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## Information



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**Surveying and Built Environment** is an international peer reviewed journal that aims to develop, elucidate, and explore the knowledge of surveying and the built environment; to keep practitioners and researchers informed on current issues and best practices, as well as serving as a platform for the exchange of ideas, knowledge, and opinions among surveyors and related disciplines.

**Surveying and Built Environment** publishes original contributions in English on all aspects of surveying and surveying related disciplines. Original articles are considered for publication on the condition that they have not been published, accepted or submitted for publication elsewhere. The Editor reserves the right to edit manuscripts to fit articles within the space available and to ensure conciseness, clarity, and stylistic consistency. All articles submitted for publication are subject to a double-blind review procedure.

### Topics

All branches of surveying, built environment, and commercial management including, but not limited to, the following areas:

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## From the Editor

There are five reviewed papers in the second issue of the Surveying and Built Environment. Major issues investigated in these papers deal with the science, technology and management aspects of the built environment which include waste recycling, advanced technology adoption, marketing and branding, drainage behaviour and performance measure for partnering.

The first three papers are extracted from the outstanding dissertations of the year 2005 awarded by the Research Committee of the Hong Kong Institute of Surveyors. First, Ng, Tam and Tam demonstrates with empirical results on how the proposed two-stage mixing for recycled aggregate concrete outperforms that of normal mixing. The second paper by Fung and Rowlinson examines the feasibility of using advanced construction technologies to improve productivity and the like problems associated with the labour-intensive nature of the Hong Kong construction industry. Kwok and Hastings in the third paper investigate the attitude of real estate agencies in Hong Kong towards marketing and branding. With referral being identified as the major source of business, the authors suggest that a corporate brand built with personalized service and service quality would help strengthening the market position of the business.

Addressing to the community's concern about virus spreading after the outbreak of the Severe Acute Respiratory Syndrome, Lee in the fourth paper investigates the hydraulic flow behavior inside the drainage system. The air and water flow patterns inside the drainage system are simulated using computational fluid dynamics. The simulated results from numerical computation help designing pipeworks objectively which is an advancement in drainage design. Finally, Lo, Wong and Cheung use the Balanced Scorecard approach to measure the partnering project performance in a holistic manner. The results of their survey support the use of the identified strategic objectives. These objectives are categorized into four perspectives: benefits (of adopting partnering), attitudes of project stakeholders, attitudes enhancement process and strategic learning and growth.

As an international peer-reviewed journal, gaining recognition worldwide is important. We look forward to publishing good quality research papers from our overseas contributors in order to integrate an international dimension into the journal. It is very encouraging to report that we have received quite a number of manuscripts from overseas since launching the Surveying and Built Environment (in place of the former Hong Kong Surveyors) last December. All of them, except those were rejected unfortunately, are in the middle of the reviewing process and thus, are yet to appear in this issue.

Prompt response is essential to the reviewing process. May I express my thanks to the editorial board members as well as the invited reviewers for their support.

Dr Franco KT Cheung
Editor Vol 17 Issue 1

# Submission Guidelines

## ELECTRONIC SUBMISSION

Full paper submission should consist of a file in Microsoft Word format attached to an e-mail message.

## FORMAT OF FULL PAPER

**Language:**

English

**Content**

Full Paper should include title of paper, author details, ABSTRACT, KEYWORDS, and REFERENCES.

**Paper length**

Full paper should not be more than 20 pages, including all text, graphs, tables, diagrams, maps, pictures, illustrations, and appendices.

**Paper size**

Set paper size to A4. The lines of text (except the text under ABSTRACT) should be indented left and right 3cm from the paper margin.

**Text font**

Times New Roman

**Abbreviations**

No full stop is needed for titles, names, acronyms, and measurement units: eg, Mr, Dr, PRC, UK, HKSAR, Jan, Feb, Mar, 4m, 5ft.

**Abstract**

Drop 2 line spaces and type **ABSTRACT** in bold, full caps, 12 point size, and centred. On the next line, type the content of the Abstract in 10-point size, indent 3cm on both margins, left and right justified.

Abstract should be a single paragraph outlining the aims, scope, and conclusion of the paper. It should be no more than 300 words in length.

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Drop 2 line spaces and type **KEYWORDS** in bold, full caps, 12-point size, and left justified. Type the keywords in the next line and indent 3cm on both margins, left and right justified. Suggest approximately 5-10 keywords spaced by commas.

**Main Text**

Drop 2 line spaces before typing each of the above topics. The text should be single spaced, single column, indented 3cm on both margins, left and right justified, and 12-point size. Paragraphs should not have any indentations. Any abbreviations used should be defined.

Section headings are in bold and full caps. There should be no blank lines between the heading and the first line of text. Separate paragraphs in each Section with one blank line. There should be two blank lines before each Section.

Equations should be centred, with a spaced line above and below. Equation font size should be the same as that of the text. Use only those mathematical symbols supported by Microsoft Word.

All graphs, tables, diagrams, maps, pictures, and other illustrations should be in black and white. They should be labeled and embedded in the text as close as possible to where they are first cited.

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Drop 2 line spaces and type **REFERENCES** in bold. All references should be in 12-point size, left and right justified, indented 3cm on both margins for the first line and 3cm on the left margin for subsequent lines. List all bibliographical references in alphabetical order by the last name of the first author at the end of the paper in the following format:

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Last name and initials of author(s), (year of publication), paper title, journal title (italics), journal volume: issue, page numbers, for example:

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Last name and initials of author(s), (year of publication), book title (italics), edition (if any), publisher, for example:

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# Deformation and Sorptivity of Recycled Aggregate Concrete Produced by Two Stage Mixing Approach

Ka-hung Ng[1], Chi-ming Tam[2*] and Vivian Wing-yan Tam[3]

## ABSTRACT

The amount of construction and demolition (C&D) waste has grown to such an extent that it has aroused much public concerns. Among them, concrete occupies more than seventy percent of the total C&D waste. As a result, landfill areas will soon be exhausted in the coming few years. However, owing to the uncertainty in using Recycled Aggregate (RA), practitioners are skeptical in using these as a natural aggregate substitute. Poor performance of RA is well acknowledged to be resulted from its higher porosity due to cement mortar remains attaching to the RA surface. Deformation and water sorptivity are of particular concern, which will affect the long term durability of building structures. To improve the quality of Recycled Aggregate Concrete (RAC), Two-Stage Mixing Approach (TSMA) is proposed, attempting to form a layer of cement slurry to fill the cracks and voids in the RA, leading to improvement at the interfacial zone of aggregate. In this study, the drying shrinkage, creeping, and water sorptivity of concrete made from the normal mixing approach and TSMA are compared. The results show that concrete from TSMA performs better than that from Normal Mixing Approach (NMA), which can be explained by the improved Interfacial Transition Zone (ITZ) around the RA. Moreover, the concrete mix that contains 20% RA substitution has performed the best.

## KEYWORDS

C&D Waste, Recycled Aggregate Concrete, Two-stage Mixing Approach, Shrinkage, Water Sorptivity, and Creeping

## INTRODUCTION

Construction and Demolition (C&D) waste has consumed a large portion of landfill areas in Hong Kong. Among various types of C&D waste, concrete occupies more than seventy percent of the total C&D waste generated. The potentials for recycling concrete are thus extremely high. To encourage recycling of concrete waste, the Hong Kong SAR Government had set up a concrete recycling plant in Area 38 at Tuen Mun.

However, Recycled Aggregate (RA) is well acknowledged having a poor quality due to its higher porosity resulted from cement mortar remains attaching to the RA surface that hampers the potential to recycle concrete waste. Many previous research works recorded reduction in strength for concrete made with RA; thus the use

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of RA is mainly confined to low-grade applications.

To improve the quality of RA and thus its recycling rate, Tam *et al.* (2005) proposed the Two Stage Mixing Approach (TSMA) for improving the strength of Recycled Aggregate Concrete (RAC). This paper attempts to compare some of the properties of RAC made from TSMA and the normal mixing approach.

## PREVIOUS WORKS

Many researchers have studied the properties of RAC. Tables 1 and 2 summarize the findings of drying shrinkage, creeping, and water sorptivity on recycled aggregate concrete.

***Table 1: Previous Study Results of Drying Shrinkage and Creep of RAC***

| Studies | Properties of RAC | Results |
|---|---|---|
| Hong Kong Housing Authority [HKHA, 2004] | Drying Shrinkage | The drying shrinkage of RAC is 7% greater than that of natural aggregate concrete. A similar result was found for RAC with 20% RA substitution. |
| Katz, 2002 | Drying Shrinkage | The drying shrinkage at the age of 90 days was 0.7-0.8 mm/m for the ordinary Portland cement and 0.55-0.65 mm/m for the white Portland cement concrete with RA. The shrinkage in the reference concrete samples at the same age was 0.27 and 0.32 mm/m, respectively. |
| Sakata et al., 2000 | Drying Shrinkage and Creep | The drying shrinkage of RAC was higher than the concrete with other types of aggregates. The creep coefficient of the concrete with the fine recycled concrete aggregate was higher than that of other concrete. |
| Hansen, 1992 | Creep | Creep of RAC might be up to 40% greater than that of conventional concrete made with natural aggregates. The creep of RAC made with coarse recycled aggregates and natural sand was in order of 20-30% higher than that of conventionally control concrete. |

***Table 2: Previous Study Results on Water Sorptivity***

| Studies | Properties of RAC | Results |
|---|---|---|
| Gomez-Seberon, 2002 | Water Sorptivity | The water absorption of RAC was about 5.8-8.1% and that of natural aggregate concrete was just 0.88%-1.49%. |
| Katz, 2002 | Water Sorptivity | The total water absorption of RAC was about 6.9-7.6%, which was greater than absorption of the reference concrete of about 3.8-3.9%. |
| Olorunsogo and Padayachee, 2001 | Water Sorptivity | The water sorptivity increased as the proportion of RA in the concrete mixes increased. The percentage increment of the water absorption of the concrete mixes with 100% RA was about 47.3%, 43.6%, 38.5% and 28.8% for curing days at 3, 7, 28, and 56, respectively. |

The above studies have found that RAC performs poorer in both drying shrinkage, creeping and water sorptivity when compared with natural aggregate concrete under the same curing conditions.

## RESEARCH METHODOLOGY

TSMA aims to improve the compressive strength of RAC and lower its strength variability. Tam *et al.*, 2005 have demonstrated that the use of TSMA does improve the strength of RAC that compensates for the lower strength resulted from the porous nature of RA. The premixing process of forming a layer of cement slurry on RA can fill up the voids and cracks and result in a denser concrete. In this study, properties of RAC made from TSMA is compared with the normal mixing approach (NMA) to ascertain any benefit or improvement that TSMA might have on RA. The procedures of the two mixing approaches are as follows:

- **Normal Mixing Approach (NMA)**
  Cement, coarse and fine aggregates, and water are added into the mixer at the same time and mixed for 120 seconds.

- **Two-stage Mixing Approach (TSMA)**
  Step 1: Coarse and fine aggregates are added into the mixer and mixed for 60 seconds.

  Step 2: The first half of water is then added to the mixed aggregate, and mixed for another 60 seconds.

  Step 3: All cement is added to the mixer and mixed for another 30 seconds.

  Step 4: The remaining half of water is added to the mixer and mixed for 120 seconds.

In this study, three tests are conducted (drying shrinkage, creeping, and water sorptivity) with six concrete mixes, namely, RAC with 0% (normal aggregate concrete), 20%, and 100% RA substitution using both NMA and TSMA. The slumps of these concrete mixes are controlled to 75 mm, and the controlled temperature and humidity for the experiments are set at 25°C and 65% respectively.

### 1. Drying Shrinkage

The definition of drying shrinkage (BS1881: Part 5: 1970) is the difference between the length of a prism of matured concrete after immersion in water and its length after subsequent drying under specified conditions. In this study, three prisms of 300 mm (l) x 75 mm (w) x 75 mm (d) were cast and cured for each mixing method (NMA and TSMA) with 0%, 20%, and 100% RA substitution. The test lasts for 210 days. The measuring apparatus is a micrometer gauge that is rigidly mounted (in a vertical direction) on a measuring frame and is adjustable for prisms of different lengths. The end of the gauge and the seating at the opposite end of the measuring frame have a conical recess with a 90-degree internal angle and a face diameter of 5.5-6.5 mm, which is located upon a 6-mm diameter stainless steel ball that is cemented in the prism.

Drying shrinkage percentage:

= (I.R. x 0.002 – F.R. x 0.002) / I.R. x 0.002 x 100%
= (I.R. – F.R.) / I.R. x 100%,
where I.R. means initial reading at day 1 and F.R. means final reading at day t.

### 2. Creep Test

The creep test (Standard: ASTM C 512 -02) examines molded concrete cylinders that are subjected to a sustained longitudinal compressive load, and measures the load-induced time-dependent compressive strain at selected ages for concrete under an arbitrary set of controlled environmental conditions. In this test, the diameter of each sample should be 150 mm and the length should be at least 292 mm. The ends of the sample are placed in contact with steel bearing plates, and the sample length should be at least equal to the gauge length of the strain-measuring apparatus plus the diameter of the sample. When the ends of the sample are in contact with other concrete samples similar to the test sample, the sample length shall be at least equal to the gauge length of the strain-measuring apparatus plus 38 mm. Between the test sample and the steel bearing plate at each end of the stack, a supplementary non-instrumented cylinder with a diameter that is equal to that of the test cylinders and a length that is at least half its diameter is installed.

The results were calculated using the following equations:

$$\varepsilon = \left(\frac{1}{E}\right) + F(K)ln(t+1) \ ,$$

where ε the total strain, $\frac{1}{E}$ is the initial elastic strain, $F(K)$ is the creep rate, and $t$ is the time after loading (in days).

$$CS_t = \varepsilon_t - \frac{1}{E} - S_t \ ,$$

where $CS_t$ is the creep strain at time $t$, $\varepsilon_t$ is the measured strain at time $t$, and $S_t$ is the shrinkage at time $t$.

$$CC_t = \frac{CS_t}{\frac{1}{E}} \ ,$$

where $CC_t$ is the creep coefficient at time $t$.

### 3. Water Sorption

Sorption means water ingress into pores under unsaturated conditions due to capillary suction. The sorptivity test (ASTM Designation: C642) measures the ability of concrete to absorb water, where sorptivity (S) means the volume of water that is absorbed per unit of cross-section (i) in absorption time (t). Three cubes of 150 mm x 150 mm x 150 mm concrete samples were cast and cured for each mixing method. Measurements were made at a 14-day interval until the 182nd day.

