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MODELLING HONG KONG RESIDENTIAL CONSTRUCTION DEMAND: EXPERIENCES GAINED AND THEIR IMPLICATIONS

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ABSTRACT: The construction industry has been a main pillar and serves as a regulator of the Hong Kong economy. Subsequently, the fluctuations in the level of construction output can induce significant rippling effects to the economy. The Asian Financial Crisis started in 1997 and the SARS outbreak in 2003 both introduced major challenges and impacts to the Hong Kong economy and consequently the construction sector. Such decline in the importance of construction has suggested a possible structural change in the sector. It is worth investigating the driving forces behind the construction demand and see if they have changed after the heavy impacts in the past decade. The above considerations have, therefore, been the motivation of the present study to model the Hong Kong residential construction demand through multiple regression technique which can identify the significant influencing factors to the residential demand. The residential construction is studied as it constitutes a significant portion of the total construction volume. The residential sector has great influence to the general economy of Hong Kong. It is found that the underlying market structure and the driving factors for Hong Kong residential demand before and after the Asian Economic Crisis and SARS outbreak are different, suggesting that the residential construction sector or even the larger construction industry may have undergone a major structural change as Hong Kong's economy approaches maturity. It is also observed that the past literatures on construction demand are mostly focusing on predicting demand under a stable economic environment. Hence, it is worth examining if it is possible to model during economic hardship when the residential sector fluctuate dramatically under different external impacts, such as the recent global financial tsunami.

Keywords: Residential demand, structural change, regression, economic environment

1. INTRODUCTION

The construction industry has undeniable contribution towards the Hong Kong economy over the years [1]. It served the role of propelling and regulating the economy growth in Hong Kong. Nevertheless, it is well recognised that construction remains a volatile industry which may fluctuate dramatically under the influence of the general economy [2][3]. Fluctuating construction outputs could trigger rippling effects to the general economy [4]. The Asian Financial Crisis in 1997 and the SARS outbreak in 2003 introduced major challenges and impacts to both the economy and the construction industry in Hong Kong. Folioing sudden collapse of the property market, the construction gross output measured in constant prices shrunk by almost one-third in 2007 as compared to its peak in 1998 and the construction level has not yet been able to climb back to the peak volume since then [5]. An inverted V-shaped relationship is observed in the construction share in total GDP to the GDP per capita for Hong Kong as suggested by Wong *et al.* [6], which is indeed more severe than the inverted U-shaped Bon curve [7] as shown in Figure 1 and beyond the observed empirical data evidence [8][9]. Such decline in the importance of construction sector over time has suggested a possible structural change in the sector, which unlike the cyclical fluctuations is irreversible, as part of the general development process of a country is moved from a less developed to an advanced economy.

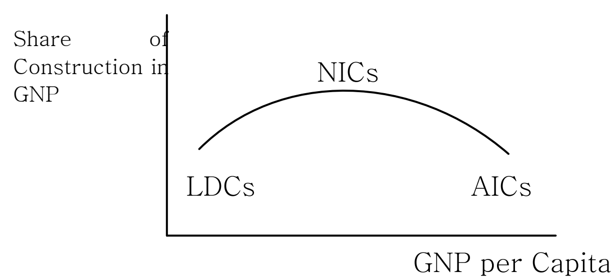

Figure 1. Share of Construction in GNP versus GNP per capita (*Source: Bon, 1992*)

It has been pointed out in various construction industry studies [10][11] that the construction industry should have forward looking plans and prepare themselves for potential future events and trends. In order to forecast into the future, it is worth investigating the driving forces behind the construction demand and see if they have changed over the several heavy impacts in the past decade. The residential construction is studied as it constitutes a significant portion of the total construction volume. The residential sector has an immense influence to the general economy of Hong Kong. The collapse of the property market triggered by the superfluous supply of residential properties propagated along the construction supply-chain and affected the general economy [12]. The above considerations have, therefore, been the motivation of the present study to model the Hong Kong residential construction demand through the multiple regression technique which can identify the significant influencing factors to the residential demand.

