National Capital Commission
Commission de la capitale nationale

20 YEAR LIFE CYCLE ANALYSIS AND COSTING GUIDE FOR WINDOW RESTORATION OPTIONS

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20 YEAR LIFE CYCLE ANALYSIS AND COSTING GUIDE

FOR
WINDOW RESTORATION OPTIONS

Case Studies #1 through #9 (by NCC Design and Construction Division):

- Charron House Rehabilitation / casement replacement
- 142 St. Patrick Street / awning in lieu of storm and casement restoration
- Residential masonry building, Ottawa / frame and sash restoration
- 541 Sussex Street / frame restoration and sash replacement
- Rideau Hall - Minto Wing - Basement floor / single hung replacement
- Rideau Hall - Minto Wing - Ground and Second floors / frame and sash restoration
- Rideau Hall - 1838, Minto and Hospitality Wings / frame and sash restoration
- 529 Richmond Road / frame and sash restoration
- Rideau Hall - 1906 and Minto Wings / frame and sash restoration

NCC Design and Construction Division

- Yves Gosselin, Director
- François LeBlanc, Chief, Architecture Section
- Jean-Yves Tremblay, Heritage Conservation Architect:
  - tel: (613) 239-5280
  - fax: (613) 239-5316
- Michael Moroz, Project Manager:
  - tel: (613) 239-5746
  - fax: (613) 239-5694

Case Studies #10 through #14 (by Consultant):

- Queen's Park Legislature Building - North Wing Steel Window Restoration
- Queen's Park Legislature Building - Frame and Sash Restoration, Phases II/III
- Queen's Park Legislature Building - Frame and Sash Restoration and Replacement, Phase IV
- Centre Block, Parliament Hill - Restoration of steel and leaded glass
- Centre Block, Parliament Hill - Steel Window Replacement

Consultant

- Craig Sims, Restoration Consultant:
  - tel: (613) 547-5658

Life Cycle Cost Analysis for Restored and Replacement Windows

Introduction

This study consists of two distinct parts. The first is a life cycle cost analysis based on nine window restoration and replacement projects (see Case Studies #1 through 9) undertaken by the National Capital Commission, (NCC) Ottawa, Ontario. Only these nine projects have been used for the life cycle cost analysis because they are similar in size, scale and scope of work; in effect, they are residential scale windows. This analysis builds on an earlier study prepared in 1993 by the NCC entitled "Standard and Costing for Window Rehabilitation".

The second part to the study consists of five window restoration and replacement projects (see Case Studies #10 through 14) in very large architecturally and historically significant institutional buildings. They have not been incorporated into the life cycle cost analysis because they are projects of such a different type and scale.

The purpose of this study is twofold; to provide costing information, based on 14 completed projects described in the Case Studies, which will aid in estimating capital costs for other similar projects and to provide a life cycle cost analysis for residential scale projects so that design choices, such as whether to restore and upgrade or replace, can be better understood in terms of initial capital costs plus maintenance and energy saving costs over a 20 year period. All costs are presented in Canadian dollars per square foot.

Context

All of the projects presented have been undertaken in the past ten years and most are in classified or recognized buildings as listed by the Federal Heritage Building Review Office (FHBRO). In 1996 FHBRO published a "Code of Practice", based on international conservation charters, to serve as a guide to decision makers charged with the care of Crown-owned historic buildings. On page 42 in section 7.3 windows are discussed; this section reads in part:

> Historic window units should be retained and upgraded rather than replaced. The need for improved thermal performance is best met with interior or exterior storm windows rather than new sealed double or triple units [and] new weather stripping can be added to either the sash or the frame.
>
> Frequently, historic windows which have deteriorated only slightly over a hundred years are being replaced with modern units which have life expectancies of twenty or thirty years. Heritage character is best protected by the repair and upgrading of original or early window units.
>
> When replacement is required, new units should match the material, profile, and detail of the original. This approach maintains heritage character and maintains compatibility with surviving examples of original sash.

The case studies presented in this paper were all projects undertaken and developed within these guidelines or earlier versions of them. For a detailed breakdown of the scope of work and capital costs for each project see the individual Case Studies. Note that only Case Studies #1 through 9 have been used for the life cycle cost analysis because they represent projects that are similar in size; all are residential scale buildings with residential scale windows.

Table # 1 - Summary of Various Window Restoration Projects in 1996$

This table is based on 9 NCC case studies and describes various window interventions and the capital cost of those interventions on a square foot basis. Similar interventions are grouped together so that both the cost for the specific project and the average cost for that type of intervention can be seen. Obviously, there are many possible reasons for the variations in cost for similar activities on different projects; for example, the project size, the state of the local economy at the time of tender and the time of year, in addition to peculiar project conditions.

Prices have been adjusted based on the 1996 Yardsticks For Costing which lists the historical price changes for Ottawa; all prices include 7% GST (Goods and Services Tax).

Table #2 - Life Cycle Maintenance & Saving Costs per Square Foot Based on a 20 Year Time Period with a 2.1% Inflation Factor

This table identifies various maintenance and energy costs on a square foot basis over a 20 year time period. Specifically, it addresses:

- glazing replacement costs
- painting costs based on a 5 year time period
- annual energy saving costs
- annual storm and screen installation costs

A. Glazing Replacement Costs

As a worse case scenario, sash with single glazing may require as much as 1% glazing replacement annually; this would translate into almost complete replacement over a 100 year period. Replacement of single glazing mounted in putty is estimated to cost $65.00 per pane; assuming 4 panes per window, with a finished opening size of 3' x 6', the annual replacement cost based on 1% annual replacement would be about $0.15 per square foot. Because storm windows are subject to more handling they may require as much as 2% glazing replacement annually estimated to cost $0.30 per square foot.

Insulated glass units are usually guaranteed for an initial 5 year period. Glazing replacement is usually required because of seal failure caused by exposure of the edge seal to moisture. After the initial 5 year period, it is anticipated that the units would require replacement at an annual rate of 2% during the remaining 15 year period. The annual replacement cost is estimated at $0.30 per square foot.