To present the results, the sorptivity (S) was derived from the relationship between the volume of water absorbed per unit of cross-section (i) and the square root of time ($t^{1/2}$) using the following equation:

$$S = i \ / \ t^{1/2},$$

$$\text{where} \quad i = \frac{(W_t - W_d) \times 10^3}{A} \, mm^3/mm^2$$

where $W_t$ is the weight at different time intervals, $A$ is the cross-sectional area, and $t$ is the time interval in minutes

## TESTING RESULTS

### 1. Drying Shrinkage

Table 3 shows the comparative results of drying shrinkage for the various concrete mixes using NMA and TSMA. On the 182nd day, the difference in shrinkage is not significant for all mixes. When the concrete samples are re-wetted for 28 days (soaking the samples in water for 28 days) to determine the permanent deformation, the rewetting process decreases the percentage of shrinkage of the concrete samples because the water molecules filled up the voids inside the concrete, making the cubes to expand. After 28-days of rewetting, the concrete samples made with NMA with 0%, 20%, and 100% RA substitution show values of 4.04%, 3.83%, and 4.33% of permanent drying shrinkage respectively. However, concrete cubes made with TSMA with 0%, 20% and 100% RA substitution give an improved shrinkage performance on the 210th day after the re-wetting process with values of 3.92%, 3.82% and 4.10% of permanent drying shrinkage respectively.

### *Table 3: Comparison of Drying Shrinkage for NMA and TSMA*

| | NMA | TSMA | NMA | TSMA |
|---|---|---|---|---|
| **Concrete sample** | **182nd day (normal drying shrinkage process)** | | **210th day (28 days for rewetting following 182 days)** | |
| **0%** | **5.59%** | **5.60%** | **4.04%** | **3.92%** |
| **20%** | **5.47%** | **5.48%** | **3.83%** | **3.82%** |
| **100%** | **5.74%** | **5.75%** | **4.33%** | **4.10%** |

Although there is no significant improvement for the mix with 20% RA substitution using TSMA in comparing with that using NMA, the lowest drying shrinkage figure is achieved, inferring the optimum percentage of RA substitution at that level. The mix with 20% RA substitution gives the strongest and densest concrete structure and therefore the lowest value of permanent shrinkage.

### 2. Creep Test

Table 4 shows a comparison of the creeping rates for the various concrete mixes. On the 182nd day, the concrete mixes made with NMA have a larger creep strain than those made with TSMA. This finding confirms that TSMA can improve the creep strain, and the improvement is more significant when the samples are unloaded (the sample rebounds to recover some of the creeping) to obtain the permanent creep strain.

### *Table 4: Comparison of Creep for NMA and TSMA*

| | NMA | TSMA | NMA | TSMA |
|---|---|---|---|---|
| **Concrete sample** | **182nd day (normal creeping process)** | | **210th day (28 days for unloading following 182 days)** | |
| **0%** | **0.000563** | **0.000530** | **0.000015** | **0.000012** |
| **20%** | **0.000754** | **0.000633** | **0.000129** | **0.000024** |
| **100%** | **0.001517** | **0.001176** | **0.000743** | **0.000575** |

Table 5 shows the recovery in creep strain for mixes made with TSMA. A comparison of the mixes on the 182nd and the 210th day shows that the samples with 0% RA achieves the greatest recovery in creep strain, 98%. However, the concrete mixes with 20% and 100% RA substitution can only recover 96% and 51% respectively. Therefore, the mix with 0% RA substitution gives the best performance among all of the samples, which is quite understandable as higher percentages of RA will decrease the quality of RAC. A comparison of the creep strains shows that the performance of the mix with 20% RA substitution is close to that of 0% RA substitution. At the same time, the 20% RA mix performs much better on recovery of creep strain in comparing with that of 100% RA mix. This also confirms that the optimal percentage of RA replacement is at 20%.

### *Table 5: Improvement in Creep Strain by TSMA*

| Concrete sample | Samples on 182nd day | Samples on 210th day | Recovery of Creep after Unloading | Percentage of Recovery |
|---|---|---|---|---|
| **0% TSMA** | **0.000530** | **0.000012** | **0.000518** | **98%** |
| **20% TSMA** | **0.000633** | **0.000024** | **0.000609** | **96%** |
| **100% TSMA** | **0.001176** | **0.000575** | **0.000601** | **51%** |

## 3. Water Sorption

Table 6 shows the comparison of water sorptivity of the various concrete mixes. Figure 1 show the water sorptivity behavior of all concrete mixes measured for 7,200 seconds during each test.

***Table 6: Comparison of Water Sorptivity for NMA and TSMA***

| Average water sorptivity rate (mm/s) | 0% | 20% | 100% | 0% | 20% | 100% |
|---|---|---|---|---|---|---|
| Time | NMA | | | TSMA | | |
| 300s | 0.0158 | 0.0109 | 0.0264 | 0.0132 | 0.0080 | 0.0130 |
| 600s | 0.0154 | 0.0109 | 0.0269 | 0.0132 | 0.0080 | 0.0130 |
| 1800s | 0.0138 | 0.0099 | 0.0255 | 0.0124 | 0.0080 | 0.0126 |
| 3600s | 0.0133 | 0.0096 | 0.0250 | 0.0122 | 0.0081 | 0.0128 |
| 7200s | 0.0129 | 0.0097 | 0.0243 | 0.0118 | 0.0085 | 0.0132 |

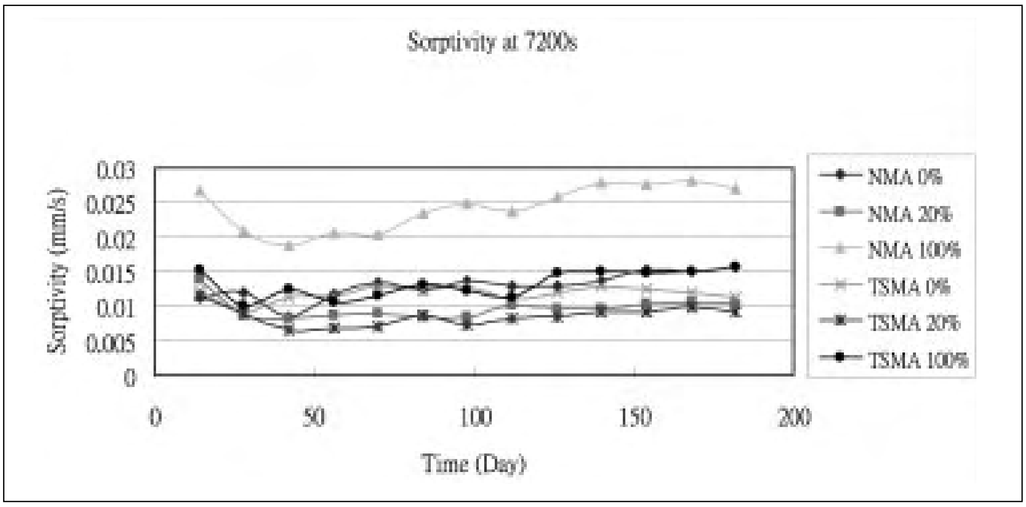


***Figure 1: Water Sorptivity Behavior of Concrete Mixes at 7,200 Seconds***

The above table and figure show that TSMA can improve the water sorptivity of the mixes with 20% and 100% RA substitution but less significant for the mix with 0% RA substitution when compared with NMA. TSMA leads to the formation of a thin layer of cement slurry on the surface of RA, giving a denser concrete. For the mixes with 0% RA substitution, TSMA contributes little improvement because the natural aggregate did not have many cracks or voids. On the other hand, it is found that the mix with 20% RA substitution gives the lowest rate of sorptivity when TSMA is adopted.

Figures 2 and 3 show the microstructure of RAC made with NMA and the TSMA, respectively. Figure 2 shows that the cracks and voids are not filled up with the cement slurry using NMA and thus the ITZ is weaker. Figure 3 shows that the cracks and voids are filled up with the cement mortar using TSMA, and the new ITZ gives a stronger structure. These can be revealed from the testing results on shrinkage, creeping and water sorptivity.

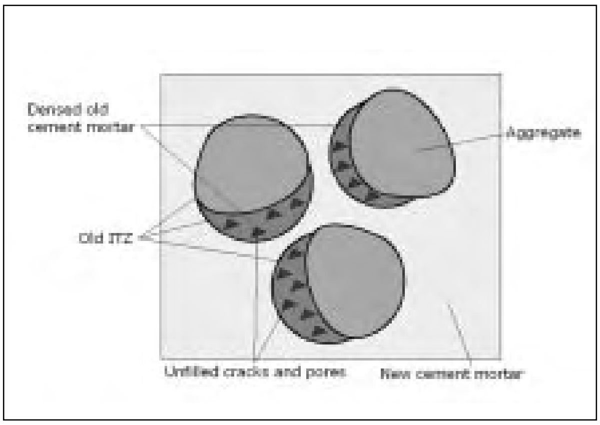


**Figure 2: RA Microstructure Using NMA**

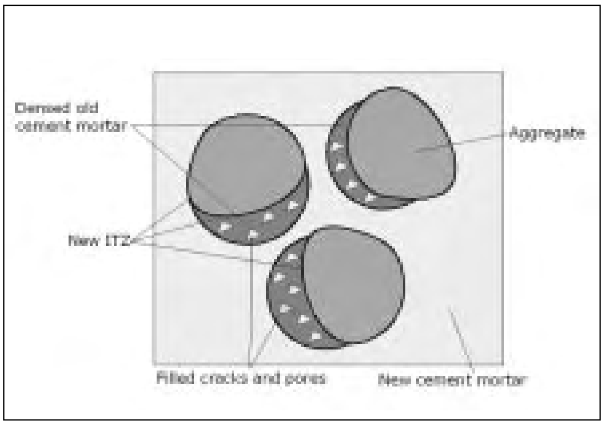


**Figure 3: RA Microstructure Using TSMA**

The findings of the above three tests show that the concrete mix at 20% RA substitution performs the best when TSMA is adopted.

## CONCLUSION

The above experiments confirm that the use of the Two Stage Mixing Approach (TSMA), can improve the quality of recycled aggregate concrete, which can compensate for the poor performance of RAC made with recycled aggregate. This enables in a wider scope of application of recycled aggregate, facilitating higher utilization levels of recycled aggregate in the industry. As the amount of construction demolition waste generation in Hong Kong is increasing, the adoption of recycled aggregate for new construction works can therefore reduce the burden on the landfill areas that can extend the servicing life of the landfills. The important aims of using recycling aggregate for concrete structures is to safeguard human life, protect our environment, and enhance the durability of concrete structures.

The use of TSMA can improve the properties of RA and RAC in comparing with NMA. This new mixing approach helps to form a thin layer of cement slurry on the surface of RA, which permeates into the porous old cement mortar and eventually fills up the old cracks and voids to reduce the porosity of RA. The adoption of TSMA can create an Interfacial Transition Zone (ITZ) with a greater surface area to which the cement mortar can attach, and thus an increased strength of concrete structure. Therefore, in this study, the concrete mixes made using TSMA give a better performance in the deformation and water sorptivity. The study also identifies that the optimal RA substitution is at 20%, which gives the optimal performance in creeping, shrinkage and water sorptivity.

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# The Adoption of Advanced Technologies in the Hong Kong Construction Industry

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## ABSTRACT

This study addresses the problems of Hong Kong construction industry's labour-intensive nature, examines the possibility of using advanced construction technologies to solve these problems and identifies the barriers to the use of these technologies.

The Hong Kong construction industry is often cited as a labour-intensive industry and it has been underachieving in terms of productivity (RCCI, 2001) but little empirical research has been done to validate this statement. Therefore, researchers used a Cobb-Douglas Production Function to investigate the ratio of labour input to capital input so as to determine the factor intensity of the local construction industry. The result affirms the labour-intensive nature of the industry. This Production Function was also used to calculate the value added total factor productivity (VATFP) growths of the construction industry. It was observed that the VATFPs of the industry sustained positive growth in the period 1985-2002. The above two findings imply that even though there have been technical changes, the construction industry still relies primarily on labour resources to increase productivity.

Four advanced construction technologies were studied and economic analyses showed that they can offer users tangible benefits such as enhancements in productivity and cost reductions as well as less tangible benefits including improvements in quality and a safer work environment. Contractors have not thus far shown great interest in these technologies because they have no guarantee of being able to utilise them frequently, thus implying a negative return on investment. Other obstacles to the use of advanced technologies were identified, they are: lack of client motivation, financial constraints, tight project timeframe, low labour capability and lack of knowledge sharing in the industry. As a result, the paper recommends that Hong Kong government should allocate more resources to both training and research and development (R&D) to engender a climate conducive to development and adoption of advanced technologies.

## KEYWORDS

advanced technology adoption, productivity improvement, Hong Kong, construction industry

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## INTRODUCTION

Despite the boom in the run up to the "Handover", the completion of the Hong Kong International Airport and its related facilities and the Asian Financial Crisis in 1997 had a serious negative impact on the construction industry in Hong Kong. The total value of construction works has followed a continuous, downward trend since then. In terms of construction spending per capita, Hong Kong ranked 9th in 1998 and 4th in 2003 behind Japan, Korea and Singapore within Asia, with Japan leading at US$3,648 (AsiaConstruct Team, 2004).

However, although the construction sector accounted for only 3.2% of the Gross Domestic Product (GDP) of Hong Kong in 2004, down from 4.9% in 2000 (Census and Statistics Department, 2005), practically all other sectors of the economy, such as the tourist industry, manufacturing industry, finance and real estate services, community services, etc. rely on the construction sector to accommodate their needs for growth and expansion (Voon and Ho, 1998). The construction industry plays an important role in Hong Kong's economy and its significance cannot be neglected despite its relatively small share of GDP.

However, there are many shortcomings in the industry's operations and in the quality of its products. The Construction Industry Review Committee (CIRC, 2001) identified local construction activities as labour-intensive, dangerous and polluting; built products as often defective; construction costs as high; practitioners as lacking a long-term view of business development and the industry reluctant to adopt new technologies to cope with new challenges. In addition, the productivity of the construction industry has been on the decline. As a result, one of the CIRC's recommendations to the industry was to use more modern construction methods and techniques as well as deployment of information and communication technology (ICT) so as to enhance efficiency and productivity.

## OBJECTIVES

This research addresses the problem of the slow uptake of new technologies and practices. Are they too costly to adopt? Are their advantages overestimated? The authors start from the propositions that the Hong Kong construction industry is labour-intensive and the decline in productivity in the construction industry is due to the low capability of labour and poor levels of uptake of new technologies and automation. It is postulated that one of the reasons for this is that, given the current structure of the industry, the benefits brought by advanced construction technologies and practices are not cost effective as far as contractors are concerned. Thus, the research has the following aims:

1. To use a scientific approach to determine the labour-intensity of the Hong Kong construction industry.

2. To calculate productivity growth in the local construction industry.

3. To analyse new construction practices and technologies to ascertain their economic feasibility and benefits to users.

4. To investigate and explain the phenomenon of the slow uptake of new construction practices and technologies in the industry.