Regression is the most common and versatile causal technique applicable in many facets of business decision-making [13]. Regression technique has often been used to model for construction variables over the years. Killingsworth [14] adopted multiple regression analysis to model the US Industrial construction demand, while Tang *et al.* [15] projected for Thai construction demand using similar approach. Akintoye and Skitmore [16] developed multiple regression models for the UK's private construction demand. More recently, Goh [17] constructed regression models for sectoral construction demand in Singapore. However, there has not been any regression model developed for Hong Kong, especially after the Asia region being hit by the economic turmoil in 1997. It is worth investigating how regression model performs before and after such acute change of trend. On top of that, the past construction theories and regression studies have provided an abundant source for the driving forces towards the residential market. However, whether these significant driving factors at different geographical areas and different timeframes would apply to the Hong Kong scenario is another aspect worth exploring.

This paper starts by revealing the construction demand series in Hong Kong. The driving factors to the residential construction demand as suggested and tested in the past literature are summarised to construct our regression model. A step-by-step procedure for developing the multiple regression model for the Hong Kong residential construction demand is then explained. Comparison is made for the regression model before and after the collapse of residential market in 1998 to see if the driving forces for residential construction demand have changed. Further discussions and conclusions are presented at the end of the paper.

2. CONSTRUCTION DEMAND IN HONG KONG

It is difficult to precisely represent construction demand by the usual statistic parameters commonly published nowadays. The gross fixed capital formation measures the expenditure on new capital goods only and hence does not cover the expenditure on repair and maintenance work, which could be a significant sector in an advanced economy [7]. The gross output value of construction work is chosen to construct the forecasting models, as it includes the repair and maintenance works and at the same time serve as a reasonable proxy to the construction volume that clients wish to buy at the actually prevailing level of construction prices, thus indicating the construction demand [18]. Such statistic is available from the Hong Kong Census and Statistics Department (C&SD), and is published in quarterly basis from the first quarter (Q1) of 1983 in constant (2000) prices series. The overall and residential construction outputs are presented in Figure 2. From Figure 2, one can see the heavy proportion of residential construction outputs in the overall construction output among the other categories including commercial, industrial and repair and maintenance works.

3. DRIVING FACTORS FOR RESIDENTIAL CONSTRUCTION DEMAND

To construct the regression model, possible influencing factors (independent variables) are collected. These factors are recorded in quarterly interval, such that they can be paired up with the dependent variable of construction demand. A literature review was first carried out to summarise the factors being considered in previous residential demand forecast studies (Table 1).

Similar statistical parameters of Hong Kong were then collected from various government sources, which are more reliable and consistent. The regression model was tested with the following independent variables: GDP, unemployment rate, payroll index, private house price index, private house rent index, interest rate, tender price index, population growth rate and residential land sale. It should be noticed that as the constant prices series construction output was used to construct the regression model, consumer price indices is not required to reflect the general inflation.

4. REGRESSION MODEL

Before constructing the regression model, the lead / lag causal relationship between the construction demand and independent variables shall be established. It is believed that a decrease in interest rate may subsequently stimulate the property market (influencing factor leading dependent variable); or on the other hand an increase in property transaction would push up the interest rate (influencing factor lagging behind dependent variable). Such approach of specifying the lag distribution was considered sensible in economic theory study [19].

The relationships were first tested with the Pearson's coefficient and F-ratio of each independent variable and the dependent variable (i.e. the gross value of residential construction site output 1983Q1–2007Q2). Akintoye and Skitmore [15] suggested that a maximum of 8 quarters lag / lead period shall be considered for the influence of a change to be reflected on private sector construction demand, and our preliminary relationship testing with Pearson's coefficient and F-ratio reflected that there could be stronger correlation of independent and dependent variables of even up to 12 quarters of lag / lead period. Hui and Ho [20] suggested that it normally takes about 6-12 months for the building plan to be approved and 2-3 years construction period for the land to be converted into marketable properties. Hence, it is not unreasonable to suggest long a lag / lead length for the contributing factors.

