RESEARCH REPORT

External Research Program

Assessment of the Capacity to Use Stochastic Models in Building Life Cycle Costing

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ASSESSMENT OF THE CAPACITY TO USE STOCHASTIC MODELS IN BUILDING LIFE CYCLE COSTING

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NOTE: LE RÉSUMÉ EN FRANÇAIS SUIT IMMÉDIATEMENT LE RÉSUMÉ EN ANGLAIS.

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DISCLAIMER

This study was conducted for Canada Mortgage and Housing Corporation under Part IX of the National Housing Act. The analysis, interpretations and recommendations are those of the consultant and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those divisions of the Corporation that assisted in the study and its publication.

This report provides the results of using statistical models to estimate maintenance and replacement expenditure levels over time in Canada's social and non-profit housing stock. Operating costs were obtained from CMHC and public and non-profit housing providers across Canada. Generally stochastic models in the building sciences literature focus on the performance of specific materials or elements of a building structure. In contrast, the economics and appraisal literature provide a number of general factors which influence maintenance and replacement expenditures. Together they provide a set of hypothesis and analytical methodologies which can be applied to understanding the factors influencing maintenance and replacement expenditures over time.

Data for approximately 75% of the Canadian social housing stock and 30% of the comparable maintenance and replacement expenditures were reviewed. However, there were inconsistencies in classifying and recording the data, and the building technical characteristics and operating and maintenance practices were missing. As such, trends were developed resulting in an explanation for 40% of the maintenance and 20% of the replacement expenditure variances.

The major factors influencing maintenance and replacement expenditures for these buildings were:

- age (original and since rehabilitated if applicable);
- location (province, size if urban community, location if remote);
- size and unit type (e.g. number of units and bedrooms, apartment row or detached);
- occupancy (e.g. senior, family, etc.);
- institutional (ownership and management); and
- building characteristics (e.g. heating system, heating energy, presence of elevators balconies and parking, etc.).

These results were used in a series of simulations which indicated that some currently prescribed replacement reserve contribution levels were inadequate for projects having multiple "risk factors". These risk factors include, for example, location in remote locales, high proportions of family housing and rehabilitation versus new construction.

Recommended future work includes the further development of a database of social housing building and project characteristics and financial data which could be used in developing cost models. Such a database requires a simple, consistent and activity based classification of financial income and expenditure accounts.

Summary

This report assesses the possibility of using stochastic (probabilistic) models to estimate building life cycle maintenance, repair and replacement costs over time. It provides an assessment of how well these models can be used in estimating these long term costs for existing social housing portfolios.

Specifically, it:

- ✔ provides a comprehensive review of the literature in the building science, economics and appraisal fields concerning general factors influencing maintenance and replacement costs over building life and the theory or application of stochastic models for estimating these costs;

- ✔ consolidates and assesses the usefulness of historical data on operating costs and replacement reserves, collected by CMHC and various housing providers throughout the country for housing built through provincial and federal housing programs for low and moderate income households and organizes these in a manner amenable to analysis; and

- ✔ develops and tests a series of models which estimate long term maintenance, repair and replacement costs in Canada's social housing stock.

Synopsis of the Literature, Model Specification and Data Sources

■ Literature Synopsis

The literature reviewed in the report comes from two general sources--the building sciences literature, and the economics and appraisal fields.

The **building sciences literature** treats time related wear-and-tear and deterioration as important factors for the modelling of optimal building maintenance and component replacement practices. Yet in the building sciences literature, there is scant attention given to the subject of life cycle costs at an aggregate level of the overall building structure. Rather, emphasis is placed upon the performance of individual building components and systems.

Predominantly, models characterize the failure patterns of building materials or components as a process occurring under a limited range of major, controlled circumstances (for example, material/component performance factors, level of degradation force etc.) which are also governed by a myriad of uncontrollable, minor factors, characterized as "error". When major factors are controlled, the effect of this myriad of minor factors have produced ranges of outcomes predictable with a high level of certainty.

The objective in the building sciences is to use these results to specify optimal maintenance and replacement regimes, holding major performance factors constant, under conditions where error is present. At an aggregate, project wide level, circumstances cannot be tightly defined, and in this literature, there is little research dedicated to what these aggregate circumstances might be. Still, the methods used provide intriguing avenues for the research conducted in this report which examines building maintenance and replacement expenditure patterns, rather than practices, of the large system of a social housing project which, at a aggregate level may be the outcome of a such a process.

Related economics and appraisal literature typically focus on maintenance and replacement expenditure levels for buildings. Most significant are studies examining a wide scope of building related and other factors which have likely influenced levels of building related expenditures. Aging, as in the materials science literature is seen to be the cumulative effect of deterioration, a factor in the decision to make maintenance/replacement expenditures. This decision is also related to two other factors--obsolescence and competing alternatives for scarce funds.[1]

Research in the area is sparse and diverse in its approach and generally has not had high degrees of success or predictive power in estimating maintenance/replacement expenditures or requirements. Still, there are strong and consistent findings which form the basis of the analysis undertaken here:

- There is a tendency for housing to deteriorate and/or become obsolete at an increasing rate with age and for the combination of maintenance, repair, alteration and renovation requirements to increase though economic life. In addition, there is evidence of a short initial expenditure peak during the early building life where remodelling and the repair of defects are quite common. Taken together, these trends produce a distribution of expected total maintenance and replacement expenditures over time which seems to correspond to a "bath tub" curve. This distribution is characteristic of the expected life patterns of a number of building components.

- In addition, a number of other general factors have been seen to significantly affect maintenance and replacement expenditure patterns. These include climatic and geographical considerations (such as community size and location), household size and composition, turnover, building form, building and unit size, and building materials.

■ Model Specification

Considerations arising from the literature review give rise to a series of hypotheses concerning

[1] A major difficulty and failure of modelling presented from this field is the inability to differentiate the effects of each of these influences. Because time series data are used in this study, there is some capacity to distinguish between the effects of "vintage" (obsolescence of technology and technique used when a building was constructed) and aging.

the major factors influencing maintenance and expenditures levels in Canada's social housing stock tested in this study (see Table S.1).

Table S.1 Summary of Factors Hypothesized to Influence Maintenance and Replacement Expenditures in Canada's Social Housing Stock	
Characteristic	**Data Available**
Building Age	* Years since construction * Years since rehabilitation (for rehab. buildings) * Original Age (for rehab. buildings)
Building Location	* Province * Population of urban area/community * Location in a northern/remote area
Project and Unit Characteristics	* Total number of units * Types of unit (apartments, row etc.) * Average number of bedrooms
Household Type	* Household Form (i.e. seniors, families, etc.)
Institutional Characteristics	* Program built under * Provider type (housing authority, co-op etc.)
Building Characteristics	* Construction type * Exterior cladding * Roof type * Heating type (forced air, hot water etc.) * Heating fuel * Presence of balconies * Presence of elevators * Predominant unit floor covering * Presence, extent of landscaping * Presence/type of parking

■ Data Sources, Quality and Methodology

Histories of annual maintenance and replacement expenditures and project characteristics covering three quarters of social housing rental stock in Canada were used in testing these hypotheses. In total, histories spanning an average of 8 years were brought together with project characteristics concerning 13,223 projects (approximately 505,000 housing units). This represents approximately 30% of all annual maintenance and replacement expenditures reported since the first major inception of social housing.

The data are not without flaws. In particular:

- There are inconsistencies in how maintenance and repair expenditure data were classified across projects and over time. These inconsistencies are largely due to changes and differences in accounting rules and difficulties in isolating and tracking expenditures in these areas;

- A number of building characteristics were available for only a small fraction of the total stock examined. The noise produced by these problems severely reduced the capacity to assess the validity of a number of research hypotheses; and

- Some factors seen in the literature to influence expenditure levels were not captured in the data available. Principally, these include tenant behaviour and characteristics (turnover, levels of vandalism, and the presence occupants with special needs) and specific evidence of maintenance and/or replacement practice.

Multivariate analysis of variance and covariance techniques were used to estimate best fitting per unit maintenance and replacement expenditure models. In addition, curves best characterized a wide range of underlying stochastic processes were fit and results compared for long individual project expenditure time series.

Results

Overall, an average of just under 40% of variations in maintenance expenditures per unit and just under 20% of variation in replacement expenditure per unit could be explained using these models. These results are strong enough to indicate general trends in maintenance and replacement expenditures, although a large majority of variation in expenditures patterns is left "unexplained". These general trends include:

- **The influence of aging:**

  - Building age was a consistent and strong predictor of both replacement and maintenance expenditures. On average, variations in building age could be used to explain 8% of all differences in replacement expenditures and 6% of differences in maintenance expenditures.