5. To propose methods to accelerate the adoption of new construction practices and technologies in the industry.

## BACKGROUND TO THE STUDY

### THE SIGNIFICANCE OF LABOUR COST IN A CONSTRUCTION PROJECT

Ganesan *et al* (1996, p49) estimate that the breakdown of total construction expenditure is approximately 35% materials, 45% labour and plant, and 20% overheads and profit. Total expenditure in this context covers building and civil engineering projects, and these percentages may vary significantly from one project to another, especially in the civil engineering sector. Voon and Ho (1998) indicate that a typical building contract has 40% labour content while a typical civil engineering contract has 20%. CIRC's (2001) benchmark study on the construction cost of building projects in Hong Kong reveals that the average labour component costs in normal building projects are 25% of the total construction costs in Hong Kong while they are 20% in Singapore making Hong Kong less competitive than its neighbour and competitor.

### THE CONCEPT OF CAPITAL

Capital refers to all man-made resources used for further production, which includes buildings, plant and equipment, and stocks of materials. The quality and quantity of capital influences not only the productivity of capital but also that of labour and total output (Kulshreshtha and Malhotra, 1998). When we talk about productivity in construction, capital often refers to the technologies adopted in the construction process because other elements such as buildings or stocks of materials owned by contractors do not have a direct impact on construction productivity on site.

Unlike labour, capital will depreciate over time. Depreciation measures the loss in value of a capital good as it ages. A capital good will also experience efficiency decline, which reflects the loss of productive services that can be drawn from it (Schreyer, 2001, p53).

### THE DEMAND FOR CAPITAL IN THE CONSTRUCTION INDUSTRY

The demand for construction plant is derived from the demand for the products and services it ultimately provides. In addition, spending on capital goods like construction plant often requires large monetary outlays with profits dependent on the flow of future revenues and costs. Because of the magnitude of the funds required, investment spending tends to be influenced by interest rates (Bumas 1999, p421) and the financial capacity of the investors.

Contractors in Hong Kong are reluctant to purchase sporadically used plant since it is difficult to amortise the investment so there is a tendency to hire. On the other hand, plant that are frequently specified in contracts, such as air compressors and concrete pumps, have high utilization rates and justify direct purchases by local contractors (Ganesan *et al*, 1996, p52). The nature and volume of work dictates the type and capacity of plant purchased by a firm.

## THE SUPPLY OF CAPITAL IN THE CONSTRUCTION INDUSTRY

Most construction plant and technologies in Hong Kong are acquired from overseas (Chau and Walker 1988; Ganesan *et al*, 1996; AsiaConstruct Team, 2003). These plant and technologies are either directly owned by the contractors or on short term hire (Ganesan *et al*, 1996, p53). In most cases, local contractors own only the most commonly-used plant, such as tower cranes and hoists, in order to increase utilisation rates and reduce unit costs.

Contractors may also invest in R&D activities to look for new technologies. However, as reported by both CIRC (2001) and AsiaConstruct Team (2003), Hong Kong construction industry's expenditure on R&D is low, leading to a dearth of inventions or improved construction technologies.

### FACTOR INTENSITY

Factor intensity is the proportion of a factor used in the production of any one final good. In economics, the concept of factor intensity tells us that in order to rank commodities, what is important is the proportion in which labour and capital are used, not their absolute quantities (Chacholiades 1990, p67). Therefore, it is necessary to investigate the labour to capital ratio before drawing any conclusion on factor intensity matters, eg labour intensity of an industry.

## *LABOUR UTILIZATION AND CAPITAL UTILIZATION IN THE LOCAL CONSTRUCTION INDUSTRY*

Many construction activities still depend heavily on skilled and unskilled labour. Ganesan *et al* (1996, p42) and Chiang *et al* (1998) identify several labour-intensive construction activities such as concreting, steel fixing, carpentry, rendering, planting, acoustical ceiling work and pipe work. In addition, various kinds of labour are employed; usually referred to as building trades, eg concreter, steel bender, plumber, painter, electrical and mechanical (E&M) workers and various managerial, administrative and professional workers, such as project managers and surveyors.

Hong Kong's civil engineering industry is more mechanized than its building construction counterpart as the large-scale nature and special requirements of civil engineering projects favour the use of construction machinery. According to Chau and Lai (1994), the use of plant and machinery has become more common and labour productivity has been improved through substitution of capital for labour, though the process is slow.

## *IS HONG KONG'S CONSTRUCTION INDUSTRY REALLY LABOUR-INTENSIVE?*

The construction industry in Hong Kong is considered labour-intensive by many researchers (Rowlinson and Walker, 1995; Ganesan *et al*, 1996; Chiang *et al*, 1998; Voon and Ho, 1998; CIRC 2001; AsiaConstruct Team, 2003) but few of these authors provide empirical verification of the industry's labour intensity. Chacholiades (1990, p67) provides a meaning for "labour-intensive" when explaining the Heckscher-Ohlin Model in macroeconomics. Take labour-capital ratio as an example. The labour-capital ratio is the quantity of labour required to produce one commodity divided by the quantity of capital required to produce that commodity. A larger labour-capital ratio indicates more labour-intensive industry, and vice versa. Thus, this research addresses factor productivity issues to investigate this aspect.

## *PRODUCTIVITY*

When we discuss how "advanced" an industry is, we usually refer to its productivity. Productivity plays a crucial role in determining the level and rate of profitability (Savidis and Mills, 2001). Economists calculate the productivity of an industry with the aid of production functions to examine the technological change in that industry. A production function can also serve as a means to reflect the factor intensity of an industry. Edison (1999) defines productivity as an all embracing term which refers to the overall net yield of goods and services during a specified period, achieved with a given volume of resources. Ive and Gruneberg (2000, p61) define productivity as the quantity of output per unit of labour in a given period of work and the output can be measured in terms of the physical units produced. Schwartzkopf (2004, p5) defines it as the units of work accomplished for the units of labour expended. There are many definitions of productivity; however, the underlying concept is the same, i.e. the ratio of output to critical input, holding other inputs constant. Olomolaiye *et al* (1998, p3) suggest that no matter which definition is used, it should bring out three distinct concepts which are:

(i) the capacity to produce,
(ii) effectiveness of productive effort, and
(iii) the production per unit of effort.

### *Single factor productivity*

Single factor productivity is a measure of output to a single measure of input (Schreyer 2001, p12). It can be calculated as labour or capital productivity, that is, net or gross output per unit of the respective input.

*Multifactor productivity (MFP)*
MFP relates a measure of output to a bundle of inputs. It helps disentangle the direct growth contributions of labour, capital, intermediate inputs and technology (Schreyer 2001, p20). Total factor productivity (TFP) is a type of Multi Factor Productivity (MFP). The distinction between the two is that the latter includes the joint productivity of labour, capital and intermediate inputs, and the former considers the joint productivity of labour and capital only (Mahadevan 2004, p6). Chau and Walker (1990) note that MFP is often used interchangeably with TFP.

## MEASURING TOTAL FACTOR PRODUCTIVITY

According to Mahadevan (2004, p5), TFP can be calculated as:

$$Q/(aL+bK) \qquad [1]$$

Q is value added output, L is labour input, K is capital input and a and b are weights given by input shares. Chau and Walker (1988) measure TFP of the Hong Kong construction industry indirectly through construction cost, price indices and other statistics, including value share of individual inputs, labour cost index, material cost index, public sector tender price index, private sector price index and average book profit margin of the construction industry. This approach can be applied to calculate value added TFP (VATFP) by the same set of data used to calculate TFP. According to Chau (1993), the difference between VATFP and TFP is that in the former approach, intermediate inputs are subtracted from both the input and output side.

## DEFINITION OF THE PRODUCTION FUNCTION

Bumas (1999, p119) defines the production function as a function which relates the maximum rate of production, Q, to the employment of the factors of production – labour, L, and capital, K – at a given level of technology, T:

$$Q = f(T; L, K) \qquad [2]$$

A production function indicates the outputs that can be obtained from various amounts and combinations of factor inputs. In particular it shows the maximum possible amount of output that can be produced per unit of time with all combinations of factor inputs, given current factor endowments and the state of available technology.

## COBB-DOUGLAS PRODUCTION FUNCTION

The most common production function used in empirical research is the Cobb-Douglas Production Function because it is simple to estimate and is consistent with the economic theory of production (Lin, 2002). It was first developed by Cobb and Douglas (1928). The production function is of the basic form:

$$Q = A\, L^{\alpha} K^{\beta} \qquad [3]$$

Q is the real production and L and K are the amounts of labour and capital employed in producing it. The exponents $\alpha$ and $\beta$ are parameters representing the elasticity of output due to labour and the elasticity of output due to capital respectively. According to Bairam ed (1998, p18), A is a time dependent 'scale parameter' which denotes a technological progress variable. One important characteristic of a Cobb-Douglas Production Function is its ability to reflect factor intensity of a firm or an industry. Mahadevan (2004) estimates the capital and labour shares of Hong Kong's manufacturing industry by means of a Cobb-Douglas Production Function. The coefficients (i.e. the exponents $\alpha$ and $\beta$ in [3]) of the independent variables can show which production factor is more intensive. For example, if the coefficient of labour is larger than that of capital, according to the definition of factor intensity, the firm or the industry is labour intensive as labour is utilized in a larger proportion than capital.

TFP can help in formulating strategies because it reflects information like efficiency and technical change, so it is used in this study rather than Labour productivity which is too narrowly defined to be of use. Therefore, for the purposes of this study, which are the determination of labour-intensiveness of Hong Kong's construction industry and the evaluation of the industry's productivity, the Cobb-Douglas Production Function will be good enough.

## ESTIMATION OF THE PRODUCTION FUNCTION

The production function was calculated from government data on construction output and the adjusted coefficient of determination was 0.92 indicating that 92% of the variations in construction output can be explained by the independent variables in the production function; thus this functional form is a good fit. The F and t-statistics indicate that all the empirical results are significant, the independent variables' coefficients are statistically significant at the 95% confidence level. Thus, Hong Kong construction industry's production function can be written as:

$$\ln Q = 0 + 0.17 \ln K + 1.27 \ln L \quad [4]$$

Taking the antilogarithms of Equation [4] to revert to the original form of the Cobb-Douglas production function gives:

$$Q = K^{0.17} L^{1.27} \quad [5]$$

Thus to increase construction output it is necessary to increase inputs of capital resources and labour, holding the technological level of the industry constant. Therefore, the variables ln K (capital) and ln L (labour) have positive coefficients (thus positive indices for K and L in the production function), which means when capital inputs and/or labour inputs increase, construction output will increase too.

The magnitudes of the coefficients also indicate the significance of the inputs in the industry. From the industry's production function, labour input has a larger coefficient than that of capital input, which means labour has a higher input share and the larger magnitude implies labour inputs have greater influence on construction output. This confirms that the construction industry in Hong Kong is labour-intensive as the equation indicates that varying the amount of labour to control the output, rather than varying the amount of capital stock, will have the largest effect.

When both capital input and labour input are increased by m, then output will become:

$$Q' = (Km)^{0.17}(Lm)^{1.27} = m^{(0.17+1.27)}K^{0.17}L^{1.27} = m^{1.44}Q$$
where $m>1$ [6]

Obviously, an increase in inputs will lead to a more than proportionate increase in output. The sum of elasticity of inputs ( $\alpha+\beta$ ) is greater than 1. For a normal Cobb-Douglas Production Function, the sum of elasticity of inputs should be equal to 1 with constant returns to scale. Hence, the production function obtained exhibits increasing returns of scale. In this case, if fewer than h units are constructed, the unit price will be higher than that of exactly h units. This coincides with the current situation at firm-level that construction companies, including consultants and contractors, tend to pursue more jobs and produce more products (outputs), in order to achieve lower average cost per unit product. This can be done by sharing resources such as plant and machinery, personnel and materials, as well as spreading overheads over a large number of projects. Of course, another purpose of such action is to maintain cash flow for the company.

## PARAMETRIC ESTIMATIONS OF VALUE ADDED GROWTH AND VATFP

If the construction industry is really labour-intensive, then is its productivity declining as postulated by researchers? Value added construction output grew from 1985-1996 reflecting the boom in the run up to handover of sovereignty, but it dropped after 1997 (particularly after the Asian Financial Crisis). This fall can be explained by two reasons: (i) in the private sector, Hong Kong was facing recession and the property market hit a trough, so less building and construction works were carried out and (ii) major infrastructure projects like the Hong Kong International Airport and Tsing Ma Bridge had been completed. As a result, both capital and labour input growth fell in this period.

Except for the period 1985-1987, VATFP growth has remained positive over time. Since VATFP growth reflects the combined effects of disembodied technical change, economies of scale, efficiency change, variations in capacity utilization and measurement errors (Schreyer 2001, p16), this indicates that the construction industry has been able to sustain a degree of productivity improvement through improvements in the performance of labour, better management and organizational change (which are classed as disembodied technical changes by Schreyer (2001, p20)), as well as gaining in technical efficiency. Thus, the proposition: low productivity in the construction industry is due to poorly skilled labour and poor project management, can be rebutted.

It is interesting to observe a downtrend of VATFP growth in the period 1994-1996, when the industry was booming. It might be expected that contractors would increase their productivity so they could build faster and build more in order to maximize their profits but, contrary to this view, VATFP growth reduced in this period. This downtrend during the construction industry boom can be explained as follows:

(i) The speed of construction was increased at the expense of a decrease in productivity, as there were overloading problems of workers on sites, lack of control of material wastage and efficient use of resources due to poor project management.

(ii) The capacity of the construction industry was not sufficient to cope with the sudden extra demand for services and products, so less productive resources were attracted to the industry.

Overall, VATFP growth shows that there have been some improvements in productivity resulting from disembodied technical changes; however, it has proved difficult to substitute capital for labour in the Hong Kong construction industry. Therefore, the labour-intensive nature of the industry is confirmed.

## MEASURING THE VALUE OF INNOVATION AND TECHNOLOGY INVESTMENTS

An economic evaluation model proposed by Warszawski (1999) is adopted in this study. For simplicity, the term "robot" in this section means any new construction technologies which are more advanced and productive (but which may not be a pure robot in the everyday sense of the word).

Ganesan *et al* (1996) identify several labour-intensive construction activities and suggest they could be replaced by more advanced construction methods. Warszawski and Navon (1998) investigate the applications of robots in different areas of construction. Four construction activities with robot applications which are currently employed in other countries are selected for this study:

A. Concrete placing,
B. Pile driving,
C. Painting, and
D. Placement of boards.

These four types of construction work were examined in order to determine the break-even value for capital investments compared with the use of conventional methods. Based on these results it was determined that all of the technological investments could improve productivity but, surprisingly, there was not necessarily a reduction in the need for labour in all instances. The results of the analyses are shown in Table 1.

