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1 **A DISCRIMINANT MODEL FOR MEASURING COMPETITION INTENSITY OF**
2 **CONSTRUCTION MARKET**

3
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18
19 **ABSTRACT**

20 “Competition intensity” is a factor in addressing competitiveness. The understanding on competition
21 intensity is prerequisite to the formulation of industrial competition policies as well as firms’ competition
22 strategies. In the construction context, whereas competition intensity can be measured using a number of
23 traditional approaches (e.g., competitor number, concentration), the measurement is often criticized for
24 poor efficiency. This study proposes a new model for measuring competition intensity in light of the
25 theory of discriminant analysis. The proposed model is composed of predictor variables concerned with
26 market operation as well as criterion variables that classify markets into a few predefined groups based
27 on the values of competition intensity. Empirical data of China’s local construction markets were
28 collected to verify the proposed model. The research findings indicate that the model can offset the
29 drawbacks of traditional measures in the construction market. It is recommended using the proposed

30 model to predict the competition trend of construction market especially when data for the traditional
31 approaches are poor or not readily available.

32

33 **KEYWORDS**

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

36

37 **INTRODUCTION**

38

39 Competing for survival is an ongoing fact of life for business to operate in an industrial context. The
40 selection rule of competition drives firms to orient business to the external changing market situations,
41 and it has been accepted as a cornerstone of market operation (Greer 1992). Therefore, properly
42 measuring and predicting the intensity of competition are foremost and paramount tasks to undertake in
43 the formulation of both industrial competition policies and competition strategies. According to Porter
44 (1980), there are five market forces that can determine competition intensity in a collective way, namely
45 the threat of substitute products, the threat of established rivals, the threat of new entrants, the bargaining
46 power of suppliers, and the bargaining power of customers. Subject to the combined effect of these forces,
47 the measurement of competition intensity is daunting. One of the primary reasons is that some of the
48 forces may exert overwhelming influence on business competition in a market, while others may not.

49

50 The measurement of competition intensity in construction enables governmental authorities to gauge
51 market operating efficiency, and helps contractors manage organizational competitiveness. On one hand,
52 industrial policies such as antitrust laws, privatization and deregulation imply that market

53 competitiveness has no root in a monopoly situation. On the other hand, market players are reluctant to
54 confront themselves with over competition. This is the case in the construction industry. Construction
55 business competition normally refers to contractors' bidding activities (Kim and Reinschmidt 2006). The
56 lowest-price bidding mechanism widely adopted by clients has created an all-pervading competition
57 atmosphere in the construction market (Gruneberg and Ive 2000). However, clients are often blamed for
58 inviting too many contractors to bid for construction contracts simultaneously (Fu *et al.* 2003; Flanagan
59 and Norman 1985). Over competition, as a consequence, shrinks business profitability and jeopardizes
60 project performance with respect to schedule, cost, quality and environment (Sturts and Griffis, 2005).
61 Therefore, competition intensity stays at the core of construction competitiveness and previous studies
62 have elaborated it at two levels – project and market (Ye *et al.* 2008).

63

64 **Measurement of competition intensity at the project level**

65

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

76

77 Implicitly embedded in this type of measurement is an assumption of two extreme competition scenarios
78 (Greer 1992). One refers to perfect competition, of which the market is populated with numerous
79 homogenous firms. The other is monopoly wherein the market is dominated by very few firms. The
80 discrepancy between these two competition scenarios offers the rationale for that researchers often
81 employ competitor number to quantify competition intensity at the project level. However, simply using
82 the number of competitors to measure project competition intensity is inadequate. First, this indicator
83 mirrors only a part of rivalry without taking into account market forces other than the incumbent. Second,
84 it pays little attention to any potentially uneven distribution of market powers between existing
85 competitors, which could be a consequence of business competition over a period of time (Newcombe
86 1990). Third, a switch from quantity competition to price competition increases the intensity of
87 competition with a decrease in firm number in the meanwhile (Aghion *et al.* 2001), suggesting that the
88 intensity cannot always be measured quantitatively by the number of competitors. Therefore, the
89 measurement of competition intensity at the project level is of limitations.