B. Regular Maintenance Costs

The regular maintenance painting program is based on a 5 year time period. The estimated costs include painting of all interior and exterior window components, repairing of all damaged putty and recaulking where required. It is assumed that the cost of a major restoration project could be avoided if maintenance was undertaken regularly. The maintenance costs are as follows:

- screen painting is estimated at $1.25 per square foot
- storm painting is estimated at $1.67 per square foot
- window painting with single glazing is estimated at $2.72 per square foot to allow for touch ups to glazing putty
- window painting with double glazing is estimated at $2.30 per square foot

C. Calculated Energy Saving Costs

A calculated energy savings based on the 541 Sussex Drive project (NCC Case Study #4) had indicated that new sashes mounted with clear single glazing and weather stripping would provide an estimated annual energy savings of 30,671 kWh or $920.00 for the entire project. The net saving would be $0.38 annual energy savings per square foot. In comparison, if the same project had been done with a Low E insulated glass unit filled with argon gas, it would provide an estimated annual energy saving of 98,600 kWh or $2,958.00 for the entire project. The net saving per window would be $1.25 annual energy savings per square foot. These savings are shown in Table #2 and are deducted from the other expenses.

Air infiltration testing indicated that the method followed for the restoration or upgrading of the single hung windows met the A1 rating whereas the casement windows met the A2 rating as described below. The following are the ratings for air tightness as listed in CAN/CSA-A440-M90:

AIR TIGHTNESS RATINGS

Window Rating	Max Air Leakage Rate (m3/hr)m-1	Max Air Leakage Rate (cfm/lin. Ft. crack)
Storm	8.35 (max) 5.0 (min)	1.498 (max) 0.897 (min)
A1	2.79	0.501
A2	1.65	0.296
A3	0.55	0.099
Fixed	0.25	0.045

The Ontario Building Code describes the A1 and A2 ratings as follows:

Windows with an A1 rating are intended for use primarily in low-rise residential (i.e., buildings of 3 stories or less and having an area not exceeding 600 square metres, or 6460 square feet), industrial and light commercial buildings. Windows with an A2 rating are intended primarily for use in medium to high rise residential, institutional and commercial buildings.

D. Annual Storm and Screen Installation Costs

Because screen and storm windows are frequent requirements in residential buildings, the costs associated with their seasonal installation, removal and storage must be taken into account. This cost is estimated to be $0.31 per square foot each, for a total of $0.62 per square foot.

Table #3 - Window Restoration Units - Life Cycle Maintenance & Saving Costs per Square Foot Based on a 20 Year Time Period - 2.1% Inflation / 6% Discount Rate

This table utilizes the life cycle costs and savings from Table 2 for the various window components, such as screen, storm and glazing in order to establish their present value in 1996 dollars. It works as follows:

> By the year 2015, for example, the screen unit will have cost in 1996 dollars a total of $11.20 per square foot to maintain (see column Estimated Cost 1996$ Sum D+J). Inflation will have increased the cost to $14.00 per square foot (see column Estimated Cost in Budget Year @ 2.1%). If the building owner wanted to invest now in 1996 dollars to have the $11.20 per square foot in the year 2015, an investment of $6.47 per square foot would be required assuming a 0% inflation and 6% discount rate. All costs estimates for future maintenance or capital expenditures are carried out in constant 1996 dollars and no allowance is made for the effects of inflation in calculating the present value of future costs. The discount rate "r" used in the financial analysis could be modified to reflect the influence of a constant rate of inflation. For the example above, an investment of $7.77 per square foot would be required assuming a 2.1% inflation rate (see Table 3B).

Table #4 - 20 Year Cash Flow Projections for Window Restoration (Initial Cost of Restoration + 20 Year Life Cycle Maintenance and Saving Costs)

This table illustrates the total present value per square foot in 1996 dollars (see Column A and B) for various window restoration options. The cash flow projection is achieved by adding the average initial cost of the option from Table 1 (see column A) to the life cycle maintenance and savings costs (see column B) shown in Table #3.

Table #5 - 20 Year Cash Flow Projections for Window Restoration Showing Four Different Schemes

This table summarizes the total present value per square foot in 1996 $ for single hung and casement options. Four different schemes, or levels of intervention, are shown and illustrate that a full restoration approach (Scheme #1) indicates a 20% savings for the single hung option compared with the full replacement approach (Scheme #3). The same comparison for the casement window indicates a 4% savings.

The full replacement option, Scheme #3, was done with an insulated glass unit, and did therefore not require a storm window. The full restoration option, Scheme #1, was fitted with restored screens and storms and still remains the most economical approach.

Summary

The figures shown in Table #5 illustrate that when the cost of restoration, energy and maintenance are considered over 20 years, the preservation and upgrading of original windows compares very favourably to the cost of replacement units in the context of FHBRO classified buildings. The costs are considered to be accurate for residential scale building projects of 30 to 40 windows.

Although this study only looks at windows over a 20 year period, original windows may last indefinitely if properly maintained. All too often the costs of good quality restoration work is weighed against the cost of new replacement window units that may only have a service life of 20 - 30 years. Ideally, it should not be necessary to argue for the retention

of historic windows on only economic grounds. The fact that the windows are architecturally significant and original to the building should in most cases be justification enough for preservation.

