A Study of the Economic Value of High-rise Office Buildings

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Keyword: cost, height, storey, building elements, office buildings

SUMMARY

Office buildings are indispensable for a metropolitan city development. For high-rise office buildings there is a tendency for constructing higher and higher in terms of the number of storeys. Since quantity surveyors play the role of both building economists and building accountants, they have to take consideration of historical costs to foresee cost implications on future projects. As a building project unfolds from planning and design, through procurement and construction, to utilization and operation, surveyors' concern for an investment project reveals a forward-looking of project costs that emphasize the importance of early decisions upon the total project costs, which is to be committed at the planning and design stage. This paper examines the economic value of project cost in respect of the cost implications of the number of storeys of high-rise office buildings. The comparative study will be focused on the cost effect of construction floor area, height and the number of storeys in respect of the elemental cost of office buildings.

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1. INTRODUCTION

Economists tend to take an ex ante or forward-looking view on investment projects while accountants take an ex post or backward-looking view (Bon, 1989). Quantity surveyors, commonly known as building economists and building accountants, take the role of providing economic value and cost information on building projects. As a building project unfolds from planning and design, through procurement and construction, to utilization and operation, surveyors' concern for an investment project reveals a forward-looking of project costs that emphasize the importance of early decisions upon the total project costs, which is to be committed at the planning and design stage. This study comprises cost analysis of seven office buildings in Hong Kong, China with mathematical cost modeling technique to address the cost implications and thus cost forecasting of office buildings in terms of the design variables of the number of storeys and building/storey heights. The result is hoped to indicate the cost effect of the number of storeys of high rise office buildings to provide a total project cost phenomena to facilitate decisions on design and planning, procurement and construction and utilization and operation.

2. ECONOMIC VALUE OF HIGH-RISE OFFICE BUILDINGS

To forecast the total project cost, three cost components are regarded important for the development of office buildings. They are rental value of the office space (Seeley, 1996; Morton & Jagger, 1995; Seeley, Ferry & Brandon, 1980), building construction costs according to the height or number of storeys of the buildings (Morton & Jagger, 1995; Flanagan & Norman, 1999) and maintenance cost or cost-in-use (Ferry & Brandon, 1980). This paper focuses on the building construction costs according to the height and the number of storeys of office buildings.

There is a general understanding that construction cost will rise as storey height increases. This is not universally true for increased number of storeys. Morton & Jagger (1995) pointed out that some cost factors will increases and some cost factors will decrease the cost per square metre as height increases and the significance of these cost factors will change at different heights. Flanagan and Norman (1999) pointed out that construction cost generally falls as the number of storeys increases. They categorize construction cost into four cost components for considering the number of storeys and the height of the buildings:

(1) Cost items fall as the number of storeys increases, e.g. roofs, foundation.
(2) Cost items rise as the number of storeys increases, e.g. lift installation, fire services.
(3) Cost items fall initially and then rise as the number of storeys increases, e.g. curtain walling.
(4) Cost items unaffected by height, e.g. floor finishes, doors.

However, it is considered that even for cost items (Category 4) which are said to be unaffected by height are in fact slightly affected by height. There is cost increase for vertical transportation. This is because labourers and materials for the specific cost items require extra time for traveling to a particular height, and the time increases as the building goes higher. In other words, the labour productivity is sparingly lower due to additional time spent on traveling vertically. To avoid such an effect on productivity, it has been common that the labourers' tea times are 'served' by the foremen or the supervisors in a way that the labourers do not need to 'go down' and 'go out' for their tea or snack. In this respect, time is 'priced'.

3. BUILDING ELEMENTS AFFECTED BY THE NUMBER OF STOREYS OR BUILDING HEIGHT

The modern trend for constructing office buildings is to build higher and higher, and developers tend to compete with one another on heights. Exceptionally tall buildings easily go beyond a total height of 200m, whereas conventionally tall buildings are commonly found with a total height of 100m in around 30 plus number of storeys. Although we have an understanding that the number of storeys are usually governed by statutory requirements such as plot ratio and daylight effect on neighbouring buildings, particularly in a high-density city like Hong Kong where land prices easily take up 70% of the property development cost. It has been said that high buildings should not be considered on cost grounds unless there is saving in land costs. So constructing tall buildings in suburban areas does not seem to justify the economic use of land and constructing in city centre is very much dependent on the density of population and the commercial activities around the locality. Planning issues require foresight, without which one has to bear the consequence of high density locality or under-utilized buildings.