  - Overall, during the first four decades of operations, maintenance expenditures increase on a yearly basis by an average of approximately $15 per year (1992 $'s) while replacement expenditures increase by about $25 annually. Placing this in perspective, during the period between 1973 and 1992, in the "average" 8 year old social housing unit annual maintenance expenditures were $659 and replacement expenditures, $286.

  - Maintenance expenditures are higher than replacement expenditures during the early years of projects. In the beginning of the third decade of operation, replacement expenditures cross over in some projects to become larger than maintenance expenditures. By the forth decade in replacement expenditures are larger than maintenance expenditures in most projects. Increases in maintenance expenditures tend to slowly creep up to and above $15 per year while replacement costs tend to stay low and tend to decline in some cases in the first decades of operation. In the middle of the second decade, replacement costs begin to slowly and consistently inch up.

- ✡ Per unit maintenance costs are consistently higher by about 10%in rehabilitated buildings.[2] These older buildings often include technology and form which is currently hard to sustain at low cost.

- ✡ The evidence seems to point at a process akin to that evident in health care requirement with human aging in replacement expenditure time series. The likelihood that health care is required is high during early life, then declines and stays low through childhood and early adulthood. In mid-adulthood, these requirements initially slowly rise, slowly accelerating to reach high levels in the senior years. There is, though, insufficient evidence to indicate that a particular stochastic process predominates in the progression of replacement expenditures over time. These trends also correspond well to the form of a "bath tub" curve.

- ✘ A clear pattern pointing at a dominant process in maintenance expenditure time series cannot be deciphered because of inconsistencies in the data collected and smaller degrees of change in maintenance costs over time.

- ✘ In comparing results from the CMHC's Federal Co-operative and Public Housing Program Evaluations, it is clear that a larger proportion of required replacement work needs to be addressed in the older, Public Housing program. The economics literature indicates that home owners and private rental building managers very often do not make maintenance and replacement expenditures which fully off-set slow, steady and accelerating deterioration in their buildings and the generality is likely also apt in the Canadian social housing context. As a result, focusing solely upon expenditures may not tell the complete story of maintenance and replacement needs over time.

- ■ **The Effects of Building Location:**

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[2] The estimated effects of various factor on replacement and maintenance expenditures are subject to considerable error and provide a very rough indication of magnitude.

- Replacement expenditures tend to be lower in larger centres. Expenditure levels in towns of 10,000 are estimated to be approximately 5% higher than in cities of 100,000. This likely reflects economies of scale in undertaking capital work in the larger projects in these areas and lower materials costs, which make up a high proportion of replacement expenditures.

- Conversely, maintenance expenditures tend to be higher in larger communities. In towns of 10,000 these average an estimated 3% less than in cities of 100,000, likely reflecting a higher labour component in this type of work and higher wage rates in urban areas.

- Maintenance expenditures are especially high in remote areas, irrespective of the part of the country. Replacement expenditures also tend to be higher, but trends were less consistent. Maintenance expenditures were consistently estimated to be well over 30% higher in remote locales all else being equal. Given high levels of deterioration due to climate and other factors and relatively short building lives in these areas, it is likely that considerable ongoing maintenance expenditures are in many cases, substitutes for replacement expenditures. Further, deterioration in many of these locations often occurs to the point where the unit becomes uninhabitable at a time where in most other locales, major replacement requirements come to the fore.

- Maintenance expenditures in the Territories and Newfoundland and Labrador stand out, reflecting the effects of high material and labour costs and climatic extremes. Even after removing the effects of small population size and remote location, in the Territories, maintenance expenditures were consistently estimated to be more than double the average of comparable projects in the remainder of the country, in Newfoundland and Labrador, approximately 30% higher.

- At the other end of the continuum, in Québec and to a lesser consistent degree in the Prairie provinces (especially Manitoba), maintenance and replacement expenditures are consistently lower than the national average. Manitoba has particularly low labour costs, a dry climate and low/average levels of sales tax. In both cases, average replacement expenditures were estimated to be approximately 15% lower that in comparable projects elsewhere. Maintenance expenditures in Québec averaged approximately 45%less and in Manitoba, 15% less than in comparable projects elsewhere.

Project and Unit Characteristics:

- Single detached housing is much more expensive to maintain than other building types, reflecting a range of factors including higher costs of travelling to these dispersed units, high amounts of exposed, exterior wall and significantly more landscaping space per unit of housing. Apartment units tended to be least expensive to maintain. Single detached units had estimated maintenance expenditures that were estimated be just under 10% higher than the norm, while apartment units were just under 5% below the norm.

- Reflecting the high levels of wear and tear associated with hostels, maintenance expenditures tend to be particularly high. Hostel units had maintenance costs that averaged in the range of 15% higher than other types of units.

- **Variations by Household Type:**

  - Projects specifically targeted to seniors consistently have considerably lower maintenance and replacement costs than those targeted to families. Maintenance costs were estimated to be between approximately 10% lower while replacement expenditures averaged roughly one third less. Some of this difference is attributable to the smaller size of senior housing units and location in relatively low cost built forms. There is also evidence that over time, replacement costs increase more quickly in family housing, possibly resulting from the cumulative effects of the heavy wear and tear of young children.

- **The Effects of Program and Management:**

  - Replacement expenditures (non-recurring costs) in Public Housing are estimated to be considerably higher than in other portfolios, averaging over twice the norm for comparable units, although these were partly off-set by lower than average maintenance (recurring) costs, which averaged 15% below the norm.

  - Maintenance expenditures are estimated to be higher in projects managed under Aboriginal housing programs by approximately 35%, holding other factors constant. These higher expenditure levels are likely a result of high levels of crowding in this housing and the location of a considerable amount of this stock in hard to reach rural, remote and far northern locales.

  - Expenditures on maintenance are particularly low in co-op housing, averaging an estimated one quarter less than in comparable units, likely due to the role of volunteer, unpaid labour and possibly due to lower levels of vandalism resulting from high level of resident attachment to their community.

■ **Variations due to Differing Building Characteristics:**

It is difficult to disentangle the effects of specific building components and maintenance/replacement expenditures because a number of these components are highly inter-related. Still, some strong trends emerge:

- ✡ Units in larger buildings with elevators and balconies tend to have relatively low maintenance expenditures, averaging approximately 10% below those of comparable housing elsewhere. This appears to reflect a range of factors including relatively small average unit sizes and various economies of scale in larger buildings.

- ✡ Units with electric baseboard heating tend to have lower replacement and maintenance expenditures, likely reflecting the simplicity of this type of heating systems vis-a-vis alternatives. Replacement costs were roughly 10% below those of comparable units, maintenance costs 2%. At the same time, utility costs in these buildings most likely far outweigh savings in this area.

Applying the Results by Simulating Social Housing Requirements and Expenditures

These empirical results were used to develop parameter inputs to simulations of maintenance and replacement expenditures over the first 35 years of the life of 6 typical social housing projects. The simulations indicate that taken together, factors leading to high cost can produce a risk of onerous burdens on operating budgets and reserves when they occur together. That is likely the case in significant numbers of social housing projects. Specifically:

- ✡ Building, tenant, locational and other risk factors (for example, detached, family housing in Newfoundland and Labrador) have considerable effects upon replacement expenditures over time. The ratio of high to low annual expenditures averaged 3 for replacements expenditure simulations and just under 2 in the maintenance simulations.

- ✡ Some risk factors predominate. Simulated replacements expenditure levels in the Public Housing project and the remote aboriginal project were high throughout the simulated life of this project, as was maintenance in the hostel simulation. At the other end of the spectrum, factors such as seniors targeted housing, location in a low cost area or member contributions of unpaid labour to maintenance work in many co-ops may translate into very low expenditure requirements.

A way of assessing risk is to assess expenditure levels given existing program provisions. Replacement reserve contributions provide such a base. An assessment of a range of simulated expenditure levels given replacement reserve provisions under various programs indicates that:

- Under existing federal provisions for non-profit housing there can be a considerable strain on replacement reserves during the second and third decade of operation. The level of strain is, though, only too high in extreme circumstances. These circumstances include the simultaneous presence of a number of risk factors (for example, Aboriginal family, detached housing in a far north, remote location). Conversely other combinations of circumstances may exist where it is very likely that a project will have more than adequate reserves (urban, high rise, senior projects are cases in point).

- The replacement reserve contribution levels which form the base of the new Ontario program, particularly when matched with the recent freeze in contribution levels significantly broaden the base of projects at risk to the point where a sizable minority of projects will likely either defer needed replacements or will be burdened with a considerable debt level during the middle life of these projects.