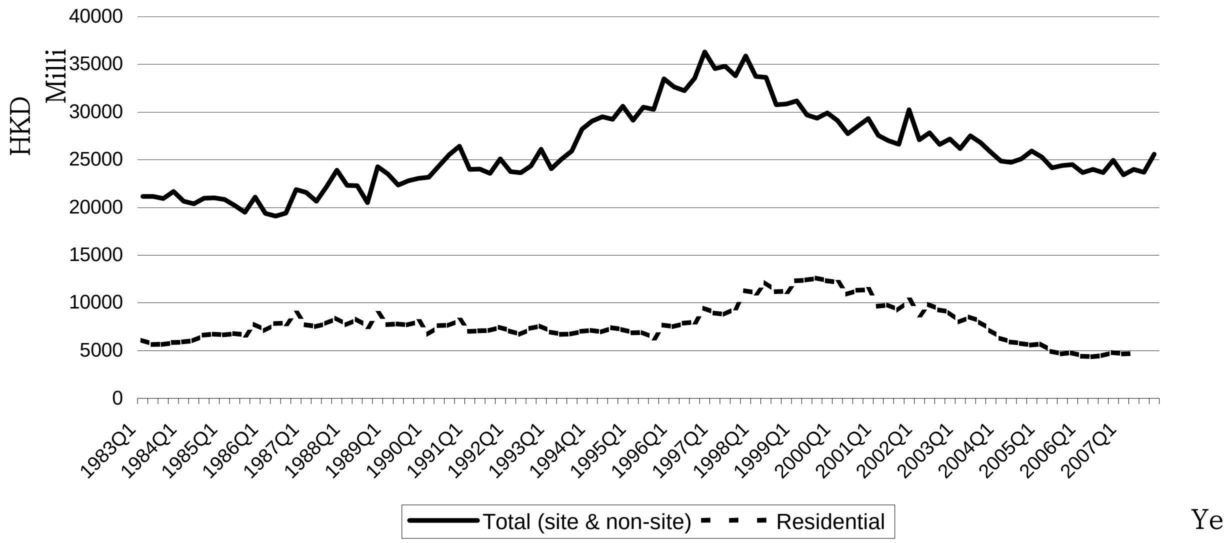

Figure 2. Quarterly gross value of total construction work and quarterly gross value of residential construction site work

Table 1. Factors affecting residential construction demand

Factor	*Considered by*	*Factor*	*Considered by*
Population structure	O, TA, G, TS, H	Income	O, H
GDP, GNP, national income	TA, A	Land supply	N
National / corporate savings	G	Housing loans	G, H
Interest rate	O, TA, A, TS, H	Property price	O, TS
Tender price index	A, G	Consumer price / spending	TA
Construction approval / completion / transaction	O, TA, G, TS	Employment / unemployment rate	A, G, H

Note: K=[14]; *O*=[23]; *TA*=[15]; *A*=[16]; *B*=[24]; *G*=[17]; *TS*=[25]; *H*=[3]; *N*=[21]

Having identified the appropriate lag and lead length of the independent variables, each of the independent variables with the lead and lag period of up to 12 quarters were stepwise selected with different transformation patterns including the original series, logarithm and square. The entry and exit probabilities of the stepwise procedure are set to 5% in a mixed manner. The R^2, overall F-ratio and t-ratio were used to compare with the transformed stepwise selection results along with the residual plot. The residue plot of a valid regression should exhibit random nature as well as constant variance interval to be consistent with the assumptions.