90

91 **Measuring competition intensity at the market level**

92

93 Competition intensity at this level has been measured in a number of ways typically including
94 concentration (Ye *et al.* 2009), which is a useful instrument that quantifies the extent to which market
95 shares are distributed among incumbents (Bajo and Salas, 2002). There are two types of concentration
96 measures, relative and absolute, that measure the extent to which a market departs from a predefined
97 competition status (Fedderke and Szalontai 2009). The concentration ratio (CR_n), where n can be 4, 8, 12,
98 *etc.* is relative, while the Lerner index (Lerner 1934), the Herfindahl-Hirschman index (Kilpatrick 1967),

99 Entropy (Hart 1971), and the Lorenz curve (Bishop *et al.* 2003) are absolute. The relative measures are
100 derivable as they place the measurement on a small number of competitors and impose little requirement
101 on the data collection. The absolute approaches have the advantage of imaging a whole scope of business
102 competition in a market, but it depends on the availability of data for all businesses. In reverse, the lack
103 or incompleteness of quality data can give rise to erroneous judgments on market competition situations.

104

105 For the reason of poor data in the construction industry (Ruddock, 2002), the measurement of
106 competition intensity in the construction market has relied on relative concentration approaches (Ye *et al.*
107 2009). The studies by both Chiang *et al.* (2001) and Wang (2004) demonstrated that the relative
108 approaches are conducive to the identification of the characteristics of construction market. Yang *et al.*
109 (2012) found that the increasing market concentration in the construction market of Jiangsu of China has
110 a negative effect on the survival of construction companies. In a same vein, Ye *et al.* (2009) revealed a
111 moderate degree of competition in the international construction market. Nevertheless, the moderate
112 competition is a result from the assumption that the population of the international construction industry
113 is composed of the largest 225 contractors listed in Engineering News-Record. In reality, these 225
114 contractors only represent a small part of the entire industry. It appears nevertheless that researchers
115 spared no effort in searching for alternatives to address the problem where data are needed for analysis
116 but are not obtainable in reality.

117

118 In appreciating the limitations of previous studies, McCloughan (2004) devised a new concentration
119 model for the assessment of competition intensity in the British construction industry. Because of the
120 British-specific statistics variables, McCloughan's approach may not fully apply to other construction
121 industries such as the Chinese construction industry. A recent study by Ye (2009) established a causal-

122 sequential coordinate system for measuring competition intensity in the construction market. Nonetheless,
123 the correlation between the two-dimensional factors was not addressed explicitly, which undermines the
124 usefulness of the model. There are some other measures such as consumer's travelling cost (Boone 2001),
125 price cost margins (Flath 2011), persistence of firm profitability (Jiang and Kattuman 2010), and residual
126 demand elasticity (Goldberg and Knetter 1999) for potential application in construction. Whilst deserving
127 attention, these measures have likewise limitation in application, as they were based on homogeneous
128 business rather than construction, which is substantially unique, one-off, and heterogeneous.

129

130 **Research gap**

131

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

144

145 **THEORIES OF DISCRIMINANT ANALYSIS**

146

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

163

164 Multivariate discriminant analysis (MDA) is a typical DA technique to predict which group (Y) an
165 observation belongs to using linear composites of predictor variables (X) (Lam *et al.* 2001). MDA has
166 become popular in the discipline of industrial economics, as it yields pragmatic solutions to many
167 industrial problems (Cabahug *et al.* 2004). The key procedure of MDA is to establish discriminant

168 functions, where scores of the predictor variables are weighted up (Ary *et al.* 1990). MDA results in the
169 establishment of multivariate discriminant function (MDF) which is in general expressed as Equation 1.
170 The parameters of Equation 1 can be quantified using a set of observations that have been categorized
171 into some known groups (Y).

172

$$173 \quad Y = f(x) = \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \dots + \alpha_n x_n + \delta \quad (1)$$

174

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

177

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

190

191 **MODEL DEVELOPMENT**

192

193 **Predictor variables**

194

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

206

207 ***Business diversity (BD)***

208 Business diversity means the heterogeneity of individual businesses in a market. Those construction
209 firms which have similar competitive strengths will compete strongly for common business, especially
210 when they are identical in either size or portfolio of investment. Therefore, a low degree of business
211 diversity can indicate intense competition in the market. In turn, fiercer competition in the market propels
212 firms to explore other opportunities. For instance, robust competition in the Chinese construction market

213 has forced contractors to diversify business structures to escape from the previously narrow competition
214 (Wang 2004).

215

216 ***Market entry barriers (MEB)***

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

226

227 ***Market growth (MG)***

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

235

236 *Market size (MS)*

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

244

245 *Market share distribution (MSD)*

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

252

253 *Profitability (PT)*

254 Profitability is a principal indicator of business performance and bears a direct relationship with the
255 intensity of competition. It seems that previous studies have not agreed with each other on the effect of
256 business competition on profitability. While intensive competition results in low profitability (Porter
257 1980), the study by Neumann *et al.* (1985) implied a loose relationship between profitability and
258 competition intensity. By contrast, Bain (1951, 1956) opined that a market moving towards a highly

259 concentrated structure (little competition) is accompanied by a higher level of profitability. Similarly, the
260 studies by both Chiang *et al.* (2004) and McCloughan (2004) demonstrated that profitability in a market
261 with little competition is higher than that in those markets with intense competition.