Technical consideration for high-rise buildings is whether the frame is constructed with structural steel or with reinforced concrete frame structure or a combination of the two. Other technical considerations involve the type of foundation support and the envelop enclosing the frame structure in which piling and curtain walling systems are commonly adopted for high-rise buildings nowadays. Economic considerations are focused on finding which of the cost elements are increased due to an increase in the number of storeys and height, particularly when height is beyond approximately 100m of a conventionally tall building. For high-rise buildings, it is considered that the lift cost will vary as the lift speed may have to increase say from 1.75m/sec. to 10.0m/sec. The utilization of lift cores for balancing its use would involve a transit floor for changing lift shaft. The cleaning and maintenance facilities have to be considered at the same time such that the built-in structure is able to accommodate the maintenance requirements. The choice of number of storey and height may also affect the use of system and equipment like the pressurized systems which may have to change at a particular height level to cater for smooth vertical water flow.

It is common to have an open floor plan compared with a partitioned floor plan for tall office buildings. This has been disregarded in the study to avoid complications of the effect of other design variables. Tall buildings call for the necessity of swift vertical transportation and fireresisting construction. Four major building elements are considered significantly affected by the number of storeys of high-rise building. They are the frame, external wall (curtain walling in most case for office buildings in Hong Kong), lift installation and fire protection (as in services), which are mainly vertical elements of the building, as the construction cost for high-rise buildings is commonly divided into elements. The building elements are conveniently grouped into five sub-groups plus preliminaries to cover site establishment cost which is not expendable on the building itself but is necessary for facilitating site operations. They are piling and substructure, carcass, finishings, furniture and fittings and services.

4. Method of Study and Data Analysis

This study takes the hypothesis that when a tall building arrives to a certain number of storeys, the construction cost will go up and will no longer be a straight line formula. It should be a staggered line. Seven buildings of different heights ranging from 22 to 68 storeys are selected for analysis for the cost effect on heights and elemental costs. The cost data collected are updated to the 4th quarter of 2006 (DLS Index 990) for comparison. Four sets of calculations are firstly worked out with the cost data collected from high-rise office buildings:
(1) Updating all building costs to the same time level for comparison
(2) The distribution of the elemental costs of the buildings
(3) The cost effect of the number of storeys on construction floor area (CFA) (see Table 1)
(4) The cost effect of the building elements of a high-rise building (see Table 2)

4.1 Cost Effect of Number of Storeys or Building Height

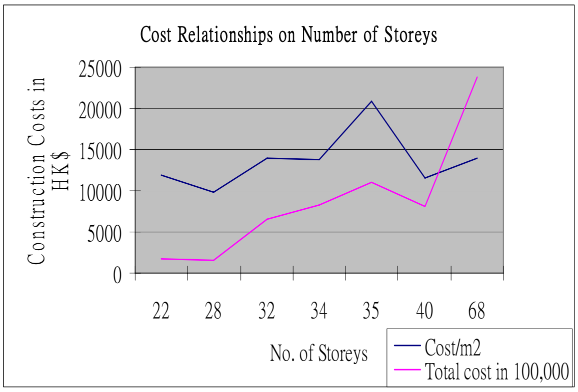
According to Graph 1, the total construction cost generally goes up as the number of storey increases although it appears that the total cost for a 40-storey building is comparatively less than a 35-storey building. This may be because of the smaller storey height of the 40-storey building (the storey height being the second lowest of the seven buildings, see Table 1). The construction cost per unit area displays a similar trend up to35-storey, but it shows a downward cost trend when buildings goes higher. Graphs 2-4 display a relationship of number of storeys with overall building height, construction floor area (CFA) and storey height respectively. The data indicates that the storey height is not consistent with the tall buildings in the study (see the stagger line in Graph 4) and it ranges from 3.94m to 5.36m (see Table 1), with a vast difference of 1.42m which is not negligible for the construction of tall buildings. The office buildings under 30 storeys possess a comparatively high storey height. This may be due the variations in the height of suspended ceiling and the inclusion of raised floor. In addition, regarding the number of storeys in Hong Kong, there are also two possibilities for explaining such peculiar cases. Firstly, the refuge floors stimulated by statutory requirements for fire protection are not counted in the number of storeys. Secondly, the floors numbered with a '4' such as '4', '14', '24' have been eliminated due to Chinese Fung Shui, whereas the number of storeys is counted with a continuous sequence. The data collected for analysis have been taken into account of refuge floors and '4's' floors. However, this indicates that statutory requirements for fire protection will lead to a higher number of storeys against usable floor areas and hence higher construction cost.