After obtaining the most significant representation of each independent variable with the appropriate lead / lag length, all the survived independent variables are again imported into the mixed stepwise selection procedure to obtain the final regression model. With a similar setting of 5% entry and exit probabilities, the survived independent variables after the selection were built into models with the dependent variable. However, the automatically selected model needs to be treated with caution. Although independent variables could correlate with justifiable relationships to the dependent variable individually, the combined independent variables while regressed against the dependent variable may not each have justifiable correlation coefficient, as reflected from the sign of coefficient of each independent variable. Hence, the stepwise selection process only identifies the significant independent variables, regardless of the change in correlation to the dependent variable once they are entered into the same model. Objective judgment is required to formulate a sound regression model. The residue plot of a valid regression model should exhibit random nature as well as constant variance interval to be consistent with the assumptions. Durbin-Watson test was applied to examine the autocorrelation. The procedures are summarised in Table 2.

Table 2. Procedures to construct forecasting regression model

Step	*Purpose*	*Model*			*Criteria*
1	Test for appropriate lagging / leading length of independent variables	Single regression	Dependent variable	Individual independent variable with different lagging / leading period	Pearson's coefficient: closer to 1 or –1 F-test: <5%
2	Identify significant lagging / leading period and transformation for each independent variable	Mixed stepwise	Dependent variable	Individual independent variable with different lagging / leading period and different transformations	Entry and exit probability: 5% R^2: closer to 1 t-test: <5% F-test: <5% Residual plot: constant variance, random pattern
3	Select significant independent variables	Mixed stepwise	Dependent variable	Selected independent variables from step 2	Entry and exit probability: 5% R^2: closer to 1 t-test: <5% F-test: <5% Residual plot: constant variance, random pattern
4	Final Multiple Regression Model	Multiple regression	Dependent variable	Selected independent variables from step 3	R^2: closer to 1 t-test: <5% F-test: <5% Coefficients: rational sign Residual plot: constant variance, random pattern 2 < DW test < 4

5. RESULTS

To compare the factors governing the residential construction demand, two regression models i.e. before and after the 1997 Asian Financial crisis were constructed. Krueger and Pischke [21] adopted such a comparative approach to analyse West German's labour markets before and after the unification. Here, the first regression model is built using the data from 1983Q1–1997Q4, before the sudden collapse of the residential market in 1998Q1 (Figure 3). After adjusting for the lag / lead factors, the final model is derived from 1986Q1–1997Q4 with a R^2 of 0.82, indicating that the model can account for over 80% of the residential construction demand movement. The Durbin-Watson stat has indicated a slight serial correlation in the data, but the inclusion of the autoregressive term to correct for such correlation is found insignificant. Hence, the final model is represented without the autoregressive term.

The data from 1983Q1–2004Q4 were used to construct the second regression model including as well the heavy impacts of 1997 Asian Financial Crisis and 2003 SARS outbreak (Figure 4). Similar lag / lead factor adjustment generates a final regression covering the time period from 1986Q1–2004Q4. The R^2 is 0.88, suggesting that almost 90% of the residential output movement has been modelled using the factors. The inclusion of the autoregressive term AR(1) has kept the Durbin-Watson stat at 2.28, an indication of free from serial correlation.

Comparing the contributing factors in the two regression models, we see a more diverse range of factors in the shorter regression model before the heavy impacts. The shorter regression model includes factors on tender price index, property rental indices, payroll indices and land supply. The later longer regression model which covers the post-impact period contains factors on tender price index and property price indices only.

The actual *vs*. fitted data series for the two models are presented in Figures 5 and 6 respectively. The regressed residential demand has fitted the actual data quite well throughout the entire series in Figure 5. However, for Figure 6, it can be observed that there is a slight sway away of the regressed data from the actual data series since 2003.

6. DISCUSSION

We have successfully capture the two different time period of the Hong Kong residential construction demand based on the possible driving factors proposed in previous similar studies and theories. The significant influencing factors identified for the time period 1986Q1–1997Q4 and 1986Q1–2004Q4 are different. In terms of R^2, the developed regression model fits the actual data better in the 1986Q1–2004Q4 model.

