (C)’ to measure a construction corporate’s asset factors and assessed the efficiency of company resource use by examining the stability of fixed asset and long-term capital management and use. This factor evaluates whether a construction corporate can achieve optimal fixed assets and long-term capital fitness rates during various operating stages, as well as optimal business performance.

**Revenue growth.** Observing the revenue and profit/loss situation of a company is the most direct and definite method to realize the operating conditions of a construction corporate. We employed ‘growth on revenues (GOR)’ to measure this factor and evaluate the performance and growth of a construction corporate.

**Resource allocation.** Previous studies have found that poor resource management (including material and human resources) will result in failure of strategy execution. For this study, we employed ‘the average allotment per employee (A)’ to measure this factor for a construction corporate. Average allotment per employee is defined as the total fixed assets of a construction corporate divided by the total number of the corporate’s employees.

**Management expenditures.** Management expenditures are an important indicator for evaluating a construction corporate’s operating performance. We measured this factor by calculating ‘management expenses per employee (EX)’. Management expenses per employee are defined as the total management expenditures spent by a construction corporate divided by the number of her employees.

The definitions of relevant measurement factors and indicators are given in Table 1. It is noted that in Table 1, the values of average per employee revenue (RPE) and management expenditures (EX) are dollar values converted using natural logarithm compression to avoid excessively large absolute values that may produce regression errors and to ensure the robustness of the regression parameter (Chu et al. 2010).

**Mathematical models**

The mathematical model of the proposed intellectual capital valuation model is given in Equations (6)–(8). A schematic representation of the analysis model framework is depicted in Figure 1, where an intermediate layer, four intellectual categories, is shown to correlate the dependent variables and the independent variables of the model.

\[
\frac{MV}{BV} = f(ROE, RPE, EXP, RD, CR, C, GOR, A, EX),
\]

(6)

Tobin’s \( q = f(ROE, RPE, EXP, RD, CR, C, GOR, A, EX), \)

(7)

VAIC\(^{TM}\) = f(ROE, RPE, EXP, RD, CR, C, GOR, A, EX).

(8)

In Equations (6)–(8), the independent variables, ROE, RPE, EXP, RD, CR, C, GOR, A, and EX, are defined as that in Table 1.

After defining the model variables, the time-series analysis method is adopted to examine the interactive relationships between the three dependent variables and the nine proxy performance indicators. In order to verify the proposed model, an empirical analysis of sample data from Taiwan’s construction industry using the three empirical model frameworks, shown in Figure 1, combined with the time-series measurement method.

<p>| Table 1. Definition of the nine intellectual capital valuation factors [21]. |
|---------------------------------------------------|-----------------|--------|---------------------------------|</p>
<table>
<thead>
<tr>
<th>Valuation factors</th>
<th>Proxy indicator</th>
<th>Code</th>
<th>Indicator definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profitability</td>
<td>Return on equity (%)</td>
<td>ROE</td>
<td>Net income/shareholder equity</td>
</tr>
<tr>
<td>Employee productivity</td>
<td>Average revenue per employee</td>
<td>RPE</td>
<td>(Revenue/number of employees)*</td>
</tr>
<tr>
<td>Costs and expenditures</td>
<td>Ratio of management costs to net operating income (%)</td>
<td>EXP</td>
<td>Management costs/net sales</td>
</tr>
<tr>
<td>R&amp;D investment</td>
<td>Ratio of R&amp;D costs to total assets (%)</td>
<td>RD</td>
<td>(R&amp;D costs + R&amp;D costs (manufacturing))/total assets × 100%</td>
</tr>
<tr>
<td>Solvency</td>
<td>Current ratio (%)</td>
<td>CR</td>
<td>Current assets/current liabilities × 100%</td>
</tr>
<tr>
<td>Company assets</td>
<td>Fixed asset turnover (%)</td>
<td>C</td>
<td>Annual revenue/average net fixed assets</td>
</tr>
<tr>
<td>Revenue growth</td>
<td>Revenue growth rate (%)</td>
<td>GOR</td>
<td>(Net operating income – net operating income from the same period of the preceding year)/net operating income from the same period of the preceding year × 100%</td>
</tr>
<tr>
<td>Resource allocation</td>
<td>Average allotment per employee (%)</td>
<td>A</td>
<td>Fixed assets/Number of employees</td>
</tr>
<tr>
<td>Management expenditures</td>
<td>Average management costs per employee</td>
<td>EX</td>
<td>(Management costs/total number of employees)*</td>
</tr>
</tbody>
</table>

