A regional construction R&D evaluation system for China

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ABSTRACT

Expenditure on R&D in the China construction industry has been relatively low in comparison with many developed countries for a number of years – a situation considered to be a major barrier to the industry's competitiveness in general and unsatisfactory industry development of the 31 regions involved. A major problem with this is the lack of a sufficiently sophisticated method of objectively evaluating R&D activity in what are quite complex circumstances considering the size and regional differences that exist in this part of the world.

A regional construction R&D evaluation system (RCRES) is presented aimed at rectifying the situation. This is based on 12 indicators drawn from the Chinese Government's R&D Inventory of Resources in consultation with a small group of experts in the field, and further factor analysed into three groups. From this, the required evaluation is obtained by a simple formula. Examination of the results provides a ranking list of the R&D performance of each of the 31 regions, indicating a general disproportion between coastal and inland regions and highlighting regions receiving special emphasis or currently lacking in development. The understanding on this is vital for the future of China's construction industry.

Keywords: China, construction industry, Factor Analysis, evaluation system, region, Research and Development.

INTRODUCTION

Investment and expenditure in Research and Development (R&D) is considered to be a major driver of construction industry development (Blayse and Manley, 2004; Mushin *et al*., 1996; Dulaimi *et al*., 2002), as it accelerates the adoption of new technology and encourages industry growth (Science and Technology Agency, 1995–1999). R&D investment has a positive relationship with the long run profitability of firms (Nelson, 1986; Collier et al., 1984), suggesting that R&D promotes business competitiveness and is worthy of the attention of the firms' managers. Similarly, it has been pointed out that many industrial problems worldwide are attributed to low R&D investment levels (C21, 1999; Construct for Excellence, 2001). The USA National Research Council, for instance, found that inadequate R&D and lack of development of new technology results in low levels of construction productivity (Nam and Tatum, 1997), while Singapore's Construction 21 Committee (1999) observed that a simple small scale investment in construction R&D in insufficient to promote significant construction productivity. Likewise, the Egan Report (1998) and 'Building for Growth'

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Report (1999) recommend more R&D investment to strengthen the competitiveness of the construction industries in the UK and Australia respectively.

The Chinese construction industry is composed of thirty-one local construction markets, each being large and with its own special industry characteristics. Despite the construction industry experiencing dramatic changes as a result of its rapid economic development, there has not been a commensurate increase the scale of investment and expenditure in construction R&D. The R&D expenditure of major construction enterprises in 2003 was only 0.25% of their total revenues, while the contribution rate of R&D to the development of science and technology in the Chinese construction industry in 2004 was reported as 20-30% (MOC, 2005). In addition, not only has insufficient R&D investment failed to support the growth of the construction industry, but it has led to further industrial problems. For example, product competitiveness and the ability of firms to produce innovative products is reduced (Hu and Jefferson, 2004).

The importance of R&D on competitiveness has prompted the development of evaluation systems for measuring R&D performance. In the USA, the National Science Foundation has been evaluating its R&D program regularly since 1950 (Werner et al., 1997), and many USA firms use R&D metric systems to assess the efficiency of their R&D investment. An extensively applied approach in Germany for measuring R&D investment involves the external assessment and self-assessment conducted by governments, universities and research institutions (Werner et al., 1997). Such evaluation systems offer a useful toolkit for understanding the life stages of R&D development, and enable more effective measures to be taken to promote R&D efficiency.

Generally speaking, while China's regional economic differences have existed for years (Jian *et al*., 1996; Kanbur and Zhang, 2005), little study has been conducted to ascertain the nature and extent of these differences in construction R&D development. An evaluation framework has been developed by the Ministry of Science and Technology (MST, 2001), namely, the National R&D Resources Inventory (NRDRI), for mirroring overall R&D development. However, the special characteristic of the regional construction industries largely reduces the applicability of the NRDRI to the thirty-one local markets. For instance, there are many indicators of R&D activity at a national level but few relating to special local attributes. The NRDRI therefore only provides a general profile of construction R&D development; it cannot be used as an evaluation toolkit to demonstrate the development level of local regions in China. In summary, therefore, it is clear that R&D evaluation in China is still in its early stages and an effective method has yet to be developed that can help understand the status of its regional R&D investment.

To rectify this situation, a regional construction R&D evaluation system (RCRDES) is developed in order to analyse the level of regional construction R&D activity in China. This is based on 12 indicators drawn from the NRDRI in consultation with a small group of experts in the field, and further factor analysed into three groups. The RCRDES can then be used to gauge the extent to which regional differences exist in the China's construction R&D activity and hence to provide more effective guidance for future development.

The paper is organized as follows. Firstly, a review of R&D evaluation methods is provided. This is followed by a brief outline of the general profile of Science and Technology (S&T) and R&D activities in the Chinese construction industry, the funding of S&T and S&T/R&D expenditure. Then, the development of the RCRDES is described. This system is then itself evaluated against the expected regional and local differences to provide an indication of its likely validity.

R&D EVALUATION METHODS

In past decades, many researchers and practitioners have studied R&D evaluation for various industries at different levels. An abundant literature exists on R&D evaluation at the micro-level - mainly focusing on evaluation methods, procedures, and guidelines for projects (UK Department of Trade and Industry, 1988; Ormala, 1989; Roessner, 1989; Tanaka, 1989; Luukkonen and Stable, 1990; Krull *et al*., 1991; Mushin *et al*., 1996). These methods can be generally classified into two groups. The first group employs a multi-criteria quantitative approach, which involves the use of a weighting method (Easton, 1973; Ormala, 1986; Mushin *et al*., 1996), scoring method (Krawiec, 1984; Pinto and Slevin, 1989; Balachandra and Brockhoff, 1996) and Analytic Hierarchy Process (AHP) (Liberatore, 1987; Wang *et al*., 2005). The weighting and scoring methods calculate relative weights and rank a set of proposed projects in order of preference, while the AHP method is used to compare a set of alternatives to assist in decision making in complex contexts (Saaty, 1980). For example, a system for evaluating the outcomes of multidisciplinary R&D projects from multiple fields was developed in China by using the AHP model (Wang et al., 2005).

The second category involves a single-criteria quantitative approach, which is limited to exclusively financial or utility aspects, such as in cost-benefit evaluation (Kuwahara and Takeda, 1990; Link, 1993) and Economic analysis (Irvine, 1988; Graves and Ringuest, 1991). For the cost-benefit evaluation approach, the consequence of a project is described in terms of cost and benefit measures. It enables the identification of critical financial profit factors in the evaluation, while its major shortcoming is that it cannot allow different kinds of projects to be compared directly (Ormala, 1986). Economic analysis is frequently applied in the form of capital budgeting techniques. This allows R&D projects to be evaluated using economic criteria, such as net present value, payback period and return on equity rate (Poh et al., 2001). However, in restricting the analysis to just one single criterion, the method can have some limitations when used to evaluate complicated R&D projects.

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Other systems are centered at the macro-level, which involves evaluation at the national level. An example is the dual proposal review system for grant applications developed by the National Institutes of Health (NIH) (Kostoff, 1994). Another example occurs in the related area of innovation, where R&D activities at national level are evaluated in the context of a framework of a national innovation system (Lundvall, 1992; Nelson, 1993; Freeman, 1997). By comparing different national systems, uneven capabilities are identified through different geographical components, frameworks and indicators. In addition, some of these attempt to measure sectoral differences within national innovation systems (Archibugi and Pianta, 1992; Patel and Pavitt, 1994; Pietrobelli, 1994).