TABLE #1
SUMMARY OF VARIOUS WINDOW RESTORATION PROJECTS
BASED ON 9 NCC CASE STUDIES
1996 $

	Type of interventions	Cost per sq. ft. based on year of construction	Year of Construction	Inflation index cost adjustment	Plus 7% GST	Less 5% work stoppage	Avg. cost per sq. ft. in Jan. 96
1	removal of steel storm	$3.74	1993	$0.18			$3.92
2	aluminum screen replacement	$4.42	1991	-$0.08			$4.33
3	screen restoration	$7.63	1996				$7.63
4	storm restoration / 10% putty	$8.80	1991	-$0.16			$8.63
5	aluminum insert sash restoration	$12.77	1993	$0.62			$13.39
6	exterior frame and sash restoration / casement						$14.29
	- case study #2 / 10% putty	$13.31	1991	-$0.24			
	- case study #7 / interior sill / dg	$13.39	1995	$0.46	$0.96	-$0.69	
	- case study #8 / 12% putty	$15.70	1996				
7	exterior frame restoration / case study #9 / based on 1 unit only	$14.84	1996		$1.03	-$0.74	$15.03
8	wood screen replacement						$18.58
	- case study #3	$20.58	1993	$1.00			
	- case study #5	$17.22	1991	-$0.32	$1.18		
	- case study #7	$16.74	1995	$0.58	$1.21	-$0.86	
	- case study #8	$15.28	1996				
	- case study #9	$19.90	1996		$1.39	-$0.99	
9	frame and sash restoration / casement / 12%	$28.80	1996				$28.80
10	storm restoration						$31.17
	- case study #8 / 30% putty	$26.82	1996				
	- case study #9 / 100% putty	$34.83	1996		$2.43	-$1.74	
11	exterior frame and sash restoration / single						$33.52
	- case study #2 / 10% putty	$26.94	1991	-$0.49			
	- case study #9 / dg	$39.82	1996		$2.78	-$1.99	
12	wood storm replacement						$34.72
	- case study #3	$33.22	1993	$1.62			
	- case study #7	$31.72	1995	$1.10	$2.29	-$1.64	
	- case study #8	$28.72	1996				
	- case study #9	$41.04	1996		$2.87	-$2.05	
13	shutter replacement	$31.71	1986	$11.40			$43.11
14	frame and sash restoration / single hung						$55.82
	- case study #3 / 35% putty	$45.02	1993	$2.20			
	- case study #6 / 100% putty	$48.97	1993	$2.39			
	- case study #7 / 100% putty	$54.73	1995	$1.91	$3.96	-$2.83	
	- case study #9 / 100% putty	$65.64	1996		$4.59	-$3.28	
15	door, sidelights and frame restoration	$55.98	1996		$3.91	-$2.79	$57.10
16	frame and sash restoration / casement / 100%	$56.05	1996		$3.92	-$2.80	$57.17
17	frame restoration and sash replacement /	$56.40	1993	$2.76			$59.16
18	frame restoration and sash replacement / single						$60.49
	- case study #4	$61.04	1993	$2.98			
	- case study #7	$53.97	1995	$1.88	$3.90	-$2.79	
19	awning and extended frame in lieu of storm	$61.94	1991	-$1.13			$60.80
20	frame and sash replacement / casement	$76.41	1986	$27.49			$103.90
21	frame and sash replacement / single hung						$126.76
	- case study #3	$133.74	1993	$6.55			
	- case study #4	$108.00	1993	$5.28			
	- case study #5	$120.66	1991	-$2.21	$8.29		
22	frame restoration and doors, screens, transoms replacement / dg	$149.64	1996		$10.47	-$7.48	$152.63

TABLE #2
WINDOW RESTORATION WORK
LIFE CYCLE MAINTENANCE & SAVING COSTS PER SQ. FT. BASED ON A 20 YEAR TIME PERIOD
2.1% INFLATION

	YEAR	GLAZING REPLACEMENT COST PER SQUARE FOOT						REGULAR MAINTENANCE COST PER SQUARE FOOT BASED ON A FIVE YEAR TIME PERIOD								ANNUAL ENERGY SAVING COST PER SQUARE FOOT				ANNUAL INSTALLATION COST PER SQUARE FOOT			
		A		B		C		D		E		F		G		H		I		J		K	
		SASH WITH SINGLE GLAZING @ 1% REPLACEMENT PER YEAR		STORM WITH SINGLE GLAZING @ 2% REPLACEMENT PER YEAR		SASH WITH DOUBLE GLAZING @ 2% REPLACEMENT STARTING AT YEAR 6		SCREEN PAINTING		STORM PAINTING		WINDOW PAINTING WITH SINGLE GLAZING		WINDOW PAINTING WITH DOUBLE GLAZING		CLEAR SINGLE GLAZING SASH MOUNTED WITH WEATHER STRIPPING		LOW E DOUBLE GLAZING FILLED WITH ARGON GAS SASH MOUNTED WITH WEATHER STRIPPING		SCREEN INSTALLATION COST		STORM INSTALLATION COST	
		1996$	INFLATED	1996$	INFLATED	1996$	INFLATED	1996$	INFLATED	1996$	INFLATED	1996$	INFLATED	1996$	INFLATED	1996$	INFLATED	1996$	INFLATED	1996$	INFLATED	1996$	INFLATED
1	1996	$0.15	$0.15	$0.30	$0.30	$0.30		$1.25		$1.67		$2.72		$2.30		-$0.38	-$0.38	-$1.25	-$1.25	$0.31	$0.31	$0.31	$0.31
2	1997		$0.15		$0.31												-$0.39		-$1.28		$0.32		$0.32
3	1998		$0.16		$0.31												-$0.40		-$1.30		$0.32		$0.32
4	1999		$0.16		$0.32												-$0.40		-$1.33		$0.33		$0.33
5	2000		$0.16		$0.33				$1.36		$1.81		$2.96		$2.50		-$0.41		-$1.36		$0.34		$0.34
6	2001		$0.17		$0.33		$0.33										-$0.42		-$1.39		$0.34		$0.34
7	2002		$0.17		$0.34		$0.34										-$0.43		-$1.42		$0.35		$0.35
8	2003		$0.17		$0.35		$0.35										-$0.44		-$1.45		$0.36		$0.36
9	2004		$0.18		$0.35		$0.35										-$0.45		-$1.48		$0.37		$0.37
10	2005		$0.18		$0.36		$0.36		$1.51		$2.01		$3.28		$2.77		-$0.46		-$1.51		$0.37		$0.37
11	2006		$0.18		$0.37		$0.37										-$0.47		-$1.54		$0.38		$0.38
12	2007		$0.19		$0.38		$0.38										-$0.48		-$1.57		$0.39		$0.39
13	2008		$0.19		$0.38		$0.38										-$0.49		-$1.60		$0.40		$0.40
14	2009		$0.20		$0.39		$0.39										-$0.50		-$1.64		$0.41		$0.41
15	2010		$0.20		$0.40		$0.40		$1.67		$2.23		$3.64		$3.08		-$0.51		-$1.67		$0.41		$0.41
16	2011		$0.20		$0.41		$0.41										-$0.52		-$1.71		$0.42		$0.42
17	2012		$0.21		$0.42		$0.42										-$0.53		-$1.74		$0.43		$0.43
18	2013		$0.21		$0.43		$0.43										-$0.54		-$1.78		$0.44		$0.44
19	2014		$0.22		$0.44		$0.44										-$0.55		-$1.82		$0.45		$0.45
20	2015		$0.22		$0.45		$0.45		$1.86		$2.48		$4.04		$3.41		-$0.56		-$1.86		$0.46		$0.46
		TOTAL	**$3.68**		**$7.36**		**$5.80**		**$6.39**		**$8.54**		**$13.91**		**$11.76**		**-$9.33**		**-$30.68**		**$7.61**		**$7.61**