*Converted through natural logarithm compression to avoid excessively large absolute values.
Data analysis methods

The data types primarily used in econometric model empirical studies are cross-sectional, time-series, and panel data (a data form simultaneously possessing cross-sectional and time-series characteristics) (Patterson 2000). Considering the long economic periodical terms (usually considering 7–10 years as a cycle) of construction industry, a set of long-term data (from the past 20 years) are used to conduct the time-series study. Besides, due to the multivariate nature of the three functions, we adopts multivariate relationship time-series models. Furthermore, the stationary of variables, long-term equilibrium between each variable, and whether significant lead–lag cause and effect relationships exist between variables are tested in order to ensure the quality of resulted models. The model verification procedure is shown in Figure 2.

The model verification procedure is described in details as follows.

Data collection and analysis

After data collection, a preliminary testing is conducted to test the normality of data distribution using the Jarque–Bera equation defined in Equation (9). The Ljung–Box Q is used to test whether the variables are independently distributed (Ljung & Box 1978).

\[
J_B = \frac{T - n}{6} \left( s^4 + \frac{1}{4} (K - 3)^2 \right),
\]

(9)

where \(s\) represents the skewness coefficient; \(K\) represents kurtosis; \(n\) is the number of parameters yet to be calculated; and \(T\) is the total number of samples.

Figure 1. Framework of analysis model for intellectual capital valuation.

Figure 2. Procedure of model testing.

Unit-root test

The unit-root test is conducted to examine whether each variable satisfies the stationary assumption. In this study, the augmented Dickey–Fuller (ADF) method proposed by Dicky and Fuller (Dickey & Fuller 1979, 1981) is employed to perform unit-root test.

Co-integration test

If the variable is non-stationary (unit-root), then the vector autoregression is tested. In this study, the vector autoregressive (VAR) model proposed by Johansen

Dependent variable
Intellectual capital category
Independent variables
MV / BV
Tobin’s Q
VAIC™
Financial capital
Human capital
Customer capital
Structural capital
ROE
RPE
EXP
RD
CR
C
GOR
A
EX

Figure 1. Framework of analysis model for intellectual capital valuation.
(1988, 1992, 1994) is employed to examine whether long-term equilibrium relationships (co-integration) exist among the variables of the three models.

Vector autoregression test
If the variable is stationary (not unit-root), or if variable is non-stationary (unit-root) and there is no co-integration relationships existing among the variables, then the VAR method proposed by Sims (1980) was employed to conduct short-term interactive variable testing.

Error correlation test
If the co-integration testing result indicates that there exist co-integration relationships among the variables, the error correction model (ECM) proposed by Granger (Granger 1988) is conducted to test the long-term equilibrium relationship among the co-integrated variables.

Granger causality test
The Granger causality test is conducted after ECM and VAR testing in order to test the cause–effect relationship among the variables. Should all tests pass, the resulted models are verified.

Empirical analysis of the construction industry’s intellectual capital valuation models

Selection of case study firms
In order to conduct empirical study of the proposed intellectual capital valuation model, the real world data from the Taiwan Economic Journal (TEJ) database are collected. The TEJ database is a commercially available financial performance database for listed companies in the Taiwan Stock Exchange Corporation (http://www.twse.com.tw/en/). Based on the categorization of the construction industry detailed in TEJ, there are four categories: (1) the realtor and brokerage sub-industry – the real estate agencies; (2) engineering consulting sub-industry – the architectural/engineering consultants; (3) construction sub-industry – the general contractors; and (4) developer sub-industry – the real estate development firms.

While selecting the representative firm from each of the four categories, two main concerns are taken into account, including (1) the completeness of the company information in the past 15 years and (2) the representativeness of its industrial type. Finally four representative firms are selected: (1) Sinyi Realty (http://www.sinyi.com.tw/) is selected for the realtor and brokerage sub-industry; (2) CTCI (www.ctci.com.tw/) is selected for the engineering consulting sub-industry; (3) DaCin Construction (http://www.dacin.com.tw/) is selected for the construction sub-industry; and (4) Pacific Construction Co. Ltd. (http://www.pacific-group.com.tw/) is selected for the developer sub-industry.