It can be seen that for each of the four types of construction work there is a minimum number of hours per job necessary to break even compared to conventional, labour intensive methods. It can also be seen that other tangible benefits as well as cost savings can accrue. For instance, the concrete pumping system can bring improvements in safety but there are concomitant changes which have to be made in concrete mix design. The use of SGPD improves production rates by up to seven times that of conventional methods and so is a major bonus, so to speak, for the investor. In addition, the system is much more accurate when driving piles and so this adds benefits and value to the project. The painting systems require extensive amounts of work in order to be viable in terms of break even and it was found that the HVLP system was in fact better than the LVHP system in that there was far less wastage. Hence, technological innovations must be assessed not solely in terms of labour-saving but also in terms of quality, cost and wastage. The manipulator must work for a minimum of 900 and hours per annum in order to accrue benefits but it should be able to improve the safety environment on the site enormously.

Saving in terms of the insurance premiums and direct and indirect accident costs, which are a major component of site costs, have been accounted for. These somewhat intangible benefits have not been included in this particular analysis but it is obvious that the larger contractors are more able to take advantage of such systems in that their investments are amortised in a different way and their cashflow requirements are different.

## *Table 1: The impacts of advanced technologies on different types of construction work*

| | Construction work | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (A) Concrete placing | | (B) Sheet pile driving | | (C) Painting | | (D) Board placing | |
| | Conventional – crane & skip | Advanced - pumping | Conventional – vibratory hammer | Advanced - SGPD | Conventional - brushing | Advanced – (a) painting robot & (b) HVLP | Conventional – manual | Advanced – light weight manipulator |
| Price or rent of advanced equipment | / | **HKD516.6/hr** | / | **HKD486.3/hr** | / | **(a) HKD661,300<br>(b) HKD23.7/hr** | / | **HKD523,320** |
| Minimum robot working hour to achieve breakeven price or rent to user | / | **14hr/job** | / | **4hr/job** | / | **(a) 700hr/yr<br>(b) Not applicable** | / | **500hr/yr** |
| Construction cost (HKD) | **438,422.1** | **425,249.9** | **811,604.6** | **571,392.6** | 5,257.3 | **(a) 4,925.6<br>(b) 2,516.3** | **6,959.8 (ceiling height 3m)** | **5,803.1 (ceiling height 3m)** |
| Cost per unit work (in HKD) | **876.8/$m^3$** | **850.5/$m^3$** | **1,746.3/$m^2$** | **1,229.9/$m^2$** | **26.3/$m^2$** | **(a) 24.6/$m^2$<br>(b) 12.58/$m^2$** | **348.0/$m^2$** | **290.2/$m^2$** |
| Cost reduction compared with conventional method (%) | **0%** | **3.0%** | **0%** | **29.6% (in total labour and plant cost)** | **0%** | **(a) 6.3%<br>(b) 48.9%** | **0%** | **16.6%** |
| Advantages of using advanced methods: | | | | | | | | |
| Reduce labour use | / | **No** | / | **Yes** | / | **(a) Yes<br>(b) No** | / | **Yes** |
| Increase productivity | / | **Yes** | / | **Yes** | / | **(a) Yes<br>(b) Yes** | / | **Yes** |
| Reduce wastage | / | **No** | / | **Yes. Less waste created due to errors** | / | **(a) Worse than conventional method<br>(b) Worse than conventional method** | / | **No** |
| Enhance safety | / | **Yes** | / | **No** | / | **(a) Yes<br>(b) No** | / | **Yes** |
| Improve quality | / | **No** | / | **Yes** | / | **(a) No<br>(b) No** | / | **No** |

## CONCLUSIONS

In the Phase I analysis, VATFP growth shows that construction productivity has been enhanced by disembodied technical changes. Nevertheless, the Hong Kong construction industry is still labour-intensive and labour is not readily replaced by capital investment in technology, in fact quite the reverse it is often substituted itself for capital such as plant and machinery in order to control production and costs. Considering the results from the Phase II analysis together with those from Phase I, it is observed that even though new technologies can provide cost reduction and many additional benefits, few companies adopt them. In fact, construction company owners still prefer to use labour to control output. Why are they reluctant to use new technologies? The breakeven values of advanced construction methods from the Phase II analysis gives some clues. Although the results show that the advanced methods (except concrete pumping) do not require very extensive employment for the user to attain a positive return, this is only an analysis based on existing data and market prices; no macroeconomic and financial management factors have been considered.

Hong Kong's construction industry is currently in recession and there is a shortage of large-scale construction projects and programmes of projects. The breakeven prices of the construction robots are in the order of hundreds of thousands of dollars and so, even though robots are economically feasible, investing in such robots will greatly reduce the liquidity of many construction firms. If they borrow money for such investments there is a high risk involved, and so many small and medium sized construction firms refuse to invest in robots. Obviously, only those firms with strong financial backing and other resources can make such technology investments. Large firms can enjoy economies of scale by introducing advanced technologies as they can lower the average cost of products by producing more with productive machines or methods. In fact, there are only a few large construction firms in Hong Kong, and most local construction firms are only medium or small sized and so unable to afford the transaction costs associated in developing advanced construction methods. The normal way for these medium and small sized construction firms to control output is to regulate the utilization of labour because redeployment of labour carries lower transaction costs in Hong Kong. When market demand for construction products increases, they employ more labour; they simply employ less people when demand is low. However, if these firms own plant and machinery, they will not be able to enjoy such flexibility. Thus, problems arise when the market is in recession, when firms have difficulties in maintaining cash flow. It will be difficult to sell job-specific plant and machinery and they will depreciate even whilst they are idling.

Renting plant and machinery from specialist suppliers or larger contractors seems to be a feasible way for medium or small sized firms to make use of such technologies as this avoids heavy capital investment. However, special training has to be provided to professionals and site workers to equip them with the necessary knowledge to use the machines. It takes significant time and effort to learn a new type of technology, especially when the technology is complicated; this learning is another transaction cost. Most decision-makers in medium or small sized firms are risk-averse because of limitations on capital and human resources so spending money and time on training their employees is risky, not least because of the transient nature of employment in the industry. There is no guarantee that employees will be more productive with first adoption of new technologies. This learning cost is just too large for many of the decision makers to bear.

Therefore, the spread of new technologies in the Hong Kong construction industry is driven by large construction firms. Smaller firms have less interest in developing or using new technologies because of their limitations in terms of capital and human resources and the inherent need to be able to manage their workforce flexibly and so still prefer to use labour as their major input. As a consequence, new technology adoption has to be driven by other forces, such as the government. Incentives need to be provided for the industry to invest in such technologies and there needs to be some form of guarantee of continuing workload to ensure that such changes are permanent, and not just a temporary move to enjoy the incentives offered.

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# Hong Kong Real Estate Agency Industry: Survey on Important Marketing Factors and Branding Attributes in light of Service Intangibility

Lai-san Kwok and Eileen Mary Hastings[1]

## ABSTRACT

The aim of the study is to investigate the attitude of real estate agency companies in Hong Kong towards marketing factors which drive the customers' service employment decision and attitude towards branding in light of service intangibility. Due to the nature of the real estate agency industry and service intangibility, it is found that personnel is one of the crucial factors which drive the customers' willingness to buy the service. Branding, on the other hand, being an indicator of service quality, can be a way of marketing real estate agency services. In establishment of a service brand, personalized service and service quality play an important role.

## KEYWORDS

Marketing Factors, Branding Attributes

## BACKGROUND OF THE STUDY

Real estate agency companies serve as middlemen between parties. They help the buyers and lessees to identify potential properties which suit their demand. On the other hand, they assist the developers, property owners or leasers to search for interested parties. The estate agents will perform all sorts of tasks including introducing a client, arranging viewing of a property, negotiating terms, arranging signing of Sales and Purchase Agreement and explaining the terms in the agreement etc. When transaction is closed, the estate agent is entitled to receive commissions. The commission is a kind of service charge.

The real estate agency companies serve to reduce transaction cost involved in property transaction, like finding interested parties, identifying potential property, conduct negotiation etc. They act as a bridge between supply and demand which facilitates the transaction. In January 2005, there were a total of 3166 registered estate agency shops and 8827 registered estate agents according to the statistic of Estate Agents Authority. Real estate agency is a highly competitive industry. In order to stand out in the market, one has to use various strategies so as to enjoy part of the market share. Marketing is one of the choices.

Appropriate marketing strategy enables the customers to know the competitive advantages of the real estate agency companies. It should be clarified that marketing is not purely advertisements and promotions. It is a process involves perception, understanding, stimulation and satisfaction of the target markets' demand.

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It channels the companies' resources to meet the demand. Therefore, marketing of real estate agency companies are not purely advertising the property available and persuade the customers to buy.

Marketing can channel the real estate agency services to meet the demand of the customers. However real estate agency is a service provision industry. It differs from goods like can of drink and set of computer. Real estate agency service is intangible in nature. It is difficult to compare the quality and price like what the customers did when they buy goods. It is hard for the customers to evaluate and compare something which is intangible. It is difficult to tell which real estate agency is better. This is not just the challenges faced by the customers, but the real estate agency themselves.

In this competitive industry, the real estate agency companies have to seek ways to attract customers. They have to make the customers know and "feel" that their services are better than that of their competitors. But intangibility of service makes marketing more difficult. The company, therefore, has to rely on some other tangible cues such as personnel, price, and facilities etc. to make service quality more easily assessable. By utilizing tangible cues, it will be easier to channel information to the customers and more importantly, to persuade the customers in service employment. As a result marketing becomes important for the real estate agency companies.

In marketing real estate agency service, benefits should be conferred to the customers. Benefits shall be conferred by some attributes which would affect the customers' choice.

Furthermore, branding exists in goods industry, for example there are popular fashion brand and food brand. Service brand is not new in other industry like banking and finance. In real estate agency industry, service brands do exist. When the customers heard of a service brand, they will immediately have a perception on the company and on the service as well. Service brand in fact serves to make intangible service tangible. It offers the real estate agency a market position. There are lots of factors contributing to a brand. All the branding attributes contribute to different extent in a brand. Branding attributes like expertise, company reputation and price etc. channel the benefits to the customers. These benefits drive the customers' decision. A brand gives meaning to an intangible service. Marketing tells the customers how customers should read the brand.

## SUMMARY OF FINDINGS

Literature search, questionnaires and interviews were used as the methodology for the study. Background information on marketing and branding was found from literature search. Questionnaires and interviews formed the source of information for the empirical study. Data on the ranking of set of attributes on marketing and branding were collected to achieve the aim of the study. Decimal scale point and weighting from Analytical Hierarchy Process would be used for analysis of data.

Two questionnaires were set. For the first set of questionnaire, 150 sets had been sent and 67 were returned. 26 respondents of the first questionnaire fell into the target group of the second questionnaire. Therefore, 26 invitation letters were sent to invite them for an interview. 13 respondents agreed to participate in the interview, but 5 interviews stopped after completing the first few questions.

Among respondents of Questionnaire 1, 33% and 39% of the respondents have specialized people responsible for marketing and a company logo respectively. The first three most important factors perceived by the respondents in affecting the customers' choice of service are "Personnel", "Location" and "Service quality". The three major sources of business of respondents are "Referral business", "cold calling or mailing" and "existing client". The three most frequently adopted communication channels are "advertisement in shops", "advertisement in newspaper" and "brochures".

Among interviewees of questionnaire 2, marketing and branding strategy is perceived to be very important to real estate agency companies. It is agreed among respondents that branding is a better indicator of service quality than price. The five most important branding attributes perceived by the practitioners are "personalized service", "quality level", "price", "expertise" and "reputation".

## DISCUSSION OF RESULT

Marketing is a process starting from the internal of company and then expands to reach the external market. Marketing is aiming at differentiating and communicating the service with the customers. Ultimately, it persuades the customer to buy the product. In the process, one need to identify the nature of product supplied, nature of the industry and competitive advantages of the company.

Marketing is important for all the real estate agency companies as it assists in matching the demand of customer with the supply of companies. By attaining equilibrium in demand and supply, the company can run in an efficient way. Marketing also assists in varying the demand curve and hence more of the service is demanded. Eventually, the company's turnover would increase. It helps in sustaining the development of the real estate agency companies at the same time. The importance of marketing is demonstrated in the Questionnaire 2. The average importance of marketing is 8.75 (maximum score = 10). Therefore the real estate companies believed marketing is essential for the success of company.

Real estate agency industry is highly competitive. In order to stand out in the market, marketing is required to build a market position. The market position assists in differentiating service supplied by one company from its competitors. It is strongly agreed among respondents that a clear market position allows more effective marketing. In order to establish a market position, attributes are needed. But before attributes are examined, it is necessary to consider the nature of the real estate agency industry.

It is argued by some scholars (like Lovelock, Patterson and Walker (2001)) that "People" of 7Ps is the most important attributes. This argument agreed with the findings. In the Questionnaire 1, "personnel" is regarded as the most important factors that the respondents perceived to affect the customer's choice on service employment. It is because real estate agency industry involves a great contact between people. The interactions between the agency personnel and customer are high. This nature of business further exaggerates the importance of personnel on business. No wonder Lovelock, Patterson and Walker (2001) write

*"It has been said that the person delivering the service is the services - that is, customer assessment of quality are often based largely on how they assess the person with whom they are dealing."*

Apart from "people", "place" in 7Ps is also important for marketing. The study agreed with the statement as "location" is ranked the second by the respondents. But it is found that the interpretation of the word is not the same between the large scale company with more than 100 staffs and that small scale with less than 20 staffs though both companies perceive convenient location is of advantage to the business. However, for large scale company, convenient scale is aiming at serving customers all around the city or even the world. They are usually located in the central business district. On the contrary, due to the constraint of small scale companies, "location" is part of the channel strategy. It is aiming at serving the peoples around that area. Therefore, they are usually located in the shopping mall of residential area or industrial area.

"Physical evidence" is one of the important factor in 7Ps as it has a profound effect on the impressions customers form about the quality of the service they received. However, it is found in this study that "technology and facilities" as a kind of physical evidence is not very important as compare to other factors. It shows that "physical evidence" is not as important as other Ps and reputation in the Hong Kong real estate agency industry.

Apart from 7Ps, Zeithaml suggests in Dodds, Monroe and Grewal (1991)
*"External cues of price, brand name and store name are three cues that influence perceptions of product quality and value, and hence willingness to buy."*

Yet it is found in this study that brand name is more important than price. In Questionnaire 1, "reputation" has a higher ranking than "price" and in the Questionnaire 2, respondent perceived "brand name" as a better indicator of service quality than "price".

It is found that 39% of the respondents have company logos which fulfill the basic requirement branding. Branding is utilized in the real estate agency industry especially for some large scale company. Branded real estate agency company perceived branding strategy to be very important to their business marketing. It agreed with Carson and Ruston (1989)
*"A service has no physical appearance... It is usually base on creating an appropriate image for provider of service... This image can be viewed as brand image of the company."*

Real estate industry is a service provision industry. Therefore branding can assist in reducing the intangibility of service. This is generally agreed among respondents.

