A DISCRIMINANT MODEL FOR MEASURING COMPETITION INTENSITY OF CONSTRUCTION MARKET

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ABSTRACT

"Competition intensity" is a factor in addressing competitiveness. The understanding on competition intensity is prerequisite to the formulation of industrial competition policies as well as firms' competition strategies. In the construction context, whereas competition intensity can be measured using a number of traditional approaches (e.g., competitor number, concentration), the measurement is often criticized for poor efficiency. This study proposes a new model for measuring competition intensity in light of the theory of discriminant analysis. The proposed model is composed of predictor variables concerned with market operation as well as criterion variables that classify markets into a few predefined groups based on the values of competition intensity. Empirical data of China's local construction markets were collected to verify the proposed model. The research findings indicate that the model can offset the drawbacks of traditional measures in the construction market. It is recommended using the proposed model to predict the competition trend of construction market especially when data for the traditional approaches are poor or not readily available.

KETWORDS

Market competitiveness, construction competition, concentration, multivariate discriminant analysis, China

INTRODUCTION

Competing for survival is an ongoing fact of life for business to operate in an industrial context. The selection rule of competition drives firms to orient business to the external changing market situations, and it has been accepted as a cornerstone of market operation (Greer 1992). Therefore, properly measuring and predicting the intensity of competition are foremost and paramount tasks to undertake in the formulation of both industrial competition policies and competition strategies. According to Porter (1980), there are five market forces that can determine competition intensity in a collective way, namely the threat of substitute products, the threat of established rivals, the threat of new entrants, the bargaining power of suppliers, and the bargaining power of customers. Subject to the combined effect of these forces, the measurement of competition intensity is daunting. One of the primary reasons is that some of the forces may exert overwhelming influence on business competition in a market, while others may not.

The measurement of competition intensity in construction enables governmental authorities to gauge market operating efficiency, and helps contractors manage organizational competitiveness. On one hand, industrial policies such as antitrust laws, privatization and deregulation imply that market competitiveness has no root in a monopoly situation. On the other hand, market players are reluctant to confront themselves with over competition. This is the case in the construction industry. Construction business competition normally refers to contractors' bidding activities (Kim and Reinschmidt 2006). The lowest-price bidding mechanism widely adopted by clients has created an all-pervading competition atmosphere in the construction market (Gruneberg and Ive 2000). However, clients are often blamed for inviting too many contractors to bid for construction contracts simultaneously (Fu *et al.* 2003; Flanagan and Norman 1985). Over competition, as a consequence, shrinks business profitability and jeopardizes project performance with respect to schedule, cost, quality and environment (Sturts and Griffis, 2005). Therefore, competition intensity stays at the core of construction competitiveness and previous studies have elaborated it at two levels – project and market (Ye *et al.* 2008).

Measurement of competition intensity at the project level

The measurement of competition intensity at the project level presents the extent to which competition happens in a pool of contractors who are bidding for common construction works. The measurement facilitates decision-making on "bid or not to bid" (Wang *et al.* 2009; Lo *et al.* 2007). The larger the number of competitors, the higher the level of competition intensity, and the lower the bid will be. Thus, the indicator of competitor number has been used as a proxy for the intensity of competition to aid construction business in understanding bidding practices. For instance, Ngai *et al*. (2002) recommended clients to adopt different strategies by changing the number of invited bidders from one market situation to another to ascertain that a certain intensity of competition can be derived. Ye *et al.* (2008) presented a competitor number - based concept of project competition intensity that is favorable for clients to screen out qualified contractors.

Implicitly embedded in this type of measurement is an assumption of two extreme competition scenarios (Greer 1992). One refers to perfect competition, of which the market is populated with numerous homogenous firms. The other is monopoly wherein the market is dominated by very few firms. The discrepancy between these two competition scenarios offers the rationale for that researchers often employ competitor number to quantify competition intensity at the project level. However, simply using the number of competitors to measure project competition intensity is inadequate. First, this indicator mirrors only a part of rivalry without taking into account market forces other than the incumbent. Second, it pays little attention to any potentially uneven distribution of market powers between existing competitors, which could be a consequence of business competition over a period of time (Newcombe 1990). Third, a switch from quantity competition to price competition increases the intensity of competition with a decrease in firm number in the meanwhile (Aghion *et al.* 2001), suggesting that the intensity cannot always be measured quantitatively by the number of competitors. Therefore, the measurement of competition intensity at the project level is of limitations.