Model verification
Following the model verification procedure of Figure 2, the results of the Jarque–Bera normality test (Jonathan & Chan 2009) (see Table 2) show that all variables of the four selected firms did not adhere to the null hypothesis of normal distribution under a 10% level of significance. Additionally, the Ljung–Box Q (Ljung & Box 1978) statistics show that all variables of the four selected firms reject the null hypothesis without autocorrelation under a 10% level of significance, which indicates that all variables possess significant autocorrelation (Dickey & Fuller 1981). Subsequently, a unit-root test, co-integration relationship, ECM, and cause and effect relationship test are conducted according to the procedure of Figure 2. The testing results are discussed in the following.

Unit root test
The ADF test (Johansen 1992; Johansen 1994) is conducted for unit-root testing. The testing results are given in Table 3; it indicates that the variable values of the four firms were not constant. The variable data rejects unit roots (under a 1% level of significance) after the first difference analysis, which implies that the first difference values of the performance variables of the four firms are constant. Therefore, the intellectual capital value variables and raw data of the performance variables employed in this study exhibit constant states after first difference, indicating that the integrated order of the previously described variable sequences is 1.0. Thus, the variables are all a series of I(1) and can be represented by $Y_t = Y_t$.

Co-integration test
To analyse whether a long-term equilibrium relationship exists between the intellectual capital valuation variables and the business performance variables, we conducted co-integration test. As shown in Table 4, a co-integration relationship exists between the intellectual capital valuation variables and the business performance variables, which indicates that a long-term equilibrium relationship exists.

Error correction model test
The results estimated using the ECM are given in Table 5. The results indicated that the variable factors positively influencing Pacific Construction’s intellectual capitals were CR, revenue growth rate, the average resource allocation per employee, ROE, revenue growth rate, and
Table 2. Basic statistics of the related variables for sample firms.

<table>
<thead>
<tr>
<th>Industry Type</th>
<th>MV/BV</th>
<th>Tobin’s q</th>
<th>VAIC</th>
<th>ROE</th>
<th>RPE</th>
<th>EXP</th>
<th>RD</th>
<th>CR</th>
<th>C</th>
<th>GOR</th>
<th>A</th>
<th>EX</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max.</td>
<td>2.9914</td>
<td>4.8434</td>
<td>7.8413</td>
<td>59.866</td>
<td>11.931</td>
<td>29.726</td>
<td>7.764</td>
<td>71.841</td>
<td>12.32</td>
<td>4.986</td>
<td>15.27</td>
</tr>
<tr>
<td></td>
<td>Min.</td>
<td>0.8421</td>
<td>0.8824</td>
<td>2.2147</td>
<td>14.581</td>
<td>8.991</td>
<td>14.137</td>
<td>2.112</td>
<td>33.758</td>
<td>2.886</td>
<td>1.891</td>
<td>6.754</td>
</tr>
<tr>
<td></td>
<td>Skewness</td>
<td>0.4211</td>
<td>0.8576</td>
<td>0.1451</td>
<td>0.0712</td>
<td>-0.0851</td>
<td>-1.7581</td>
<td>-0.6314</td>
<td>0.1478</td>
<td>-0.2147</td>
<td>-0.5127</td>
<td>0.0814</td>
</tr>
<tr>
<td></td>
<td>Jarque–Bera</td>
<td>99.27***</td>
<td>105.53***</td>
<td>100.89***</td>
<td>47.78***</td>
<td>41.88***</td>
<td>51.25***</td>
<td>87.23***</td>
<td>62.12***</td>
<td>88.63***</td>
<td>77.61***</td>
<td>81.55***</td>
</tr>
<tr>
<td></td>
<td>L-B Q(24)</td>
<td>66.93***</td>
<td>71.11***</td>
<td>78.46***</td>
<td>30.63***</td>
<td>71.89***</td>
<td>98.56***</td>
<td>88.27***</td>
<td>78.78***</td>
<td>69.89***</td>
<td>71.86***</td>
<td>32.76***</td>
</tr>
<tr>
<td></td>
<td>Notes: 1. * * * indicates the rejection of the null hypothesis under 10%, 5%, and 1% levels of significance. 2. Jarque–Bera is the normality test statistic. The formula is $JB = \frac{T}{2}(s^2 + \frac{1}{4}(K - 3)^2)$. Here, $s$ represents the skewness, $K$ represents kurtosis, $n$ is the number of parameters yet to be calculated, and $T$ is the total number of samples. 3. L-B Q is the Ljung–Box Q statistics.</td>
<td></td>
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</tbody>
</table>
fixed asset turnover. The primary factors influencing the MV/BV for DaCin Construction were ROE, CR, and fixed asset turnover; the factors influencing Tobin’s q value were ROE, revenue growth rate, and the average resource allocation per employee; and the factors influencing VAICTM were ROE and the CR. The impact direction for every factor was positive. And so forth for the other two case study firms.