Customers are not buying a service brand. They buy benefits instead. Therefore branding must serve to communicate the benefits provided by the service to the customers. It is strongly agreed among respondents that a brand name can translates attributes into functional or emotional benefits. Therefore a real estate agency service brand should give a collected perception of benefits to the customer. Keller (1998) suggests that
*"Brands provide a shorthand device or means of simplification for their product decision."*

The respondents in this study strongly agreed this statement. Consumers simplify information process by forming subjective judgment or beliefs about brands. A brand's subjective judgments are the perceived positions of the brand in the perceptual product attributes space. Therefore, evaluation on the service benefits is based on the branding attributes communicated to the customers.

An effective way to make branding tangible is to use as many physical elements as possible e.g. employees, buildings, physical facilities etc. However it is found from the study that it is not the case for the Hong Kong real estate agency industry. Branding attributes which is physical in nature such as "technology" and "good customer service" are ranked lower than those intangible in nature like "quality" and "reputation". "Technology" and "good customer service" are served to support the service instead of being the core of branding. Respondents also agreed on this point as they perceived "service" as the most important marketing factor category. The core of the branding is "service". Therefore the service itself has to be of high quality and suit the need of customers. Otherwise marketing cannot achieve anything no matter how well the plan is. It is true for the real estate agency industry. Agency has to provide tailor made and high quality service to customers. Without these two branding attributes, a brand cannot last long. Additional premium can never be charged and reputation can never be built.

The resulted ranking of branding attributes can be read from another angle. The branding attributes which have higher ranks are, in reality, those having direct and easily observable benefits to the company, for example turnover and volume of transaction to the company. Moreover, these benefits can be identified by the customer and affecting their choice of service easily. For example, people would like to buy "expertise" service instead of "responsive" staff. High quality service is an important benefit to the customer which increase willingness to buy with no doubt. "Reputation" attract customer instead of long company history. As a result, high rank branding attributes is worth promoted. Even so it is built on top of low ranked attributes. High branding attributes are just like the building, while low ranked branding attributes are acting as a foundation which supports the building.

Promotion is another important step in marketing. Apart from advertisement in various media, large scale "branded" real estate agency companies adopted public relation as another important communication channels. The reason is of course due to resources constraint for agency of smaller scale. Public relation is a long term investment which helps to develop a long term relations with customer by reinforcing the company's brand in their mind.

After discussing about the attributes and communication channels, source of business for the real estate agency companies are to be discussed. From the study, it is found that "referral business" is the major source of business for real estate agency companies of different scale. This characteristic of the real estate agency industry implies that relationship between the company and the customers is very important. One can imagine if the serving process is not satisfactory, the customers will certainly not employ the service again. They, of course, will not recommend the company to others. Therefore, it is crucial to make the existing clients satisfied. But it is not enough. A relationship has to be built in order to get the referral business or repeated buying.

As mentioned by Lovelock, Patterson and Walker (2001)

*"Person delivering the service becomes inseparable from service as a trusting relationship between the client and service provider sometimes develops a large extent. The trusting relationship developed is essential in gaining customer satisfaction and loyalty."*

Therefore, the key for trusting relationship is "personnel". Referral business being the major source of business implies the importance of personnel in the real estate agency industry. Furthermore, it also implies the use of communication channels to promote the service may not be put in a very important position, especially for small scale company established for a long time.

## CONCLUSION

Hong Kong real estate agency is a highly competitive industry. One cannot deny the importance of marketing in this industry. Some real estate agency may have a marketing department, while some may have no knowledge on this area. But it is not arguable that they all have implemented marketing, though to different extent.

Further to previous discussion, there are a few points that the author would like to reiterate. First, real estate agency is a typical service provision. It encountered the same challenges as other service provision industry. Intangibility has to be solved in service marketing. In a service industry like real estate agency where high interactions between company personnel and the customer is required, personnel become the most important asset of the company. Moreover, it is found that referral business is the major source of business. It enlarges the effect of personnel on company business. The key to referral business is building a good relationship between the customers and personnel. Personnel reflect the service quality and are one of the crucial factors in driving customers' choice of service.

Second, it is found that "branded real estate agency" (as defined in this study) perceived branding strategy to be very important in marketing business. Branding simplify the customers' decision making process by translating the attributes into functional or emotional benefits. It is found in this study that branding is perceived to be a better indicator of service quality than price. Brands serve to indicate the service quality and more importantly, it enables the real estate agency to change a higher premium on the service as compare to other competitors. Therefore, branding is worth adopting marketing strategy for larger scale real estate agency companies. Branding can be a way to reduce the service intangibility in marketing.

Third, concerning the branding attributes. It is found that the branding attributes which occupied a higher rank is related directly to the core of the brand: service. For example, service quality is the attribute which directly driven the customers' decision making, while expertise are people who represent the service. Supporting attributes like technology are found to be less important. Therefore, in establishing a service brand, it is necessary to ensure the service itself meets the demand of the markets and with the support of non-core branding attributes. Furthermore, branding attributes which have high ranks are attributes which will have direct and easily observable benefits to the real estate agency companies.

Fourth, business operation and services offer to the customers are more or less of same nature in the real estate agency industry. It makes differentiation of intangible service provision even more difficult. Therefore, the focus of marketing real estate agency is not purely on the service itself, but on the corporate image. Marketing of real estate agency companies has an option of establishing a corporate brand. The corporate brand in fact serves the purpose of gaining a market position in the customers' mind. It tries to differentiate the companies from its competitors. The corporate brand can somehow provide an "understanding" or "guarantee" on the service quality.

Marketing is a process which matches the company resources with the customers' needs. Although it is found in this study that some marketing factors or branding attributes are important, however, it is noted that a company or a service brand cannot be successful without the support of non-core attributes. But of course, resources availability of the companies has to be considered.

In light of service intangibility, marketing is worth adopting for the real estate agency industry. Branding can actually be a way out in the competitive real estate agency services in light of service intangibility.

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# Preliminary Study on the Application of Computational Fluid Dynamics to Building Drainage System Design

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## ABSTRACT

The building drainage system is the oldest building service system. It conveys waste and soil water from an occupied building to an external disposal system and has a direct effect on the hygienic environment of a building. The improper design of the building drainage system may also cause pipe clogging, leakage, or the overflow of waste water. Traditionally, the drainage system is designed according to the most probable usage concept, which was developed from probability and steady hydraulic flow theories. These approaches have been used all over the world for more than 80 years. Since the outbreak of severe acute respiratory syndrome [SARS] in 2003, the community is no longer concerned only with the effectiveness of the drainage system but also with the possibility of it spreading viruses. A detailed investigation into the hydraulic flow behavior inside the drainage system has become a new trend of study in the field. This paper introduces a novel approach to the investigation of air and water flow patterns inside the drainage system by using the computational fluid dynamics (CFD) approach. The CFD simulation results can provide useful information for a detailed study of the fluid behavior of the building drainage system.

## KEYWORDS

Building Drainage, Computational Fluid Dynamics, Foam Flooding, Floor Drain, Multiphase Flow

## INTRODUCTION

The building drainage system design is the oldest in building services engineering. It is a basic system that is required for all occupied buildings. The controlled water and sanitation systems can be traced back 10,000 years (Swaffield and Galowin, 1992). Before the outbreak of SARS in March 2003, the drainage system was designed according to statutory requirements (Cap123I, 1997) and relevant design guidebooks (e.g. IoP (1988) and BSEN12056 (2000)). These guides generally govern the hydraulic performance of the drainage systems. However, the practical guides do not address the possible infection that is caused by contaminated droplets inside the building drainage system that are transported to the interiors of the lavatories via the dry water traps of the floor drains. Before 2003, the majority of people ignored the importance of filling the drainage system U-trap with water. In fact, floor drains may have only been filled with water overflow from other sanitary fitments (such as water closet cisterns and wash basins), which seldom occurred. People were unlikely to clean lavatory floors by pouring a bucket of water onto them. Floors were usually mopped and dried by

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natural ventilation. It was unlikely that the floor drain's U-trap was filled by people cleaning their homes.

SARS was first reported in November 2002, and appeared in Hong Kong in late February 2003. Initially, hospitals were the main sites of infection with health care workers and patients succumbing to SARS. Doctors at this stage said the virus could only be spread by coughing and sneezing. However, a cluster of SARS cases later broke out in March 2003 among residents who were living in Block E of Amoy Gardens, which was a large residential estate. Amoy Gardens housed approximately 20,000 residents in 19 33-storey towers. A detailed environmental study of Amoy Gardens was subsequently carried out by the Department of Health of the Hong Kong Special Administrative Region (HKSAR). It was reported that SARS may have been transmitted through the building sewage system to the indoor environment DoH (2003), which was confirmed by the environmental investigation team of the World Health Organization in May 2003 (WHO, 2003). Based on the pattern of infection at Amoy Gardens, it was determined that an asymptomatic SARS infection inside one domestic premise had spread to another premise via a common vertical drainage stack that was connected to the floor drains of the bathrooms or kitchens of the premises. The drying out of the water traps of the floor drains provided a free passage for the spread of SARS from one premise to another.

The drying of the water traps of the floor drains was not uncommon as the water traps may only have been filled by water from floor washing or the overflow from washbasins or sinks. Floor flushing was uncommon as most households were in the habit of cleaning their floors by mopping. The schematic diagram in Figure 1 illustrates the proposed transmission of the virus through the dry water traps of the floor drains. Fine water droplets are first created inside Bathroom A during the taking of a hot shower. The droplets become contaminated if the person who is taking the shower is infected with the virus. If the water

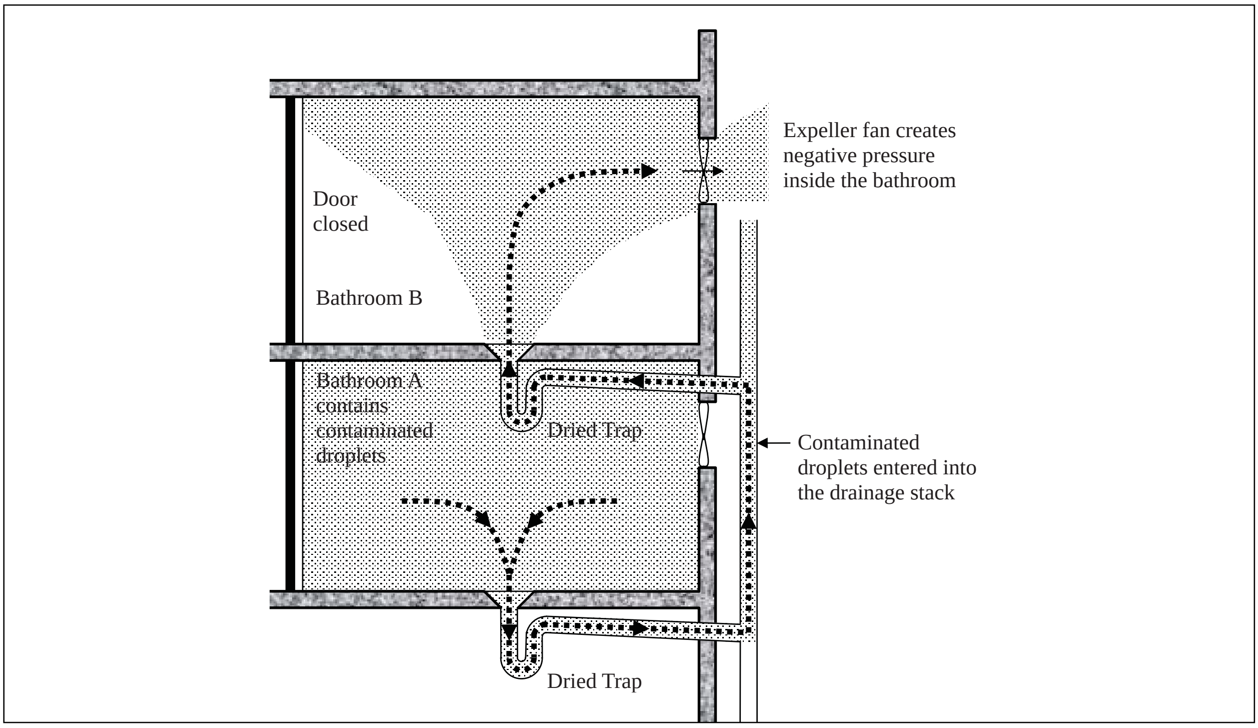



***Figure 1 The schematic diagram shows the transmission of the virus through the dried water traps of the floor drains inside the bathroom.***

traps of the floor drains of Bathroom A and B are dry, then the expeller fan of Bathroom B draws the contaminated droplets from the floor below to the interior of Bathroom B via the vertical drainage system. Occupants inside Bathroom B are subsequently infected. The infection may spread to other bathrooms if the water traps of the floor drains are dry.

## CURRENT RESEARCH

The possible cause of the infection via a vertical drainage stack has attracted the attention of the building industry to improve the existing design practice of the building drainage system. Since the SARS outbreak, the Buildings Department of the HKSAR has released a PNAP277 (2003) to all building professionals to guide the design of the drainage configuration that connects the floor drains and the vertical drainage stack. It focuses on preventing floor drain water traps from drying out and proposes that the waste water which is discharged from either washbasins or kitchen sinks be discharged into the inlet of the water traps of floor drains prior to its being disposed into the vertical drainage stack. The water seal of the floor drain's trap can then be replenished automatically by any operation of the waste fitment. This approach can effectively prevent the drying out of the water traps of the floor drains. Different designs of the drainage configurations have been developed by the building industry in Hong Kong. The Hong Kong Institution of Engineers and the Hong Kong Institute of Vocational Education have successfully developed an effective drainage configuration to prevent the drying out of the water trap (HKIE, 2003). The configuration is illustrated in Figure 2.