In reviewing these systems, three deficiencies are apparent. Firstly, they are exclusively focused on micro or macro level activities, with no provision for the meso-level, such as regional R&D investment and expenditure. Secondly, most studies focus on a specific subset of issues that are important for understanding R&D performance through the opinions and experiences of informed practitioners or observers. Of course, this approach is highly subjective. Less susceptible to possible bias would be a method that uses objective data, such as government statistics, as a basis for evaluation. Thirdly, very few evaluation methods are applied directly to the analysis of construction R&D activity, which leaves a clear research gap to be addressed.

Of particular relevance to China is that the regions and industries within a nation can be quite diverse and with distinct R&D characteristics and capabilities (Nelson and Rosenberg, 1993; Carlsson and Stankiewicz, 1995). These differences became particularly acute under the previous R&D evaluation system used in China. One issue is that China is a developing country with a centrally planned political system. Another is that China has experienced dramatic changes after its economic reform since the introduction of the Open Door Policy in 1979, during which time a large number of construction R&D projects were conducted in different regions. In addition, China is a vast territory with rich resources and the wide discrepancies among its regions make the evaluation process quite complex, to the point that the existing evaluation methods described above are unsuitable. A new method is needed for the evaluation of regional construction R&D in China.

THE SCALE OF S&T AND R&D ACTIVITIES IN CHINA

During the years 2001 to 2002, the MOC launched its substantial 2000 R&D inventory of resources, comprising all the R&D active enterprises and institutions within each industry of the national economy. Of the 50,813 units involved, 4,477 units (8.8 percent) are attributable to Farming, Forestry, Animal Husbandry and Fishery, 708 units (1.4 percent) to Mining and Quarrying, 30,756 units (60.5 percent) to Manufacturing, 921 units (1.8 percent) to Electric Power, Gas and Water production and supply, and 738 units (1.4 percent) to construction work. Of the units with construction S&T activity, there are 455 (61.7 percent) with R&D

activity, of which 311 (68.4 percent), 85 (18.7 percent) and 59 (13.0 percent) are associated with China's eastern region, central region and the western region respectively – suggesting a possible disproportion between regions.

Of the 24.2 million construction personnel working in the China National Construction Industry in the year 2000, 61,700 (0.25 percent) were engaged in construction S&T activities. Of these, there are a total of 38,000 (62 percent of S&T personnel) professional scientists and engineers. The personnel engaged in construction industry R&D work a full-time equivalent of 9,446 man-years, of which scientists and engineers account for 6,975 man-years (73.8 percent). There are also 3,716 construction industry personnel who possess a college graduate certificate or higher.

Construction industry S&T funding

Technology funding levels, particularly those for R&D, reflect not only one country or region's strength and commitment to S&T, but also the amount of S&T support from the government and the entire community. Table 1 summarises the funds allocated from various sources for the year 2000 for the construction industry as a proportion of all industries, showing that, of the total funds of 234.67 billion Yuan, only 2.02 billion Yuan (0.86 percent) is attributable to the construction industry.

<Insert Table 1 here>

Included in this total are internal technology funds of 1831.69 million Yuan (90.8%) provided by enterprises, 73.15 million Yuan (3.6%) by the government, and 2 million Yuan (0.1%) by foreign funds. Thus, S&T construction funding is predominantly provided by individual enterprises, with only a small fraction of the total being from the government and foreign funding.

In addition, the S&T activities are uneven by region with 69.7 percent, 12.9 percent and 17.4 percent of overall funds provided for the eastern region, central region and the western region respectively.

Construction industry S&T and R&D expenditure

In the year 2000, the total funding of China's construction industry R&D was 5.32 million Yuan, of which the funds for basic research, applied research and experimental development were 0.11 million Yuan (2.07%), 0.64 million Yuan (12.03%) and 4.57 million Yuan (85.34%) respectively (see Table 2 for details). From a regional perspective, R&D funding (409 million Yuan or 76.9 percent of the total) mainly focuses on the eastern areas, while the equivalent for the central and western areas is only 23.1 percent. Funding for basic research in the central and western regions is even less, accounting for only 0.7 percent of the total.

<Insert Table 2 here>

Basic research in the construction industry is relatively low in China (Cheah and Chew, 2005) and, as noted above, particularly in the central and western regions. It is generally believed that basic research involves scientific activities that provide basic knowledge of the world, and its contribution to regional economic development is far less obvious than that obtained by experimental development and applied research (Wagner, 1997). In terms of the construction industry, basic research is relatively important for its development, and so the research funding affects the quantity and quality of the innovation and originality of construction products. Research shows that the rational allocation of R&D funding for these three kinds of research activities is as follows: 10 to 12 percent for basic research, 25 to 30 percent for applied research and 60 to 63 percent for experimental development (Zeng and Tan, 2003). In contrast, it is clear that funding for China construction R&D basic research is so low that the development of the industry is jeopardised, reflecting the over-emphasis of practical experimental development at the expense of basic research. This suggests that more useful results could be achieved by a change in current research funding policy. However, in the long-term, without this change, the overall coordination of S&T development would necessarily be constrained - making development potential inadequate and consequently affecting the economic development of the construction industry as a whole.

A REGIONAL CONSTRUCTION R&D EVALUATION SYSTEM (RCRDES)

Research method

In order to develop the regional construction R&D evaluation system (RCRDES), the first task is to identify the indicators that can demonstrate how the construction R&D activities are implemented and to organize the indicators into an appropriate structure based on principles such as ease of operation and cost effectiveness. This then enables the factor analysis method to be used to extract principal components and calculate an integrated RCRDES score as described below.

Indicator selection and data collection

The only possible statistical indicators and data in China are available in the Ministry of Science and Technology's (MST) NRDRI inventory. This substantial inventory is conducted every ten years by the China government, the latest being in 2001. The MST provide a methodological framework for setting up the national surveys involved in the collection of their data, which can be classified into three sections: 1) the socio-economic context for construction R&D activities; 2) construction R&D scale and status; and 3) the construction R&D development capability. Few opportunities exist for the alterative collection of data by independent surveys as these are currently disallowed by the Chinese authorities. The list is designed and provided by Chinese authorities, which makes it difficult to extend or change by individuals. However, the inventory is very extensive and includes most of the indicators that could be imagined to be relevant. In fact, there are so many potential indicators in the inventory that it is impossible to include them all and a separate study was needed to identify those most relevant to the needs of the RCRDES.

This comprised two major steps: (1) literature review and (2) a series of in-depth interviews with several R&D experts. Firstly, a provisional set of indictors was chosen by the researchers from the MST list based on a comprehensive literature review. Next, a small interview survey of five R&D experts was conducted to examine the suitability and comprehensiveness of this provisional list. The experts comprised two professors in the discipline of construction R&D, one senior executive official from the MST and two senior R&D personnel who are familiar with R&D in the China construction industry. They were asked to assess whether the provisional list was appropriate in capturing the real issues relevant to local construction R&D activities in China; or whether some indicators could be deleted from the list or others could be added. Valuable comments were received and only minor amendments were made to the provisional list. As a result, a finalised list of 12 indicators was produced (Table 3).