Tested was conducted to see if the 1986Q1–1997Q4 is being extended to 2004Q4 the original factors would affect the model performance in capturing the residential output behaviour. This suggests that the underlying driving factors and the market structure of generating the residential demand in Hong Kong may have changed after the several major impacts since 1998. Bon [7] advocated for an inevitable gradual decline in the importance of construction sector in any economy as the economy approaches maturity while Wong *et al.* [6] suggested a much more dramatic change (inverted V-shaped pattern) for Hong Kong. The Hong Kong residential construction sector, after being tested with the regression technique, has shown a rapid structural change in the market driving factors. It is possible that the overall construction industry is starting to follow the declining trend and the industry stakeholders and policy makers should start preparing for that.

Dependent Variable: RESIDENTIAL
Method: Least Squares

Sample (adjusted): 1986Q1 1997Q4
Included observations: 48 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Sq (Architectural Services Dept. TPI Lag 1)	0.001394	0.000398	3.498467	0.0011
Sq (Domestic Rental Indices lag 8)	-0.163709	0.020419	-8.017269	0.0000
Sq (Payroll Indices lead 3)	0.249426	0.083255	2.995942	0.0045
Sq (Residential Land Supply ($M) lead 3)	2.02E-06	7.36E-07	2.739343	0.0089
C	7460.407	218.6290	34.12359	0.0000

R-squared	0.818815	Mean dependent var	7697.473
Adjusted R-squared	0.801960	S.D. dependent var	898.2202
S.E. of regression	399.7231	Akaike info criterion	14.91775
Sum squared resid	6870477.	Schwarz criterion	15.11267
Log likelihood	-353.0261	F-statistic	48.58146
Durbin-Watson stat	1.782704	Prob(F-statistic)	0.000000

Figure 3. Multiple regression model of residential construction demand 1986Q1−1997Q4

Dependent Variable: RESIDENTIAL
Method: Least Squares

Sample: 1986Q1 2004Q4
Included observations: 76
Convergence achieved after 8 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Sq (L&B TPI lead 1)	0.001411	0.000386	3.652995	0.0005
Sq (Domestic Property Price lag 8)	-0.098814	0.030891	-3.198740	0.0021
Sq (Domestic Property Price lead 9)	0.102518	0.039377	2.603500	0.0113
Sq (Domestic Property Price lag 3)	-0.070512	0.032044	-2.200460	0.0311
C	6897.181	489.1365	14.10073	0.0000
AR(1)	0.601362	0.109428	5.495490	0.0000

R-squared	0.875454	Mean dependent var	8440.519
Adjusted R-squared	0.866558	S.D. dependent var	1783.488
S.E. of regression	651.5035	Akaike info criterion	15.87210
Sum squared resid	29711979	Schwarz criterion	16.05610
Log likelihood	-597.1398	F-statistic	98.40822
Durbin-Watson stat	2.280082	Prob(F-statistic)	0.000000
Inverted AR Roots	.60		

Figure 4. Multiple regression model of residential construction demand 1986Q1−2004Q4