For the CTCI Corporation, the primary factors influencing MV/BV were ROE, the ROE, CR, fixed asset turnover, revenue growth rate, and the average resource allocation per employee; the factors influencing the Tobin’s q value were ROE, CR, and fixed asset turnover; and the factors influencing the intellectual capital value-added coefficient (VAICTM) were ROE, the ratio of R&D expenditures to total assets, revenue growth rate, and the average resource allocation per employee. Excluding management costs, the influence direction of each factor was positive. Because ROE, CR, fixed asset turnover, revenue growth rate, and the average resource allocation per employee are indicators of business performance or asset measurement indicators, higher values indicate a positive correlation between company business performance and corporate value.

Finally for Sinyi Realty, the primary factors significantly influencing market value and book value were ROE, CR, fixed asset turnover, revenue growth rate, and the average resource allocation per employee; the factors significantly influencing the Tobin’s q value were ROE, CR, and fixed asset turnover; and the factors significantly influencing VAICTM were ROE, revenue growth rate, and the average resource allocation per employee. The direction of influence for all factors was positive.

### Summary of empirical analysis

The empirical results of the four sample firms are summarized in Table 6. The primary factors influencing the value of Taiwan’s construction industry’s intellectual capital were return on equity (ROE), current ratio (CR), fixed asset turnover (C), revenue growth rate (GOR), and the average resource allocation per employee (A). Of these, ROE was the most significant common factor; the intellectual capital value for three of the four firms (Sinyi, CTCI, and Da Cin) was significantly influenced by ROE. These results show that the value of intellectual capital was affected by company profitability, solvency, asset status, operating state, and resource allocation.

Furthermore, these factors are the primary indicators for observing and measuring the business condition and performance of a company. As a result, the value of a company is reflected by its business performance conditions. When the business condition and performance is maintained optimally, the asset value of a company, including the value of intellectual capital will increase. This finding can provide company managers with improvement recommendations for better performance of the firm’s business operations.

It is notable that for CTCI Corporation, the ratio of R&D expenditures to total assets (R&D cost ratio) is an important valuation factor that significantly influences the intellectual capitals. Such a condition does not exist in valuations of the other three firms. This is because the
## Table 4. Johansen co-integration test results.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Model 1 $H_0$ $T_0$ ($r$)</th>
<th>$C_0$ ($5%$)</th>
<th>Model 2 $H_1$ $T_1$ ($r$)</th>
<th>$C_1$ ($5%$)</th>
<th>Model 3 $H_2$ $T_2$ ($r$)</th>
<th>$C_2$ ($5%$)</th>
<th>Model 4 $H_3$ $T_3$ ($r$)</th>
<th>$C_3$ ($5%$)</th>
<th>Model 5 $H_4$ $T_4$ ($r$)</th>
<th>$C_4$ ($5%$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MV/BV = f(ROE, REP, EXP, RD, CR, C, GOR, A, EX)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>$r = 0$ 35.774 40.175 45.331 54.079 37.158 47.856 56.771 63.876 62.112 55.246</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>$r = 1$ 30.25 40.175 35.193 25.723 29.797 37.253 42.915 36.752 35.011</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Pacific Construction**

|      | Tobin's $Q = f(ROE, REP, EXP, RD, CR, C, GOR, A, EX)$ |       |                             |       |                             |       |                             |       |                             |       |
| 1    | $r = 0$ 45.966 40.175 58.736 54.079 36.542 47.856 58.871 63.876 63.261 55.246 |       |                             |       |                             |       |                             |       |                             |       |
| 2    | $r = 1$ 28.771 24.276 38.364 35.193 27.265 29.797 36.310 42.915 37.863 35.011 |       |                             |       |                             |       |                             |       |                             |       |