TABLE #3
WINDOW RESTORATION UNITS *
LIFE CYCLE MAINTENANCE & SAVING COSTS PER SQ. FT. BASED ON A 20 YEAR TIME PERIOD
2.1% INFLATION / 6% DISCOUNT RATE

YEAR	ELAPSED YEARS	SCREEN UNIT			STORM UNIT			CLEAR SINGLE GLAZING WINDOW UNIT			LOW E DOUBLE GLAZING WINDOW UNIT		
		ESTIMATED COST 1996$ SUM (D + J)	ESTIMATED COST IN BUDGET YEAR @ 2.1%	PRESENT VALUE 1996$ @ 6% DISCOUNT RATE	ESTIMATED COST 1996$ SUM (B + E + K)	ESTIMATED COST IN BUDGET YEAR @ 2.1%	PRESENT VALUE 1996$ @ 6% DISCOUNT RATE	ESTIMATED COST 1996$ SUM (A + F + H)	ESTIMATED COST IN BUDGET YEAR @ 2.1%	PRESENT VALUE 1996$ @ 6% DISCOUNT RATE	ESTIMATED COST 1996$ SUM (C + G + I)	ESTIMATED COST IN BUDGET YEAR @ 2.1%	PRESENT VALUE 1996$ @ 6% DISCOUNT RATE
1996	0	$0.31	$0.31	$0.31	$0.61	$0.61	$0.61	-$0.23	-$0.23	-$0.23	-$1.25	-$1.25	-$1.25
1997	1	$0.31	$0.32	$0.29	$0.61	$0.62	$0.58	-$0.23	-$0.23	-$0.22	-$1.25	-$1.28	-$1.18
1998	2	$0.31	$0.32	$0.28	$0.61	$0.64	$0.54	-$0.23	-$0.24	-$0.20	-$1.25	-$1.30	-$1.11
1999	3	$0.31	$0.33	$0.26	$0.61	$0.65	$0.51	-$0.23	-$0.24	-$0.19	-$1.25	-$1.33	-$1.05
2000	4	$1.56	$1.70	$1.24	$2.28	$2.48	$1.81	$2.49	$2.71	$1.97	$1.05	$1.14	$0.83
2001	5	$0.31	$0.34	$0.23	$0.61	$0.68	$0.46	-$0.23	-$0.26	-$0.17	-$0.95	-$1.05	-$0.71
2002	6	$0.31	$0.35	$0.22	$0.61	$0.69	$0.43	-$0.23	-$0.26	-$0.16	-$0.95	-$1.08	-$0.67
2003	7	$0.31	$0.36	$0.21	$0.61	$0.71	$0.41	-$0.23	-$0.27	-$0.15	-$0.95	-$1.10	-$0.63
2004	8	$0.31	$0.37	$0.19	$0.61	$0.72	$0.38	-$0.23	-$0.27	-$0.14	-$0.95	-$1.12	-$0.60
2005	9	$1.56	$1.88	$0.92	$2.28	$2.75	$1.35	$2.49	$3.00	$1.47	$1.35	$1.63	$0.80
2006	10	$0.31	$0.38	$0.17	$0.61	$0.75	$0.34	-$0.23	-$0.28	-$0.13	-$0.95	-$1.17	-$0.53
2007	11	$0.31	$0.39	$0.16	$0.61	$0.77	$0.32	-$0.23	-$0.29	-$0.12	-$0.95	-$1.19	-$0.50
2008	12	$0.31	$0.40	$0.15	$0.61	$0.78	$0.30	-$0.23	-$0.30	-$0.11	-$0.95	-$1.22	-$0.47
2009	13	$0.31	$0.41	$0.15	$0.61	$0.80	$0.29	-$0.23	-$0.30	-$0.11	-$0.95	-$1.24	-$0.45
2010	14	$1.56	$2.09	$0.69	$2.28	$3.05	$1.01	$2.49	$3.33	$1.10	$1.35	$1.81	$0.60
2011	15	$0.31	$0.42	$0.13	$0.61	$0.83	$0.25	-$0.23	-$0.31	-$0.10	-$0.95	-$1.30	-$0.40
2012	16	$0.31	$0.43	$0.12	$0.61	$0.85	$0.24	-$0.23	-$0.32	-$0.09	-$0.95	-$1.32	-$0.37
2013	17	$0.31	$0.44	$0.12	$0.61	$0.87	$0.23	-$0.23	-$0.33	-$0.09	-$0.95	-$1.35	-$0.35
2014	18	$0.31	$0.45	$0.11	$0.61	$0.89	$0.21	-$0.23	-$0.33	-$0.08	-$0.95	-$1.38	-$0.33
2015	19	$1.56	$2.32	$0.52	$2.28	$3.38	$0.75	$2.49	$3.70	$0.82	$1.35	$2.00	$0.45
TOTAL		$11.20	$14.00	**$6.47**	$18.88	$23.51	**$11.02**	$6.28	$8.27	**$3.07**	-$11.30	-$13.12	**-$7.93**

* EXAMPLE
SCREEN UNIT COMPRISES WORK ACTIVITIES IDENTIFIED AT COLUMNS D & J (SCREEN PAINTING & SCREEN INSTALLATION) OF TABLE 2

TABLE #3B
WINDOW RESTORATION UNITS *
LIFE CYCLE MAINTENANCE & SAVING COSTS PER SQ. FT. BASED ON A 20 YEAR TIME PERIOD
2.1% INFLATION / 6% DISCOUNT RATE