Recommendations for Further Work

There is no published work which systematically examines the magnitude of maintenance and replacement expenditures in Canadian housing and the factors which contribute to variations in these costs. Even internationally, this type of work is relatively rare. Much of the material contained in this report will not surprise property management professionals, especially those involved with Canada's social housing stock. Yet the details of this work, and more broadly, the news that there is capacity to use existing information to estimate these costs, provide a considerable extension on existing knowledge in the area.

The study points out a number of inexpensive research efforts that would considerably enhance these findings:

➜ There is a need for a census of building and project characteristics. Such a census should include broad elements of building infrastructure (type of construction, building type, presence and type of parking facility). It is clear from the results above that these attributes may have a considerable impact on maintenance and replacement expenditure patterns over time and that better estimates of these impacts would enhance the capacity to undertaken long term expenditure forecasting and planning.

- ➔ There is a need to develop a broad but uniform classification of accounts and instructions which define how various operating and capital costs fit within this framework within the building management field. For the purposes of this type of work, activity based account complexes are particularly useful and should be encouraged.

- ➔ There exists a considerable amount of data in the field on existing maintenance and replacement expenditures, especially within the Public Housing portfolio. Much of this is already in computer readable form. Minimal effort could consolidate this material into a formidable research data base.

- ➔ There is almost no research which examines buildings as holistic systems. Yet it is clear that there are definite and marked trends in broad classes of buildings in maintenance and replacement expenditure requirements over the life cycle. With minimal additional work to enhance the data base established in this work, there is promise of considerable additional progress in strengthening the groundwork of results provided here in developing reasonable estimates of maintenance and replacement expenditures usable in life cycle costing exercises. This would allow for a better capacity to plan expenditure levels, especially for large providers able to make decisions at a portfolio level, and to better manage scarce funds in the intermediate and long term.

Conclusions

The number of very clear results which emerge are very encouraging and point at the potential usefulness of this methodology. Aging has a considerable effect on both maintenance and replacement expenditures, and it is clear that the great majority of social housing projects that are now moving through the second and third decades of operation will be facing rapidly increasing replacement requirements and significant but more slowly increasing maintenance needs. Further, factors such as location, built form and household composition make considerable differences in the level of maintenance need and the expected service life of building components.

The large degree of error in maintenance/replacement expenditure data and the limited available data on building characteristics severely constrained the scope and strength of the conclusions drawn. Work designed to gather consistent, uniform data on replacement expenditures, and to capture and create a data base to inventory detailed project characteristics would almost certainly enhance the predictive capacity of the model developed above and provide useful insights into long term maintenance and replacement requirements in the social housing stock.

There is some evidence that the most recent replacement reserve provisions in federally funded non-profit programs generally provide adequate levels of reserves for this sector. Results from the recent co-operative housing evaluation indicates, further, that given present expenditure patterns and the condition of this stock, these contribution levels will, in most circumstances, lead to housing that satisfies current adequacy standards. These provisions, though, do not take into account significant variations in maintenance and replacement requirements that are tied to risk factors such as client type, location and built form, especially when combinations of high risk factors simultaneously exist. Further, while leaner levels of replacement funding such as that provided in the new Ontario provisions may prove adequate for a majority of social housing providers, they cut much closer to the bone. Where risk factors such as remote location, or housing geared towards families occur, there is a very high likelihood that long term replacement requirements cannot be met.

Finally, an implicit but very strong theme in this work has been the need to refocus a small amount of the considerable expertise, effort and resources that are dedicated to the technical audit of specific buildings and projects. This study points to the potential of developing a strong set of general principles concerning the behaviour of existing building systems over time at a macro level. Technical audits may in many cases be telling the same story over and over and on a project by project basis--that certain types of forms, uses and locations, especially in combination, are expensive. Systematically doing this fundamental research, and portraying and communicating these to the building sciences, design, policy and delivery communities can only serve to enhance our capacity to manage and conserve the very scarce and very valuable social housing resources available today.

Évaluation de la possibilité d'utiliser des modèles stochastiques pour déterminer le coût global des bâtiments

SOMMAIRE

Dans ce rapport, on évalue la possibilité d'utiliser les modèles stochastiques (aléatoires) pour estimer les frais d'entretien, de réparations et de remplacement durant le cycle de vie d'un bâtiment. En outre, on évalue la façon d'utiliser ces modèles pour estimer les coûts à long terme des portefeuilles existants de logements sociaux.

Plus particulièrement on :

✓ effectue un examen bibliographique global des ouvrages en sciences du bâtiment, en science économique et en évaluation concernant les facteurs généraux grâce auxquels on peut déterminer les frais d'entretien et de remplacement au cours du cycle de vie d'un bâtiment, ainsi que la théorie ou l'application de modèles stochastiques pour estimer ces coûts;

✓ regroupe les données de nature historique pour les frais d'exploitation et les réserves de remplacement, qu'ont cueillies la SCHL et divers fournisseurs de logements partout au pays relativement aux logements construits dans le cadre de programmes provinciaux et fédéraux d'habitations pour ménages à faible revenu, en évalue l'utilité et les organise pour en faciliter l'analyse;

✓ élabore et met à l'épreuve une série de modèles pour estimer les coûts de l'entretien à long terme, des réparations et du remplacement du parc de logements sociaux au Canada.

Examen bibliographique; modélisation; et sources, qualité et méthodes de cueillette des données

■ ***Examen bibliographique***

L'examen bibliographique effectué pour ce document porte sur deux domaines généraux : celui des sciences du bâtiment et celui des sciences économiques et de l'évaluation.

Les **ouvrages portant sur les sciences du bâtiment** traitent de l'usure et de la détérioration liées au temps comme d'importants facteurs dans la modélisation des pratiques optimales d'entretien des immeubles et de remplacement des composants. Néanmoins, dans les ouvrages portant sur les sciences du bâtiment, on trouve assez peu de matériel sur les coûts durant le cycle de vie au niveau global de la structure des bâtiments. On y met plutôt l'accent sur le rendement de composants et de systèmes individuels des bâtiments.

En majorité, les modèles traitent les défaillances des matériaux de construction ou des composants de bâtiments comme un processus résultant d'un éventail limité de facteurs dominants contrôlables (p. ex. les facteurs de rendement des matériaux ou composantes, et le niveau de la force de dégradation) et aussi d'une pléthore de facteurs accessoires et incontrôlables qu'on appelle *erreur+. Une fois les facteurs

dominants contrôlés, cette pléthore de facteurs accessoires exerce des conséquences prévisibles avec un niveau élevé de confiance.

En sciences du bâtiment, l'objectif est d'utiliser ces résultats pour préciser les régimes optimaux d'entretien et de remplacement, les facteurs dominants de rendement étant tenus constants mais les conditions laissant place à l'erreur. Au niveau global de l'ensemble d'habitations, on ne peut pas définir avec grande précision ces circonstances et, dans les ouvrages consultés, on ne trouve que bien peu de recherche sur ce qu'elles pourraient être. Néanmoins, les méthodes utilisées laissent entrevoir d'intéressantes possibilités pour la recherche effectuée aux fins de ce document, dans lequel on examine non pas les pratiques d'entretien et de remplacement des bâtiments pour le système global d'un ensemble de logements sociaux mais plutôt les schèmes de dépenses qui, au niveau agrégatif, peuvent résulter d'un tel processus.

Dans les ouvrages relatifs aux sciences économiques et à l'évaluation, on met habituellement l'accent sur les niveaux des frais d'entretien et de remplacement des bâtiments. Particulièrement importantes sont les études portant sur un large éventail de facteurs touchant la construction ou d'autres domaines, qui ont vraisemblablement influencé les niveaux de dépenses immobilières. Dans les ouvrages sur la science des matériaux, le vieillissement désigne la somme des effets de la détérioration et constitue un facteur dans la décision d'entreprendre des dépenses d'entretien et(ou) de remplacement. Cette décision est également fondée sur deux autres facteurs : l'obsolescence et la concurrence pour des ressources limitées[1].

La recherche dans ce domaine est disparate et limitée; règle générale, elle ne permet guère de prévoir ou d'estimer les frais d'entretien et(ou) de remplacement. Néanmoins, on en a tiré de solides constatations qui forment la base de l'analyse exposée ci-dessous :

- Les logements ont tendance à se détériorer et(ou) à se démoder à un rythme croissant avec l'âge; de même, l'ensemble des frais d'entretien, de réparation, de modification et de rénovation ont tendance à augmenter durant la vie économique du bâtiment. En outre, on remarque une courte période culminante de dépenses au tout début de la vie des bâtiments, les retouches et la correction des défauts étant alors très fréquentes. Prises ensemble, ces tendances produisent avec le temps, pour les frais totaux d'entretien et de remplacement, une courbe analogue à une *baignoire+. Cette courbe est caractéristique des cycles de vie prévus pour un certain nombre de composants des bâtiments.