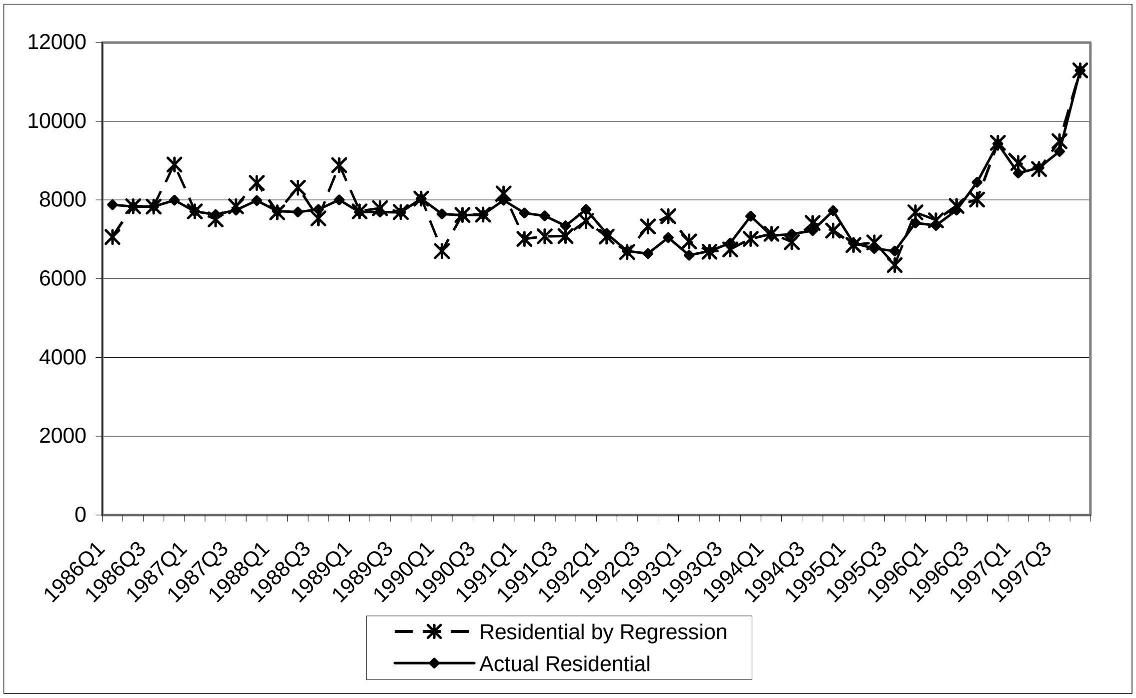

Figure 5. Regressed and actual residential construction demand 1986Q1−1997Q4

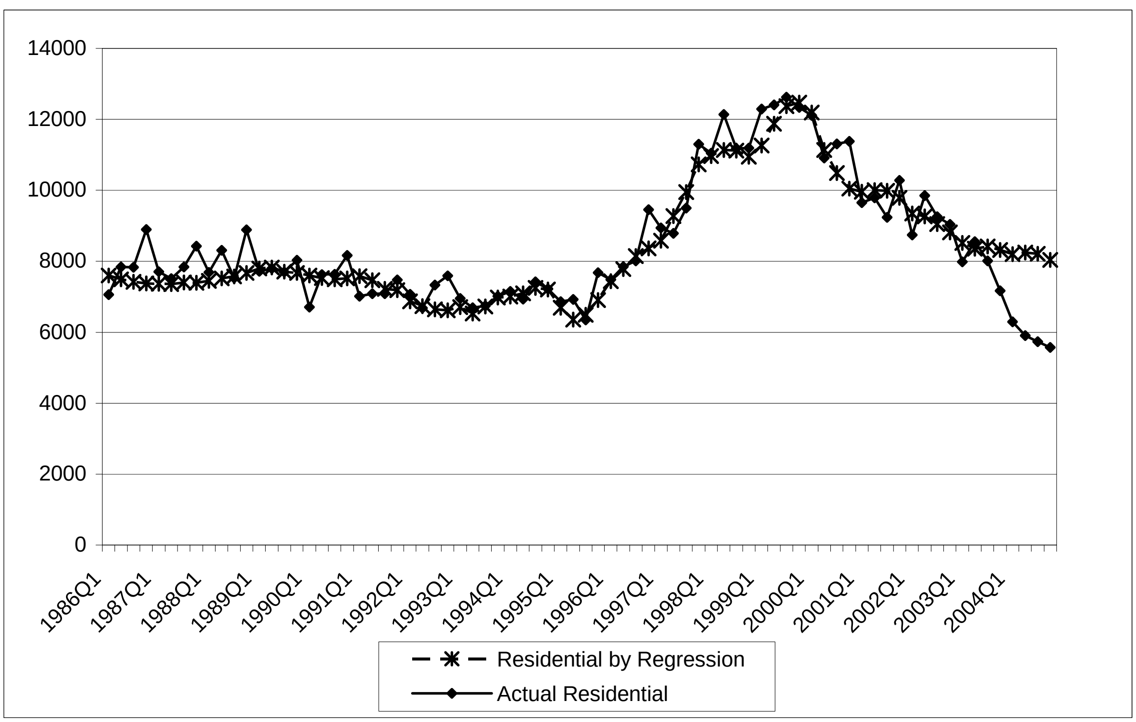

Figure 6. Regressed and actual residential construction demand 1986Q1−2004Q4

In the 1986Q1–1997Q4 model, the significant factors, including the tender price index, property rental indices, payroll indices and land supply are commonly found and suggested in previous studies. The payroll indices also suggest how residential demand is derived from the general income of house buyers. However, the later one, i.e. the 1986Q1–2004Q4 model, only includes factors on tender price index and property price indices. The residential construction output of Hong Kong has deeply plunged after the Asian financial turmoil in 1998. The collapse can be partly explained by the market imbalance in supply and demand and the property bubble created around 1997 [22].

These factors being rather specific and more related to the general economic performance are seldom mentioned and considered by previous literature on construction demand. Hence, our study could inspire some future works in using more Hong Kong-specific as well as economic-related factors to capture the behaviour of the residential construction demand in the past decades. The construction demand theories are mostly focusing on deriving residential demand under a stable economic situation, while the past construction demand studies seldom cover any major hard times in the construction industry. Therefore, it is worth investigating into the dynamic behaviour of construction demand using our past experience, such that we can well prepare for similar events like the recent global financial tsunami in future.

We have noticed in Figure 6 that the regressed data are swaying away from the actual data. It is found that the independent variables did not exhibit such drastic swing as the residential construction output itself did. This could inspire further discussions into whether the collapse of the residential market is one of the triggers to the various impacts from the Asian Financial Crisis. The SARS outbreak in 2003 could be one the key influences driving down the residential construction demand.

7. CONCLUSIONS

The Hong Kong construction industry has suffered from the Asian economic turmoil in 1997 and the SARS outbreak in 2003. The construction volume plunged and created a rippling effect to other related industries. In order to better understand the change gone through by the important residential construction sector during these heavy external impacts regression technique has been applied to unmask the driving factors in generating the residential demand. It is found that the underlying market structure and driving factors for