YEAR	ELAPSED YEARS	SCREEN UNIT		
		ESTIMATED COST 1996$ SUM (D + J)	ESTIMATED COST IN BUDGET YEAR @ 2.1%	PRESENT VALUE BUDGET YEAR (2.1%) @ 6% DISCOUNT RATE
1996	0	$0.31	$0.31	$0.31
1997	1	$0.31	$0.32	$0.30
1998	2	$0.31	$0.32	$0.29
1999	3	$0.31	$0.33	$0.28
2000	4	$1.56	$1.70	$1.34
2001	5	$0.31	$0.34	$0.26
2002	6	$0.31	$0.35	$0.25
2003	7	$0.31	$0.36	$0.24
2004	8	$0.31	$0.37	$0.23
2005	9	$1.56	$1.88	$1.11
2006	10	$0.31	$0.38	$0.21
2007	11	$0.31	$0.39	$0.21
2008	12	$0.31	$0.40	$0.20
2009	13	$0.31	$0.41	$0.19
2010	14	$1.56	$2.09	$0.92
2011	15	$0.31	$0.42	$0.18
2012	16	$0.31	$0.43	$0.17
2013	17	$0.31	$0.44	$0.16
2014	18	$0.31	$0.45	$0.16
2015	19	$1.56	$2.32	$0.77
TOTAL		$11.20	$14.00	**$7.77**

* EXAMPLE
SCREEN UNIT COMPRISES WORK ACTIVITIES IDENTIFIED AT COLUMNS D & J (SCREEN PAINTING & SCREEN INSTALLATION) OF TABLE 2

TABLE #4
20 YEAR CASH FLOW PROJECTIONS FOR WINDOW RESTORATION
(INITIAL COST OF RESTORATION + 20 YEAR LIFE CYCLE MAINTENANCE AND SAVING COSTS)

NO.	VARIOUS WINDOW RESTORATION OPTIONS	A AVERAGE INITIAL COST PER SQ. FT. 1996$	B PRESENT VALUE OF 20 YEAR LIFE CYCLE MAINTENANCE & SAVING COST PER SQ. FT. 1996$ @6% DISCOUNT RATE	A + B TOTAL PRESENT VALUE PER SQ. FT. 1996$
3	SCREEN RESTORATION	$7.63	$6.47	**$14.10**
4	STORM RESTORATION / 10% PUTTY	$8.63	$11.02	**$19.65**
6	EXTERIOR FRAME AND SASH RESTORATION / CASEMENT	$14.29	$3.07	**$17.36**
8	WOOD SCREEN REPLACEMENT	$18.58	$6.47	**$25.05**
9	FRAME AND SASH RETORATION / CASEMENT / 12% PUTTY	$28.80	$3.07	**$31.87**
10	STORM RESTORATION / 100% PUTTY	$31.17	$11.02	**$42.19**
11	EXTERIOR FRAME AND SASH RESTORATION / SINGLE HUNG	$33.52	$3.07	**$36.59**
12	WOOD STORM REPLACEMENT	$34.72	$11.02	**$45.74**
14	FRAME AND SASH RESTORATION / SINGLE HUNG / 100% PUTTY	$55.82	$3.07	**$58.89**
16	FRAME AND SASH RESORATION / CASEMENT / 100% PUTTY	$57.17	$3.07	**$60.24**
17	FRAME RESTORATION AND SASH REPLACEMENT / CASEMENT	$59.16	$3.07	**$62.23**
18	FRAME RESTORATION AND SASH REPLACEMENT / SINGLE HUNG	$60.49	$3.07	**$63.56**
19	AWNING AND EXTENDED FRAME IN LIEU OF STORM	$60.80	-$7.93	**$52.87**
20	FRAME AND SASH REPLACEMENT / CASEMENT	$103.90	-$7.93	**$95.97**
21	FRAME AND SASH REPLACEMENT / SINGLE HUNG	$126.76	-$7.93	**$118.83**

TABLE #5

20 YEAR CASH FLOW PROJECTIONS FOR WINDOW RESTORATION

(INITIAL COST OF RESTORATION + 20 YEAR LIFE CYCLE MAINTENANCE AND SAVING COSTS)

	TOTAL PRESENT VALUE PER SQ. FT. 1996$ (TABLE 4)	
	SINGLE HUNG	CASEMENT
SCHEME #1: FULL RESTORATION		
#3 SCREEN RESTORATION	$14.10	$14.10
#10 STORM RESTORATION	$42.19	$42.19
#14 & #16 FRAME AND SASH RESTORATION	$58.89	$60.24
TOTAL	**$115.18**	**$116.53**
SCHEME #2: PARTIAL RESTORATION		
#8 SCREEN REPLACEMENT	$25.05	$25.05
#12 STORM REPLACEMENT	$45.74	$45.74
#18 & #17 FRAME RESTORATION AND SASH REPLACEMENT	$63.56	$62.23
TOTAL	**$134.35**	**$133.02**
SCHEME #3: FULL REPLACEMENT		
#8 SCREEN REPLACEMENT	$25.05	$25.05
#21 & #20 FRAME AND SASH REPLACEMENT	$118.83	$95.97
TOTAL	**$143.88**	**$121.02**
SCHEME #4: MIXED SOLUTION		
#2 ALUMINUM SCREEN REPLACEMENT		* $4.33
#19 AWNING AND EXTENDED FRAME IN LIEU OF STORM		$52.87
#16 FRAME AND SASH RESTORATION		$60.24
TOTAL		**$117.44**

* NO CASH FLOW PROJECTION INCLUDED IN #2

NCC CASE STUDY #1

Project title:	Charron House Rehabilitation, Hull Casement replacement
FHBRO:	Recognized, 52 points
Project No:	8419
Contract amount:	$19,983.00
Year completed:	1986
Glazing pattern	3/3

Cost Breakdown

The replacement cost did not include for the reconstruction of the interior window reveals and sills.