- De plus, un certain nombre d'autres facteurs généraux semblent affecter substantiellement les cycles de frais d'entretien et de remplacement. Ces facteurs comprennent les aspects climatiques et géographiques (p. ex. la taille et la position géographique de la collectivité), la taille et la composition du ménage, le taux de roulement, la forme du bâtiment, la taille des logements et du bâtiment, et les matériaux de construction.

▪ Modélisation

1 L'incapacité à distinguer les effets de chacune de ces influences constitue l' un des principaux problèmes, l'une des principales causes d'échec, des modèles examinés. L'utilisation de séries chronologiques dans cette étude permet toutefois de distinguer dans une certaine mesure les effets de l'obsolescence (la désuétude de la technologie et des méthodes de construction utilisées) et ceux du vieillissement.

L'examen bibliographique permet d'établir une série d'hypothèses concernant les principaux facteurs qui influencent les niveaux des frais d'entretien et de remplacement pour la partie du parc canadien de logements sociaux examinés aux fins de cette étude (voir le tableau S.1).

Tableau S.1
Liste des facteurs réputés susceptibles d'influencer les frais d'entretien et de remplacement dans le parc canadien de logements sociaux

Caractéristique	Données disponibles
Âge du bâtiment	* Années depuis la construction * Années depuis la remise en état (bâtiments remis en état) * Années d'existence (bâtiments remis en état)
Situation géographique	* Province * Population dans la zone urbaine et(ou) la collectivité * Localisation dans une zone nordique ou éloignée
Caractéristiques de l'ensemble et des logements	* Nombre total de logements * Types de logements (appartements, en rangée, etc.) * Nombre moyen de chambres à coucher
Type de ménage	* Genre de ménage (aînés, familles, etc.)
Caractéristiques organisationnelles	* Programme de parrainage * Type d'organisme parrain (office d'habitation, coopérative, etc.)
Caractéristiques du bâtiment	* Type de construction * Revêtement extérieur * Type de toit * Type de chauffage (à air pulsé, à calorifère, etc.) * Type de combustible * Présence de balcons * Présence d'ascenseurs * Type prédominant de couvre-plancher * Présence et étendue de l'aménagement paysager * Présence et genre de stationnement

■ Sources, qualité et méthodes de cueillette des données

Pour vérifier ces hypothèses, on a utilisé les dépenses annuelles engagées dans le passé pour l'entretien et le remplacement, ainsi que les caractéristiques des ensembles immobiliers, pour les trois quarts du parc canadien de logements sociaux. Au total, les chiffres s'appliquent à une période moyenne de huit ans, et les caractéristiques, à 13 223 ensembles immobiliers (quelque 505 000 logements). Cela représente environ 30 p. cent de tous les frais annuels d'entretien et de remplacement déclarés depuis le début des principaux ensembles de logements sociaux.

Ces données comportaient des lacunes, notamment :

- La classification des frais d'entretien et de réparations n'a pas toujours été constante d'un ensemble à l'autre ou au cours de la période. Ces différences résultent en bonne part de changements et d'un manque d'uniformité dans les règles de comptabilisation, ainsi que de difficultés à cerner les frais engagés dans ces domaines.

- Un certain nombre de caractéristiques des bâtiments étaient disponibles pour une petite partie seulement du parc total de logements examinés. Les problèmes résultant de cette lacune ont gravement diminué la capacité d'évaluer la validité d'un certain nombre d'hypothèses de recherche.

- Les données utilisées ne comprenaient aucun chiffre pour certains facteurs qui, selon les ouvrages examinés, étaient censés influencer les niveaux de frais. Principalement, ces facteurs portaient sur les comportements et les caractéristiques des locataires (taux de roulement, niveau de vandalisme et présence d'occupants ayant des besoins spéciaux) et la description précise des pratiques d'entretien et(ou) de remplacement.

L'analyse multivariée de la variance et de la covariance a servi à déterminer quels modèles convenaient le plus aux frais d'entretien et de remplacement par logement. En outre, on a déterminé quelles courbes décrivaient le mieux une large gamme de processus stochastiques de base et on a comparé les résultats pour de longues séries chronologiques de frais par ensemble de logements.

Résultats

Au total, on a pu expliquer en moyenne un peu moins de 40 p. cent des variations dans les frais d'entretien par logement et un peu moins de 20 p. cent des variations dans les frais de remplacement par logement au moyen de ces modèles. Ces résultats suffisent néanmoins à indiquer les tendances générales dans les frais d'entretien et de remplacement, même si la majeure partie des variations dans les habitudes de dépenses demeurent «inexpliquées». Ces tendances générales comprennent :

- **L'influence du vieillissement :**

  - L'âge de l'immeuble constituait un facteur constant et important de prévision des frais de remplacement et d'entretien. En moyenne, les variations dans l'âge des immeubles pouvait expliquer 8 p. cent de toutes les différences dans les frais de remplacement et 6 p.cent de toutes les différences dans les frais d'entretien.

  - Au total, durant les quatre premières décennies d'exploitation, les frais d'entretien ont augmenté en moyenne d'environ 15 $ par année (en dollars de 1992), et les frais de remplacement, d'environ 25 $ par année. Si l'on replace ces chiffres en perspective, au cours de la période de 1973 à 1992, on constate que les frais annuels d'entretien s'élevaient à 659 $ tandis que les frais de remplacement atteignaient 286 $ pour les ensembles de logements sociaux ayant en «moyenne» 8 ans.

  - Les frais d'entretien ont dépassé les frais de remplacement durant les premières années des ensembles immobiliers. Au début de la troisième décennie d'exploitation, les frais de remplacement ont commencé à dépasser les frais d'entretien dans certains ensembles immobiliers. Durant la quatrième décennie, les frais de remplacement avaient dépassé les frais d'entretien dans la plupart des ensembles immobiliers. Les accroissements dans les frais d'entretien tendaient à augmenter lentement et à dépasser 15 $ par année tandis que les frais de remplacement tendaient à demeurer bas et même à baisser dans certains cas durant les premières décennies d'exploitation. Au milieu de la deuxième décennie, les frais de remplacement ont commencé à augmenter lentement et constamment.

- Les frais d'entretien par logement sont constamment plus élevés de quelque 10 p. cent dans les bâtiments remis en état[2]. La technologie et la forme de ces bâtiments plus âgés rendent souvent difficile de les préserver à un faible coût.

- Les constatations faites au moyen des séries chronologiques de frais de remplacement font voir un processus analogue à un autre que l'on observe dans les soins de santé avec le vieillissement de la population. Les besoins de soins de santé sont vraisemblablement élevés durant les premières années de la vie, puis diminuent et restent faibles tout au long de l'enfance et au début de l'âge adulte. Au milieu de l'âge adulte, ces besoins augmentent d'abord lentement puis plus rapidement pour atteindre des niveaux élevés durant les années d'âge d'or. Toutefois, on dispose de données insuffisantes pour indiquer la prédominance d'un processus stochastique particulier dans la progression des frais de remplacement avec le temps. Ces tendances correspondent bien aussi à la courbe de *baignoire+.

- Il est impossible de dégager clairement une tendance ou un processus dominant dans la série chronologique de frais d'entretien à cause du manque d'uniformité dans les données cueillies et des faibles degrés de changement dans les frais d'entretien durant la période.

- Lorsqu'on compare les résultats des évaluations du Programme fédéral des coopératives d'habitation et du Programme de remodelage des logements publics (tous deux de la SCHL), il est manifeste que ce dernier programme, mis sur pied depuis plus longtemps, nécessite davantage de travaux de remplacement. Les ouvrages de nature économique indiquent que les propriétaires de maisons et les gestionnaires d'immeubles de logements locatifs privés omettent très souvent les travaux d'entretien et de remplacement qui pourraient annuler complètement la détérioration graduelle, ce qui est vraisemblablement applicable à l'ensemble du contexte canadien des logements sociaux. Ainsi, les seules dépenses peuvent ne pas révéler tous les aspects des besoins d'entretien et de remplacement au cours d'une longue période de temps.

- **Les effets de la localisation des bâtiments** :

  - Les frais de remplacement tendent à être moins élevés dans les grands centres. Selon les estimations, les niveaux de ces frais dans les villes de 10 000 habitants sont de quelque 5 p. cent supérieurs à ceux des villes de 100 000 habitants. Cet écart résulte vraisemblablement des économies d'échelle dans l'exécution des travaux d'immobilisation entrepris sous forme

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[2] Les effets estimatifs de divers facteurs sur les frais de remplacement et d'entretien sont sujets à une marge d'erreur considérable et ne donnent qu'une indication grossière de l'ordre de grandeur.

de grands projets dans ces zones et du faible coût des matériaux, qui constituent une proportion élevée des frais de remplacement.