<Insert Table 3 here>

The relevant data for the 12 indicators were acquired from the MST NRDRI inventory for the year 2001. Each of the 12 indicators has 31 values corresponding to the 31 regions of China. The data were carefully checked and entered into SPSS 17.0 for conducting the factor analysis.

FACTOR ANALYSIS FOR RCRDES

Factor analysis is used to identify a relatively small number of factor groupings that can be used to represent relationships among sets of many inter-related factors (Norusis, 1992; Li et al., 2005). It is therefore a popular method for making comparisons between objects measured on several dimensions or criteria, such the level of welfare between individuals (Maasoumi and Nickelsburg 1988). The method relies solely on the variation and covariation of the variable matrix to construct weights, which are then used to produce a small number of comprehensive variables, or factors, in place of many original variables, simplify the data structure and minimise original data information loss. This can then be subjected to various forms of rotation to check orthogonality. Many procedures have been proposed for determining the number of factors to be retained in the Factor Analysis model (Jackson 1991) and additionally, although somewhat controversially (eg. Sternberg 1977), the method can be used to help identify the concepts underlying the data. Factor Analysis is also well supported by standard statistical software and therefore, in the current context, provides a simple and efficient method to identify the groups or concepts for use in evaluating a region's construction R&D.

<Insert Table 4 here>

The correlation matrix of the 12 variables from the inventory data shows that all are significant correlated at the 5% level (Table 4), suggesting that there is no need to eliminate any of the variables for the ensuing Factor Analysis). Bartlett's test of sphericity is 295.770 (p=0.000), indicating that the correlation matrix is not an identity matrix. The value of the KMO statistic is 0.640, which is satisfactory for Factor Analysis (Norusis, 1992).

<Insert Table 5 here>

The Factor analysis itself produces a three-factor solution with eigenvalues greater than 1.000, explaining 73.67% of the variance, as shown in Table 5. The remaining factors together account for 26.33% of the variance. As can be seen, the contribution rate is calculated from the Varimax normalized factor analysis. This suggests that factor analysis can be used in several different ways in constructing the development level of construction R&D. The values of the eigenvectors of the three factors are given in Table 5, the vectors being scaled so that the maximum weighting is 0.883.

The factors equations are

$$F_1 = 0.379 * X_1 + 0.838 * X_2 + 0.792 * X_3 - 0.373 * X_4 + 0.887 * X_5 + 0.635 * X_6 + 0.420 * X_7 + 0.839 * X_8 + 0.261 * X_9 + 0.576 * X_{10} + 0.655 * X_{11} + 0.811 * X_{12} \quad \textbf{\textit{(1)}}$$

$$F_2 = 0.568 * X_1 - 0.417 * X_2 - 0.374 * X_3 + 0.216 * X_4 + 0.114 * X_5 + 0.660 * X_6 + 0.508 * X_7 + 0.147 * X_8 + 0.004 * X_9 - 0.553 * X_{10} + 0.493 * X_{11} - 0.434 * X_{12} \quad \textbf{\textit{(2)}}$$

$$F_3 = -0.332 * X_1 + 0.092 * X_2 + 0.087 * X_3 + 0.768 * X_4 + 0.170 * X_5 + 0.081 * X_6 - 0.010 * X_7 + 0.097 * X_8 + 0.835 * X_9 - 0.077 * X_{10} + 0.127 * X_{11} + 0.206 * X_{12} \quad \textbf{\textit{(3)}}$$

where F is the factor score and X the variables values.

Factor 1- Construction R&D development capability

<Insert Table 6 here>

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As Formula 1-3 and Table 6 show, Factor 1 gives high positive weightings to X_2, X_3, X_5, X_6, X_8 and X_{10}. The components of this group are:

- X_2- GDP per capita by region
- X_3- Urbanization rate
- X_5-Full-time equivalent of R&D Personnel
- X_6-Funding for R&D
- X_8-Number of R&D Topics
- X_{10}-Percentage of S&T personnel in the construction industry index.

The construction R&D can be driven by various elements, including social, economic and the creativity of individual S&T personnel. X_3 has a high loading on Factor 1, indicating that the social environment, such as the urbanisation process can greatly affect the development of construction R&D. The other two high loading variables are X_2 and X_6, demonstrating that the rapid development of construction R&D cannot be separated from economic drivers such as GDP per capita and R&D funding. To guarantee the continued development of construction R&D, the 'the creativity of individual S&T personnel' element is also another important contribution to construction R&D development. This is reflected in X_5, X_8 and X_{10} being highly correlated with Factor 1.

Factor 2- Economic foundation

Factor 2 is predominantly loaded with X_1 and X_7 where

- X_1-GDP of the construction industry
- X_7-Original value of fixed asset for R&D institutions

This indicates that a favourable economic foundation allows regional construction R&D to go smoothly, particularly at the earlier stage of some regions in China. This is supported by much research indentifying the contribution of GDP to R&D development (eg. Comin, 2004).

Factor 3- Interaction between construction enterprises and the social environment

Factor 3 is predominantly loaded with X_9 and X_4 where

- X_9-The ratio of enterprise funds to total R&D fund
- X_4-Urban Household's Engle coefficient

This points to the interaction between construction enterprises with external social environment. In order to guarantee the progressive development of construction R&D, the active participation of construction enterprises *and* their interaction with the external social environment is needed. For example, 'Urban Household's Engle coefficient' represents

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people's living standard. So, if a high living standard is provided, extra effort is made to contribute to R&D.

Factor analysis can be used to rank cases by determining the objective weighting of measured variables (Jeffers, 1967; Cheng *et al*, 2000). In this context, the determination of weighting is critical for evaluating the regional development level of construction R&D. A simple but arbitrary rule of thumb, which has proved to be useful in practice, is to take the variability contribution rate as the weighting of each principal component (Cheng *et al*, 2000; Fu and Ji, 1999).

Multiplying the principal components (F1, F2 and F3) by the corresponding weights (E1, E2 and E3) from ***(1)*** to ***(3)*** gives the relative eigenvalues and integrated scores for each region, the order of which is as follows:

$$RCRDES_j = F_1 * E_1 + F_2 * E_3 + ... + F_i * E_i \,(j = 1,2,3..,m) \qquad \textbf{\textit{(4)}}$$

where *j* denotes the region, *m* denotes the total number of regions, F_i denotes the *i* factor and E_i denotes the percentage variability contribution rate of the *i* factor, which is $\frac{F_i}{F_1 + F_2 + ... + F_i}$.

RCRDES RANKING ANALYSIS

The total RCRDES score of each region can be calculated by each of the $F_i * E_i$ in ***(4)***, with this scaled score of "m" regions. The ranking order is shown in Table 7. In addition, each F_i denotes that every region has characteristics of development level in a specific area. For example, the ranking order of different regions can be identified only in an area like the Construction R&D development capability (F_1). The results of this are shown in Table 7 and highlighted in Fig 1.