Measuring competition intensity at the market level

Competition intensity at this level has been measured in a number of ways typically including concentration (Ye *et al.* 2009), which is a useful instrument that quantifies the extent to which market shares are distributed among incumbents (Bajo and Salas, 2002). There are two types of concentration measures, relative and absolute, that measure the extent to which a market departs from a predefined competition status (Fedderke and Szalontai 2009). The concentration ratio (CR_n), where n can be 4, 8, 12, *etc*. is relative, while the Lerner index (Lerner 1934), the Herfindahl-Hirschman index (Kilpatrick 1967), Entropy (Hart 1971), and the Lorenz curve (Bishop *et al.* 2003) are absolute. The relative measures are derivable as they place the measurement on a small number of competitors and impose little requirement on the data collection. The absolute approaches have the advantage of imaging a whole scope of business competition in a market, but it depends on the availability of data for all businesses. In reverse, the lack or incompleteness of quality data can give rise to erroneous judgments on market competition situations.

For the reason of poor data in the construction industry (Ruddock, 2002), the measurement of competition intensity in the construction market has relied on relative concentration approaches (Ye *et al.* 2009). The studies by both Chiang *et al.* (2001) and Wang (2004) demonstrated that the relative approaches are conducive to the identification of the characteristics of construction market. Yang *et al.* (2012) found that the increasing market concentration in the construction market of Jiangsu of China has a negative effect on the survival of construction companies. In a same vein, Ye *et al.* (2009) revealed a moderate degree of competition in the international construction market. Nevertheless, the moderate competition is a result from the assumption that the population of the international construction industry is composed of the largest 225 contractors listed in Engineering News-Record. In reality, these 225 contractors only represent a small part of the entire industry. It appears nevertheless that researchers spared no effort in searching for alternatives to address the problem where data are needed for analysis but are not obtainable in reality.

In appreciating the limitations of previous studies, Mccloughan (2004) devised a new concentration model for the assessment of competition intensity in the British construction industry. Because of the British-specific statistics variables, Mccloughan’s approach may not fully apply to other construction industries such as the Chinese construction industry. A recent study by Ye (2009) established a causalsequential coordinate system for measuring competition intensity in the construction market. Nonetheless, the correlation between the two-dimensional factors was not addressed explicitly, which undermines the usefulness of the model. There are some other measures such as consumer's travelling cost (Boone 2001), price cost margins (Flath 2011), persistence of firm profitability (Jiang and Kattuman 2010), and residual demand elasticity (Goldberg and Knetter 1999) for potential application in construction. Whilst deserving attention, these measures have likewise limitation in application, as they were based on homogeneous business rather than construction, which is substantially unique, one-off, and heterogeneous.

Research gap

While there lacks sufficient data to adopt the absolute concentration approaches, scholars are apt for the relative concentration approaches. Nevertheless, in many developing countries (e.g., China), data for calculating relative concentration indices of construction markets are not released until several years later. As a consequence, the competition situation of construction market is very hard to inform in a timely fashion to support the development of bidding strategies and industrial policies. It is very important in this content to identify alternative methods that can complement the relative approaches. This study aims to propose a new approach to improve the measurement of competition intensity in the construction market. The remainder of the paper is structured as follows. The theory of discriminant analysis is discussed in Section 2, providing a solid grounding for model development in the study. The discussion leads to the establishment of multivariate discriminant functions as addressed in Section 3. Using the empirical data collected from China, the developed functions are demonstrated in Section 4. Section 5 discusses the research findings and draws conclusions.

THEORIES OF DISCRIMINANT ANALYSIS

Competition intensity is a relative term that reflects the level of rivalry within a given market environment (Ramaswamy and Renforth 1996). The relativity is usually presented by making comparison between different markets over a period of time or between different periods of time for a same construction market (Ye *et al.*, 2009). This relativity attribute suggests that the intensity of competition in an observed market can be indicated by situating it into a set of markets that have competition features in common. In light of the work by Kim *et al.* (2008), the technique of discriminant analysis (DA) was therefore adopted for model development in the study. DA is a useful approach for classifying a set of observations into predefined groups. Dating back to the 1920s, this approach has deserved much attention in the areas of biology, business, education, engineering and psychology (Huberty and Olejnik 2006). DA plays two roles in the study. One is for descriptive discriminant analysis (DDA), which elaborates how well the selected variables separate a set of observations into groups and which specific latent variables (discriminant functions) can provide the most suitable group discrimination. The other is for predictive discriminant analysis (PDA), which focuses on the prediction of group membership. PDA and DDA variables are interchangeable. Predictor variables in PDA (independent variables) are response variables in DDA (dependent variables), while PDA's criterion variables (dependent variables) are DDA's grouping variables (independent variables).

Multivariate discriminant analysis (MDA) is a typical DA technique to predict which group (Y) an observation belongs to using linear composites of predictor variables (X) (Lam *et al.* 2001). MDA has become popular in the discipline of industrial economics, as it yields pragmatic solutions to many industrial problems (Cabahug *et al.* 2004). The key procedure of MDA is to establish discriminant functions, where scores of the predictor variables are weighted up (Ary *et al.* 1990). MDA results in the establishment of multivariate discriminant function (MDF) which is in general expressed as Equation 1. The parameters of Equation 1 can be quantified using a set of observations that have been categorized into some known groups (*Y*).

$$Y = f(x) = \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \ldots + \alpha_n x_n + \delta \qquad (1)$$

Where *Y* is the response variable, x_n is the predictor variables, a_n is discriminant coefficients for variables x_n, and δ is a constant.