262

263 *Technical efficiency (TE)*

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

269

270 *Average wage (WG)*

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

278

279 **Criterion variables**

280

281 The classification cut-off points in previous studies usually follow rules of a thumb. For instance, a five
 282 point category scale was appreciated effective in the studies by both Cabahug *et al.* (2004) and Kim *et al.*
 283 (2008) to classify research objects into several groups. In a same way, this study adopted the CR_n
 284 approach ($n = 4, 8, 12, \text{etc.}$), which refers to the total amount of market shares of the largest n firms, to
 285 indicate the intensity of competition. As a major relative concentration measure, CR_n is derivable and the
 286 variable n normally depends on the availability of data. As discussed earlier, although CR_n is not ideal to
 287 present the powers of all businesses in a market, it is practicable for the study to predefine the group
 288 memberships of observed construction markets. In line with the availability of data and its widely
 289 accepted criteria, CR_4 was thus employed in the study.

290

291 Basically, the larger the CR_4 index, the lower the competition intensity. To ascertain effective
 292 classification, high, average and low levels of competition intensity are coded with an ordinal number i
 293 (criterion variables, $i = 1, 2, 3$) respectively, each being defined in Equation 2, provided that
 294 $C_1 < C_2 < C_3$,

295

$$296 \quad f(x) = \begin{cases} 1 \text{ (Group 1), if } CR_4 \leq C_1, \text{ strong competition} \\ 2 \text{ (Group 2), if } C_1 < CR_4 \leq C_2, \text{ moderate competition} \\ 3 \text{ (Group 3), if } CR_4 > C_3, \text{ low competition} \end{cases} \quad (2)$$

297

298 The criteria stated in Equation 2 serve to measure the intensity of construction business competition at
 299 intervals. The intervals have been indicated in previous studies. Shepherd (1982) pointed out four types
 300 of market structures, namely competition ($CR_4 < 60\%$), oligopoly ($CR_4 > 60\%$), dominant firm
 301 ($50\% < CR_4 < 90\%$) and monopoly (CR_4 at or near 100%). Using CR_4 coefficients, Oster (1999) illustrated
 302 competition cases with highly concentrated oligopoly ($0.75 < CR_4 < 1.00$), moderately concentrated

303 oligopoly ($0.50 < CR_4 < 0.749$), oligopoly ($0.25 < CR_4 < 0.499$), and atomism ($0.00 - 0.249$). Nevertheless, as
304 reported by McClough (2004) and Ye *et al.* (2009), the construction market is fragmented, and CR_4
305 coefficients in construction are usually numerically very small. As such, a small change in CR_4 numerical
306 value may not mirror effectively a small movement in the level of market competition. For instance,
307 according to Wang's (2004) calculation, CR_4 indices for those construction markets of China (1996), US
308 (1997), UK (1999) and Japan (1999) are 0.63, 3.23, 8.65 and 3.30 respectively, indicating minor
309 difference between countries in the globe. Therefore, the values of C_1 , C_2 and C_3 in Equation 2 shall be
310 adjusted to reflect the characteristics of construction industries to ascertain that markets are grouped
311 appropriately.

312

313 **Discriminant functions**

314

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

317

$$318 \quad f(x) = \alpha_1 x_{BD} + \alpha_2 x_{MEB} + \alpha_3 x_{MG} + \alpha_4 x_{MS} + \alpha_5 x_{MSD} + \alpha_6 x_{PT} + \alpha_7 x_{TE} + \alpha_8 x_{WG} + \delta \quad (3)$$

319

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

323

324 <<Insert Table 1 here>>

325

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

329

330
$$X_{BD} = (BD - \underset{i=1}{\overset{m}{\text{Min}}} BD_i) / (\underset{i=1}{\overset{m}{\text{Max}}} BD_i - \underset{i=1}{\overset{m}{\text{Min}}} BD_i)$$

331
$$X_{MEB} = (\underset{i=1}{\overset{m}{\text{Max}}} MEB_i - MEB) / (\underset{i=1}{\overset{m}{\text{Max}}} MEB_i - \underset{i=1}{\overset{m}{\text{Min}}} MEB_i)$$