<Insert Fig 1 here>

<Insert Table 7 here>

<Insert Fig 2 here>

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Fig 2 demonstrates these results in a geographical format. For illustrative purposes, these are shown in five arbitrary groups in decreasing order of RCRDES values as follows:

Group α. Shanghai, Tianjin, Beijing and Guangdong are the strongest group. These are the districts in China with the largest economic growth. Shanghai and Tianjin, with large scores, display a greater construction R&D development capability (F1).
Group β. Fujian, Jilin, Hebei, Shanxi and Qinghai belong to the second strongest group, with the integrated score between 0 and 50. Except for Qinghai and Shanxi, the other provinces of the first two strong groups are among the eastern regions (where the construction industry is more active), with Sichuan being the strongest province among the western regions.
Group γ. This comprises the third strongest group, with the total score below 0. The group comprises Jiangsu, Inner Mongolia, Ningxia, Sichuan, Chongqing and Xinjiang. In general, the regions in this group are less economically developed that in the *α* and *β* groups. However, Zhejiang is the quite well developed economically.
Group δ. This is a relatively weaker group within the range (-20, 0) and comprises Inner Mongolia, Hubei, Chongqing, Xinjiang, Hunan, Ningxia, Heilongjiang, Henan, Guangxi, Shandong, Liaoning, Hubei, Zhejiang, Hunan, Guangxi and Heilongjiang. As can be seen from Fig 2, most of the regions lie in the middle and western areas of China.
Group ε. This is the weakest group of all with the scope (-60, -20), comprising Shanxi, Yunnan, Henan, Anhui, Gansu, Guizhou, Jiangxi, Hainan and Tibet. From the perspective of construction R&D development, F1, F2 and F3 are relatively weaker than the other groups. Taking Guizhou and Tibet as an example, both the construction R&D environment and the development potential are the weakest due to their being very socioeconomically underdeveloped.

VALIDATION: COASTAL AND INLAND REGIONS

The ranking analysis capability of RCRDES also provides an indication of its soundness. That is, the extent to which the results of the ranking analysis conform to current expectations. To examine this further, it is necessary to consult the literature on the nature of the regional economic differences that exist in China. As Jian *et al* (1996) point out, these are associated with internal geography. However, there is no previous work on the equality of otherwise if China's regional construction R&D development. Of indirect relevance, however, is the influence of economic growth on *income* inequality. This has been discussed extensively, particularly as a result of the transition to a market-based system (see Chen and Fleisher 1996 for a summarised review). Of note, under the old centrally planned economy classification of east-central-west regions, is the lack of agreement on whether inequality had grown or declined between the late 1940's and mid-1970's, despite an overall trend of moderate economic growth. Upon transition from a socialist economy, however, it is accepted that inequality increased at first and then later decreased as the country approached a more advanced stage of industrialization. Rural–urban inequalities for example, one of the principal sources of regional inequality in China, have narrowed since the advent of economic reform in the late 1970's (Oi, 1993). On the other hand, there has been a widening income gap between coastal and interior regions, particularly in the 1990's (Yang and Wei, 1995). One reason for this is that, "in order to speed up integration with world markets, China has implemented a coastal-biased policy, such as establishing special economic zones in coastal cities and providing favourable tax breaks to coastal regions. Obviously, the policy is biased against inland regions and may have enlarged inland–coastal disparity" (Kanbur and Zhang, 2005:97). As a result, coastal regions have attracted far more foreign direct investment and generated more trade volume than inland regions during the liberalization process, with the difference in the growth rates between the coastal and inland regions being as high as three percentage points during the past two decades (Kanbur and Zhang, 2005).

Table 8 summarises the ranking results classified by the coast-inland and old east-central-west system for comparison. This shows the results fit the coast-inland classification quite well, but with the notable exceptions of Guangxi, Liaoning and Sichuan. However, these appear to be exceptional cases.

<Insert Table 8 here>

Guangxi

Although classed as "coastal", Guangxi province is notable for two aspects:

1. The overall scale of its construction industry is relatively small. In 2003, there were 892 construction enterprises, which ranked Guangxi as 20th among all the 31 regions. Approximately 354,000 practitioners (ranked as 22nd) were engaged in the construction industry. The total added value of the construction sector in Guangxi was 6.12 billion Yuan, total output value is 28.18 billion Yuan, and output value completed is 20.93 billion Yuan - ranked as 25th, 24th and 25th respectively – while the amount machinery and equipment is ranked 25th. This suggests that overall, Guangxi is ranked between 20th and 25th (State Statistics Bureau, 2006), and therefore its overall strength limits its R&D development level.
2. The total construction R&D input in Guangxi is quite small. Compared with the average level (1.66%) of China, the R&D investment in construction sector to the total investment ratio in Guangxi is only 0.84%, which is 0.82% lower than average. The infrastructure investment in the construction sector to the total infrastructure investment ratio is 0.25%, which is 1.31% lower than the national average level (1.66%) (State Statistics Bureau, 2006). Clearly, the lack of construction R&D input has a detrimental effect on its construction R&D competitiveness.

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Sichuan

Sichuan province, in contrast, is classed as an “inland” region and yet is one of the leading regions in the construction industry among China. Its total construction output value from 2003 to 2007 was 789.84 billion Yuan. The average increase rate is 15.7% per year, with an added value of 278.4 billion Yuan, which ranked as 7th position among China (Tan, 2008). In 2005, the number of practitioners, number of enterprises and the total output value ranked as 4th, 5th, and 7th in China and highest of all the inland regions. At the end of 2005, the total number of construction enterprises was 3500, which is ranked as 5th behind the Jiangsu, Shandong, Guangdong and Zhejiang provinces (State Statistic Bureau, 2006). This suggests that its integrated strength has helped it improve its R&D competitiveness from many perspectives (State Statistic Bureau, 2006).

Zhejiang and Liaoning

The Zhejiang and Liaoning provinces are both classified as “coastal” regions. Taking Zhejiang as an example, its construction industry output value in 2003 ranked as second place in China in accounting for 10.7% of the total. Since 2005, its construction industry output value has increased from 471.6 billion Yuan (in the year 2005) to 820 billion Yuan (in the year 2008). However, many problems have accumulated over the years, such as the reliance on a strategy of low cost, low price, quantitative expansion and resource degradation (Chen, 2009).

Although the Zhejiang province plays a leading role in the China construction industry, its scientific innovation is relatively weak. The construction enterprises in this region aim for extensive expansion and production value, while R&D investment is overlooked. There is also a lack of proprietary intellectual property rights, technical know-how and technical monopoly in this region. All of these factors have affected its competitiveness in exploring high-end markets, and thus makes Zhejiang province a relatively backward region of China (China Architecture Industry Association, 2009).

DISCUSSION

In general, the research findings highlight the general disproportion between coastal and inland regions. Based on the results of the analysis, the following suggestions are put forward for possible improvement of the Chinese regional construction industry:

- On the basis of existing construction R&D development capacity, high ranked regions should benefit by increasing R&D input and improved construction output targets by exploiting their superior geographical and economic advantages and vast consumer

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markets. In addition, it is expected that the contribution rate from construction R&D would be improved through a greater variety of approaches, such as through joint-research with academic institutions, trial R&D experiments within industry, and shared experiences with other countries.

- The construction R&D benefit-cost ratio in the low ranked regions should be maximised by using an appropriate financial strategies and policies. In order to provide a solution to this fundamental problem, these regions should integrate their R&D inputs and outputs through by making yearly budget plans, explicating benefit-cost efficiency strategies and cooperating with the higher ranked regions in using their advanced construction R&D technologies.
- China is now following the "Western Region Development" policy, which has brought about a variety of opportunities, such as helping the western regions gain more construction R&D funding from central government and attracting more professionals from other regions of China. This should enable the lower ranked regions to obtain advanced technology, with good implementation prospects, to solve their core construction R&D problems with minimum input and maximum output.