MDA seems to be multidimensional scaling (MDS) or multivariate analysis of variance (MANOVA). In effect, they differ from each other. MDS contains a series of techniques used to identify key dimensions of objects, while MANOVA is to determine whether multiple levels of independent variables on their own or in combination with one another have effects on the dependent variables. By contrast, MDA is more suitable for the study for two main reasons. First, multivariate discriminant function (Equation 1) can detect the group membership of new observations. This prediction functions satisfies the research purpose, while it is beyond the capacity of MDS and MANOVA. Second, to ensure that any statistically insignificant variables are eliminated, a stepwise procedure is usually followed. Variables included in a final MDF are thus not always the originally recognized ones. As such, different markets may have different MDFs composed of different variables, despite that they have model structure in common. This suggests that MDA be a better way to mirror flexibly the different combined effects of market powers on competition intensity.

MODEL DEVELOPMENT

Predictor variables

Competition intensity has been studied for long time with a large number of resultant publications in the area of industrial economics. Through extensive literature review, Ye (2009) identified more than 105 technical papers that address the subject of competition intensity, and 55 of them are concerned with the factors of competition intensity. Using the method of content analysis on the 55 publications, Ye (2009) unveiled a set of key indicators of competition intensity, namely business diversity (BD), market entry barriers (MEB), market growth (MG), market size (MS), market share distribution (MSD), profitability (PT), technical efficiency (TE), and average wage (WG). As the literature review is based on a thorough analysis and detailed discussion in the construction context, the derived indicators were accepted as predictor variables of MDF in the study. The determination of these variables concurs with previous studies on that to ensure effective MDA reliability, the number of predictor variables should be manipulated to be between 8 and 10 (Guo 2002). For simplicity, these variables are discussed as follows.

Business diversity (BD)

Business diversity means the heterogeneity of individual businesses in a market. Those construction firms which have similar competitive strengths will compete strongly for common business, especially when they are identical in either size or portfolio of investment. Therefore, a low degree of business diversity can indicate intense competition in the market. In turn, fiercer competition in the market propels firms to explore other opportunities. For instance, robust competition in the Chinese construction market has forced contractors to diversify business structures to escape from the previously narrow competition (Wang 2004).

Market entry barriers (MEB)

Competition in a market consists of two parts - existing competition among the incumbents and potential competition posed by new entrants (Porter 1980). Market entry barriers, such as economy of scale, product differentiation, capital requirement, access requirement and government policy, put obstacles to potential entrants into a new market (Bain 1956; Porter 1985). Potential competition is therefore determined by market entry barriers. Previous studies have acknowledged the presence of market entry barriers in the construction industry, and found them similar to other industries (Gruneberg and Ive 2000; Ofori 1990). Higher entry barriers inhibit the entrance of new competitors significantly, and thereby lower the intensity of potential competition. On the other hand, lower entry barriers facilitate the entrance of new firms, giving rise to an increase in the number of firms as well as competition intensity.

Market growth (MG)

Market growth means the speed of market expansion. George (1967) pointed out that industry growth decreases the level of competition intensity. This is because the existing competition in a market erodes with the expansion of market volume which releases more spaces for incumbents to survive (Owen 1971). However, there are different opinions. Baumol (1962) argued that rapid growth of an industry encourages potential entrants, strengthening business competition as a result. Such point of view has been echoed by other researchers (for example, Nelson 1960; Shepherd 1964) stating that a growing market will become less concentrated and will have ascending intensity of competition.

Market size (MS)

Market size is an important factor that firms take into account when launching a new product/service program. A larger market size generates more business opportunities and the business competition can be lessened accordingly. However, Mueller and Hamm (1974) claimed that market size has minor impact on competition intensity if market demand is equivalent to supply. In effect, the impact of market size on competition intensity depends on whether a variation in market size can render competition pressures onto existing competitors. Therefore, a larger industry size causes business competition to intensify as the entry barriers become lower (Bain 1956).

Market share distribution (MSD)

Business competition brings change to the distribution of market shares. Specifically, the distribution of market shares will be concentrated if the market is dominated by a few firms. In reverse, market share distribution will be more even if the existing competitors have equivalent market powers over product prices. Market share distribution, therefore, may be a useful indicator of intensity of competition (Davies and Geroski 1997; Ye *et al.* 2009). A more outspread distribution of market share means acuter competition in the market (Alexander 2001).