The result of the above findings shows that storey height varies quite a lot with buildings of different heights. This makes the building more expensive to construct per unit area. There would be certain building elements affecting height for which buildings of different storey number would not required to be considered. Within the scope of this study, there is no indication of the reason for this and this requires further detail examination.

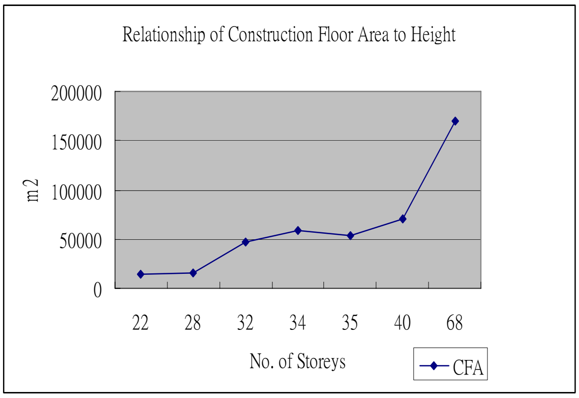
Cost Effect of Area and Height on Number of Storeys

Building	No. of Storeys	Area	Height	Storey Ht.	Area/St.No
1	22	13,967	118	5.36	635
2	28	15,810	134	4.79	565
3	32	46,762	126	3.94	1,461
4	34	59,121	179	5.26	1,739
5	35	52,964	149	4.26	1,513
6	40	70,442	160	4.00	1,761
7	68	170,000	300	4.41	2,500

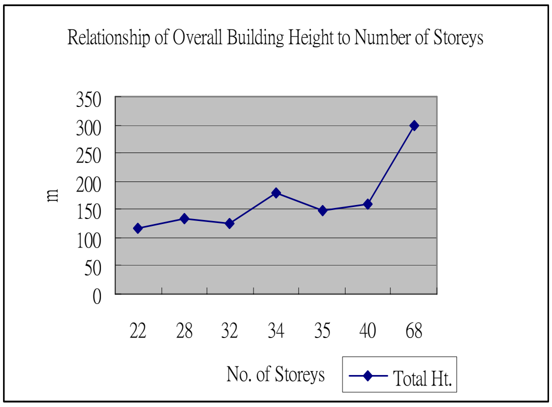
Table 1 Cost Effect of Area and Height on Number of Storeys