**VAIC = f(ROE, REP, EXP, RD, CR, C, GOR, A, EX)**

|      | Da Cin Construction |       |                             |       |                             |       |                             |       |                             |       |
| 1    | $r = 0$ 30.331 40.175 30.851 54.079 51.586 47.856 66.752 63.876 51.289 55.246 |       |                             |       |                             |       |                             |       |                             |       |
| 2    | $r = 1$ 17.251 24.276 21.331 35.193 32.251 29.797 35.481 42.915 32.124 35.011 |       |                             |       |                             |       |                             |       |                             |       |

**CTC Corporation**

|      | $r = 0$ 48.587 40.175 36.771 54.079 56.771 47.856 71.854 63.876 61.521 55.246 |       |                             |       |                             |       |                             |       |                             |       |
| 2    | $r = 1$ 31.754 24.276 25.336 35.193 36.853 29.797 48.736 42.915 38.231 35.011 |       |                             |       |                             |       |                             |       |                             |       |

**Sinyi Realty**

|      | $r = 0$ 2.658 40.175 54.079 39.211 42.915 31.312 35.011 |       |                             |       |                             |       |                             |       |                             |       |

Note: 1. Model selection was conducted under a 5% level of significance. According to the model principles proposed by Nieh and Lee (2001), the order is left to right, from the first model to the fifth model, from low moments to high moments, and from the rejection of the null hypothesis until the null hypothesis cannot be rejected for selecting the Johansen co-integration model most capable of explaining long-term trends.

2. The limit value data was obtained from Osterwald-Lenum (1992).

3. The selection of the optimal lag number was based on the AIC principle. Rank represents the assumed number of co-integration vectors.
### Table 5. ECM estimation results.