However, two limitations of the research discourage generalisation of the findings of the study to other industries or other countries. One is that the list of indicators used in the RCRDES was necessarily restricted to those contained in the NRDRI inventory instead of a free choice based on the rational investigation of the most effective indicators. However, the interviews and abundant empirical literature support of many of the indicators chosen. For example, Wang (2007) has shown that R&D activities are affected by many social-economic factors, which vary from country to country, with several environmental variables used in order to distinguish between the external elements and R&D internal capability effects. In the RCRDES framework, the first economical indicator proposed is the GDP of the construction industry on the basis of a hypothesized positive relationship between GDP and R&D investment and expenditure. This is confirmed by an empirical study by Comin (2004), where he evaluates the contribution of R&D to GDP growth in U.S. Similarly, in referring to the social aspects, Urban Household's Engle coefficient is considered to be one of the key factors involved (Sustainable Development Research Group, 2000).

Another limitation is that geographical distribution of R&D expenditure is not necessarily a guide to its application. China has central publicly funded research institutes and, although they are located in specific provinces, their research is applied nationally. As for research funded by companies, which appears to be the greater proportion, no data is available on whether this is related to large national firms or to smaller local enterprises. However, most R&D expenditure is likely to be made by larger firms, so the research should have a potentially wide geographical application.

CONCLUSIONS

The evaluation of construction R&D development in China is currently at a rather rudimentary, subjective, level while the complexities involved warrant a more sophisticated and objective approach. As a result, it is not clearly known which regions receive greater or lesser emphasis in contributing to their development. For a planned economy such as exists in China, such knowledge is vital for the future of the county's construction industry and building and infrastructure activity.

This paper provides a method to further understand the status quo of China's regional construction R&D development. The major contribution of the method is to provide a measure of the development status (including the scale, fund collection and fund expenditure) in the form of an index assessment system. Using Factor Analysis, the 12 indicators involved were reduced to three principal factors, which were then named according to their intuitive meaning. In demonstrating its use, the RCRDES scores were calculated for each region. This highlighted some important differences between each region, with a general trend of reducing scores from coastal to inland regions.

Overall, the study provides valuable information for both practitioners and academics. For R&D practitioners, the general overview of R&D evaluation practices in construction industry is a useful reference for benchmarking their own R&D measurement procedures at the provincial or city level. By using the RCRDES, practitioners can compare their own location with the industry average and other regions. This is an important step towards the practical orientation of the model itself, allowing an in-depth understanding of strategic objectives and the consequent dimensions of performance to be monitored.

For academic researchers, the results offer insights into the meso-level evaluation of R&D investment and activity. The RCRDES also provides an increased understanding of the current situation and opportunity for further theoretical development. This should ultimately help in future R&D policy to promote technical innovation and enhancement of the overall development of the construction industry in China.

Finally, it should be noted that the RCRDES as it stands is unlikely to have application outside China due to its reliance on the localised MST statistical data provided by the government. As a *method* for objectively evaluating R&D development, however, it clearly has considerable potential. Centrally planned economies such as China are likely to have similar statistical data and which can be subjected to the same analysis as described here. Even in western-style free market economies, sufficient statistical data may still be available to enable a similar form of analysis. Should this be the case, it would be a relatively simple matter to develop a system for individual countries to help address the national policy challenge of the appropriate development and management of their construction R&D investment and expenditure.

REFERENCES

Almus M. and Czarnitzki D. (2003). *Journal of Business and Economic Statistics*, 21(2), 226-236

Andersson R., Quigley J.M., and Wilhelmsson M. (2009). Urbanization, Productivity, and Innovation: Evidence from Investment in Higher Education, *Journal of Urban Economics*, 66, 2-15.

Archibugi, D. and Pianta, M., 1992. The technological specialization of advanced countries. In: A Report to the EEC on International Science and Technology Activities. Kluwer Academic Publishers,

Balachandra R. and Brockhoff K. (1996). Are R&D project termination factors universal? *Research Technology Management*, 39(1), 31-36.

Blayse A. M. and Manley K. (2004). Key influences on construction innovation. *Construction Innovation*, 4(3), 143–154

Bolthole, H., de Sires, A., Molnar, M. (2008), The Contribution of Economic Geography to GDP per capita, OECD *Economic Studies*, No. 44, Vol.2, 287-323.Archibugi and Pianta, 1992;

Building for Growth (1999) An Analysis of the Australian Building and Construction Industries, Industry Science Resources, Commonwealth of Australia.

C21 (1999) Construction 21: Re-Inventing Construction, Ministry of Manpower and Ministry of National Development, SNP, Singapore.

Carlson, B. and Stankiewicz, R. (1995). On the nature, function and composition of technological systems. In: Carlsson, B. (ed.): *Technological Systems and Economic Performance: The Case of Factory Automation.* Kluwer Academic Publishers. Dordrecht, pp. 21-56.

Cheah C.Y.J., Chew D.A.S. (2005) Dynamics of strategic management in the Chinese construction industry, *Management Decision*, 43(4), 551-567.

Chen (2009) (Available at website: http://www.sdjgj.gov.cn/mainsubend.aspx?id=194A047AA4364237&sortid=F3698BBEC2767DC6&subsortid=74B9BF6260F04B79&endsortid=64FD1BF596C00021) (accessed 18 October 2009).

Chen, J., Fleisher, B.M. (1996) Regional income inequality and economic growth in China, *Journal of Comparative Economics*, 22, 141–164.

Cheng T.X., Wu H.G., and Sun X.H. (2000). A method of tender evaluation based on PCA, *Systems Engineering-Theory and Practice*, 20(2), 118-121. (in Chinese).

China Architecture Industry Association (2009). (Available at website: http://www.zgjzy.org/guild/sites/ccia/detail.asp?i=ZT&id=20304 (accessed 18 October 2009).)

Collier, D.W., Mong, J., Conlin, J. (1984). How effective is technological innovation?, *Research Management*, pp.11-16.