Profitability (PT)

Profitability is a principal indicator of business performance and bears a direct relationship with the intensity of competition. It seems that previous studies have not agreed with each other on the effect of business competition on profitability. While intensive competition results in low profitability (Porter 1980), the study by Neumann *et al.* (1985) implied a loose relationship between profitability and competition intensity. By contrast, Bain (1951, 1956) opined that a market moving towards a highly concentrated structure (little competition) is accompanied by a higher level of profitability. Similarly, the studies by both Chiang *et al.* (2004) and McCloughan (2004) demonstrated that profitability in a market with little competition is higher than that in those markets with intense competition.

Technical efficiency (TE)

Technical efficiency exhibits the utilization of technical resources in an industry. Primeaux (1977) revealed that product cost can be decreased by increasing technical efficiency in response to market competition, indicating that technical efficiency is an indicator of the intensity of competition. The work by Ramaswamy and Renforth (1996) shows that a market with intensive competition urges firms to improve technical efficiency continually.

Average wage (WG)

Cutting labor costs is an effective way for business to keep production cost as low as possible in reaction to market competition (Ramaswamy and Renforth 1996; Bradburd *et al.* 1991). Nonetheless, this may not be generalized in the construction context. Given a labor shortage, competition for labor resources will be robust and labor costs will increase subsequently. It has been the norm that that employers tend to improve staff strengths by reducing the number of less skilled employees while retaining good quality staff who normally get more payment. Therefore, a higher level of competition increases the average wage among competing firms.

Criterion variables

The classification cut-off points in previous studies usually follow rules of a thumb. For instance, a five point category scale was appreciated effective in the studies by both Cabahug *et al.* (2004) and Kim *et al.* (2008) to classify research objects into several groups. In a same way, this study adopted the CR_n approach (n = 4, 8, 12, *etc.*), which refers to the total amount of market shares of the largest *n* firms, to indicate the intensity of competition. As a major relative concentration measure, CR_n is derivable and the variable *n* normally depends on the availability of data. As discussed earlier, although CR_n is not ideal to present the powers of all businesses in a market, it is practicable for the study to predefine the group memberships of observed construction markets. In line with the availability of data and its widely accepted criteria, CR_4 was thus employed in the study.

Basically, the larger the CR_4 index, the lower the competition intensity. To ascertain effective classification, high, average and low levels of competition intensity are coded with an ordinal number *i* (criterion variables, *i* = 1, 2, 3) respectively, each being defined in Equation 2, provided that $C_1 < C_2 < C_3$,

$$f(x) = \begin{cases} 1\ (Group\ 1),\ if\ \ CR4 \le C_1,\ strong\ competition \\ 2\ (Group\ 2),\ if\ \ C_1 < CR4 \le C_2,\ \mathrm{mod}\,ernate\ competition \\ 3\ (Group\ 3),\ if\ \ CR4 > C_3,\ low\ competition \end{cases} \quad (2)$$

The criteria stated in Equation 2 serve to measure the intensity of construction business competition at intervals. The intervals have been indicated in previous studies. Shepherd (1982) pointed out four types of market structures, namely competition (CR_4<60%), oligopoly (CR_4>60%), dominant firm (50%<CR_4<90%) and monopoly (CR_4 at or near 100%). Using CR_4 coefficients, Oster (1999) illustrated competition cases with highly concentrated oligopoly (0.75<CR_4<1.00), moderately concentrated oligopoly ($0.50<CR_4<0.749$), oligopoly ($0.25<CR_4<0.499$), and atomism (0.00-0.249). Nevertheless, as reported by McClough (2004) and Ye *et al.* (2009), the construction market is fragmented, and CR_4 coefficients in construction are usually numerically very small. As such, a small change in CR_4 numerical value may not mirror effectively a small movement in the level of market competition. For instance, according to Wang's (2004) calculation, CR_4 indices for those construction markets of China (1996), US (1997), UK (1999) and Japan (1999) are 0.63, 3.23, 8.65 and 3.30 respectively, indicating minor difference between countries in the globe. Therefore, the values of C_1, C_2 and C_3 in Equation 2 shall be adjusted to reflect the characteristics of construction industries to ascertain that markets are grouped appropriately.

Discriminant functions

Taking account of the predictor variables, Equation 1 is rewritten into the following multivariate discriminant function (MDF):

$$f(x) = \alpha_1 x_{BD} + \alpha_2 x_{MEB} + \alpha_3 x_{MG} + \alpha_4 x_{MS} + \alpha_5 x_{MSD} + \alpha_6 x_{PT} + \alpha_7 x_{TE} + \alpha_8 x_{WG} + \delta \quad (3)$$

The relationships between competition intensity and predictor variables, as discussed in Section 3.1, are summarized in Table 1. Of the relationships, the variables MEB, MG, and PT have negative relationships with competition intensity, while the remaining variables are positively related.