<table>
<thead>
<tr>
<th>Company</th>
<th>Pacific Construction</th>
<th>Da Qin Construction</th>
<th>CTCI Corporation</th>
<th>Sinyi Realty</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV/BV Variable</td>
<td>MV/BV</td>
<td>MV/BV</td>
<td>MV/BV</td>
<td>MV/BV</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.025088</td>
<td>-0.01526</td>
<td>-0.001941</td>
<td>-0.011322</td>
</tr>
<tr>
<td></td>
<td>[-0.31643]</td>
<td>[-1.177125]</td>
<td>[-0.19931]</td>
<td>[-1.10756]</td>
</tr>
<tr>
<td>Error correction term</td>
<td>-0.000407***</td>
<td>0.063599**</td>
<td>0.031585**</td>
<td>0.004260**</td>
</tr>
<tr>
<td></td>
<td>[-2.59204]</td>
<td>[2.21789]</td>
<td>[3.14741]</td>
<td>[2.31925]</td>
</tr>
<tr>
<td>ROE,1</td>
<td>-0.001541</td>
<td>0.056221**</td>
<td>0.035102</td>
<td>0.006829**</td>
</tr>
<tr>
<td></td>
<td>[0.16398]</td>
<td>[0.31528]</td>
<td>[0.21463]</td>
<td>[0.727300]</td>
</tr>
<tr>
<td>ROE,2</td>
<td>0.010537</td>
<td>0.004667</td>
<td>-0.097978</td>
<td>0.003137**</td>
</tr>
<tr>
<td></td>
<td>[0.03610]</td>
<td>[0.03099]</td>
<td>[0.065167]</td>
<td>[0.004260]</td>
</tr>
<tr>
<td>RPE,1</td>
<td>-0.002853</td>
<td>-35.10467</td>
<td>-63.34978</td>
<td>0.059713</td>
</tr>
<tr>
<td></td>
<td>[-1.14562]</td>
<td>[-0.90751]</td>
<td>[-0.14484]</td>
<td>[0.63864]</td>
</tr>
<tr>
<td>RPE,2</td>
<td>-1.12179</td>
<td>33.54533</td>
<td>277.0882</td>
<td>-0.020366</td>
</tr>
<tr>
<td></td>
<td>[-1.46211]</td>
<td>[-1.07701]</td>
<td>[-0.78661]</td>
<td>[0.69863]</td>
</tr>
<tr>
<td>EXP,1</td>
<td>0.109569</td>
<td>0.172653</td>
<td>-2.36777</td>
<td>0.009057**</td>
</tr>
<tr>
<td></td>
<td>[0.91985]</td>
<td>[-1.86544]</td>
<td>[-1.43920]</td>
<td>[-0.65299]</td>
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<tr>
<td>EXP,2</td>
<td>0.100369</td>
<td>0.099583</td>
<td>0.042945</td>
<td>0.007903**</td>
</tr>
<tr>
<td></td>
<td>[0.47538]</td>
<td>[0.64146]</td>
<td>[0.02447]</td>
<td>[0.69863]</td>
</tr>
<tr>
<td>RD,1</td>
<td>-0.006688</td>
<td>-0.018008</td>
<td>-0.204557</td>
<td>0.004075**</td>
</tr>
<tr>
<td></td>
<td>[-0.33882]</td>
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<td>[-1.04691]</td>
<td>[-0.88867]</td>
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<td>[0.32668]</td>
<td>[-0.90590]</td>
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<tr>
<td>CR,1</td>
<td>0.29703**</td>
<td>0.023348</td>
<td>1.656-05**</td>
<td>0.059713**</td>
</tr>
<tr>
<td></td>
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<td>[2.41074]</td>
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<tr>
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<td>[-0.06688]</td>
<td>0.006688</td>
<td>-0.383-05</td>
<td>0.009057**</td>
</tr>
<tr>
<td>CR,2</td>
<td>0.007511</td>
<td>0.049412</td>
<td>4.689-05**</td>
<td>0.007903**</td>
</tr>
<tr>
<td></td>
<td>[0.49090]</td>
<td>[0.36092]</td>
<td>[2.61366]</td>
<td>[0.69863]</td>
</tr>
<tr>
<td>C,1</td>
<td>-0.796387</td>
<td>-0.000921</td>
<td>2.677-05</td>
<td>-0.020366</td>
</tr>
<tr>
<td></td>
<td>[-1.50627]</td>
<td>[-0.07358]</td>
<td>[0.38004]</td>
<td>[0.69863]</td>
</tr>
<tr>
<td>GOR,1</td>
<td>1.879907</td>
<td>0.026203</td>
<td>-0.178935</td>
<td>0.004075**</td>
</tr>
<tr>
<td></td>
<td>[2.23723]</td>
<td>[2.03011]</td>
<td>[-0.87716]</td>
<td>[-0.90590]</td>
</tr>
<tr>
<td>GOR,2</td>
<td>0.225377</td>
<td>0.58337</td>
<td>0.18417</td>
<td>0.007903**</td>
</tr>
<tr>
<td></td>
<td>[0.46201]</td>
<td>[-1.29618]</td>
<td>[1.12098]</td>
<td>[-0.90590]</td>
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<tr>
<td>A,1</td>
<td>0.002350**</td>
<td>12.1467</td>
<td>0.000467</td>
<td>0.007903**</td>
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<tr>
<td></td>
<td>[2.37600]</td>
<td>[0.41437]</td>
<td>[-0.60915]</td>
<td>[0.63864]</td>
</tr>
<tr>
<td>A,2</td>
<td>0.016533**</td>
<td>0.0019448</td>
<td>0.000141</td>
<td>0.007903**</td>
</tr>
<tr>
<td></td>
<td>[-0.50995]</td>
<td>[1.45684]</td>
<td>[0.07196]</td>
<td>[-0.90590]</td>
</tr>
<tr>
<td>EX,1</td>
<td>0.18317</td>
<td>0.00579</td>
<td>0.000595</td>
<td>0.007903**</td>
</tr>
<tr>
<td></td>
<td>[0.95234]</td>
<td>[0.05054]</td>
<td>[0.65409]</td>
<td>[0.63864]</td>
</tr>
<tr>
<td>EX,2</td>
<td>0.15697</td>
<td>0.052717</td>
<td>-0.00023</td>
<td>0.007903**</td>
</tr>
<tr>
<td></td>
<td>[-0.20473]</td>
<td>[0.32503]</td>
<td>[-0.43230]</td>
<td>[0.63864]</td>
</tr>
</tbody>
</table>