Comin D. (2004). “R&D: A Small Contribution to Productivity Growth”. *Journal of Economic Growth*, 9(4), 391–421.
Construct for Excellence (2001) Report of the Construction Industry Review Committee, January, SAR, Hong Kong.
Construction 21 Committee. (1999). Construction 21: Re-inventing Construction, Ministry of Manpower and Ministry of National Development, Singapore.
Cork, Ireland, De Leeuw J. (1982) Nonlinear principal component analysis and related techniques. In: COMPSTAT Proceedings in Computational Statistics, 77–89. Vienna: Physica Verlag.
Dulaimi M.F., Ling FY. Y., Ofori G., Silva N De. (2002). Enhancing integration and innovation in construction. *Building Research and Information*, 30(4), 237-247
Easton A. (1973). *Complex managerial decisions involving multiple objectives*. New York: John Wiley and Sons.
Egan, J. (1998) Rethinking Construction. Report of the Construction Task Force, July, Department of Environment, Transport Regions, London.
Fraumeni, B., and Okubo S.(2004). R&D in U.S. National Accounts. Paper presented at the International Association for Research on Income and Wealth (IARIW) 28th General Conference, August 26, 2004,
Freeman, C., 1997. The “National System of Innovation” in historical perspective. In: Archibugi, D., Michie, J. (Eds.), Technology, globalization and economic performance. Cambridge University Press, Cambridge, pp. 24–49.
Fu X. and Ji C.M. (1999). “A comprehensive evaluation of the regional water resource carrying capacity- application of main component analysis method”, *Resources and Environment in the Yangtze Basin*, 8(2), 168-173.
Graves S.B. and Ringuest J.L. (1991). Evaluating competing R&D investments. *Research Technology Management*, 34(4), 32-35
Griffith R., and Harrison R. (2003). Understanding the UK’s poor technological performance. IFS Briefing Notes (BN37). Institute for Fiscal Studies, London, UK. Can be accessed at website: http://eprints.ucl.ac.uk/14919/
Guellec D., de la Potterie B.V.P. (2004) From R&D to productivity growth: Do the institutional setting and the source of funds of R&D matter? *Oxford Bulletin of Economics and Statistics* 66: 353–378.
Hou C.M., and Gee S. (1993). National systems supporting technical advance in industry: the case of Taiwan. In: Nelson, R. (Ed.), *National Innovation System*. Oxford University Press, Oxford.
Hu AG, and Jefferson GH. (2004). Returns to research and development in Chinese industry: Evidence from state-owned enterprises in Beijing, *China Economic Review*, 15(1), 86-107
Irvine J. (1988). Evaluating applied research: lessons from Japan. London: Pinter Publishers.
Jackson J.E. (1991) *A user’s guide to Principal Components*, Wiley, New York, 1991.
Jeffers, J.N.R. (1967) Two case studies in the application of principal component analysis, *Journal of the Royal Statistical Society Series D*, 16(3), 225-236.
Jian, T., Sachs, J., Warner, A. (1996) Trends in Regional Inequality in China, NBER working

paper 5412.
Kanbur, R., Zhang, X. (2005) Fifty years of regional inequality in China: a journey through central planning, reform, and openness, *Review of Development Economics* 9(1) 87-106.
Kim B and Oh H. (2002). An effective R&D performance measurement system: survey of Korean R&D researchers. *Omega*, 30(1), 19-31
Kostoff, R.N., 1994, Assessing research impact: federal peer review practices, *Evaluation Review* 18, 31-40.
Krawiec F. (1984). Evaluating and selecting research projects by scoring. *Research Management*, 6(4), 16-22.
Krull, W., D. Sensi and O. Sotiriou, 1991, Evaluation of Research and Development: Current Practice and Guidelines, Commission of the European Communities Report EUR 1333 (Brussels).
Kuwahara Y. and Takeda Y. (1990). Managerial approach to research and development cost-effectiveness evaluation. *IEEE Transactions on Engineering Management*, 37(2), 134-138.
Lach S. (2003). “Do R&D Subsidies Stimulate or Displace Private R&D? Evidence from Israel.” *The Journal of Industrial Economics*, 50(4), 369-390.
Li B., Akintoye A., Edwards P.J., and Hardcastle C. (2005). Critical success factors for PPP/PFI projects in the UK construction industry . *Construction Management and Economics*, 23(5), 459- – 471
Liberatore M.J. (1987). An extension of the Analytic Hierarchy Process for industrial R&D project selection and resource allocation. *IEEE Transactions on Engineering Management*, 34(4), 12-18.
Link A.N. (1993). Methods for evaluating the return of R&D. In *Evaluating R&D impacts: methods and practice*, ed. By Bozeman B., and Mellers J. Boston: Kluwer Academic publishers.
Lundvall, B.-A. (Ed.), 1992. *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. Pinter Publishers, London.
Luukkonen, T. and B. Stable, 1990, Quality evaluations in the management of basic and applied research, *Research Policy* 19, 357-368.
Luwel M. (2004). *The Use of Input Data in the Performance Analysis of R&D Systems: potentialities and pitfalls. Handbook of Quantitative Science and Technology Research*, pp. 315-338. Springer Netherlands.
Maasoumi, E. and Nickelsburg, G. (1988) Multivariate measures of well being and an analysis of inequality. *Journal of Business and Economic Statistics* 6: 327-334.
Ministry of National Resources Inventory R&D Comprehensive Compilations Science and Technology (MST). (20012) *National Resources Inventory R&D Comprehensive Compilations*, China Statistical Press.
MOC (Quality Safety Supervision & Development Division and Industry Policy Research Centre, Ministry of Construction and Engineering, RPC). (2005) Reports on China construction reform and development, Beijing, China Construction Industry Press, 34-35.
Mushin L, Byoungho S, and Kiyong O. (1996). Evaluation of national R & D projects in

Korea. *Research Policy*, 25.(5), 805-818.

Nam C. H. and Tatum C. B.(1997). “Leaders and champions for construction innovation”. *Construction Management Economics*, 15(3), 259-270

Nelson and Rosenberg, 1993 R. Nelson and N. Rosenberg, Technical innovation and national systems. In: R. Nelson, Editor, *National Innovation Systems: A Comparative Analysis,* Oxford University Press, New York and Oxford (1993), pp. 3–22.

Nelson, R.R. (1986), *The Technology Gap: Analysis and Appraisal*, Rand Corporation, Santa Monica, CA, .

Nelson, R.R. (Ed.), 1993. *National Innovation Systems*. Oxford University Press, New York.

Norusis, M.J., 1992. *SPSS for Windows: Base System User’s Guide*. Release 5.0, SPSS, Chicago, IL.

Oi, J.C., (1993), Reform and urban bias in China. *J. Dev. Stud*. 29 (4):129–148.

Ormala E. (1986). *Analysis and supporting R&D project evaluation*. Technical Research Centre of Finland, Espoo.

Ormala, E., 1989, Nordic experiences of the evaluation of technical research and development, *Research Policy* 18, 333-342.

Patel, P., and Pavitt, K., 1994. National innovation systems: why they are important and how they might be measured and compared. *Economics of Innovation and New Technology* 3, 7–95.

Pietrobelli, C., 1994. National technological capabilities: an international comparison. *Development Policy Review*,12 (2), 115–148.

Pinto J.K., and Slevin D.P. (1989). Critical success factors in R&D projects. *Research Technology Management*, 32(1), 31-35

Poh K.L., Ang B.W., and Bai F. (2001). “A comparative analysis of R&D project evaluation methods”. *R&D Management*, 31(1), 63-75.

Roessner, J.D., 1993, Use of quantitative methods to support research decisions in business and government, in: B. Bozeman and J. Melkers (Eds), *Evaluating R&D Impacts: Methods and Practice* (Kluwer Academic Publishers) pp. 179-205.

Saaty T.L. (1980). *The Analytic Hierarchy Process: planning, priority, setting resource allocation*. New York: McGraw Hill.

Science and Technology Agency Japan. (1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999). White paper on science and technology. Tokyo: Japan Information Centre of Science and Technology.

State Statistics Bureau. (2006) Available at website: http://www.ln.stats.gov.cn/infopub25/PubTemplet/%7B538116AD-AF2A-4978-B786-5A2A1621E91C%7D.asp?infoid=1797&style=%7B538116AD-AF2A-4978-B786-5A2A1621E91C%7D) (accessed 18 October 2009).

Sternberg, R. J. (1977) *Intelligence, information processing, and analogical reasoning: The componential analysis of human abilities*. Hillsdale, NJ: Erlbaum.