	Number of units	Cost breakdown	Cost per unit	Avg. area per unit in sq. ft.	Cost per sq. ft.
Frame and sash replacement / casement / dg / w / h	19	$16,986.00	$894.00	11.7	$76.41
Shutter replacement / h	9 sets	$2,997.00	$333.00	10.5	$31.71

TOTAL **$19,983.00**

legend	
s.g:	single glazing
d.g:	double glazing
w:	weatherstripping
h:	hardware
b:	balance

NCC CASE STUDY #2

Project title:	142 St. Patrick Street, Ottawa Awning in lieu of storm and casement restoration
FHBRO:	Recognized, 54 points
Project No:	9101
Contract Amount:	$34,301.00
Year completed:	1991
Glazing pattern	3/3

Cost Breakdown

A new awning window with an extended frame was installed in lieu of the original storm window and equipped with weatherstripping and hardware.

	Number of units	Cost breakdown	Cost per unit	Avg. area per unit in sq.ft.	Cost per sq. ft.
Frame and sash restoration / casement / 10% of putty repair	11	$3,311.00	$301.00	22.6	$13.31
Awning and extended frame in lieu of storm / dg / w / h	11	$15,400.00	$1,400.00	22.6	$61.94
Aluminum screen replacement	11	$1,100.00	$100.00	22.6	$4.42
Exterior frame and sash restoration / single hung / w	21	$10,920.00	$520.00	19.3	$26.94
Storm restoration / 10% of putty repair	21	$3,570.00	$170.00	19.3	$8.80

TOTAL **$34,301.00**

legend	
s.g:	single glazing
d.g:	double glazing
w:	weatherstripping
h:	hardware
b:	balance

NCC CASE STUDY #3

Project title:	Residential masonry building, Ottawa Frame and sash restoration
FHBRO:	N/A
Project No:	RD 2620-4
Proposed budget:	$152,306.00 (estimate)
Year of implementation:	Project on hold
Glazing patterns	6/6, 6/1, 8/1, 3/3, 4/4, 3/6, 2/2

Cost Breakdown

	Number of units	Cost breakdown	Cost per unit	Avg. area per unit in sq. ft.	Cost per sq. ft.
Removal of steel storm	72	$4,660.00	$64.00	17.1	$3.74
Frame and sash restoration / single hung / 35% of putty repair sg / w / b / h	75	$61,800.00	$824.00	18.3	$45.02
Frame and sash replacement / single hung / dg / w / b / h	5	$15,180.00	$3,036.00	22.7	$133.74
Wood screen replacement / h	57	$19,950.00	$350.00	17.0	$20.58
Wood storm replacement / h	62	$36,456.00	$588.00	17.7	$33.22
Repair & clean aluminum insert sash	124	$14,260.00	$115.00	9.0	$12.77

TOTAL **$152,306.00**

legend	
s.g:	single glazing
d.g:	double glazing
w:	weatherstripping
h:	hardware
b:	balance

NCC CASE STUDY #4

Project title:	541 Sussex and 25 George Streets,Ottawa Frame restoration and sash replacement
FHBRO:	Recognized, 69 points
Project No:	RD 2460-1
Contract amount:	$157,041.00
Year completed:	1993
Glazing patterns	6/6, 2/2, 1/1

Cost Breakdown

The restoration work was limited to the window frame and did not include any work on the interior sills and window reveals.

	Number of units	Cost breakdown	Cost per unit	Avg. area per unit in sq. ft.	Cost per sq. ft.
Frame restoration and sash replacement / single hung / sg / w / b / h	87	$137,025.00	$1,575.00	25.8	$61.04
Frame restoration and sash replacement / casement / sg / w / h	18	$14,616.00	$812.00	14.4	$56.40
Frame and sash replacement / single hung / sg / w / b / h	2	$5,400.00	$2,700.00	25.0	$108.00

TOTAL **$157,041.00**

legend	
s.g:	single glazing
d.g:	double glazing
w:	weatherstripping
h:	hardware
b:	balance

NCC CASE STUDY #5

Project title:	Rideau Hall - Minto Wing, Basement Floor Single hung replacement
FHBRO:	Classified, 91 points
Project No:	9027
Contract amount:	$32,256.00 (0% GST)
Year completed:	1991
Glazing pattern	2/2

Cost Breakdown

The single hung replacement windows with thermopane were designed with a full wood screen unit. The project also included all associated costs related to the interior window reveal restoration (replacement of 5 out of 12 interior sills and trims). GST was not included.

	Number of units	Cost breakdown	Cost per unit	Avg. area per unit in sq. ft.	Cost per sq. ft.
Frame and sash replacement / single hung / dg / w / b / h	12	$28,236.00	$2,353.00	19.5	$120.66
Wood screen replacement / h	12	$4,020.00	$335.00	19.5	$17.22

TOTAL **$32,256.00**

legend	
s.g:	single glazing
d.g:	double glazing
w:	weatherstripping
h:	hardware
b:	balance

NCC CASE STUDY #6

Project title:	Rideau Hall - Minto Wing, Ground and Second Floors Frame and sash restoration
FHBRO:	Classified, 91 points
Project No:	RD 2610-52
Contract amount:	$35,263.00 (0% GST)
Year completed:	1993
Glazing pattern	2/2

Cost Breakdown

The cost reflects only the restoration work related to the windows themselves since there was no need to restore the interior window reveals. GST was not included.

	Number of units	Cost breakdown	Cost per unit	Avg. area per unit in sq. ft.	Cost per sq. ft.
Frame and sash restoration / single hung / 100% of putty repair / sg / w / b /h	25	$35,263.00	$1,410.00	28.8	$48.97

TOTAL **$35,263.00**

legend	
s.g:	single glazing
d.g:	double glazing
w:	weatherstripping
h:	hardware
b:	balance

NCC CASE STUDY #7

Project title:	Rideau Hall - 1838, Minto and Hospitality Wings Frame and sash restoration
FHBRO:	Classified, 91 points
Project No:	RD 2610-93 & RD 2610-94
Contract amount:	$48,652.00 (0% GST and 5% work stoppage included)
Year completed:	1995
Glazing patterns	6/6, 1/1, 4/4, 8/8

Cost Breakdown

All double hung windows were modified into a single hung window with new balance and weatherstripping installed into lower sash frame. The original weight cavity was then filled with insulation. Paint was removed entirely. The contract amount included 0% GST and 5% for work stoppage during construction.