Note: `*`, `**`, and `***` represent the rejection of the null hypothesis under 10%, 5%, and 1% levels of significance, respectively. The values within [] are the t-values.
CTCI Corporation is a firm in the engineering consulting industry that emphasizes on technology innovation. Because the business conducted by the CTCI Corporation includes engineering technology services, such as engineering planning, design, procurement, construction, case management, equipment manufacturing, production supervision, and environmental evaluation, it requires greater innovation investments in construction methods and technology compared to firms in the other three sub-industries. The results indicate that the R&D cost ratio had a significant influence on the value of intellectual capital for engineering consultants. The managers of engineering consultants are encouraged to invest in R&D expenditure to increase their intellectual capital. Such a result also proves that Taiwan’s construction industry has already shifted from the traditionally capital- and labour-intensive industry to a knowledge-based industry with high intellectual capital.

The empirical results also show that intellectual capital influences the construction industry’s business performance. Thus, the managers of construction industry should emphasize on the investment and management of intellectual capital.

**Findings and discussions**

The following findings are obtained from the empirical study results of the four selected construction-related firms. Based the findings, some issues can be addressed for future applications of the intellectual capital valuation model proposed in this study.

**Findings from empirical study**

**Construction is an industry possessing intellectual capital**

Construction is an industry that possesses intellectual capital and that intellectual capital affects the industry’s business performance. The construction industry has been traditionally conceived a ‘capital- and labor-intensive’ industry. However, empirical results reveal that the average values of the MV/BV and Tobin’s q values for all four sample firms are significantly greater than 1.0. This finding complies with that of Łataś and Walasek’s (2016) work that employed VAICTM to measure the intellectual capital of construction projects of two Polish developers. It shows that all four selected construction-related firms are regarded as corporations with high intellectual capitals based on the same definition in high-tech industry (e.g. information technology and biotechnology). Such a result also proves that Taiwan’s construction industry has already shifted from the traditionally capital- and labour-intensive industry to a knowledge-based industry with high intellectual capital.

**The intellectual capital of construction corporates can be valued**

A construction industry intellectual capital valuation model is proposed in the study for valuation of the intellectual capital of the construction industry. Through empirical study of Taiwan’s construction industry from 1990 to 2010, we verify the applicability of the proposed intellectual capital valuation model evaluating the intellectual capitals using a unit-root test and the constancy of the proxy variables of the nine selected valuation factors. Additionally, this study also confirmed that a long-term equilibrium co-integration relationship exists between variables through co-integration testing. These results indicate that a stable long-term equilibrium relationship exists between the values of intellectual capitals and business performance indicators for the Taiwan’s construction industry. These valuation factors can be used to establish a construction industry intellectual capital valuation model that can also be used as a basis to evaluate intellectual capitals of construction industry in the other countries.

<table>
<thead>
<tr>
<th>Name of sample firm (sub-industry)</th>
<th>Valuation factors/evaluation method</th>
<th>ROE</th>
<th>RPE</th>
<th>EXP</th>
<th>RD</th>
<th>CR</th>
<th>C</th>
<th>GOR</th>
<th>A</th>
<th>EX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinyi Realty (realtor and brokerage)</td>
<td>MV/BV, Tobin’s q, VAICTM</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>CTCI Corporation (engineering consulting)</td>
<td>MV/BV, Tobin’s q, VAICTM</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>Da Cin Construction (constructor)</td>
<td>MV/BV, Tobin’s q, VAICTM</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>Pacific Construction (developer)</td>
<td>MV/BV, Tobin’s q, VAICTM</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
</tbody>
</table>

Note: ☑️ indicates relevance between dependent and independent variables.
Managing intellectual capital improves business performance of construction industry

The proposed intellectual capital valuation model provides managers of construction industry a tool to improve their firms’ business performance. While considering VAIC™ model, the higher CEE, HCE, and SCE values imply greater business efficiency. In this regard, we found that the construction industry has substantial space for improvement regarding capital, human capital, and structural capital investment efficiency. Construction industry decision-makers can improve industry (company) competitiveness by adjusting the investment of resources.