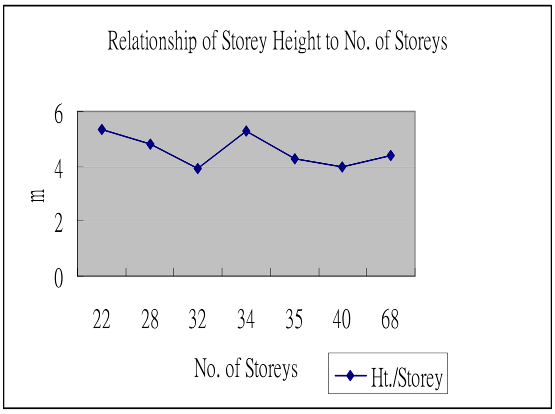
Graph 1



Graph 2



Graph 3



Graph 4

4.2 Cost Effect of Construction Elements

The cost distribution of the different building elements of the buildings is worked out as shown in Table 2. The cost data is then divided by the number of storeys to indicate the unit cost per storey in buildings of different heights (see Table 3). According to Table 3 and Graph 1, the cost per square metre (unit area of CFA) generally goes up with an increase of number of storeys but tends to goes down when the height reaches about 35-40 storeys. Referring to Table 3 and Graph 5, the elemental costs for carcass and finishings tend to go down with the number of storeys at about 35-40 storeys, whereas the cost for piling and substructure and preliminaries maintains more or less the same for an increase in number of storeys although there shows some minor fluctuation with the cost of piling and substructure. The elemental cost for services tends to have a high fluctuation with the number of storeys and the line of the graph shows a staggered line. This means that the cost for services is highly cost sensitive and the cost for piling and substructure is marginally cost sensitive to an increase in the number of storeys for buildings of different heights.

Cost Distribution of Office Buildings vs Number of Storeys

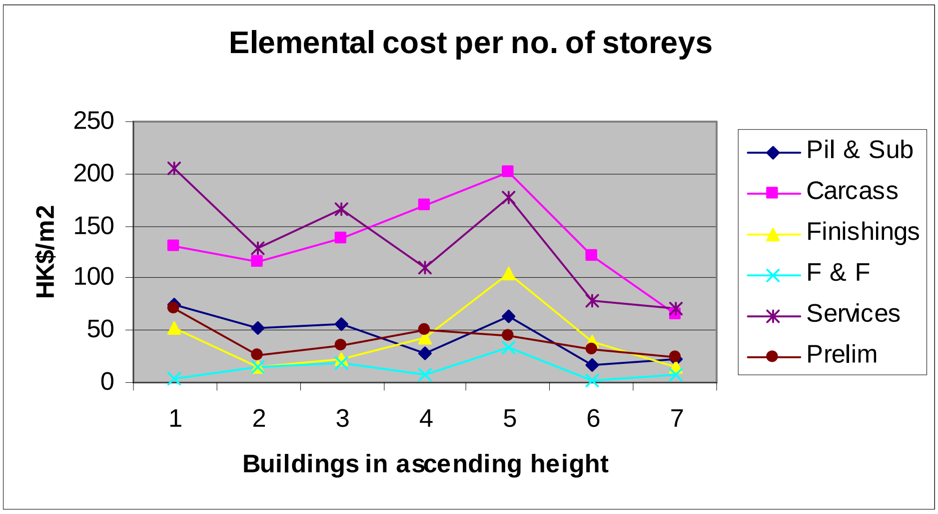
Case	No. of Storeys	Cost per m2 HK$	Pil & Sub	Carcass	Finishings	F & F	Services	Prelim
1	22	11,813	1,637	2,876	1,168	65	4,526	1,541
2	28	9,870	1,460	3,232	418	418	3,606	736
3	32	14,007	1,812	4,412	726	624	5,288	1,145
4	34	13,866	959	5,766	1,475	230	3,723	1,712
5	35	20,788	2,195	7,021	3,677	1,156	6,180	1,559
6	40	11,546	638	4,867	1,584	61	3,114	1,282
7	68	13,982	1,531	4,491	1,062	458	4,807	1,633

Table 2 Cost Distribution of Office Buildings vs Number of Storeys

Cost Effect per Number of Storeys

Building	No. of Storeys	Cost per m2 in HK$ per storey	Pil & Sub	Carcass	Finishings	F & F	Services	Prelim
1	22	537	74	131	53	3	206	70
2	28	353	52	115	15	15	129	26
3	32	438	57	138	23	20	165	36
4	34	408	28	170	43	7	110	50
5	35	594	63	201	105	33	177	45
6	40	289	16	122	40	2	78	32
7	68	206	23	66	16	7	71	24

Table 3 Cost Effect of Number of Storeys



Graph 5

The elemental cost distribution of tall buildings shows high percentages for carcass and services. This indicates that cost savings achieved by height or the number of storeys can significantly affect the overall construction cost. In view of this, building items relevant to carcass and services are further detailed as shown in Table 5 for analysis. In addition, it also indicates that the foundation cost per unit area does not necessarily go up with increased number of storeys and that the elemental cost distribution percentage also displays a staggered effect.