- Par contre, les frais d'entretien tendent à être plus élevés dans les grandes collectivités. Dans les villes de 10 000 habitants, ces frais sont, selon les estimations, de 3 % inférieures à ceux des villes de 100 000 habitants, ce qui résulte vraisemblablement de la proportion plus élevée de frais de main-d'oeuvre pour les travaux de ce genre et de taux supérieurs de rémunération dans les centres urbains.

- Les frais d'entretien sont spécialement élevés dans les zones éloignées, quelle que soit la partie du pays. Les frais de remplacement aussi tendent à être plus élevés, mais les tendances sont moins constantes. Selon les estimations, les frais d'entretien étaient toujours bien au-delà de 30 p. cent supérieurs dans les zones éloignées, toutes choses étant égales par ailleurs. Vu les niveaux élevés de détérioration causés par le climat et par d'autres facteurs, ainsi que la vie relativement courte des bâtiments dans ces zones, il est vraisemblable que les énormes frais courants d'entretien soient, dans de nombreux cas, des substituts pour les frais de remplacement. De plus, la détérioration dans bon nombre de ces zones atteint souvent un point où le logement devient inhabitable, tandis que dans la plupart des autres zones il est encore possible d'effectuer d'importants travaux de remplacement.

- Les frais d'entretien dans les territoires et à Terre-Neuve et au Labrador sont particulièrement onéreux par suite du coût élevé des matériaux et de la main-d'oeuvre ainsi que des conditions climatiques extrêmes. Même après avoir tenu compte des effets de la faible population et de l'éloignement dans les territoires, les frais d'entretien ont constamment été estimés à plus du double de la moyenne des ensembles de logements comparables dans le reste du pays; à Terre-Neuve et au Labrador, ils étaient d'environ 30 p. cent supérieurs.

- À l'autre bout du spectre, au Québec et, dans une moindre mesure, dans les provinces des Prairies (particulièrement au Manitoba), les frais d'entretien et de remplacement étaient constamment inférieurs à la moyenne nationale. Au Manitoba, les frais de main-d'oeuvre sont particulièrement bas, le climat est sec et les niveaux de taxation sont faibles ou moyens. Dans les deux cas, les frais moyens de remplacement étaient estimés être d'environ 15 p. cent inférieurs à ceux des ensembles de logements comparables ailleurs. Pour des ensembles de logements comparables, les frais d'entretien au Québec étaient en moyenne d'environ 45 p. cent inférieurs, et au Manitoba, de 15 p. cent.

- **Caractéristiques de l'ensemble et des logements :**

  - Les maisons individuelles coûtent beaucoup plus cher à entretenir que les autres types de bâtiments, ce qui résulte d'une gamme de facteurs, notamment de frais plus élevés de déplacement entre ces logements dispersés, de la grande superficie de murs extérieurs exposés et d'une superficie d'aménagement paysager substantiellement plus grande par logement. Les appartements tendent à être moins coûteux à entretenir. On a estimé que les frais d'entretien pour les maisons individuelles étaient de presque 10 p. cent supérieurs à la norme, tandis que ceux des appartements y étaient de presque 5 p. cent inférieurs.

- Vu le rythme accéléré d'usure, les foyers ou auberges tendent à coûter particulièrement cher à entretenir. Un logement de ce genre coûte en moyenne quelque 15 p. cent de plus à entretenir que les autres genres de logements.

- **Écarts selon les types de ménages :**

  - Pour les ensembles immobiliers qui ciblent spécialement les aînés, les frais d'entretien et de remplacement sont considérablement et constamment inférieurs à ceux des logements destinés aux familles. On estime que les frais d'entretien sont d'environ 10 p. cent inférieurs, tandis que les frais de remplacement sont en moyenne à peu près d'un tiers inférieurs. Une partie de cette différence est attribuable à la plus petite superficie des logements pour aînés et au fait que ces logements sont habituellement situés dans des immeubles relativement moins coûteux à construire. On constate aussi qu'avec le temps les frais de remplacement augmentent plus rapidement pour les logements destinés aux familles, ce qui pourrait résulter des effets cumulés de l'usure accélérée causée par les jeunes enfants.

- **Les effets du programme et de la gestion :**

  - Les frais de remplacement (non récurrents) engagés pour les logements publics sont considérés être beaucoup plus élevés que pour les autres types de logements dans le portefeuille, soit en moyenne deux fois la norme pour des logements comparables, mais sont partiellement compensés par des frais d'entretien (récurrents) inférieurs de 15 p. cent à la norme.

  - Les frais d'entretien sont estimés être environ 35 p. cent plus élevés dans les ensembles immobiliers financés au moyen des programmes d'habitations pour autochtones, toutes autres choses étant égales par ailleurs. Ces niveaux supérieurs de frais résultent vraisemblablement du surpeuplement des logements et de la localisation d'un nombre considérable de ces habitations dans des zones rurales éloignées, difficiles à atteindre et nordiques.

  - Les frais d'entretien sont particulièrement faibles dans les logements coopératifs, étant en moyenne inférieurs d'un quart aux logements comparables, vraisemblablement par suite du rôle de la main-d'oeuvre bénévole, non rémunérée, et peut-être aussi des niveaux inférieurs de vandalisme résultant d'un sens d'appartenance plus prononcé envers la collectivité.

- **Variations résultant des caractéristiques des immeubles :**

Il est difficile de distinguer les effets de composants précis des bâtiments et les frais d'entretien et(ou) de remplacement parce qu'un certain nombre de ces composants sont très étroitement liés. Néanmoins, on peut percevoir de fortes tendances :

- Les logements situés dans de grands immeubles avec ascenseurs et balcons tendent à coûter relativement moins cher à entretenir, soit environ 10 p. cent de moins que les logements comparables ailleurs. Cette tendance semble résulter d'une gamme de facteurs, dont la superficie relativement plus petite des logements et diverses économies d'échelle dans les grands immeubles.

- Les logements chauffés par plinthes électriques nécessitent, règle générale, des frais moins élevés de remplacement et d'entretien, vraisemblablement à cause de la simplicité de ce genre de système de chauffage par rapport aux autres. Les frais de remplacement sont d'environ 10 p. cent inférieurs à ceux des logements comparables, et les frais d'entretien, de 2 p. cent. Par contre, les frais de services d'utilité publique dans ces immeubles dépassent très vraisemblablement les épargnes ainsi réalisées.

Application des résultats par simulation des besoins et des frais des logements sociaux

Ces résultats empiriques ont servi à élaborer les paramètres utilisés comme intrants dans les simulations de frais d'entretien et de remplacement au cours des 35 premières années de vie de 6 ensembles de logements sociaux caractéristiques. Les simulations indiquent que, conjugués, les facteurs causant les frais élevés risquent de grever substantiellement les budgets d'exploitation et les réserves. C'est d'ailleurs probablement ce qui arrive dans un nombre considérable d'ensembles de logements sociaux. Plus particulièrement :

- Les facteurs de risque liés au bâtiment, aux locataires, à la situation géographique et aux autres éléments (p. ex. les maisons individuelles à Terre-Neuve et au Labrador) influencent considérablement les frais de remplacement au cours d'une longue période. Selon les résultats des simulations, le rapport entre les niveaux annuels supérieur et inférieur des frais était en moyenne de 3 pour les frais de remplacement et d'un peu moins de 2 pour les frais d'entretien.

- Certains facteurs de risques sont prédominants. Les simulations ont révélé des niveaux élevés de frais de remplacement pour les ensembles de logements publics et pour les ensembles immobiliers destinés aux autochtones habitant dans des endroits éloignés tout au long de la période de simulation; il en était de même pour les frais d'entretien d'auberges ou foyers. Par contre, à l'autre bout du spectre, certains facteurs, comme le ciblage des aînés, la localisation dans une zone à faible coût ou le travail non rémunéré des membres aux fins d'entretien dans de nombreuses coopératives, peuvent résulter en de très faibles niveaux de dépenses.