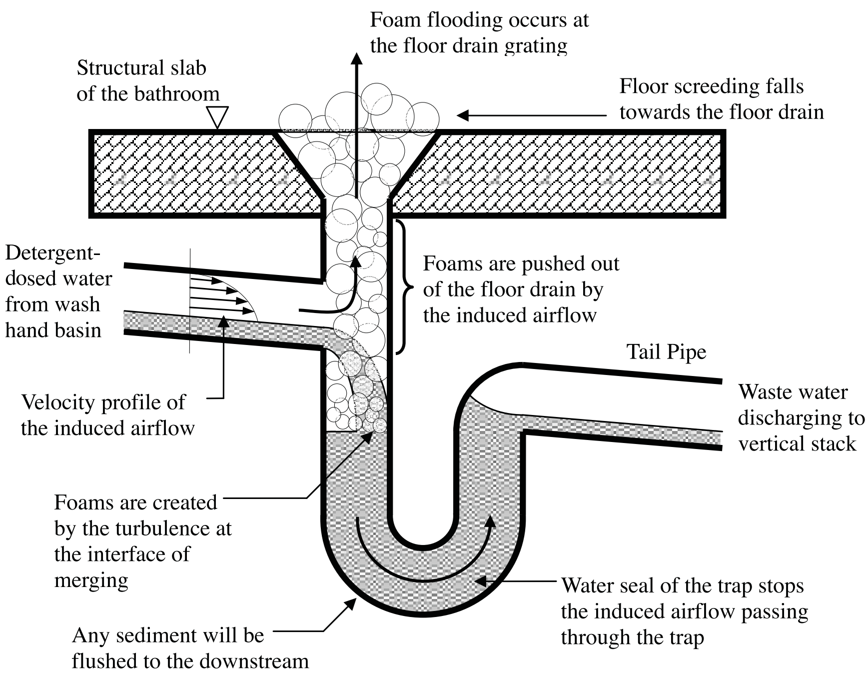



***Figure 2 The configuration of the proposed drainage connection. The ambient air is drawn by the free surface of the water that is flowing into the trap. As the air cannot penetrate through the water seal of the water trap, the entrained air can only escape from the trap into the atmosphere via the floor drain grating which pushes out the foam that is created at the interface of the water that merges with the water inside the water trap.***

It is shown that the water being discharged from the wash basin drives the air flow above the free surface of the water that is running in the horizontal drain. The air being driven into the inlet of the water trap is released into the atmosphere via the grating of the floor drain as it cannot pass through the water seal of the water trap. The blooming foam bubbles are pushed by the air flow out of the floor drain grating and flood onto the floor. This was verified by a series of full-scale drainage tests that were conducted by Yuen et al. (2003), of which the setup of the full-scale test rig is shown in Figure 3.

When draining detergent-dosed water, the foam flooded from the grating of the floor drain back onto the floor of the lavatory. This caused a slipping risk to occupants inside the bathroom.

***Figure 3  A full-scale drainage test rig. The drainage configuration that was proposed by the HKIE (2003) is shown at the upper storey of the setup. The Back-filling drainage configuration as proposed by Yuen et al. (2003) was installed at the lower storey of the test rig.***

In view of the foam flooding problem, a drainage configuration was proposed by Yuen et al. (2003). The configuration is shown in Figure 4. In this design, the discharge pipe that conveys wastewater that is being discharged from the wash basin is proposed to be connected at the tail pipe of the floor drain's water trap.

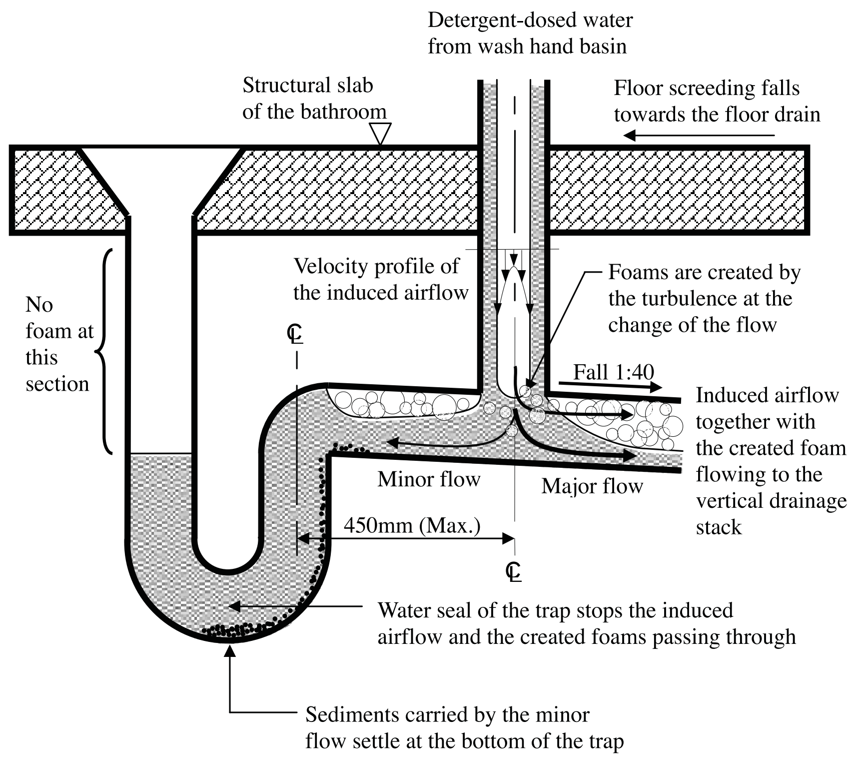



***Figure 4 The detailed configuration of the proposed drainage connection. Wastewater that is discharged from the wash basin is discharged into the inclined tail pipe. While the downstream flow is discharged into the vertical drainage stack, the minor upstream flow replenishes the water trap. In addition, foam is unable to penetrate the water seal of the water trap and foam flooding is prevented.***

Due to the tail pipe's gradient fall of the floor drain's water trap, the majority of the waste water that is discharged from the wash basin flows downstream towards the outlet pipe of the water trap. However, a minor flow in an upstream direction remains, which is employed to top up the water seal to prevent the water trap from drying out. However, the distance between the connection to the wash basin and the trap outlet is limited to not more than 450 mm when the outlet pipe of the water trap is laid to a 1:40 gradient fall. This restricts the flexibility of the drainage configuration in an actual installation. In addition, any sediment that is carried by the upstream minor flow to the water trap will settle inside the trap. Additional effort is required to clean the trap regularly and a wire mesh is recommended at the outlet of the wash basin.

## MOTIVATION

Over 20 different drainage configurations were proposed by different professionals in the building industry and were tested in the laboratory of the Department of Building and Construction at the City University of Hong Kong. The qualitative results of the experiments provided information for the modification of the drainage configuration so that the water trap of the floor trap can be replenished when using the connected waste fitment and the design of the configuration can include the prevention of foam flooding in the case of draining the detergent-dosed waste water. However, every change of design parameter (such as the length of the pipe, pipe inclination, and the design of the water trap) requires substantial demolition and installation work of the test setup. This not only increases the cost of the entire investigation but also lengthens the period of the experiment. In addition, the experimental results are qualitative in nature. Video recorders were employed to capture the visual performance of the drainage configurations. Such qualitative information is not sufficient to understand the flow behavior: the physical quantities of the fluids inside the drainage configuration (that is, air and water pressure distributions, velocities, and mixture fractions of air and water) are unknown from the qualitative results but are important to the design and development of the drainage configuration.

## COMPUTATIONAL FLUID DYNAMICS

Computational fluid dynamics (CFD) is a powerful tool to simulate the behavior of fluid flows. It has been widely applied to areas such as urban drainage (Ma et al., 2002), nuclear industry (Yadiaroglu, 2005), food engineering (Xia and Sun, 2003), and clinical applications (Mueller et al., 2002). The CFD modeling approach is able to achieve high spatial resolution. It uses the finite volume method (Patankar, 1980) and divides the region of interest into many small control volumes. For each local control volume, a set of local conservation laws for physical quantities - such as mass, momentum, energy, and species concentration - is employed as the governing equations of the computational domain. These conservation laws can be written in a general partial differential equation that is called the 'general transport equation' where $\varnothing$ is the variable that represents various physical quantities, $\rho$ is the mass density of the fluid, $U$ represents the velocity vector of the flow field, $\Gamma_\varnothing$ is the diffusivity of physical quantities $\varnothing$, and $S_\varnothing$ is the creation or destruction rate of $\varnothing$.

$$\frac{\partial \rho \varnothing}{\partial t} + div(\rho U \varnothing) - div(\Gamma_\varnothing grad \varnothing) = S_\varnothing$$

This set of governing equations is discretized all over the computational domain by using the finite volume method to form a set of linear algebraic equations. By solving the set of linear equations, the physical quantities and field information can be obtained in the computational domain. The basic architecture of a typical CFD model consists of 4 major components that are described below.

**Geometry Builder -** The geometry builder is used to input the geometry of the physical problem under investigation. In addition, the volume mesh is applied to the computational domain to divide it into many small control volumes.

**Pre-processor -** The user can specify the walls and conditions of the fluid flow into and out of the computational domain at the boundaries of the computational domain. The pre-processor sets up the complete computational problem for the computer to solve.

**Solver -** The solver is the kernel of the CFD model. It determines the physical quantities (such as velocity, mixture fraction, and temperature) of all of the small control volumes within the computational domain by solving a large set of partial differential equations that describe the interactions between the physical quantities of the small control volumes.

**Post-processor -** After solving the physical quantities of all of the small volumes, the data is further processed to be presented graphically by, for example, a colour contour or velocity plot, from which professionals can determine the fluid behavior that is predicted by the CFD simulation.

The CFD simulation in a partially filled conduit flow (such as a drainage pipe or river) involves computations not only for a liquid but also for the air above the free surface of the liquid. This kind of fluid flow involves more than one kind of fluid. It is called a multiphase-flow in which Volume-of-fluid (VOF) technique (Hirt and Nichols, 1981) was adopted to simulate the free surface flow inside the water trap.

## RESULTS

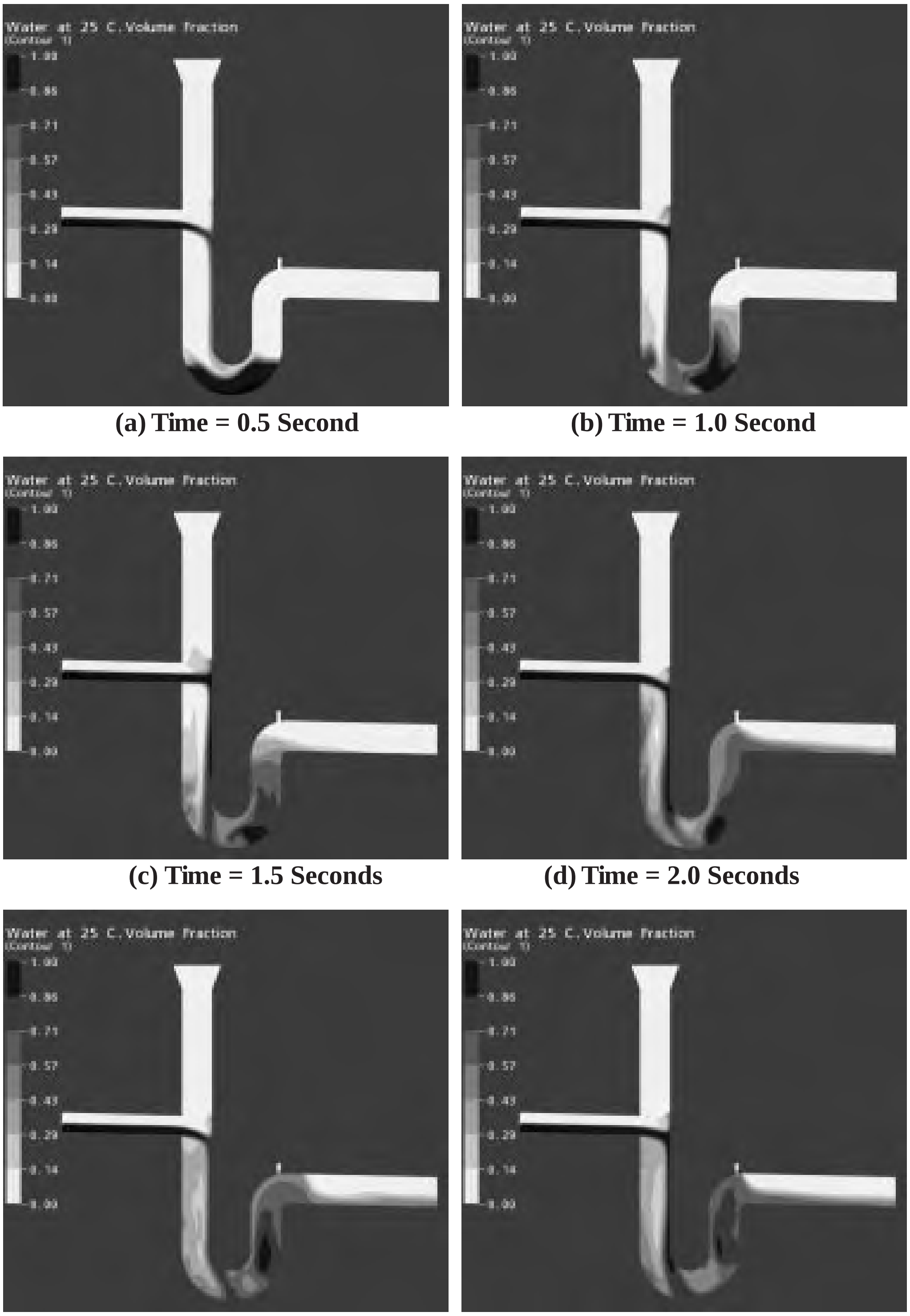
The dynamic behavior of fluids that are running through the drainage configuration that was developed by HKIE (2003) was simulated by the CFD. The configuration consists of a floor drain, a water trap, a back-inlet pipe, and a tail pipe. The computational model is shown in Figure 5. The back-inlet pipe conveys the waste water that is being discharged from the wash basin to replenish the water seal of the water trap prior to it being discharged into the tail pipe. The discharge rate was determined to be 0.15 liters/second (IoP, 1988) which is the nominal discharge rate of the water tap of the wash basin for which the size of the waste pipe is ⌀32 mm. The floor drain, the water trap, and the downstream pipe are ⌀50 mm.

The entry of the back-inlet pipe and the outlet of the tail pipe are in partial flow conditions for which the water depths were estimated by using hydraulic calculation that is based on the flow rate, pipe material, pipe size, and the gradient of the drainpipe. The extended region was provided at the inlet of the floor drain. Atmospheric pressure was patched to the boundaries of the extended region to simulate the natural release of the air from the floor drain to the atmosphere via the grating. Other boundary surfaces of the geometry were patched into solid walls. The initial condition was set to the scenario that the water seal is filled to a level just blocking the free passage of air flowing across the water trap. The CFD simulation was performed and the simulation results are shown in Figure 5. The simulation results show the dynamics of the water as it flows through the floor drain's water trap. The CFD simulation results also show that the ambient air that is drawn from the back-inlet pipe into the water trap may pass through the water trap initially but be blocked by the water seal eventually. That is, the air inside the bathroom in which the floor drain is situated may pass through the water trap at the beginning of the water trap replenishment. The study demonstrates that the CFD simulation can provide useful information for future modification of the water trap.