Sustainable Development Research Group (2000). *China’s Sustainable Development Strategy in the year of 2000*. Chinese Academy of Sciences, Beijing: Science Press.

Tan X.Y. (2008). The problems and solutions to the construction industry development in

Sichuan. *Sichuan Provincial Conditions*, 10, 45-48.

Tanaka, M., 1989, Japanese-style evaluation system for R&D projects: the MITI experience, *Research Policy* 18, 361-378.

UK Department of Trade and Industry, 1988, *Evaluation of R&D-A Policy Maker's Perspective* (Her Majesty's Stationary Office, London).

Wagner C.S. (1997) International Cooperation in Research and Development: An Inventory of U.S. Government Spending and a Framework for Measuring Benefits. Research report written by the RAND's Critical Technologies Institute, Santa Monica, CA. Available at website: http://www.rand.org/pubs/monograph_reports/2007/MR900.pdf.

Wang E.C. (2007). R&D efficiency and economic performance: A cross-country analysis using the stochastic frontier approach, *Journal of Policy Modeling*, 29(2), 345-360.

Wang K.M., Wang C. K., and Hu C. (2005). Analytic Hierarchy Process with Fuzzy Scoring in Evaluating Multidisciplinary R&D Projects in China. *IEEE Transactions on Engineering Management*, 52(1), 119-129.

Werner B.M., and Souder W.E. (1997). Measuring R&D Performance--US and German Practices, *Research Technology Management*, 40(3), 28–32.

Yang, D.L., Wei, H., 1996, Rural enterprise development and regional policy in China, Asian Perspective 35.

Zeng G.P. and Tan W.H. (2003) The development path of states R&D and basic research and its inspirations, Studies In Science of Science, (2), (in Chinese)

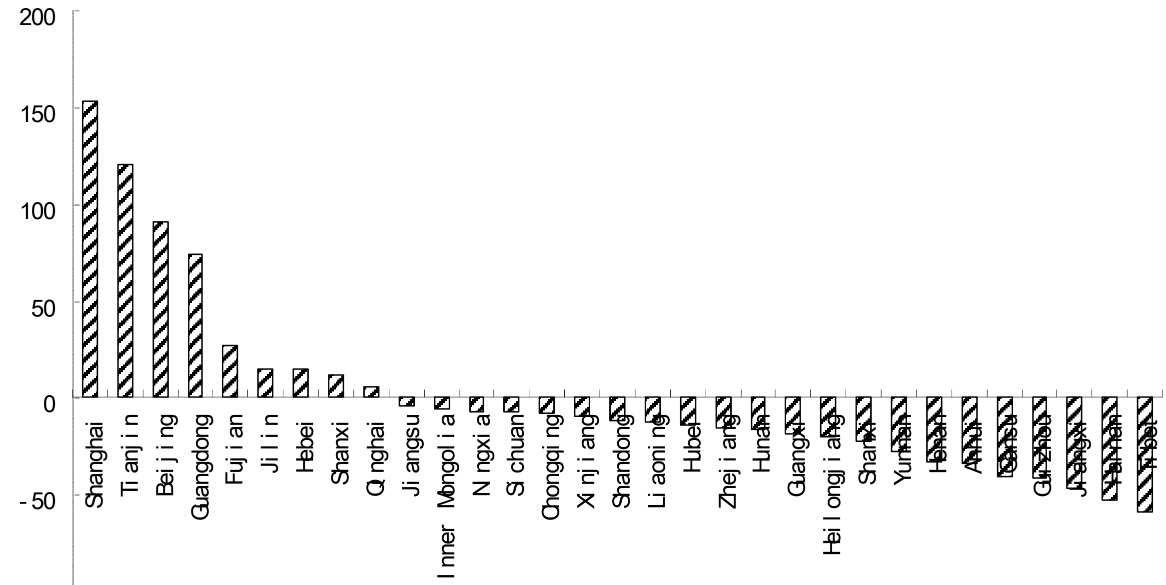

Fig 1 The integrated frequency order chart of RCRDES

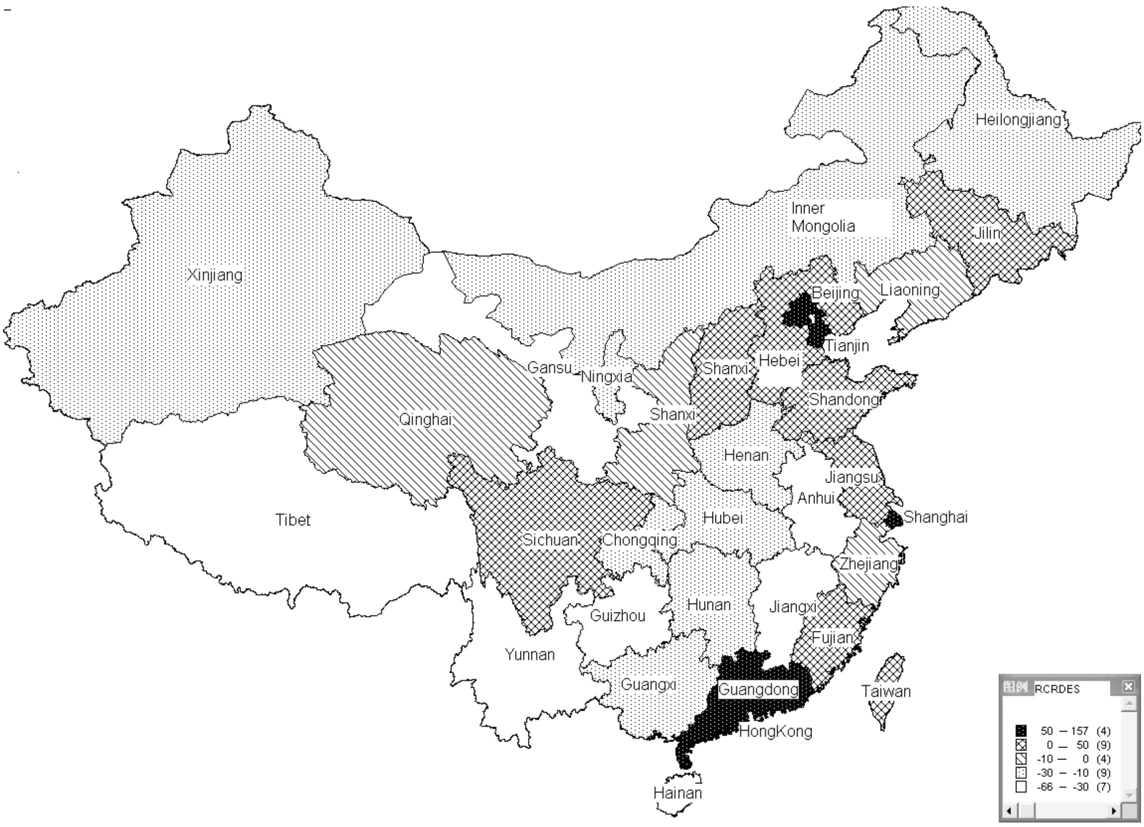

Fig. 2 The scored integrated thematic map of RCRDES

Table 1 Funding sources of S&T in China for the year 2000 (unit: 10^9 Yuan)