332
$$X_{MG} = (\underset{i=1}{\overset{m}{\text{Max}}} MG_i - MG) / (\underset{i=1}{\overset{m}{\text{Max}}} MG_i - \underset{i=1}{\overset{m}{\text{Min}}} MG_i)$$

333
$$X_{MS} = (MS - \underset{i=1}{\overset{m}{\text{Min}}} MS_i) / (\underset{i=1}{\overset{m}{\text{Max}}} MS_i - \underset{i=1}{\overset{m}{\text{Min}}} MS_i)$$

334
$$X_{MSD} = (MSD - \underset{i=1}{\overset{m}{\text{Min}}} MSD_i) / (\underset{i=1}{\overset{m}{\text{Max}}} MSD_i - \underset{i=1}{\overset{m}{\text{Min}}} MSD_i) \quad (4)$$

335
$$X_{PT} = (\underset{i=1}{\overset{m}{\text{Max}}} PT_i - PT) / (\underset{i=1}{\overset{m}{\text{Max}}} PT_i - \underset{i=1}{\overset{m}{\text{Min}}} PT_i)$$

336
$$X_{TE} = (TE - \underset{i=1}{\overset{m}{\text{Min}}} TE_i) / (\underset{i=1}{\overset{m}{\text{Max}}} TE_i - \underset{i=1}{\overset{m}{\text{Min}}} TE_i)$$

337
$$X_{WG} = (WG - \underset{i=1}{\overset{m}{\text{Min}}} WG_i) / (\underset{i=1}{\overset{m}{\text{Max}}} WG_i - \underset{i=1}{\overset{m}{\text{Min}}} WG_i)$$

338

339 These normalized equations are based on the relationships given in Table 1. It is important to note that an
 340 increase in any variable of MEB, MG and PT means a decrease in competition intensity. On the other
 341 hand, an increase in any of BD, MS, MSD, TE and WG reflects an increase in competition intensity.
 342 Therefore, the discriminant model for measuring competition intensity is composed of Equations 2, 3 and
 343 4.

344

345 EMPIRICAL ANALYSIS

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

351

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

359

360 **Criterion variables**

361

362 Previous studies have demonstrated that the annual revenue of construction firms is used to calculate CR₄
363 for criterion variables (Ye *et al.* 2009). CR₄ indices were calculated per local market per year, and the
364 150 markets were then grouped into three in accordance with Equation 2. Comparing with the U.S., Li *et*
365 *al.* (2002) disclosed that China's construction industry has very small Gini coefficients, suggesting that
366 construction firms are unable to differentiate effectively in terms of company size. Kang and Zhang
367 (2008) revealed that the construction market is non-concentrated, and each firm has negligible market

368 power. These studies agree with each other on the segmentation of the Chinese construction market.
369 Therefore, Equation 2 was re-expressed as follows to meet the segmentation features of China's
370 construction market.

371

$$372 \quad f(x) = \begin{cases} 1 \text{ (Group 1), if } CR4 \leq 10\%, \text{ highly competitive} \\ 2 \text{ (Group 2), if } 10\% < CR4 \leq 20\%, \text{ moderately competitive} \\ 3 \text{ (Group 3), if } CR4 > 20\%, \text{ lowly competitive} \end{cases} \quad (5)$$

373

374 **Predictor variables**

375

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

378

379 ***Business diversity (BD)***: As reported by the Centre for Policy Research the Ministry of Construction
380 (2007), construction firms in China supply diverse services such as construction, contract management,
381 architecture, consultancy, equipment leasing, and maintenance to the market. The structure of the income
382 composition of an individual firm, indicated by the proportion of auxiliary revenue to total business
383 revenue, can mirror a firm's business distribution. Therefore, the auxiliary income proportion of
384 construction firms was adopted as an indicator of business diversity in this study. The larger the average
385 proportion, the higher the level of business diversity in the market.

386

387 ***Market entry barriers (MEB)***: In manufacturing industries, researchers have suggested measuring
388 market entry barriers by plant capacity required for business operation in (Holtermann 1977; Farber
389 1981). However, the application of this method is less relevant in the construction industry. The

390 possession of construction plant does not erect substantial barriers to potential entrants. Contractors
391 normally rent large items of plant only for the project period needed. Similarly, the average capital
392 among those existing firms registered to operate is employed to quantify market entry barriers. The larger
393 the average registered capital per firm, the higher the entry barrier.