	Number of units	Cost breakdown	Cost per unit	Avg. area per unit in sq. ft.	Cost per sq. ft.
Frame and sash restoration / single hung / 100% of putty repair / sg / w / b / h	12	$13,733.00	$1,144.00	20.9	$54.73
Minor restoration of casement / interior sill	1	$478.00	$478.00	35.7	$13.39
Wood storm replacement / h	34	$26,315.00	$774.00	24.4	$31.72
Wood screen replacement / h	35	$7,731.00	$221.00	13.2	$16.74
Frame restoration and sash replacement / single hung / sg / w / b / h	1	$734.00	$734.00	13.6	$53.97

TOTAL **$48,652.00**

legend	
s.g:	single glazing
d.g:	double glazing
w:	weatherstripping
h:	hardware
b:	balance

NCC CASE STUDY #8

Project title:	529 Richmond Road, Ottawa Rochester House Frame and sash restoration
FHBRO:	Classified, 81 points
Project No:	RD 2400-06-03
Contract amount:	$34,510.00 (7% GST included)
Year completed:	1996
Glazing patterns	12/12, 10/10, 2/2

Cost Breakdown

Hardware replacement was limited to new hinges only. No weatherstrippings were installed in this project. Paint was removed only where needed.

	Number of units	Cost breakdown	Cost per unit	Avg. area per unit in sq. ft.	Cost per sq. ft.
Exterior frame and sash restoration / casement / 12 % of putty repair / sg	36	$11,300.00	$314.00	20.0	$15.70
Frame and sash restoration / casement / 12% of putty repair / sg	5	$1,930.00	$368.00	13.4	$28.80
Storm restoration / 30% of putty repair	37	$18,755.00	$507.00	18.9	$26.82
Wood storm replacement / h	1	$517.00	$517.00	18.0	$28.72
Screen restoration	1	$84.00	$84.00	11.0	$7.63
Wood screen replacement / h	7	$1,924.00	$275.00	18.0	$15.28
TOTAL		**$34,510.00**			

legend	
s.g:	single glazing
d.g:	double glazing
w:	weatherstripping
h:	hardware
b:	balance

NCC CASE STUDY #9

Project title:	Rideau Hall - 1906 and Minto Wings Frame and sash restoration
FHBRO:	Classified, 91 points
Project No:	RD 2610-120
Contract amount:	$28,627.00 (0% GST and 5% work stoppage included)
Year completed:	1996
Glazing patterns	1/1, 3/3

Cost Breakdown

	Number of units	Cost breakdown	Cost per unit	Avg. area per unit in sq. ft.	Cost per sq. ft.
Frame and sash restoration / single hung / sg / w / b / h	6	$5,517.00	$919.00	14.0	$65.64
Storm restoration / 100% of putty repair / h	3	$1,620.00	$540.00	15.5	$34.83
Wood storm replacement / h	4	$1,613.00	$403.00	9.8	$41.04
Wood screen replacement / h	12	$1,721.00	$143.00	7.2	$19.90
Frame restoration	1	$141.00	$141.00	9.5	$14.84
Door, sidelights and frame restoration / w	1	$2,631.00	$2,631.00	47.0	$55.98
Frame and sash restoration / casement / sg / w / h	1	$981.00	$981.00	17.5	$56.05
Exterior frame and sash restoration / single hung / dg	5	$3,329.00	$666.00	16.7	$39.82
Frame restoration and doors, screens, transoms replacement / dg / w / h	1	$11,074.00	$11,074.00	74.0	$149.64
TOTAL		**$28,627.00**			

legend	
s.g:	single glazing
d.g:	double glazing
w:	weatherstripping
h:	hardware
b:	balance

CASE STUDY #10

Project Title: Queen's Park Legislature Building
North Wing Steel Window Restoration

Cost:

Contract Amount -	$625,000.00
Scaffold (est.) -	180,000.00
Temporary Protections -	200,000.00
Consultant's Fees -	56,250.00
Total	1,061,250.00

Year Completed: 1995-96

Typical Scope of Work for Steel Window Restoration:

- complete paint removal and reproduction of original interior/exterior finishes
- repair and reproduction of bronze hardware
- weather stripping
- replacement of all ground floor glass with laminated glass
- resetting of all glass
- a typical unit consists of two casement ventilators, each with a duplex closer and casement stay, and a transom hopper ventilator with side stays and a pole catch
- no units showed heavy corrosion
- extensive interior and exterior protections were required, the former to isolate the work area from the public and office occupants, the latter to isolate the work area from masonry restoration work
- ventilators were removed to shop for restoration, restoration of frames occurred in situ but after hours to avoid disturbing occupants
- contract amount included allowance of $75,000 for reproduction of broken or missing hardware components

Cost Breakdown

Number of Units	Cost	Cost per Unit	Avg. area per unit in sq. ft.	Cost per sq.ft.
250	$1,061,250	$4,245	34.0	$125

CASE STUDY #11

Project Title: Queen's Park Legislature Building -
Single Hung Wood Window Restoration
Phases II & III

Cost:

Contract Amounts -	$ 952,390.00
	750,000.00
Scaffold (est.) -	400,000.00
Temporary Protections (est.)-	400,000.00
Consultants' Fees -	204,286.00
Total	$2,706,676.00

Year Completed: 1992-94

Typical scope of work for single hung wood window restoration:

- complete paint removal and reproduction of original exterior paint colours and interior grained finishes
- repair and reproduction of bronze hardware
- average of 3 dutchman repairs per sash
- weather stripping of lower sash, upper sash sealed shut from interior
- replacement of all glass in ground floor, Premier's Suite and Legislative Chambre with laminated glass
- resetting of all glass
- epoxy repairs to 50% of sills
- sash removed to shop for restoration, frames restored in situ
- original counter balance systems adjusted and retained
- most of these windows were large, i.e., 6' wide by 10' tall, in a 2/1 glazing pattern
- protections were required to isolate the window frame from
- the public and office occupants on the interior, and to prevent infiltrating dust from exterior masonry restoration work

Cost Breakdown

Number of Units	Cost	Cost per Unit	Avg. area per unit in sq. ft.	Cost per sq.ft.
500	$2,706,676	$5,413	65	$83.28

CASE STUDY #12

Project Title: Queen's Park Legislature Building
Single Hung Wood Window Restoration
Phase IV, Basement

Cost:

Contract Amount -	$ 248,000.00
Temporary Protections (est.)-	25,000.00
Consultants' Fees -	24,800.00
Total	$ 297,800.00

Year Completed: 1994-95

Typical scope of work for single hung wood window restoration:

- similar to Case Study #11 except for the following:
- window interiors were painted, not grained
- all original glass was replaced with laminated glass and weights were adjusted
- windows averaged 6' wide x 6' high with a 3/2 glazing pattern

Typical scope of work for single hung wood window reproductions:

- contract amount includes for removal of non-original fixed aluminum windows but not for repairs to interior plaster
- new units were double glazed by use of an interior glazing panel set into rebates on inside face of sash
- all glass was tempered
- new units matched originals in terms of joinery details, counter balance system, etc.