Une façon d'évaluer le risque est d'estimer les niveaux des frais en fonction des dispositions actuelles des programmes. Les sommes versées à titre de réserves de remplacement procurent une telle base. L'évaluation d'une gamme de niveaux simulés de frais, compte tenu des versements aux réserves de remplacement dans le cadre de divers programmes, indique que :

- En application des dispositions actuelles des programmes fédéraux de logements à but non lucratif, les réserves aux fins de remplacement peuvent subir des pressions considérables durant la deuxième et la troisième décennies d'exploitation. Toutefois, le niveau de pression n'est excessif que dans certaines circonstances extrêmes. Ces circonstances comprennent la conjonction d'un certain nombre de facteurs de risque (p. ex. famille autochtone, maison individuelle dans le Grand Nord, endroit éloigné). Par contre, d'autres combinaisons de circonstances peuvent rendre très probable que l'ensemble d'habitations dispose de réserves plus qu'adéquates (zone urbaine, immeuble en hauteur, logements pour aînés).

- Les niveaux de contribution aux réserves de remplacement, qui forment la base du nouveau programme ontarien, risquent fort, particulièrement dans le contexte du récent gel des niveaux de contribution, d'accroître considérablement le nombre d'ensembles (proportion minoritaire mais néanmoins substantielle) qui devront vraisemblablement reporter les remplacements à effectuer ou assumer un fardeau considérable de dette durant leur vie.

Recommandations d'études ultérieures

Aucun ouvrage publié n'examine systématiquement l'ordre de grandeur des frais d'entretien et de remplacement dans le parc canadien de logements, ni les facteurs qui contribuent aux écarts entre ces frais. Même à l'échelle internationale, ce genre de travaux est relativement rare. Une bonne partie du matériel que contient le présent rapport ne surprendra guère les professionnels de la gestion immobilière, particulièrement ceux qui gèrent le parc canadien de logements sociaux. Néanmoins, les renseignements détaillés pour ce travail, et plus particulièrement la constatation qu'il est possible d'utiliser les données existantes pour estimer ces frais, étendent considérablement les connaissances existantes dans le domaine.

L'étude permet de dégager un certain nombre de projets de recherche peu coûteux grâce auxquels on pourrait approfondir considérablement ces constatations :

- Il existe un besoin de recenser les bâtiments et les caractéristiques des ensembles immobiliers. Ce recensement devrait comprendre les éléments généraux de l'infrastructure immobilière (le genre de construction, le type de bâtiment, la présence et le genre d'espaces de stationnement). Les résultats ci-dessus indiquent clairement que ces attributs peuvent avoir des répercussions considérables sur les caractéristiques des frais d'entretien et de remplacement au cours d'une longue période et que de meilleures estimations de ces répercussions amélioreraient la capacité de faire des prévisions et une planification à long terme des dépenses.

- Il est nécessaire de mettre au point un plan comptable général mais uniforme, ainsi que des directives, afin de déterminer comment les frais d'exploitation et les coûts en immobilisation s'intègrent dans ce cadre de gestion immobilière. Aux fins de ce genre de travail, une classification en fonction des activités serait particulièrement utile et devrait être encouragée.

- Dans ce domaine, il existe une quantité considérable de données empiriques sur les frais d'entretien et de remplacement actuels, particulièrement au sein du portefeuille des logements publics. Ces données sont déjà en bonne part informatisées. Avec des efforts minimes, on pourrait regrouper ce matériel et fournir une formidable base de données aux chercheurs.

- La recherche sur les bâtiments comme systèmes holistiques est pratiquement inexistante. Néanmoins, on peut percevoir clairement des tendances précises et marquées dans les frais d'entretien et de remplacement pour certaines classes de bâtiments durant leur cycle de vie. Avec une quantité minime de travail supplémentaire en vue d'améliorer la base de données établie pour le présent ouvrage, on pourrait facilement réaliser des progrès considérables dans l'approfondissement des résultats actuellement obtenus grâce à l'élaboration d'estimations raisonnables des frais d'entretien et de remplacement, ces estimations pouvant servir à l'étude des coûts durant le cycle de vie. Ces résultats procureraient une meilleure capacité de planifier les niveaux des coûts, particulièrement pour les fournisseurs de logements capables de prendre des décisions au niveau de leur portefeuille, ainsi qu'une meilleure capacité de gérer leurs fonds limités à moyen et à long termes.

Conclusions

Le nombre de résultats très clairs qui émergent est très encourageant et indique l'utilité potentielle de cette méthode. Le vieillissement affecte considérablement les frais d'entretien et de remplacement, et il est manifeste qu'en grande majorité les ensembles de logements sociaux actuellement dans leur deuxième ou troisième décennie d'exploitation feront face à des frais de remplacement qui augmenteront à un rythme accéléré, ainsi qu'à des frais d'entretien substantiels mais à croissance plus modérée. De plus, les facteurs comme la localisation, la forme du bâtiment et la composition du ménage causent des différences considérables dans le niveau des frais d'entretien et dans la vie utile prévue des composants des bâtiments.

La marge considérable d'erreur dans les données des frais d'entretien et de remplacement, ainsi que la quantité limitée de données disponibles concernant les caractéristiques des immeubles, restreignent considérablement la portée et la valeur des conclusions tirées. Le travail en vue de cueillir des données constantes et uniformes sur les frais de remplacement et de saisir et créer une base de données pour les caractéristiques détaillées des ensembles immobiliers permettrait très probablement d'améliorer la qualité prévisionnelle du modèle élaboré ci-dessus et de mieux comprendre les besoins à long terme d'entretien et de remplacement dans le parc de logements sociaux.

Certaines indications laissent croire que les plus récentes dispositions concernant les réserves de remplacement dans les programmes à but non lucratif financés par le gouvernement fédéral sont, règle générale, adéquates pour ce secteur. Les résultats de la récente évaluation des logements coopératifs indiquent en outre que, compte tenu des régimes actuels de dépenses et de l'état de ce parc de logements, ces niveaux de contribution permettront dans la plupart des cas d'offrir des logements convenables selon les normes actuelles de qualité. Toutefois, ces dispositions ne tiennent pas compte des écarts considérables dans les frais d'entretien et de remplacement liés aux facteurs de risque comme le genre de clients, la localisation et la forme de bâtiment, particulièrement quand se conjuguent les facteurs à risque élevé. En outre, quoique les niveaux moins élevés des fonds de remplacement, notamment ceux que l'on prévoit dans les nouvelles dispositions ontariennes, peuvent s'avérer adéquates pour la majorité des fournisseurs de logements sociaux, ils ne laissent guère de marge de manoeuvre. Lorsqu'on tient compte des facteurs de risque, comme les zones éloignées ou les logements ciblés sur les familles, il est très probable que les besoins de remplacement à long terme ne pourront pas être satisfaits.

En dernier lieu, un thème implicite, mais néanmoins très présent dans cet ouvrage, est le besoin de recentrer le point focal d'une petite partie de la somme considérable de compétences, d'efforts et de ressources consacrée à la vérification technique d'immeubles et d'ensembles immobiliers particuliers. Dans le présent ouvrage, on souligne la possibilité de mettre au point un ensemble utile de principes généraux concernant le comportement des systèmes existants d'immeubles au cours d'une longue période de temps à un niveau élevé d'agrégation. Les vérifications techniques peuvent dans de nombreux cas indiquer les mêmes constatations ou conclusions coup après coup et ensemble après ensemble, c.-à-d. que certaines formes de bâtiments, certaines utilisations et certaines localisations, particulièrement en conjonction, sont coûteuses. Par des efforts systématiques, cette recherche fondamentale, cette description des constatations et leur communication aux collectivités des sciences du bâtiment, de la conception, des stratégies et de la prestation de logements ne peuvent qu'améliorer notre capacité à gérer et à conserver nos actuelles ressources très rares et très précieuses de logements sociaux.

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I. Introduction

A. Scope and Rationale

This work assesses the possibility of estimating building life cycle maintenance, repair and replacement costs, at an aggregate level, using well known stochastic (probabilistic) models. It provides an assessment of how well these models perform in estimating these long term costs for existing social housing portfolios.

Specifically, it:

- provides a comprehensive review of the literature in the building science, economics and appraisal fields concerning general factors influencing maintenance and replacement costs over building life and the theory or application of stochastic models for estimating these costs;

- consolidates and assesses the usefulness of historical data on operating costs and replacement reserves, collected by CMHC and various housing providers throughout the country for housing built through provincial and federal housing programs for low and moderate income households and organizes these in a manner amenable to analysis; and

- develops and tests a series of models which estimate long term maintenance, repair and replacement costs in this portfolio.

A lack of systematic treatment is a major deficiency in the knowledge base needed in both the day to day management of the existing portfolio and the development of parameters for program design. A first assessment is thus provided of how well probabilistic models might do in answering these questions. As will be shown, major obstacles to their use are the inadequacy of existing data and the very sparse research and formal knowledge base in this area. Extant research does not generally address concerns about non-profit or other forms of social housing. It has, though been a major policy concern, as evidenced in the continuing debate between federal and provincial governments. and the non-profit sector and the frequent revisions to practice regarding replacement reserve funding.