<<Insert Table 1 here>>

The predictor variables assume different units in practice. Since competition intensity is a relative measure, the values of all the variables are normalized into relative values. Comparing *m* markets for relative competition intensity, the normalization of the independent variables is conducted as follows:

$$X_{BD} = (BD - \underset{i=1}{\overset{m}{Min}}\, BD_i) \Big/ (\underset{i=1}{\overset{m}{Max}}\, BD_i - \underset{i=1}{\overset{m}{Min}}\, BD_i)$$

$$X_{MEB} = (\underset{i=1}{\overset{m}{Max}}\, MEB_i - MEB) \Big/ (\underset{i=1}{\overset{m}{Max}}\, MEB_i - \underset{i=1}{\overset{m}{Min}}\, MEB_i)$$

$$X_{MG} = (\underset{i=1}{\overset{m}{Max}}\, MG_i - MG) \Big/ (\underset{i=1}{\overset{m}{Max}}\, MG_i - \underset{i=1}{\overset{m}{Min}}\, MG_i)$$

$$X_{MS} = (MS - \underset{i=1}{\overset{m}{Min}}\, MS_i) \Big/ (\underset{i=1}{\overset{m}{Max}}\, MS_i - \underset{i=1}{\overset{m}{Min}}\, MS_i)$$

$$X_{MSD} = (MSD - \underset{i=1}{\overset{m}{Min}}\, MSD_i) \Big/ (\underset{i=1}{\overset{m}{Max}}\, MSD_i - \underset{i=1}{\overset{m}{Min}}\, MSD_i) \qquad (4)$$

$$X_{PT} = (\underset{i=1}{\overset{m}{Max}}\, PT_i - PT) \Big/ (\underset{i=1}{\overset{m}{Max}}\, PT_i - \underset{i=1}{\overset{m}{Min}}\, PT_i)$$

$$X_{TE} = (TE - \underset{i=1}{\overset{m}{Min}}\, TE_i) \Big/ (\underset{i=1}{\overset{m}{Max}}\, TE_i - \underset{i=1}{\overset{m}{Min}}\, TE_i)$$

$$X_{WG} = (WG - \underset{i=1}{\overset{m}{Min}}\, WG_i) \Big/ (\underset{i=1}{\overset{m}{Max}}\, WG_i - \underset{i=1}{\overset{m}{Min}}\, WG_i)$$

These normalized equations are based on the relationships given in Table 1. It is important to note that an increase in any variable of MEB, MG and PT means a decrease in competition intensity. On the other hand, an increase in any of BD, MS, MSD, TE and WG reflects an increase in competition intensity. Therefore, the discriminant model for measuring competition intensity is composed of Equations 2, 3 and 4.

EMPIRICAL ANALYSIS

Empirical data from the Chinese construction industry were collated to demonstrate the efficiency and effectiveness of the proposed MDFs (Equations 2, 3, and 4). To ensure the reliability of MDFs, the sample size should be 10-20 times the number of variables, and the numbers of cases per group should not be insignificantly different (Guo 2002). Therefore, China's local construction industries were adopted to ascertain sufficient samples.

The collected data are about construction firms' annual revenues larger than one hundred million RMB for the years of 2002, 2003, 2005, 2006, and 2007. For Xizang, a north-west province of China, some data were missed, and the province was thus excluded from the analysis. The samples for testing the established MDFs are thirty provincial construction markets in China for five years as mentioned above. In total, a set of 150 observations were documented, which satisfies the requirement of MDF development. In addition, yearly statistical data published in the official website of National Statistics Bureau (www.stats.gov.cn) were gathered to calculate all the variables as discussed below.

Criterion variables

Previous studies have demonstrated that the annual revenue of construction firms is used to calculate CR_4 for criterion variables (Ye *et al.* 2009). CR_4 indices were calculated per local market per year, and the 150 markets were then grouped into three in accordance with Equation 2. Comparing with the U.S., Li *et al.* (2002) disclosed that China's construction industry has very small Gini coefficients, suggesting that construction firms are unable to differentiate effectively in terms of company size. Kang and Zhang (2008) revealed that the construction market is non-concentrated, and each firm has negligible market power. These studies agree with each other on the segmentation of the Chinese construction market. Therefore, Equation 2 was re-expressed as follows to meet the segmentation features of China's construction market.

$$f(x)=\begin{cases}1\ (Group\ 1),\ if\ \ CR4\le 10\%,\ highly\ competitive\\ 2\ (Group\ 2),\ if\ \ 10\%<CR4\le 20\%,\ \mathrm{mod}\,erately\ competitive\\ 3\ (Group\ 3),\ if\ \ CR4>20\%,\ lowly\ competitive\end{cases} \quad (5)$$

Predictor variables

Predictor variables were quantified in accordance with the nature of the Chinese construction industry as described below.