Based on Tables 5-6 and Graph 6, the cost for carcass generally goes up with height but goes down as the number of storeys increases to 35 in this study. The same cost trend is also revealed for the frame cost. This means that the frame cost significantly affect the cost for carcass. The costs for internal wall, external wall and the curtain walling and its associated work do not varies much in ascending height. Regarding the cost for services (see Graph 7), the overall services and MVAC costs tend to go down with height, but they fluctuate at times. The line curve is a staggered line as suggested earlier. It is noted that services cost takes up an average of 33% of the total construction cost whereas the MVAC cost takes up an average of 34% of the cost for services. The lift cost decreases as the height of the building increases and the line curve (see Graph 7) is a staggered line. The average percentage for lift cost in the overall services cost is 18%, and is comparatively a high cost besides MVAC cost. The change of costs due to ascending height for plumbing and disposal and fire protection is marginal with respect to its cost level in this study, as the cost percentages are represented by an average of 6% and 9% respectively of the services cost. However, this shows that the functional requirement of plumbing and disposal cost is less than fire protection cost due to statutory control.

Building Elements	**Elemental Cost Distribution Percentage**						
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**
Pilings and substructure	6	7	14	15	11	11	13
Carcass	42	32	24	34	34	32	31
Finishings	14	10	10	13	13	8	5
Furniture and fittings	1	2	1	3	6	3	4
Services	27	33	38	30	30	34	38
Preliminaries	11	12	13	7	7	12	8
	100	100	100	100	100	100	100

Table 4 Elemental Cost Distribution of Tall Buildings

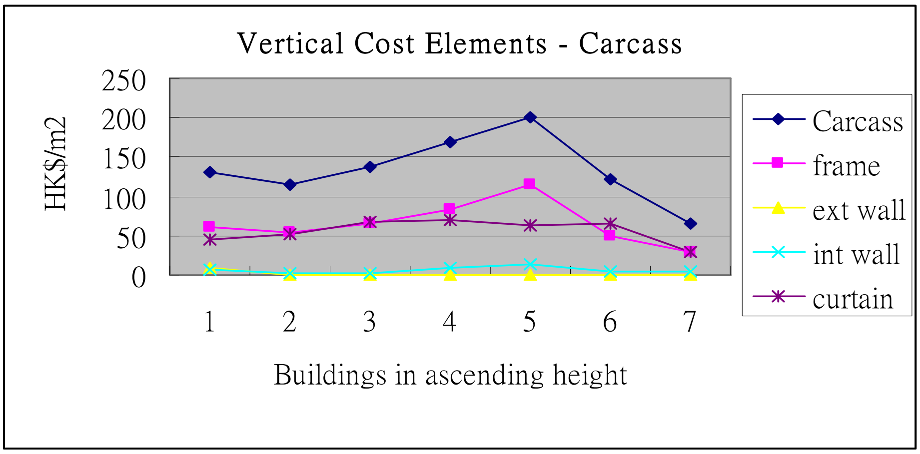
Elemental Costs per Number of Storey for Carcass and Services HK$/m2

Carcass total	131	115	138	170	201	122	66
Frame & slab	61	54	66	84	116	50	29
Ext. wall	8	1	0	0	0	0	0
Int. wall	7	1	2	8	13	4	5
Curtain walling	46	51	66	70	64	66	30
Services total	206	116	145	98	177	78	71
Plumbing & disposal	10	8	3	6	13	5	6
Fire services	11	9	12	5	16	10	12
Lifts	35	18	28	15	35	13	18
MVAC	80	32	75	27	46	23	27