Funds raising channel	**Total**	**Proportion from each source (%)**	**Construction**	**Proportion of construction industry (%)**
Enterprises Funds	129.637	55.24	1.832	1.41
Government Funds	59.339	25.29	0.073	0.12
Finance Institution Loans	19.621	8.36	0.060	0.31
Establishments units Funds	13.647	5.82	0.011	0.08
Others	9.391	4.00	0.039	0.42
Foreign Investment	3.034	1.29	0.002	0.07
Total	*234.668*	*100.00*	*2.017*	*0.86*

(Source: Ministry of National Resources Inventory R&D Comprehensive Compilations, 2001)

Table 2 R&D expenditure for the year 2000

Region	**Basic research**	**Applied research**	**Experimental development research**	**Total R&D expenditure**
Eastern	998	5270	34654	40922
Central	34	828	6085	6947
Western	57	350	4934	5341
Total	*1089*	*6448*	*45673*	*53210*

(Source: Ministry of National Resources Inventory R&D Comprehensive Compilations, 2001)

Table 3 The indicator system

Level	**Indicator**	**Unit**	**References**
1) Socio-economic construction R&D indicators	X_1-GDP of the construction industry	100 million Yuan	Comin, 2004; Guellec and de la Potterie, 2004
	X_2- GDP per capita by region	Yuan/person	Bolthole et al., 2008
	X_3- Urbanization rate	%	Andersson et al., 2009
	X_4-Urban household’s Engle coefficient	%	(Sustainable Development Research Group, 2000)
2)R&D Status indicators	X_5-Full-time equivalent R&D personnel	Man-year	Wang, 2007;
	X_6-Funding for R&D	10,000 Yuan	Almus and Czarnitzki, 2003; Lach, 2003
	X_7-Original value of fixed asset for R&D institutions	10,000 Yuan	Fraumeni and Okubo, 2004; Guellec and de la Potterie, 2004
	X_8- Number of R&D topics	Unit	Luwel, 2004
3)R&D Development Capability indicators	X_9-The ratio of enterprises fund to total R&D fund	%	Hou and Gee, 1993
	X_{10}-Percentage of scientific and technical personnel of the construction industry indices (number of scientific and technical personnel as a percentage of total number of staff and workers in construction industry)	%	Kim and Oh, 2002; Wang, 2007
	X_{11}- The ratio of gross expenditure on R&D to construction industry GDP	%	Griffith and Harrison, 2003
	X_{12}-Number of scientists and engineers per 10,000 population	Unit	Wang, 2007;

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Table 4 Correlation matrix

Correlation matrix												
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12
V1	1.00											
V2	.177	1.00										
V3	.084	.891**	1.00									
V4	-.180	-.314	-.356*	1.00								
V5	.365*	.682**	.553**	-.112	1.00							
V6	.475**	.255	.323	-.083	.552**	1.00						
V7	.286	.096	.129	-.142	.434*	.527**	1.00					
V8	.507**	.666**	.542**	-.174	.896**	.546**	.231	1.00				
V9	.278	.113	.087	-.561**	.148	.100	.066	.128	1.00			
V10	-.106	.590**	.515**	-.368*	.435*	.031	.037	.328	.190	1.00		
V11	.263	.259	.354	-.084	.548**	.880**	.440*	.503**	.130	.186	1.00	
V12	-.070	.858**	.782**	-.213	.708**	.220	.205	.574**	.105	.658**	.380*	1.00

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

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Table 5 Eigenvalues and variability contributions of RCRDES (%)

Factor	**Factor 1**	**Factor 2**	**Factor 3**
Eigenvalue	5.169	2.147	1.523
Percentage variability contribution	43.07	17.90	12.70
Cumulative variability contribution rate	43.07	60.97	73.67

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Table 6 Rotated factor matrix (loadings)

Variable	Factor 1	Factor 2	Factor 3
X2	.838		
X3	.792		
X5	.887		
X6	.635		
X8	.839		
X10	.576		
X11	.655		
X12	.811		
X1		.568	
X7		.508	
X4			.768
X9			.835

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Table 7 Eigenvalues and the integrated scores by region

Region	Factor1	Factor2	Factor3	RCRDES
Shanghai	3.833	-0.381	-0.449	152.57
Tianjin	2.115	1.305	0.444	120.08
Beijing	2.277	-0.849	0.599	90.49
Guangdong	-0.246	4.548	0.224	73.67
Fujian	0.473	0.775	-0.559	27.13
Jilin	0.443	-0.282	0.032	15.04
Hebei	-0.545	1.085	-0.282	14.42
Shanxi	0.163	-0.836	0.268	11.74
Qinghai	-0.133	0.433	1.026	5.42
Jiangsu	-0.282	0.403	1.315	-4.52
Inner Mongolia	-0.281	-0.563	0.816	-5.64
Ningxia	0.212	-0.126	-1.513	-7.12
Sichuan	-0.411	-0.732	0.647	-7.65
Chongqing	-0.293	-0.644	0.678	-8.40
Xinjiang	-0.011	0.142	0.265	-9.79
Shandong	-0.289	-0.570	1.339	-11.83
Liaoning	-0.233	-0.110	-0.171	-12.33
Hubei	-0.249	-0.267	0.559	-14.17
Zhejiang	-0.329	-0.544	1.111	-15.52
Hunan	-0.463	-0.452	0.926	-16.25
Guangxi	-0.141	-0.415	0.501	-18.87
Heilongjiang	-0.323	-0.248	-0.127	-19.99
Shanxi	-0.781	-0.529	0.792	-22.60
Yunnan	-0.593	0.517	-0.203	-27.99
Henan	-0.054	-0.306	-2.063	-33.05
Anhui	-0.501	0.343	-0.989	-33.99
Gansu	-0.810	-0.191	-0.217	-41.08
Guizhou	-0.812	-0.398	-0.363	-42.50
Jiangxi	-0.913	-0.241	0.168	-46.69
Hainan	-0.315	-0.400	-2.531	-52.86
Tibet	-0.508	-0.465	-2.243	-58.72

Table 8 Classification of regions

Region	**Rank**	**Kanbur & Zhang's classification**	**First national economic census**
Shanghai	1	Coastal	Eastern
Tianjin	2	Coastal	Eastern
Beijing	3	Coastal	Eastern
Guangdong	4	Coastal	Eastern
Fujian	5	Coastal	Eastern
Jilin	6	Inland	Central
Hebei	7	Coastal	Eastern
Shanxi	8	Inland	Central
Qinghai	9	Inland	Western
Jiangsu	10	Coastal	Eastern
Inner Mongolia	11	Inland	Western
Ningxia	12	Inland	Western
Sichuan	13	Inland	Western
Chongqing	14	Inland	Western
Xinjiang	15	Inland	Western
Shandong	16	Coastal	Eastern
Liaoning	17	Coastal	Eastern,
Hubei	18	Inland	Central
Zhejiang	19	Coastal	Eastern,
Hunan	20	Inland	Eastern
Guangxi	21	Coastal	Western
Heilongjiang	22	Inland	Central
Shaanxi	23	Inland	Central
Yunnan	24	Inland	Western
Henan	25	Inland	Central
Anhui	26	Inland	Central
Gansu	27	Inland	Western
Guizhou	28	Inland	Western
Jiangxi	29	Inland	Central
Hainan	30	Inland	Eastern
Tibet	31	Inland	Western