394

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

401

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

407

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

412

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

415

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

419

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

423

424 **Descriptive discriminant functions**

425

426 Researchers have used computer software programs to conduct multivariate data analysis (Huberty and
427 Olejnik 2006). The Statistics Package for the Social Scientist (SPSS 15.0) was employed to model the
428 MDFs. Two discriminant functions (Function 1 and Function 2) are derived as indicated by the
429 eigenvalues and relative variances shown in Table 2. Total variance of the two functions is estimated at
430 100%, indicating that the classification of all construction markets can be explained adequately with the
431 two discriminant functions.

432

433 <<Insert Table 2 here>>

434

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

440

441 <<Insert Table 3 here>>

442

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

449

450 <<Insert Tables 4 & 5 here>>

451

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

456

457 <<Insert Figure 1 here>>

458

459 **Predictive discriminant functions**

460

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

463

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

465

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

467

468 <<Insert Table 6 here>>

469

470 Discriminant scores for the yet to be analyzed construction markets can be determined using Equation 6.

471 Of the three scores derived, the group with the largest score categorizes a construction market. For

472 instance, for the Beijing construction market (2002):

473

474 $CR_4=0.0690$, $X_{MS-bj}=0.4611$, $X_{MSD-bj}=0.5411$, and $X_{PT-bj}=0.2803$

475

476 Then, according to Equation 6,

477

478 $f_1(X) = 9.1571$, $f_2(X) = 9.1501$, and $f_3(X) = 8.1566$

479

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

483

484 ***Validation***

485

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

494

495 <<Insert Table 7 here>>

496

497 **DISCUSSION**

498

499 In this study, multivariate discriminant functions (MDFs) were developed as alternatives to traditional
500 approaches in measuring competition intensity in the construction context. The developed MDFs
501 encompass one criterion variable and eight predictor variables, namely business diversity, market entry
502 barriers, market growth, market size, market share distribution, profitability, technical efficiency, and

503 average wage. Using the empirical data of China's construction industry, it was found that discriminant
504 analysis has the efficiency in measuring the intensity of competition in the construction market.
505 Specifically, of all the eight predictor variables, market size, market share distribution, and profitability
506 are identified as the elements of MDFs in China's local construction industries. These three predictor
507 variables were found effective to facilitate the classification of China's local construction markets into
508 three groups - high, moderate, and low level of intensive competition. Arguably, it could be the case that
509 other variables will eventually be key attributes in the discriminant model when examining other
510 construction markets. Different variables included in MDFs in different construction markets mirror the
511 changing combined effect of five market forces on competition intensity.

512

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

525

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

539

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

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

555

556 **CONCLUSIONS**

557

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

573

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711

712
713

Table 1 Indicators of competition intensity

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

714
715

716
717

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

718
719
720

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

721
722

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

723 At each step, the variable that minimizes the overall Wilks' Lambda is entered.

724 a Maximum number of steps is 16.

725 b Minimum partial F to enter is 3.84.

726 c Maximum partial F to remove is 2.71.

727 d F level, tolerance, or VIN insufficient for further computation.

728
729

730
731

Table 4 Standardized Canonical Discriminant Function Coefficients

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

732
733

734
735

Table 5 Functions at Group Centroids

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

736 Unstandardized canonical discriminant functions evaluated at group means
737

738
739

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

740
741
742
743

Fisher's linear discriminant functions

744
745

Table 7 Classification Results^{b,c}

			Predicted Group Membership			Total
			1	2	3	
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

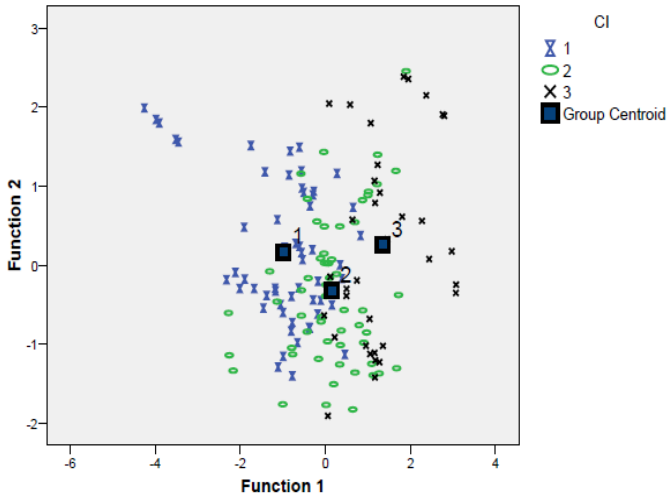
a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

b. 66.0% of original grouped cases correctly classified.

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

746
747

Canonical Discriminant Functions



748
749

Figure 1 Canonical Discriminant Functions