Business diversity (BD): As reported by the Centre for Policy Research the Ministry of Construction (2007), construction firms in China supply diverse services such as construction, contract management, architecture, consultancy, equipment leasing, and maintenance to the market. The structure of the income composition of an individual firm, indicated by the proportion of auxiliary revenue to total business revenue, can mirror a firm’s business distribution. Therefore, the auxiliary income proportion of construction firms was adopted as an indicator of business diversity in this study. The larger the average proportion, the higher the level of business diversity in the market.

Market entry barriers (MEB): In manufacturing industries, researchers have suggested measuring market entry barriers by plant capacity required for business operation in (Holtermann 1977; Farber 1981). However, the application of this method is less relevant in the construction industry. The possession of construction plant does not erect substantial barriers to potential entrants. Contractors normally rent large items of plant only for the project period needed. Similarly, the average capital among those existing firms registered to operate is employed to quantify market entry barriers. The larger the average registered capital per firm, the higher the entry barrier.

Market growth (MG): Market growth is normally calculated by growth of market demand (Collins and Preston 1966). It is noted that market demand in the construction industry is hard to forecast exactly. For example, the volume of civil engineering works is vulnerable to many external factors, such as governmental policy, employment rate, and economic prosperity (Tan 1989). To mitigate this difficulty, the growth rate of building works under construction was adopted to reflect the growth of a construction market. The higher the growth rate, the less intense the competition in the market.

Market size (MS): Market size can be measured from the perspective of either suppliers or consumers (Noh 2000; Mueller and Hamm 1974). Because of its close association with the magnitude of construction firms, construction market size was measured by the volume of construction works committed by all firms in a year. The larger the average volume of work in an area, the larger the market size.

Market share distribution (MSD): China's state-owned construction enterprises (CSCE) play leading roles in local construction industries (Shen and Song 1998; Zou *et al.* 2007). They usually possess a significant proportion of market share and dominate business competition in the industry. It was therefore considered effective to measure MSD based on the market shares of CSCEs.

Profitability (PT): Profitability refers to profit rate (Bonardi 2001). An average profit rate for construction business is published by the National Statistics Bureau, and was thus adopted in this study.

Technical efficiency (TE): Wang (2004) suggested using the percentage of investment return on the technical capital possessed by firms to measure technical efficiency. This percentage was similarly adopted as a TE indicator in this study.

Average wage (WG): The level of average wage has been commonly measured either by hourly wage rates or by annual wages (Haworth and Reuther 1978; Horowitz 1971). The total wage per person per year was adopted as a WG indicator in this study.

Descriptive discriminant functions

Researchers have used computer software programs to conduct multivariate data analysis (Huberty and Olejnik 2006). The Statistics Package for the Social Scientist (SPSS 15.0) was employed to model the MDFs. Two discriminant functions (Function 1 and Function 2) are derived as indicated by the eigenvalues and relative variances shown in Table 2. Total variance of the two functions is estimated at 100%, indicating that the classification of all construction markets can be explained adequately with the two discriminant functions.

<<Insert Table 2 here>>

As discussed above, the discriminant functions are preliminarily composed of eight predictor variables (BD, MEB, MG, PT, MS, MSD, TE, and WG). With the application of a stepwise procedure embedded in SPSS, three variables were found sufficient for the two functions (Table 3). It seems from Table 3 that although the other criterion variables may influence market competition, a portfolio of three variables (MSD, MS, PT) yielded sufficient discriminating results in relation to China's local construction markets.

<<Insert Table 3 here>>

The discriminant analysis derives two sets of standardized coefficients (Table 4). Based on these coefficients, two discriminant scores, (f1, f2), for a local construction market can be detected. The combined scores (f1, f2) enable the classification of a construction market by comparing the scores with the group centroids shown in Table 5. Thereby, the group membership of a construction market can be determined. As shown in Table 5, Group 1 has a negative mean for function 1, Group 2 has a negative mean for function 2, and Group 3 has a positive mean for both functions 1 and 2.

<<Insert Tables 4 & 5 here>>

Territorial maps (Figure 1) were plotted in accordance with the combined scores (f1, f2). All construction markets had values falling into the region bordered by the three groups. With the values determined for the group centroids of 1, 2 and 3, it is seen that the three groups have mean values which are very close, indicating the models for describing the competition status of local construction markets are similar.

<<Insert Figure 1 here>>

Predictive discriminant functions

In accordance with the theory of discriminant analysis, predictive discriminant functions can be established. The coefficients shown in Table 6 are rewritten as follows.

$$
\begin{aligned}
f_1(X) &= 20.319X_{MS} + 11.980X_{MSD} + 9.046X_{PT} - 9.230 \\
f_2(X) &= 14.569X_{MS} + 14.008X_{MSD} + 11.627X_{PT} - 9.388 \\
f_3(X) &= 13.911X_{MS} + 20.698X_{MSD} + 13.267X_{PT} - 13.919
\end{aligned}
\qquad (6)
$$

Where $f_i(X) \quad (i = 1, 2, 3)$ is the discriminant score for a given construction market in China.