Hong Kong residential demand before and after the impacts from the 1997 Asian Economic Crisis and 2003 SARS outbreak are different, suggesting that the residential construction sector or even the larger construction industry has undergone a major structural change as Hong Kong's economy approaches maturity. It is also observed that the past literatures on construction demand are mostly focusing on derived demand under stable economic environment. Hence, it is worth considering some special considerations during economic hard times when the residential sector can fluctuate dramatically under different external impacts.

The study could help Hong Kong construction industry in particular stakeholders in the residential construction sector to better understand the driving force of the market. It also inspires further research into understanding the residential market in face of unstable economic environment like the recent global financial tsunami. Last but not least, it adds to the knowledge of the limited regression studies done for Hong Kong residential construction demand, especially after various external impacts since 1997.

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S7-6

A NEW FEEDBACK TECHNIQUE FOR TUNNEL SAFETY BY USING MEASURED DISPLACEMENTS DURING TUNNEL EXCAVATION

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ABSTRACT: This research project was carried out to develop the technique to assess quantitatively and rapidly the stability of a tunnel by using the measured displacement at the tunnel construction site under excavation. To achieve this purpose, a critical strain concept was introduced and applied to an assessment of a tunnel under construction. The new technique calculates numerically the strains of the surrounding ground by using the measured displacements during excavation. A numerical practical system was developed based on the proposed analysis technique in this study. The feasibility of the developed analysis module was verified by incorporating the analysis results obtained by commercial programs into the developed analysis module. To verify the feasibility of the developed analysis module, analysis results of models both elastic and elasto-plastic grounds were investigated for the circular tunnel design. Then the measured displacements obtained in the field are utilized practically to assess the safety of tunnels using critical strain concept.

It was verified that stress conditions of in-situ ground and ground material properties were accurately assessed by inputting the calculated displacement obtained by commercial program into this module for the elastic ground. However for the elasto-plastic ground, analysis module can reproduce the initial conditions more closely for the soft rock ground