## CONCLUSION

The importance of the building drainage system to the hygienic environment of the building has been described. Different designs of the floor drain's water trap were developed to tackle the emptying of the water trap and the prevention of foam flooding. The designs were developed based only on the performance in the experiments without consideration of fluid pressures and velocities inside the water trap. This study demonstrates the application of CFD in the simulation of the fluid flow inside the floor drain's water trap. The CFD modeling is able to depict the physical quantities (such as velocities and pressures) of the fluid, which is very useful information for the industry to design an effective and safe water trap. In future, the CFD simulation will be verified by a full-scale experiment to confirm the practical application of this approach.

This preliminary study explores a new approach to the design of the building drainage system by employing CFD techniques. It is able to simulate the performance of the drainage configuration prior to actual erection and provides useful quantitative hydraulic information for a future engineering design. The advancement of the numerical computation may lead to a performance based building drainage design in the future.




(a) Time = 0.5 Second

(b) Time = 1.0 Second

(c) Time = 1.5 Seconds

(d) Time = 2.0 Seconds

(e) Time = 2.5 Seconds

(f) Time = 3.0 Seconds

***Figure 5 The CFD simulation of the dynamics of water and air flow inside a floor drain water trap. The contour plots indicate the mixture fractions of air and water that runs inside the water trap at different time intervals.***

## ACKNOWLEDGEMENT

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# Using Balanced Scorecard (BSC) Approach to Measure Performance of Partnering Projects

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## ABSTRACT

Partnering has been advocated as one of the plausible solutions for improving project performance. Notwithstanding a number of studies about partnering had been undertaken, few of them were contributing to the measure the performance of partnering projects in a holistic manner. This study seeks to investigate the use of Balanced Scorecard (BSC) approach to measure the partnering project performance in a holistic manner. Through an extensive literature review, 36 strategic objectives were identified as the metrics for measuring the partnering project performance. In accordance with their nature, these are further classified into four different perspectives namely: Benefits, Attitudes of project stakeholders, Attitudes enhancement process and Strategic learning & growth. The results of the questionnaire survey generally support the importance to measure the partnering project performance by these perspectives.

## KEYWORDS

Partnering, project performance, Balanced Scorecard

## INTRODUCTION

Effective coordination and non-adversarial collaboration among developers, professionals, specialist contractors and labours are critical to the successful project management. However, conflicts and disagreements are inevitable in the course of construction. They can easily escalate into disputes that are detrimental to relationships among contracting parties. Wong et al. (2002) indicated that adverse relationship among the collaborating parties in a construction project induced many consequential harmful effects such as declining profits margin, delay in completion, poor quality standard of works etc.

Many published researches advocated the use of partnering as one of the plausible solutions for improving working relationships and project performance (Weston & Gibson 1993, Ellison et al. 1995, Bennett and Jayes 1998, Bresnen and Marshall 2000). As such, implementing partnering in construction projects aims at establishing mechanism for better communication in order to prevent dispute or settle it effectively and economically without destroying the working harmony (Wong et al. 2002). In recent years, adopting partnering approach to deliver construction projects has become popular in

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many countries (Kadefors 2003). In Hong Kong, many projects from the public sector organizations like the Housing Authority, the Housing Society, the Mass Transit Railway Corporation and the Kowloon-Canton Railway Corporation are adopting partnering approach. Several successful partnering projects were also reported in previous literatures (Howlett 2002, Cheung et al. 2003).

Many researches about construction partnering focused on identifying critical success factors, models, barriers, and effective tools for implementation (Black et al. 2000, William et al. 2002, Cheung et al. 2003). However, little attention was given to the development of the model or conceptual framework for performance measurement (Pocock et al. 1997). As Li et al. (2000) emphasized, the performance indicators were not comprehensive enough in evaluating performance. Most traditional performance measurements merely focused on the result-orientated indicators, such as Return on Equity (ROE), Return on Asset (ROA) and the growth rate. Nevertheless, they failed to include the leading performance indicators, which are critical determinants leading to the success of the performance outcomes, into account (Atkinson & McCrindell 1997, Niven 2002). Previously reported studies identified that leading performance indicators should include productivity rate, process efficiency, process effectiveness, employee's capability of learning and growth (Atkinson & McCrindell 1997, Niven 2002). As pinpointed by Crane et al. (1999), the performance of strategic partnering in construction projects should be measured proactively using both financial & non-financial performance indicators. Evaluations on the project performance outcomes, the process of collaboration in the course of construction, as well as the relationships among partners are of equal importance (Crane et al. 1999).

The significance of using the Balanced Scorecard (BSC) approach in measuring project performance has previously been addressed in this connection (Amaratunga et al 2000, Landin and Nilson 2001). The BSC was developed by Professor Robert Kaplan and Professor Davis Norton in 1992. It has been described as an approach to evaluate whether the predetermined project goals are achieved in terms of 'financial, customer perspective, internal business processes, and learning and growth' aspects (Landin and Nilsson 2001, Mohamed 2003). Kagioglou et al. (2001) further described performance indicators with regard to the financial aspect as the 'lagging' indicators which report 'the results and decisions made in the past and therefore are of little use in improving current performance'. Performance indicators which relate to the customer perspective, internal business processes, and learning and growth aspects were described as the 'leading indicators' which help identifying mistakes and wrong strategies for project goals achievement (Kagioglou et al. 2001). Nevertheless, 'lagging indicators' are rarely found in the performance measurement systems developed in previous studies (Kagioglou et al. 2001). In this regard, Landin and Nilsson (2001) described the BSC approach to performance measurement system development ensures a balance between the 'leading' and 'lagging' performance indicators in the system (Landin and Nilsson 2001). As such, BSC is an approach for translating the organization's strategy into operational terms, aligning organization into strategy, making strategy everyone's job and making strategy a continual process, in which it can cope with what objectives the partnering intends to achieve (Atkinson & McCrindell 1997, Kaplan and Norton 1996, 2001). In construction, a number of performance measurement systems were developed by the BSC approach. For example, Landin and Nilsson (2001) based on the literature reviews and developed a framework for measurement construction quality in BSC approach. Likewise, Mohamed (2003) reviewed literatures and applied the BSC approach to develop the construction safety performance indicators. Based on the case studies in United Kingdom, Kagioglou et al. (2001) applied the

BSC approach to develop a conceptual framework for evaluating contractors' project performance. This study describes a holistic approach to develop a performance measurement system for partnering projects using Balanced Scorecard (BSC) as the conceptual framework.

The anticipated benefits of adopting the BSC approach in partnering project performance measurement include:

### *Achievement of common goals*

The BSC approach facilitates transformation of the common strategic objectives among partners to a set of standardized and measurable performance metrics. This facilitates partners' continual review of their performance in terms of their achievement of pre-determined strategic objectives in the course of construction.

### *Better Communication*

Using BSC approach to develop the performance measurement system ensures partners using a common set of metrics to gauge and interpret project performance. This facilitates each collaborating party to understand the strategic objectives and become explicit in discussing and improving performance through the information feedback channel.

### *Creativity and Innovation*

Strategy is not a static matter (Kaplan and Norton 1992). Instead, project strategies and working procedures require continuous revisions in order to suit the changing environment. BSC enables partners to focus on this issue by measuring project performance in terms of their creativity and innovation for performance enhancement.

### *Enhancement of partners' relationships*

Performance measurement system using BSC approach highlights the importance of partners' communication and working under communal goals and project strategies. This avoids arguments and disputes caused by misunderstanding among partners.

### *Incentivization and Motivation*

The BSC links the performance of strategy measures with the incentives and reward system. In this way, it motivates the partners to work as a team that works towards project success.

## BALANCED SCORECARD (BSC) APPROACH TO MEASURE STRATEGIC PARTNERING PROJECT PERFORMANCE

BSC emphasized a comprehensive and holistic approach in performance evaluation. BSC consists of both financial and non-financial performance metrics, which are developed in Financial, Customer, Internal Business Process and Learning and Growth perspectives (Kaplan and Norton 1992). Nevertheless, these measures are not stone casted. Indeed, BSC is no more than a template in which it can be customized for the specific elements of an organization or industry. The selection of the perspectives should be based on what are necessary to tell the story of the strategy and create a competitive advantage for the organizations. In this study, a set of performance measurement metrics are developed under the following four perspectives:

### *Benefits Perspective*

It refers to what constitute project success in the view of clients. The project success can be defined from the missions and visions mentioned from above, some of them are focused on client's objectives, which are completion on time and within budget, products completed in quality, safety and environmental standard and improved end users satisfaction. Relationship measure, like reduction of the number of disputes, is one of the leading objectives that lead to the lagging objectives mentioned. As project success focuses on the objectives which are more than simply financial success, the "financial perspective" should be replaced by the "Benefits" which encompasses many non-monetary or intangible benefits derived by partnering.

### *Attitudes of Project Stakeholders Perspective*

The second perspective refers to what attitudes should the project stakeholders have in order to achieve partnering success. This perspective focuses on the partnering alliance internally and is different from the external-oriented Customer perspective suggested by Kaplan and Norton. The difference is due to nature of the subject matter that needs to be measured. Kaplan and Norton's perspectives are derived from business operation whereby financial success of an organization is related to customer's value preposition since whether the customers buy their product or services directly affect the income of the organization. Moreover, this study is focuses on the performance of the partnering system in which the success of partnering is mainly related to the internal factors, such as the attitudes of the project stakeholders.

### *Attitudes Enhancement Process Perspective*

The third perspective refers to the processes or activities that should be organized in order to excel the attitudes of the project stakeholders in achieving the success of partnering. The implementation of this perspective should cover all the project stakeholders in the partnering alliances in order to align the partnering with the partnering alliances.

### *Strategic Learning and Growth's Perspective*

The last perspective refers to what the partner's skills and knowledge are. The company infrastructure should be changed in order to achieve the attitude enhancement process. This perspective differs from the "benefits" perspective as long-term strategic goal of the partnering alliance is directed. Such change requires cultural transformation which cannot be simply achieved through one-off project (i.e. project partnering).

A conceptual framework of developing a performance measurement system is thus developed as shown in Figure 1.

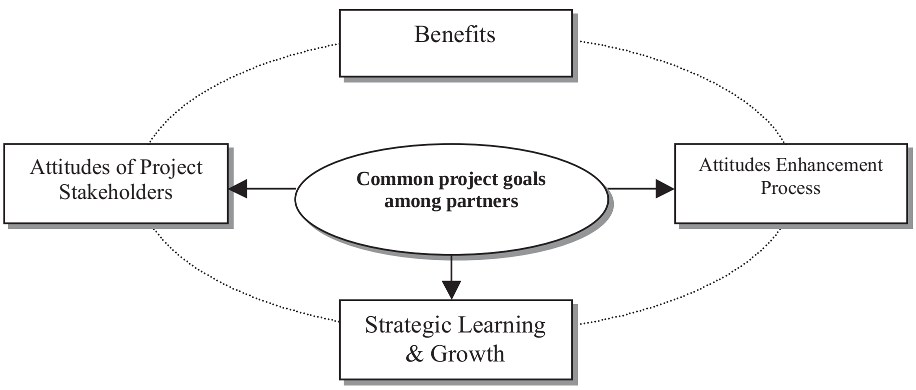


***Figure 1: Conceptual framework of developing a performance measurement system for partnering projects employing a BSC approach***

A holistic approach for performance measurement system development using the above framework starts with the identification of strategic objectives. In this aspect, previous literatures on this topic identified a number of strategic objectives to be achieved in the partnering projects. They are summarized under different perspectives as shown in Table 1.

**Table 1: Strategic objectives of partnering projects**

| Strategic objectives of partnering projects | Bresnen & Marshall (2000) | Black *et al.* (2000) | Cheng *et al.* (2001) | Crane *et al.* (1997) | Li *et al.* (2000) | DeVilbiss and Leonard (2000) | Cheung *et al.* (2003) | Naoum (2003) | Ng *et al.* (2002) |
|---|---|---|---|---|---|---|---|---|---|
| ***In Benefits Perspective:*** | | | | | | | | | |
| Reduce project cost | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| Reduce project time | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| Improve quality | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| Reduce disputes | | | | √ | | | √ | | |
| Improve end user satisfaction | | | | √ | | | √ | | |
| Improve safety issues | | | | | | | √ | | |
| Improve environmental issues | | | | | | | √ | | |
| ***In Attitudes of project stakeholders Perspective:*** | | | | | | | | | |
| Mutual Trust | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| Open communication | | √ | √ | √ | √ | | √ | | √ |
| Top level commitment | √ | √ | | √ | | | | | |
| Long term perspective | √ | | √ | | √ | | | √ | |
| Clear understanding of parties | | √ | | | | √ | | √ | √ |
| Creativity | | | √ | √ | √ | | | | |
| Select the right partners | √ | | | √ | | | | | |
| Leadership | | √ | | | | | | | √ |
| Establish clear roles & responsibilities | | √ | | | | | | | |
| Questioning attitude | | √ | | | | | | | |
| ***In Attitudes enhancement process Perspective:*** | | | | | | | | | |
| Issue elevation & problem resolution process | | | √ | √ | | √ | √ | √ | |
| Team building exercises | √ | | √ | √ | √ | | √ | √ | |
| Held regular partnering review meetings | | | | √ | | | √ | | |
| Promote using joint risk contractual arrangement | | | | | √ | | | √ | √ |
| Promote using value engineering exercise | √ | | | | √ | | | √ | |
| Emphasis on partnering experience & culture in selection of partners | √ | | | | | | √ | | |
| Social function | √ | | | | | | √ | | |
| Early involvement of subcontractors | √ | | | | | | | | |
| Establish IT system | √ | | | | | | | | |
| ***In Strategic learning & growth Perspective:*** | | | | | | | | | |
| Employee's financial incentive system | √ | | √ | √ | | | | √ | √ |
| Employee non-financial incentive system | √ | | √ | √ | | | | √ | √ |
| Employee's morale | | √ | | | | | √ | | |
| Improve leadership skills | | | √ | √ | | | | | |
| Employee's awareness of strategy | | | | √ | | | | | |
| Employee satisfaction | √ | √ | | | | | √ | | |
| Strategic skills | √ | | √ | | | | | | |
| Employee suggestion system | | | √ | | | | | | |
| Sufficiency of IT infrastructure | √ | | | | | | | | |
| IT application | √ | | | | | | | | |

## THE STUDY

This study seeks to investigate the use of Balanced Scorecard (BSC) to measure the performance of the construction partnering projects. To accomplish the research objectives, a postal questionnaire survey was conducted. The questionnaire has two parts; the first part consists of questions on demographic information such as working experiences, as well as particulars of the referenced project. The second part contains 40 questions. The first four questions were designed to measure the importance of measuring the strategic partnering performance by the four perspectives. The remaining questions are about the 36 strategic objectives as summarized in Table 1. Respondents were asked to provide their assessment on the importance of including the strategic objectives in their respective Performance Measurement Perspectives (PMPs) for measuring the strategic partnering performance. A seven-point Likert scale was used, with 7 as the most important and 1 as the least important.