<<Insert Table 6 here>>

Discriminant scores for the yet to be analyzed construction markets can be determined using Equation 6. Of the three scores derived, the group with the largest score categorizes a construction market. For instance, for the Beijing construction market (2002):

CR_4=0.0690, $X_{MS\text{-}bj}$=0.4611, $X_{MSD\text{-}bj}$=0.5411, and $X_{PT\text{-}bj}$=0.2803

Then, according to Equation 6,

$f_1(X)$ = 9.1571, $f_2(X)$ = 9.1501, and $f_3(X)$ = 8.1566

Because the largest discriminant score is $f_1(X)$, the Beijing construction market (2002) can be classified into Group 1. This accords with the CR4-based grouping, as the CR_4 coefficient suggests the group number of the market should be 1 according to Equation 5.

Validation

It is noted that predictions for future construction markets are outside the known observations from which the discriminant model was built. To be sure at this stage that the derived model will suffice for future predictions, measurement of the predictive accuracy of the mode is important. The accuracy is detected by comparing the observed misclassifying rate to that expected by chance alone. The percentage of the construction markets classified correctly is taken as an index of the effectiveness of the discriminant function (Guo 2002). Results of the validation are shown in Table 7. it can be seen that the percentage of cases correctly classified within groups 1, 2, and 3 are 71.9%, 65.5% and 57.1% respectively, indicating a satisfactory degree of accuracy in the derived model.

<<Insert Table 7 here>>

DISCUSSION

In this study, multivariate discriminant functions (MDFs) were developed as alternatives to traditional approaches in measuring competition intensity in the construction context. The developed MDFs encompass one criterion variable and eight predictor variables, namely business diversity, market entry barriers, market growth, market size, market share distribution, profitability, technical efficiency, and average wage. Using the empirical data of China's construction industry, it was found that discriminant analysis has the efficiency in measuring the intensity of competition in the construction market. Specifically, of all the eight predictor variables, market size, market share distribution, and profitability are identified as the elements of MDFs in China’s local construction industries. These three predictor variables were found effective to facilitate the classification of China’s local construction markets into three groups - high, moderate, and low level of intensive competition. Arguably, it could be the case that other variables will eventually be key attributes in the discriminant model when examining other construction markets. Different variables included in MDFs in different construction markets mirror the changing combined effect of five market forces on competition intensity.

The MDFs contain the separation of construction markets into three groups (Groups 1, 2, and 3) in accordance with the levels of competition intensity. Technically, while the separation is based on the attributes of construction market, different criteria can be adopted by different researchers to satisfy dissimilar intentions of discriminant analysis. Therefore, it is important to know what MDFs imply when the criteria are laid down. In effect, the intensity of competition in two construction markets may not differ significantly from each other if they are classified into a same group, while the difference will be distinctive if the two markets fall into different groups. Therefore, it is implied that construction firms take into account the group memberships of individual markets and make response to different market situations in due manners. Reconsidering competition strategies is paramount when contractors are transferring between different construction markets. For instance, in China, contractors moving from Group 1 construction market to Group 2 will encounter more intensive competition, thus they have to reevaluate competitive strategies accordingly.

The MDFs can complement the traditional measures of competition intensity in construction context. In previous studies, competition intensity in the construction market was usually measured through relative concentration approaches. As discussed earlier in this study, the concentration-based measurement has limited applications due to its onerous need for data input. Data about individual firms, the basis for the concentration-based measurement, are difficult to collect in the vast majority of construction markets worldwide. This impairs the effectiveness of the resultant concentration indices in reflecting competition intensity in the construction market. The MDFs developed in this study are based on statistical data, instead of detailed information about individual business, that are publicly ready in many countries. Hence, the MDFs developed in the study are more applicable than traditional concentration methods. Furthermore, with the assistance of MDFs, it is feasible to conduct a longitudinal analysis of a construction market by taking into consideration the statistical data over a specific period of time. An overview on the development of competition situations in a construction market can therefore be examined.

Results of the MDFs indicate the group membership of a construction market, which states the interval of competition intensity that the market belongs to, say $0\%<CR_4<10\%$ (highly competitive). The interval can be narrowed to improve the robustness of the measurement by giving more levels of criterion variables of the MDFs. Therefore, the MDFs can aid construction professionals to understand the statuses of market competition in due ways and results of the MDFs are informative to construction businesses and the construction industry as a whole. With this knowledge of competition intensity, contractors are more able to match business strategies to external market environments to ensure that their strategies are competitive. In addition, construction clients can apply the MDFs to formulate more effective contractor selection criteria during project tendering process, ensuring that an qualified contractor is selected.

Furthermore, governments can apply the model to monitor various local construction markets from the perspective of competition intensity and adopt proper leverage measures to improve resource deployment efficiency across construction industries. While market players can gent benefits from the MDFs, more efforts are necessitated to examine the nexus between competition intensity and competitiveness to guide market players to make due response to the changing competition situations as indicated by the results of discriminant model.