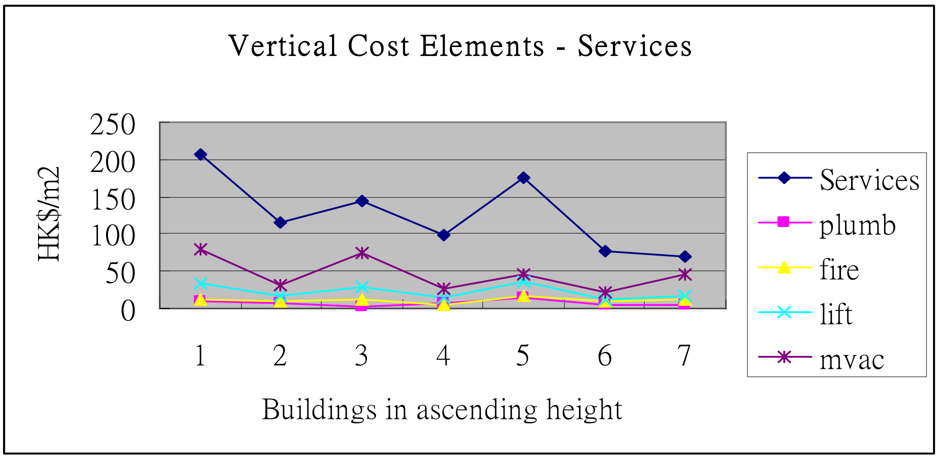
Table 5 Elemental Costs of Carcass and Services of Tall Buildings

Building Elements	**Cost percentage within group per number of storey**						
Carcass	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**
Frame and slab	46%	46%	47%	49%	57%	40%	43%
External wall	6%	1%	0%	0%	0%	0%	0%
Internal wall	5%	1%	1%	5%	6%	3%	8%
Curtain wall	35%	44%	47%	41%	31%	54%	45%
Services	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**
Plumbing and disposal	5%	7%	2%	6%	7%	6%	8%
Fire services	5%	8%	8%	5%	9%	13%	17%
Lifts	17%	16%	19%	15%	20%	17%	25%
MVAC	39%	28%	52%	28%	26%	29%	38%

Table 6 Percentage Significance of Elemental Costs for Carcass and Services



Graph 6



Graph 7

Based on the scatter diagram derived from SPSS Version 11, it indicates that when the number of storeys acts as the X-axis with area (CFA) and building height as the Y-axis (see Graphs 8-9 in Appendix), a straight line can be drawn and the straight line phenomena can be established with the coefficient tables for Graphs 8-9. Due to the limited number of samples analysed in this study, the straight line formula is not verified further and the graphs are shown for indication only. But when the number of storeys acts as the X-axis with cost per unit area as the Y-axis, no straight line can be verified and this means that cost does not vary proportionally with number of storeys and there are other factors influencing cost. Graph 10 shows other scatter diagrams of cost relationship with overall building height, storey height and area of office buildings where there is no linear result.

5. CONCLUSION

The two main considerations other than economic value are the client's preference and the statutory requirements on tall buildings. The cost effect of high-rise buildings concerns the quality and the quantity change of different building elements. This calls for a sensible choice of the systems or the type of materials used for a say, a 10-storey building, 20-storey building, a 30-storey building and so on, up to a height or number of storey permitted by the statutory requirements. This study presents a cost data analysis of the building elements in respect of the number of storey and height of seven office buildings which provide an indication of the cost trend and the cost change for a change of the numbers of storeys and heights. In conclusion, the carcass and services groups are the two groups that constitute higher cost weightings for tall buildings and that the frame and the mechanical ventilation system need detail examination in considering the design variables in addition to client's preference. The result here is not conclusive and shows only a selected sample of high-rise buildings to provide an insight in the economic considerations of tall buildings. Other buildings elements such as lifts and fire protection would require further analysis for better economic considerations in conjunction with the construction of tall buildings in respect of the number of storeys and height.

Note: The study is to acknowledge with thanks for those who contribute in providing cost data for making the analysis possible including Davis, Langdon & Seah.