Cost Breakdown for Restoration:

Number of Units	Cost	Cost per Unit	Avg. area per unit in sq. ft.	Cost per sq.ft.
40	$148,900	$3,722.50	32	$116.33

Cost Breakdown for Replacement Units:

Number of Units	Cost	Cost per Unit	Avg. area per unit in sq. ft.	Cost per sq.ft.
40	$148,900	$3,722.50	36	$103.40

CASE STUDY #13

Project Title: Centre Block, Parliament Hill, Ottawa
South Facade Restoration
Restoration of Original Steel and Leaded Glass Windows

Cost:

Contract Amount -	$	385,000.00
Temporary Protections -		151,400.00
Consultants' Fees (est.) -		38,500.00
Scaffold (est.) -		150,000.00
Total	$	724,900.00

Year Completed: 1994-95

Typical Scope of Work:

- units were a mixture of window types including: 26 dormer windows with clear single glazing in steel ventilators; 16 units consisting of leaded glass assemblies (no stained or coloured glass) set directly into masonry in complicated Gothic shapes; 30 units consisting of leaded glass assemblies set into steel frames anchored in masonry in simple Gothic shapes
- restoration of bronze hardware, duplex handles and casement stays, required on 56 operating ventilators
- 1% of replacement glass required, patterned obscure type to match existing
- all glass was reset in glazing compound
- no units showed heavy corrosion
- approximately 60% of leaded work repaired and retained, remaining replaced
- all steel frames were electroplated with copper to match original finish, lead cames were patinated with copper; all coated in a pigmented wax finish inside and out
- all perimeter putty replaced
- extensive interior and exterior protections were required, the former to isolate the work area from the public and office occupants, the latter to isolate the work area from masonry restoration work
- most units were removed to shop for restoration

Cost Breakdown:

Number of Units	Cost	Cost per Unit	Avg. area per unit in sq. ft.	Cost per sq.ft.
72	$724,900	$10,068	22	$458

CASE STUDY #14

Project Title: Centre Block, Parliament Hill, Ottawa
South Facade Restoration
Reproduction of Missing Steel Windows

Cost:

Contract Amount -	$1,862,000.00
Temporary Protections -	298,598.00
Consultants' Fees (est.) -	112,000.00
Scaffold (est.) -	350,000.00
Total	$2,622,598.00

Year Completed: 1994-95

Typical Scope of Work:

- removal of all c.1960 aluminum units and perimeter caulking
- all replacement units were single glazed but consisted of a double window system; typically this was one steel window system on the exterior in the plane where the original unit was positioned, usually consisting of 2 or 3 individual units fitted within the stone tracery, as well as a large interior unit completely covering the individual exterior units and stone tracery
- variations in the masonry openings were such that templates were required for each individual opening
- all steel profiles, hardware and finishes were standard commercially available types
- approximately 20 units were fitted with bullet proof glass

Cost Breakdown:

Number of Units	Cost	Cost per Unit	Avg. area per unit in sq. ft.	Cost per sq.ft.
222	$2,622,598.00	$11,813.50	62	$190.54

ANNEX #1

A contract with Riteway Window Cleaners Ltd. in november 1997 for the window cleaning services and the storm and screen installations done twice a year on 8 buildings at Rideau Hall revealed that the annual costing per square foot for the following activities are:

-storm installation is $0,31 per square foot
-screen installation is $0,31 per square foot
-window cleaning is $0.08 per square foot
-dismantling and reinstallation of aluminum storm for cleaning or painting purposes are $0.25 per square foot.

ANNUAL INSTALLATION COST PER SQUARE FOOT FOR STORM AND SCREEN (WOOD) (twice a year)

Buildings	total annual cost	total area of storm & screen (sq ft.)	cost per (sq.ft.)
Rideau cottage	$457.00	1756	$0.26
Minto (Bas+GF)	$241.00	1268	$0.19
Government House/Private Quarters *	$685.00	1362	$0.50
Dome building	$192.00	720	$0.27
RCMP Guard House	$107.00	364	$0.30
TOTAL	***$1,682.00***	***5470***	***$0.31***

** Third floor window only*

ANNUAL CLEANING GLAZING COST
PER SQUARE FOOT
FOR
SASHES AND STORM (WOOD OR ALUMINUM)
(twice a year)

Buildings	total annual cost	total area of glazing	cost per (sq.ft.)
Rideau cottage	$559.00	8240	$0.06
Minto (Bas+GF)	$294.00	5072	$0.05
Government House/Private Quarters *	$837.00	5572	$0.15
Dome building	$192.00	2268	$0.08
RCMP Guard House	$107.00	1092	$0.09
NCC Adm.Offices	$150.00	2748	$0.05
Official Car Garage and Apartments	$128.00	2136	$0.05
11 Rideau Gate	$176.00	1674	$0.10
TOTAL	***$2,443.00***	***28802***	***$0.08***

** Third floor window only*

ANNUAL COST
PER SQUARE FOOT
FOR
DISMANTLING ALUMINUM STORM
(twice a year)

Buildings	total annual cost	total area of aluminum storm	cost per (sq.ft.)
NCC Adm.Offices	$150.00	834	$0.18
Official Car Garage and Apartments	$128.00	528	$0.24
11 Rideau Gate	$176.00	430	$0.40
TOTAL	***$454.00***	***1792***	***$0.25***