To ensure the relevance of data, responses have to be collected for those who have had partnering experience. The names and the postal addresses of the respondents are obtained from the web pages of the local professional institutes as well as the Hong Kong Builder Directory. In order to safeguard the reliability of the received responses, respondents were asked to provide information on their experiences in partnering projects. If the respondents replied that they had not taken part in any partnering projects, their returned questionnaires were discarded. Therefore, the reliability of the survey results is assured.

## THE RESPONSE RATE

A total of 60 questionnaires were sent to private and public sector developers, consultant firms and contractor firms. A total of 25 replies were received, representing a 42.0% response rate. 56% of the respondents have over 10 years of working experience in the construction industry. As this research is largely exploratory, the relatively small number of responses is acceptable with the understanding that the findings are indicative only.

## DISCUSSION

### *Relative importance ranking of the PMPs*

The importance of the PMPs was ranked by their mean scores derived from all valid responses. If two or more PMPs happened to have the same score, the one with the lower standard deviation will be assigned the higher ranking. The results are shown in Table 2.

***Table 2: Relative importance ranking of the PMPs***

| PMP | Mean | Std. Deviation | Rank |
|---|---|---|---|
| Attitudes of project stakeholders | 6.5200 | .7703 | 1 |
| Benefits | 6.4400 | .6506 | 2 |
| Strategic learning & growth | 6.0000 | 1.2247 | 3 |
| Attitudes enhancement process | 5.6800 | 1.5199 | 4 |

The mean scores of the PMPs range from 5.68 to 6.52, which are greater than 3.5 on a 7-point likert scale. This indicates that the respondents generally agreed with the importance to include all these PMPs for measuring the strategic partnering performance. Attitudes of project stakeholder ranked highest among PMPs. The result is in line with Cheung et al. (2003) who recognized that the collaborative attitudes among partners are crucial for sustaining the long term relationship, and thus for partnering project success.

## *Relative importance ranking of the strategic objectives*

The importance of the strategic objectives was also ranked by their mean scores (Table 3 refers). The mean scores of the 36 strategic objectives are higher than 5. This indicates that they are all considered by the respondents as important strategic objectives to be included in their respective PMPs for measuring the strategic partnering performance.

***Table 3: Relative importance ranking of the strategic objectives***

| Performance Measurement Perspectives | Strategic Objectives | Mean | Std. Deviation | Rank |
|---|---|---|---|---|
| Benefits | Reduce disputes | 6.72 | 0.68 | 1 |
| | Reduce project cost | 6.52 | 0.71 | 2 |
| | Reduce project time | 6.32 | 0.90 | 3 |
| | Improve quality | 6.08 | 1.15 | 4 |
| | Improve safety issues | 5.60 | 1.00 | 5 |
| | Improve end user satisfaction | 5.48 | 1.12 | 6 |
| | Improve environmental issues | 5.00 | 1.61 | 7 |
| Attitudes of project stakeholders | Top level commitment | 6.64 | 0.64 | 1 |
| | Mutual Trust | 6.64 | 0.57 | 2 |
| | Open communication | 6.44 | 0.82 | 3 |
| | Select the right partners | 6.40 | 1.12 | 4 |
| | Leadership | 6.12 | 1.36 | 5 |
| | Long term perspective | 6.08 | 1.47 | 6 |
| | Establish clear roles & responsibilities | 6.20 | 0.96 | 7 |
| | Clear understanding of parties | 5.96 | 0.73 | 8 |
| | Questioning attitude | 5.44 | 1.16 | 9 |
| | Creativity | 5.40 | 1.58 | 10 |
| Attitudes enhancement process | Emphasis on partnering experience & culture in selection of partners | 5.96 | 1.14 | 1 |
| | Issue elevation & problem resolution process | 5.92 | 1.08 | 2 |
| | Team building exercises | 5.60 | 1.58 | 3 |
| | Held regular partnering review meetings | 5.76 | 1.01 | 4 |
| | Promote using joint risk contractual arrangement | 5.88 | 0.88 | 5 |
| | Promote using value engineering exercise | 5.40 | 1.55 | 6 |
| | Early involvement of subcontractors | 5.48 | 1.05 | 7 |
| | Social function | 5.24 | 1.45 | 8 |
| | Establish IT system | 5.08 | 1.50 | 9 |

| | | | | |
|---|---|---|---|---|
| Strategic learning & growth | Employee's morale | 6.28 | 0.89 | 1 |
| | Improve leadership skills | 6.12 | 1.05 | 2 |
| | Employee's awareness of strategy | 6.20 | 0.91 | 3 |
| | Employee satisfaction | 6.08 | 1.04 | 4 |
| | Strategic skills | 6.08 | 1.08 | 5 |
| | Employee's financial incentive system | 5.84 | 0.94 | 6 |
| | Employee suggestion system | 5.80 | 1.08 | 7 |
| | Employee non-financial incentive system | 5.48 | 1.26 | 8 |
| | Sufficiency of IT infrastructure | 5.20 | 1.55 | 9 |
| | IT application | 5.04 | 1.46 | 10 |

Nevertheless, the close range of the mean scores for the strategic objectives makes the results interpretation difficult and a small difference of their mean scores would cause a noticeable variation of the rankings. In this respect, grouping of strategic objectives into a smaller number of factors may prove useful. This is because the factors identified could better represent the underlying construct of the similar type of strategic objectives in a more concise and interpretable form (Dulaimi et al. 2002, Hair et al. 1998). In this connection, a principal component factor analysis (PCFA) was conducted by the use of the Statistical Package of Social Science (SPSS) - Version 11.0. In general, PCFA requires a sample size of at least five times greater than the number of variables (Hair et al. 1998). Nevertheless, in this study, only 25 samples were invited which cannot fulfill the above requirement. In this connection, the findings from the PCFA in this study can only be treated as a pilot study.

### *Grouping strategic objectives using PCFA*

In connection with exploring the factors of the strategic objectives for measuring the strategic partnering performance in perspective of Benefits, Attitudes of project stakeholders, Attitudes enhancement process and Strategic learning & growth, four PCFAs were conducted in this study. The suitability of the data set for the four PCFAs was firstly investigated. As shown in Table 4, the sample data is deemed to be adequate as supported by the results from the Bartlett Test of Spericity (all are significant at $p<0.00$) and the KMO Measure of Sampling Adequacy (all with values higher than the threshold of 0.50) (Sharma 1996, Dulaimi et al. 2002).

***Table 4: Adequacy of the data set for PCFAs***

| PCFA for factorizing strategic objectives in perspective of | Kaiser-Meyer-Olkin (KMO) Measure of Sample Adequacy | Bartlett Test of Spericity | | |
|---|---|---|---|---|
| | | Chi-square | Df | p value |
| Benefits | 0.548 | 104.371 | 21 | 0.000 |
| Attitudes of project stakeholders | 0.525 | 231.858 | 45 | 0.000 |
| Attitudes enhancement process | 0.724 | 207.615 | 36 | 0.000 |
| Strategic learning & growth | 0.675 | 221.063 | 45 | 0.000 |

Strategic objectives in these analyses are factorized under the Eigenvalue greater than 1 rule (Sharma 1996). The results of the PCFAs are shown in Table 5. The total variance explained in these results range from 70.89% to 83.24%. Thus, the factors grouped in these analyses are considered sufficient to represent the underlying construct of their respective strategic objectives (Wong et al. 2003, Wong and Cheung 2004). Considering the sample size of this survey, strategic objectives with factor loadings 0.75 or above were retained (Hair et al. 1998). They became the basis of the factors interpretation enlisted in the same table. From the PCFAs, the following findings are observed:

1. The strategic partnering performance in respective of Benefits is suggested to be measured in terms of the Long-term benefits and the Short-term benefits for the projects.

2. The strategic partnering performance in respect of project stakeholders' Attitudes is suggested to be measured in terms of the partners' levels of Open communication & Creativity, as well as of Mutual trust & commitment.

3. The strategic partnering performance in respect of Attitudes Enhancement Process is suggested to be measured in terms of the partners' effectiveness of introducing integration processes as well as joint risk contractual arrangement in their projects.

4. The strategic partnering performance in respect of Attitudes Enhancement Process is suggested to be measured in terms of the partners' awareness & implementation of the strategic skills, the IT infrastructure of their respective projects and the effectiveness of introducing the incentive schemes for encouraging partners' learning.

### Relationships among the identified factors

The PCFAs performed enable the suggestions of the major factors for measuring the strategic partnering performance in different perspectives. In addition, it is mindful that the importance of these factors for measuring the strategic partnering performance varies. In this connection, the relative importance of these major factors (as well as their respective PMSs) is compared. This is achieved by computing the factor score using the following formula:

$$F_i = \frac{\sum_{j=1}^{n} A_{ij}}{n}$$

Where *Fi* is the Factor score, *Aij* is the mean score of the jth strategic objective of factor i.

The factor score of each factor is the mean score of the strategic objectives grouped accordingly to the PCFA. For example, the factor score of Long term benefits (Factor 1 of the Benefits Perspective) is computed as follows:

Factor 1
= [6.08 (Improve quality) +
5.48 (Improve end user satisfaction)] / 2
= 5.78

Therefore, the factor scores are ranked in descending order as shown in Table 6.

Mutual trust and commitment is ranked as the most important factors in measuring the partnering strategic performance. The findings augmented previous studies which identified the establishment of mutual trust as the most important factors for partnering success (Wood and McDermott 1999, Kadefors 2004).

**Table 5: PCFAs results and factor interpretations**

| Perspective | Strategic Objective | Component | | |
|---|---|---|---|---|
| | | Factor 1 | Factor 2 | Factor 3 |
| **Benefits** (Total Variance Explained: 70.89%) | | **Long-term benefits** | **Short-term benefits** | |
| | Improve quality | .885 | | |
| | Improve end user satisfaction | .880 | | |
| | Improve environmental issues | .746 | | |
| | Improve safety issues | .701 | | |
| | Reduce project cost | | .932 | |
| | Reduce project time | | .852 | |
| | Reduce disputes | | .749 | |
| **Attitudes of project stakeholders** (Total Variance Explained: 72.82%) | | **Open communication & Creativity** | **Mutual trust & commitment** | |
| | Leadership | .901 | | |
| | Open Communication | .862 | | |
| | Creativity | .851 | | |
| | Clear understanding of parties | .847 | | |
| | Long term perspective | .791 | | |
| | Establish clearroles & responsibilities | .710 | | |
| | Questioning attitude | .639 | | |
| | Mutual trust | | .888 | |
| | Top level commitment | | .801 | |
| | Select the right partners | | .597 | |
| **Attitudes enhancement process** (Total Variance Explained: 80.74%) | | **Introducing integration processes** | **Introducing joint risk contractual arrangement** | |
| | Team building exercises | .953 | | |
| | Establish IT system | .924 | | |
| | Promote using value engineering exercises | .917 | | |
| | Social functions | .898 | | |
| | Emphasis on partnering experience & culture in selection of partners | .797 | | |
| | Held regular partnering review meetings | .765 | | |
| | Issue elevation & problem resolution process | .694 | | |
| | Early involvement of subcontractors | .661 | | |
| | Promote using joint risk contractual arrangement | | .965 | |
| **Strategic learning & growth** (Total Variance Explained: 83.24%) | | **Awareness & implementation of strategic skills** | **IT infrastructure of the partnering project** | **Effectiveness of introducing the incentive schemes** |
| | Strategic skills | .911 | | |
| | Employee satisfaction | .877 | | |
| | Employee's morale | .787 | | |
| | IT application | | .928 | |
| | Sufficiency of IT infrastructure | | .883 | |
| | Employee suggestion system | | .504 | |
| | Employee non-financial incentive system | | | -.944 |
| | Employee's financial incentive system | | | -.798 |
| | Improve leadership skill | | | -.783 |

***Table 6: The factor score ranking***

| Ranking | | Factor | Factor Score |
|---|---|---|---|
| 1 | Attitudes of project stakeholders | Mutual trust & commitment | 6.64 |
| 2 | Benefits | Short-term benefits | 6.59 |
| 3 | Strategic learning & growth | Awareness & implementation of strategic skills | 6.15 |
| 4 | Attitudes of project stakeholders | Open communication & Creativity | 6.00 |
| 5 | Attitudes enhancement process | Introducing joint risk contractual arrangement | 5.88 |
| 6 | Strategic learning & growth | Effectiveness of introducing the incentive schemes | 5.81 |
| 7 | Benefits | Long-term benefits | 5.78 |
| 8 | Attitudes enhancement process | Introducing integration processes | 5.51 |
| 9 | Strategic learning & growth | IT infrastructure of the partnering project | 5.12 |

Short-term benefits ranked second, while among the Introducing integration processes ranked eighth identified factors. As such, strategic objectives that are grouped in the factor 'Introducing integration processes' have long been identified as the leading performance indicators of the partnering projects (Landin and Nilson 2001, Rivan 2002). They were described as the performance drivers that lead to the achievement of the project performance (Landin and Nilson 2001, Rivan 2002). Conversely, strategic objectives that are grouped were known as the lag performance indicators which could merely be used for reporting the past project performance (Rivan 2002). These results are generally in line with many previous literatures claiming that stakeholders in the partnering projects often ignore the importance of including the leading performance indicators in the project performance measurement system (Amaratunga et al 2000, Landin and Nilson 2001).

## CONCLUSION

This study employs the Balanced Scorecard (BSC) methodology as a conceptual framework for measuring the partnering project performance in a holistic manner. An extensive review on literatures of both partnering and balanced scorecard was conducted. Accordingly, the perspectives (4 nos.) and the strategic objectives (36 nos.) were developed, followed by data analysis from a questionnaire survey.

25 valid responses were collected through the questionnaire survey in which the target sampling was the project stakeholders who experienced on partnering. The results presented in this study support the importance of using the identified strategic objectives (and their respective perspectives) to measure the partnering project performance. However, as the study can only be treated as exploratory due to the limitation of small sample size, further study with larger sample size should be conducted in order to provide a more statistically significant result.

Moreover, the identified strategic objectives, as well as the measurement perspectives may require refinements and revisions according to different nature and aims in different partnering projects. Notwithstanding, the proposed BSC approach for measuring partnering project performance integrates a variety of project stakeholders as a project team so that it makes everyone know the partnering strategy which can foster the achievement of common goals.

The results of this study are consistent with some previous findings that the result-orientated indicators were viewed as more important than those leading indicators for project performance measurement. There is no attempt to undervalue the role play by those lag performance indicators in facilitating partnering success. Nevertheless, as emphasized by Kaplan and Norton (1992), the designers of the BSC system, the imbalance weightings between lag and lead performance indicators in the performance measurement systems should be avoided, as this may hamper the identification of the correct path to achieve the project goals efficiently and effectively (Kaplan and Norton 1992).

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