Based on MCMs (MV/BV and Tobin’s q), the three most important influencing factors were ‘profitability (ROE)’, ‘solvency (CR)’, and ‘company assets (fixed asset turnover)’. Based on empirical results of the four sample firms, we can infer that realtors, developers, engineering consultants, and construction firms in the construction industry rely on low costs, management of financial capital, excellent processes, superior institutions, and supply chain relationships to achieve profitable and sustainable growths. Thus, ‘profitability’, ‘solvency’, and ‘company assets’ are the most important factors driving the value of intellectual capitals for realtors, engineer consultants, and the construction firms.

The VAIC™ method measures the efficiency of a company’s resource use to create added value. Under the ROA method (VAIC™), the most important factor was ‘resource allocation’. Based on empirical results, the primary source of intellectual capital for realtors, engineering consultants, and the construction firms is ‘resource allocation’. It indicates the importance of a company to possess complete internal procedures, a positive corporate culture, an efficient organizational structure, and the high-quality staffs. Such findings provide the managers of construction corporations with strategies to enhance their business performance.

Potential applications

There are some potential applications for the proposed intellectual capital valuation model as described in the following.

For managers of construction firms

Since intellectual capital is closely linked to the value of intangible assets, corporation managers should develop their own intellectual capital valuation models adapting to the respective sub-industries (realtor, engineering consultants, construction, and developer) and market characteristics to continually monitor improvements and resource investments, thereby increasing the value of the firm’s intellectual capitals.

For investors of construction industry

Corporation evaluation models should be shifted from traditional tangible assets to new models capable of expressing the value of intellectual capitals (intangible assets); the intellectual capital valuation model proposed in this study can be used as a reference framework. Additionally, a firm’s intellectual capital management capabilities exert a moderating effect on the generation of intellectual capitals. Thus, when investors are evaluating the investment value of a corporation, the intellectual capital management capabilities of company managers should be taken into account as an important factor.

For government construction agencies

Intellectual capital investment requires long-term and continuous investments. Since public construction projects are the primary source of business for the nation’s construction industry, the government agencies play an important role in enhancing the intellectual capitals of the construction industry. To improve the competitiveness of the construction industry, the government construction agencies should compile company intellectual capital capability evaluations as a measurement indicator for evaluation of the tenders of public works. The proposed model provides a useful tool to compile such a measurement indicator. By favouring high intellectual-based construction firms in their tendering process, the government agencies are able to encourage construction firms to enhance their intellectual capitals.

Conclusions and recommendations

Conclusions

The business performance of the construction industry has rarely been examined from the perspective of intellectual capital. The current research measures the intellectual capital of a construction corporate using three different quantitative models – MV/BV, Tobin’s q, and VAIC™ – and confirms that the construction industry, similar to the other high-tech industries, is an intellectual industry with high intellectual capital indexes. Moreover, the management of intellectual capital also affects the business performance of the construction industry. Furthermore, the empirical testing results show a co-integration relationship between the nine business performance indicators and intellectual capitals. In addition, the empirical results show that long-term cause and effect relationships exist between the
intellectual capital valuation indexes and the business performance indicators of construction corporates. It indicates the management of construction corporates should emphasize on strategies to allocate appropriate resources on increasing the intellectual capitals of the corporates in order to improve their business performance.

**Recommendations**

Due the availability of required data, this study employed only listed firms in Taiwan to examine the relationship between the construction industry’s intellectual capital and business performance. Other research limitations and assumptions may affect the results attained. Therefore, the following recommendations are addressed for future studies.

- It is recommended for future researchers to continue exploring the co-integration relationship between the intellectual capital and performance indicators in order to establish a long-term baseline of construction intellectual capital, so that it can serve as a benchmark of intellectual capital management for different construction corporates.
- For this study, we limited the research subjects to listed firms in the local construction industry in Taiwan. Other over-the-counter, publicly traded, and untraded companies were not included in the research scope. Similar study with entire scope of the industry can also be conducted.
- Due to limitation of data availability, other intellectual capital valuation methods were not conducted and compared in this research. Future researchers are encouraged to acquire relevant data to compare the values calculated using various intellectual capital valuation models.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

**References**