Past assessments of the stock of social housing have relied upon technical audits and inspections. Their emphasis has largely been the identification of project-specific problems and solutions. The results have neither been collated nor synthesized in the public domain, and behavioral costs are very rarely factored into these analyses. At best, a number of rule-of-thumb estimates of the effects of selected building characteristics, geographical variations and household mix on maintenance, repair and replacement requirements exist in the field. These estimates guide administrators in the development of subsidy levels and practitioners in assessing what costs are likely to be. Major exceptions include the work undertaken by Canada Mortgage and Housing Corporation in its recent evaluations of the Public Housing and Co-operative Housing Programs (CMHC (1990) and (1992)). In the case of the Public Housing evaluation, much of the stock examined requires, or is likely to require, capital investment well beyond the limits of existing budgetary provisions. Yet most work has shown that the majority of the stock is still providing adequate housing. The theme of making do for now, yet viewing the future with an impending sense of doom is an old one in the non-profit sector and reflects a lack of a systematic empirical research on how the stock as a whole has performed and on the variables that have influenced performance. This study provides some general findings, using aggregate figures from housing providers across Canada, on the importance of considering building aging and other broad factors in characterizing differences in maintenance and replacement requirements.

The diversity of accounting and record keeping practices within the non-profit sector severely complicates efforts to remedy this situation (see for example Moershel's (1992) experience with co-op housing operating data). As a result, it is extremely difficult to find studies and data which use sufficiently similar concepts and classifications in addressing the issue. Thus, this study also discusses some of the accounting and management data issues which make it difficult to determine adequate cash flow and reserves for replacement/maintenance requirements.

In the absence of systematic work in the area, a number of long standing issues have never been satisfactorily resolved within the social housing sector:

- Is a revenue generation mechanism in place which assures that housing remains "adequate" (i.e. in a reasonable state of repair and in compliance with health and safety standards) over the life of the non-profit social housing portfolio?

- Can a subsidy system be put in place based upon standard expectations of maintenance costs and what factors are relevant to determining these criteria?

- What is the expected useful life of the existing social housing stock and what factors influence useful life?

- What level of reserves is required for non-profit housing to assure that large capital replacement can be undertaken as required?

It is noteworthy that the latter two issues were at the centre of discussions between the Ontario Ministry of Housing, and the Cooperative Housing Association of Ontario and the Ontario Non-profit Housing Association, concerning the provincially funded non-profit program JoHomes (ONPHA 1992). More generally, government contribution levels to reserves for replacements in federal and provincial non-profit housing programs are formula driven and are usually related to initial capital costs alone. Variations in building characteristics and use may lead to large differences in component lives and thus financial requirements. Some buildings may as a result, have been "doomed from the start" while others may remain with more than healthy reserves.

B. Report Structure

The report begins in Chapter II with an overview of the nature of maintenance and replacement activity, and costs. It follows with a description of stochastic modelling and an explanation of how and why this type of model might be appropriate. Here, a number of simple stochastic models are introduced that may usefully characterizing elements of these activities and their costs. Also introduced here is a functional form that is possibly appropriate in creating a more general model.

Chapter III provides a review of the current literature on maintenance, repair and replacement and on optimized behaviours and requirements within the housing sector. Special emphasis is placed upon developing extensions of the results of this work to the study of non-profit housing behaviours and costs.

In Chapter IV a description of the general model linking age, building, tenant and institutional characteristics to maintenance and replacement costs is discussed. This examination is followed by a detailed specification of hypotheses which link the theoretical discussion of Chapters II and III to available data.

Chapter V explore the data used in model testing. It includes a section on data quality, where the considerable difficulties with data definition and reporting inconsistencies are explored. Because the emphasis of this study is the prediction of the time series of expenditure data, subject to inflation, Chapter V concludes with the methodology used to develop estimates of constant dollar expenditures.

Chapter VI provides a detailed overview of the statistical methodology utilized and VII is a report of the results of estimating the parameters of replacement and maintenance models. The study then moves, in Chapter VIII to an evaluation of the implications of this research in terms of forecasting expenditure patterns and addressing the issues of what adequate maintenance/repair and replacement provisions should be over the life of a social housing portfolio. This evaluation involves a series of simulation models of archetypical non-profit projects and the assessment of the adequacy of replacement provisions in a number of existing federal programs and the new Ontario provincial program.

The study concludes with an analysis of this implications of the results detailed here and recommendations for further work in the area.

II. The Basics:
Costs, Stochastic Models and their Interlinkage

This chapter provides a sketch of the nature of residential building maintenance/repair and replacement costs. It follows with a definition of stochastic modelling and then review common models used in characterizing change over time in related phenomena. It concludes by showing how these models might be appropriate to characterizing activity and costs.

A. Maintenance and Repairs--Day to Day Operations

Maintenance and repair costs for housing are substantial, requiring a significant expenditure of effort, time and resources. They range in scope, but generally involve repetition within a relatively short period of time or relatively small investments of time or resources. On a day to day basis, residential property requires housekeeping (cleaning, pest control, garbage and snow removal), monitoring and tending (grass cutting, gardening), small repairs (a thermostat or a few shingles on a roof), adjustments and minor replacements (light bulbs, faucet washers etc.). Some activities occur occasionally, for example the re-application of coatings required to sustain and protect components or enhance their aesthetic appeal (paints, waxes or other coatings). Therefore, short term maintenance and repair activities allow the ongoing functioning of existing building components, grounds and facilities within design parameters and standards considered as adequate.

Table II.1 provides cost categories characterized as maintenance and repairs within the accounting scheme of sample non-profits. It is illustrative of the difficulties of analyzing maintenance/repair costs among different providers in two ways. Record keeping does not always split activities in a manner which allows the isolation of activities that are consistent with the objectives of this exercise. Table II.1 shows that in Ontario Housing Corporation accounts salaries and wages pertaining to operating buildings are aggregated with other expenses, and there is a large group of miscellaneous expenditures (sundry materials and services). In addition, the concepts of maintenance versus capital expenditures are not universally applicable. OHC currently uses, for example, the concepts of recurring (repeated) versus non-recurring (occasional) cost. In many cases, the allotment of expenditures to categories utilizing these concepts match well with the needs of this study--but the match is far from guaranteed. In still other cases, (including some interpretations of information concerning expenditures submitted to CMHC), activities included in these two lists are characterized as "operations" along with, for example, utility bills (most notably caretaking expenses) rather than "maintenance" costs.

Table II.1 Sample of Maintenance Accounts	
Detailed List of Accounts Pertaining to Maintenance or Repair Used by a Western Canada municipal non-profit	Roll-up of Accounts Referring to Maintenance and Repair Activities Ontario Housing Corporation
Custodial Staff Wages Custodial Staff Benefits Grounds: Lawns/Shrubs Trees Lot Sanding Lot Sweeping Snow Clearing Grounds Supplies Buildings: Bulbs, Lamps and Ballasts Carpentry Carpet/Floor, Cleaning/Repair Door/Window Maintenance Electrical Equipment and Small Tools Licences and Permits Locks and Keys Painting--Exterior Painting--Interior Plumbing and Heating Security Suite Cleaning Cleaning Supplies Waste Removal Appliance Repair Laundry Equipment Ranges Appliance Repair (Other) Other: Management Fees	Salaries and Wages Employee Benefits Roof, Recurring Building General, Recurring Energy Conservation, Recurring, Elevators, Recurring Electric, Recurring Equipment, Recurring Grounds, Recurring Heat and Plumbing, Recurring Painting, Recurring Sundry Materials and Services

B. Capital Expenditures for Replacements, Improvements and Modernization

Capital expenditures involve the replacement, renovation, addition or modification of major building components (for example, roofs, balconies, elevators, floor covering) which require replacement or substantial rehabilitation. This work is done infrequently and the resultant product or "asset" has considerable endurance--the value it produces can continue for a considerable length of time. Reasons for undertaking such work might include:

- functional failure (i.e. inability to perform previously defined design or legal requirements essential to resident, staff and/or the community well being) which cannot be ameliorated adequately or economically through repair;
- building components reaching the end of their useful lives (where imminent failure or uneconomic repair requirements are anticipated);
- the presence of technological improvements or modifications which increase operating efficiency or extend viable building life;

- modifications and additions to health, safety and other standards, regulations, ordinances, or statutes; or taking into account conditions discovered to affect the resident staff and/or community well being (for example, recent requirements to replace asbestos fibre insulation, or retrofitting to increase accessibility to those with health or activity limitations); or
- changes in building/project function (for example, conversion from senior to family units).