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BIOGRAPHICAL NOTES

Dr. Ellen Lau is a fellow member of HKIS and RICS. Her academic background is quantity surveying and management related with BSc in Quantity Surveying, MSc in Construction Project Management and PhD in (Strategic Management). She started practicing as a quantity surveyor but joined City University of Hong Kong in the mid-1980s. She presently teaches quantity surveying related subjects and actively involves in research-related activities in management and in surveying.

Introduction

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Master of Project Management, The New South Wales University in Australia
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Mr. Yam started his career as Quantity Surveyor since 1977, and has been involved in many residential, hotel, office, retail, embassy, educational, medical, industrial, channel and harbour works at various levels in China, Hong Kong, Macau and Australia.

Mr. Yam has served on the HKIS Quantity Surveyors Division Council as a Council Member, and wrote a few of technical papers which were published in the Cities of Hong Kong, Shenzhen and Changchun.

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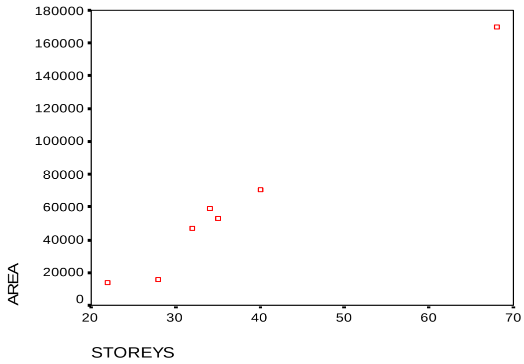
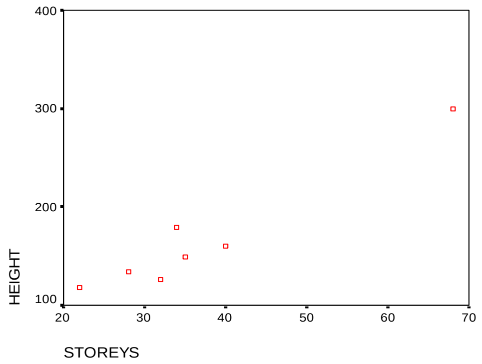


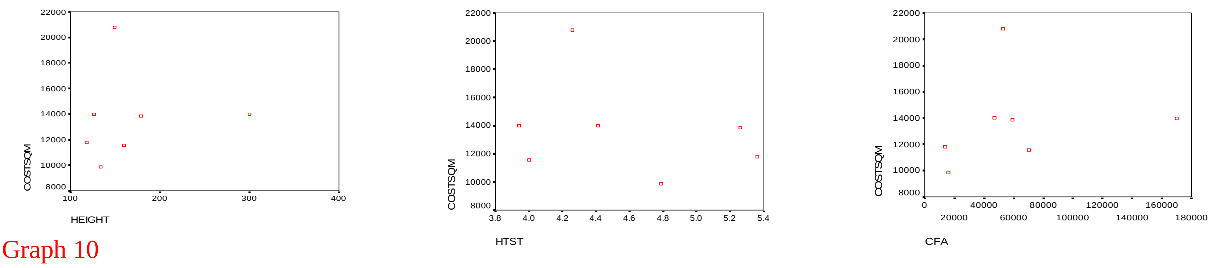
Graph 8



Graph 9

Coefficients(a) for Graph 8						
		Unstandardized Coefficients		**Standardized Coefficients**	**t**	**Sig.**
Model		**B**	**Std. Error**	**Beta**		
1	**(Constant)**	-68583.023	8486.556		-8.081	.000
	STOREYS	3510.221	215.093	.991	16.320	.000
a Dependent Variable: AREA						

Coefficients(a) for Graph 9						
		Unstandardized Coefficients		**Standardized Coefficients**	**t**	**Sig.**
Model		**B**	**Std. Error**	**Beta**		
1	**(Constant)**	16.234	19.966		.813	.453
	STOREYS	4.063	.506	.963	8.029	.000
a Dependent Variable: HEIGHT						



Graph 10

Appendix