CONCLUSIONS

The construction market is characterized by fierce competition, requiring construction firms to carefully identify the markets where they can find competitive advantages by understanding the competition intensity between markets. Traditional approaches for analyzing market competition intensity have found limitation in application. The discriminant model proposed in this study offers an alternative solution to this limitation. The model consists of multivariate discriminant functions which quantify the intensity of competition in a construction market by classifying the market into some predefined groups that have known competition intensity. The values of the variables in these functions can be obtained from statistical data which are commonly available. Therefore, the discriminant model is effectively applicable in measuring the intensity of competition in the construction market. The application of the model helps professionals in the construction industry understand competition situations in a construction market. Thus, both competition strategies and policies can be formulated in due ways. The proposed model is a development of the literature in examining competition intensity. Nevertheless, it is appreciated that the empirical analysis of the proposed model is based on data which were collected from local construction markets in China. Therefore, the applicability of the model in other construction contexts needs to be further studied.

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Table 1 Indicators of competition intensity

Competition intensity	↑	↑	↑	↑	↑	↑	↑	↑
Indicators/independent variables	BD ↑	MEB ↓	MG ↓	MS ↑	MSD ↑	PT ↓	TE ↑	WG ↑

Table 2 Eigenvalue

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	.818[a]	92.4	92.4	.671
2	.067 [a]	7.6	100.0	.251

a. First 2 canonical discriminant functions were used in the analysis

Table 3 Variables Entered/Removed(a,b,c,d)

Step	Entered	Wilks' Lambda							
						Exact F			
		Statistic	df1	df2	df3	Statistic	df1	df2	Sig.
1	MSD	.658	1	2	147.000	38.136	2	147.000	.000
2	MS	.560	2	2	147.000	24.564	4	292.000	.000
3	PT	.515	3	2	147.000	19.002	6	290.000	.000

At each step, the variable that minimizes the overall Wilks' Lambda is entered.
a Maximum number of steps is 16.
b Minimum partial F to enter is 3.84.
c Maximum partial F to remove is 2.71.
d F level, tolerance, or VIN insufficient for further computation.

Table 4 Standardized Canonical Discriminant Function Coefficients

	Function	
	1	2
MS	-.463	.780
MSD	.657	.761
PT	.414	-.223

Table 5 Functions at Group Centroids

CI	Function	
	1	2
1	-.983	.168
2	.151	-.321
3	1.351	.258

Unstandardized canonical discriminant functions evaluated at group means

Table 6 Classification Function Coefficients

	Construction market group		
	1	2	3
MS	20.319	14.569	13.911
MSD	11.980	14.008	20.698
PT	9.046	11.627	13.267
(Constant)	-9.230	-.9.388	-13.919

Fisher's linear discriminant functions

Table 7 Classification Results[b,c]

			Predicted Group Membership			
		CI	1	2	3	Total
Original	Count	1	41	13	3	57
		2	10	38	10	58
		3	1	14	20	35
	%	1	71.9	22.8	5.3	100.0
		2	17.2	65.5	17.2	100.0
		3	2.9	40.0	57.1	100.0
Cross-validated[a]	Count	1	40	14	3	57
		2	10	38	10	58
		3	1	14	20	35
	%	1	70.2	24.6	5.3	100.0
		2	17.2	65.5	17.2	100.0
		3	2.9	40.0	57.1	100.0

a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

b. 66.0% of original grouped cases correctly classified.

c. 65.3% of cross-validated grouped cases correctly classified.

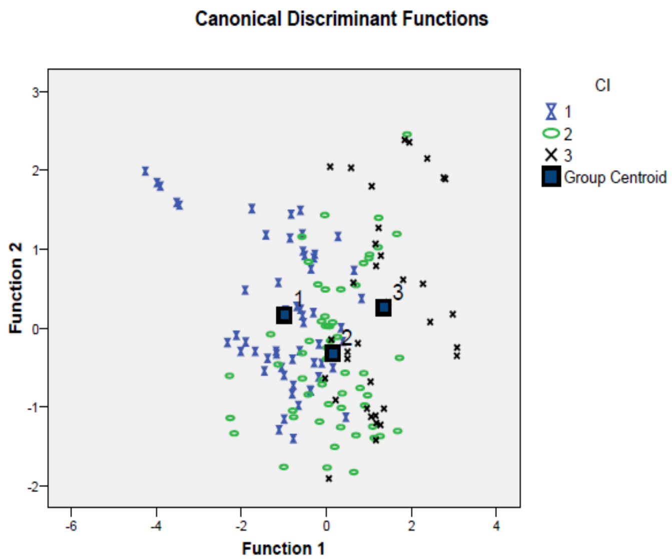

Figure 1 Canonical Discriminant Functions