Table II.2 provides a list of building components approved by CMHC, for which replacement reserve funding can be used for non-profit housing.

Table II.2 Current CMHC List of Items eligible for Replacement Reserve Funding
Stoves Refrigerators Roofs Plumbing Equipment Heating Equipment Carpeting, flooring Exterior Cladding Windows Asphalt
Source: CMHC correspondence to non-profit providers concerning replacement reserve contributions, 1993.

The difficulties noted in the last section also apply here. The issues of how to develop an adequate definition of maintenance versus capital further complicates matters. In examining Table II.2, it is clear that replacement reserve funding does not extend to a number of building elements. Whether or not these are examples of major building components is a matter of interpretation. For example, elements of electrical equipment such as signage and entry boxes/telephone systems are not included here. A more general problem relates to where to draw the line between maintenance related expenditures and capital replacements. Here, usually, rules of thumb come into play in dividing up what goes where. Minimum expenditure rules (for example, "expensing rather than capitalizing expenditures below, $2,000"), or assessments of the magnitude of work involved (for example, minimum square footage for the repair of shingled roofs) are common strategies. Finally, because the line between maintenance and capital replacement is often fuzzy, it sometimes becomes an issue of the exigency and budget restrictions of the moment (of end-of-fiscal-year constraint) as to what gets allocated where.

C. What is an Adequate Level of Maintenance?

Both maintenance and capital replacements are provided in order to sustain management goals and strategies. Within the non-profit sector, there is agreement about goals--the provision of modest housing of at least minimum standard, as defined by building codes, property standards and various health, safety and security standards. But numerous tradeoffs exist in strategies adopted to implementing these goals. For example, how important should the possible reductions of major future capital and maintenance expenditures be in day to day maintenance/repair activities and decision making? Should an element of strategy be the maximal extension of building or component life, when this may lead to considerable short term cost?

Optimally, management strategies include a blending of the exigencies of building economics. Thus, decisions theoretically should be based upon knowing the likely present value of the streams of net benefits resulting from all feasible maintenance/replacement options. This presumes a substantial knowledge base and degree of flexibility. However, in reality, this cannot be the case for a number of reasons. First and foremost, some of this knowledge is impossible to come by. No one knows what the future has in store in terms of inflation, relative prices, and the effects of a whole score of factors which influence building wear and tear. Secondly, a considerable number of maintenance/replacement strategies are concurrently available. For example, maintenance and replacement activities usually do not have to occur at precise times. They can often be deferred, or combined with other activities (for example, a minor chimney repair might be combined with shingle replacement in order to piggy back the cost of putting up the scaffolding necessary to both activities). Limiting these trade-offs are factors which extend beyond the exigencies of scheduling work. For example, in many cases, component deterioration accelerates quickly with deferral of maintenance. Sometimes loss of tenant satisfaction can lead to further revenue loss and additional maintenance expenditures due to increasing turnovers/vacancies (McDermott et. al. (1987)).

Finally, within the non-profit sector, management goals are often intertwined with issues of funding availability and rules. For example, regulator approval or allotment may on occasion restrict the use of funds directed towards long term replacement and force either less than optimal building performance and/or substitution of solutions using other, more readily available short term maintenance funding. Both of these strategies may have been a result of the arbitrary freezing of replacement reserve contributions in Ontario for a period of two years to meet provincial budgetary problems. In addition, nowhere do programs' funding mechanisms allow for the accumulation of the reserves required for long-term eventualities such as the replacement of obsolete or uneconomic buildings, or wholesale rehabilitation, and thus may influence decisions towards to less efficient, higher cost maintenance/repair expenditures on outmoded buildings or components.

D. Characterizing Maintenance and Replacement Costs

Reviews of maintenance and replacement expenditures predominantly focus upon normative models. These point the way to what one should do in order to develop, within a specific context, a regimen which optimizes expenditure patterns. Seeley (1987), for example, emphasizes how to best establish maintenance budgets and operational practices for a specific building based upon common practices. Ruegg and Marshall (1990) prescribe how to assess the cost factors and make trade-offs in establishing such a regimen for operating, maintenance, and replacement practices using life cycle costing. This literature is extremely useful in setting out guidelines and possible strategies for a building manager or maintenance supervisor. Unfortunately, the complexity and diversity of objectives and strategies, the existence of many unknowns, and the diversity of residential building forms, make it quite difficult to envision the adoption of normative models in describing actual practices, and their resultant expenditure patterns. As a result, normative models, the emphasis of most literature concerning building maintenance, is of limited use in examining or modelling practice.

In dealing with the complexity of practice, an alternative set of models is assessed here. Stochastic models treat a wide range of variations in conditions, including decision making practices, as a series of random events or shocks underlying a process generating a series of maintenance/replacement expenditures. The process involves building components eventually failing, or falling below some acceptable level of operation, and corresponding activities or ameliorative actions (maintenance, repair or replacement) which involve expenditures. In addition, the process of undertaking maintenance and replacement is seen itself to be a stochastic process, generated by random components but associated with age-related building deterioration. As such, expenditures in these areas are seen as being strongly related, but not directly linked to building deterioration.

The general hypothesis put forward here is that buildings and associated maintenance/repair replacement regimes may act in the aggregate in a manner similar to a considerable amount of industrial equipment and machinery and their upkeep. Practices there are often extensively based upon stochastic models, established within reliability and maintainability theory. Some extensions of this literature are well known to those testing building materials. Decision making is based upon an assessment of characteristics of the distribution of various random events which can serve as indicators of building performance. These characteristics may include:

- the expected time to failure of a building component, or the expected time at which a certain proportion of components will have likely failed;
- the likelihood of failure at various times during building life;
- the distribution of failures over a building life; and/or
- the dispersion or spread of failures over building life.

The likelihood of failure at various times can be combined with unit cost data to produce a distribution of expected costs over building life.

When combined with other data including other building costs, revenues and a minimum rate of return threshold, a point may be estimated where expected maintenance and/or replacement costs are so high that continued operation provides less than market returns. This end point is estimated economic building life, a type of "expected time to failure".

Equation 2.1 provides an example of a functional form, linking expected cost to the incidence of residential building maintenance/repair and replacements[3]:

[3] This form assumes no interaction between level of maintenance, repair and eventual replacement. In reality, these are highly related.

$$C(t) = (1-p_i)\left(\sum_{i=1}^{n} c_{mi}(t_i)\, m_i(t_i) + q_i c_{ri}(t_i)\, r_i(t_i)\right) + p_i\left(\sum_{i=1}^{n} c_{fi} f_i(t_i)\right) \qquad \textbf{(2-1)}$$

where:

t is building age[4]
C(t) is the expected total cost of maintenance, repair and replacements at age t and
p is the probability of a component failure requiring replacement
q is the probability of a component failure requiring repair
n is the number of components making up a building
$c_{mi}(t_i)$ is the cost of maintenance for component i of component age t_i
$m_i(t_i)$is the likelihood of undertaking maintenance of component i of component age t_i
$c_{ri}(t_i)$ is the cost of repair for component i of component age t_i
$r_i(t_i)$ is the probability of repair of component i of component age t_i
$c_{fi}(t_i)$ is the cost of replacement for component i of component age t_i
$f_i(t_i)$ is the probability of replacement of component i of component age t_i

An intuitively attractive scenario of the expected distribution of maintenance/repair and replacements costs over time in residential buildings is the "bathtub curve" (see Nelson (1982), and Figure II.1). In this case, a new building would pass through an initial period where there would be a high expectation of significant initial maintenance and/or replacement costs, reflecting "fatal" material/workmanship defects. In many cases, these expenditures would be covered by warranty arrangements. This would then be followed by a hiatus of relatively failure free performance, and low annual cost as the building is "worked in". A third stage is then seen to ensue where expected annual replacement requirements and expenditures increase. During this time, the rate of increase of annual maintenance and replacement expenditures slowly increase to the point where both costs and expected short term increases would be substantial.

Complicating matters, maintenance and replacement patterns, and resultant expenditures are influenced by policy and procedures which can very considerably and lead to vary different outcomes when combined with variations in quality (reliability) characteristics of building components and/or the presence and strength of degradation factors.[5] Siemes et. al. (1986) for example, show how the expected life of a concrete balcony slab in the climatic conditions of the Netherlands vary, depending upon initial specifications and the maintenance regime, from 34 years to 400 years. In this case, slab life is limited by the accumulation of corrosion to a critical level. The life of the slab varies with the thickness of the slab, the presence and thickness of a protective coating and the frequency of maintenance and renewal of that coating, each of which

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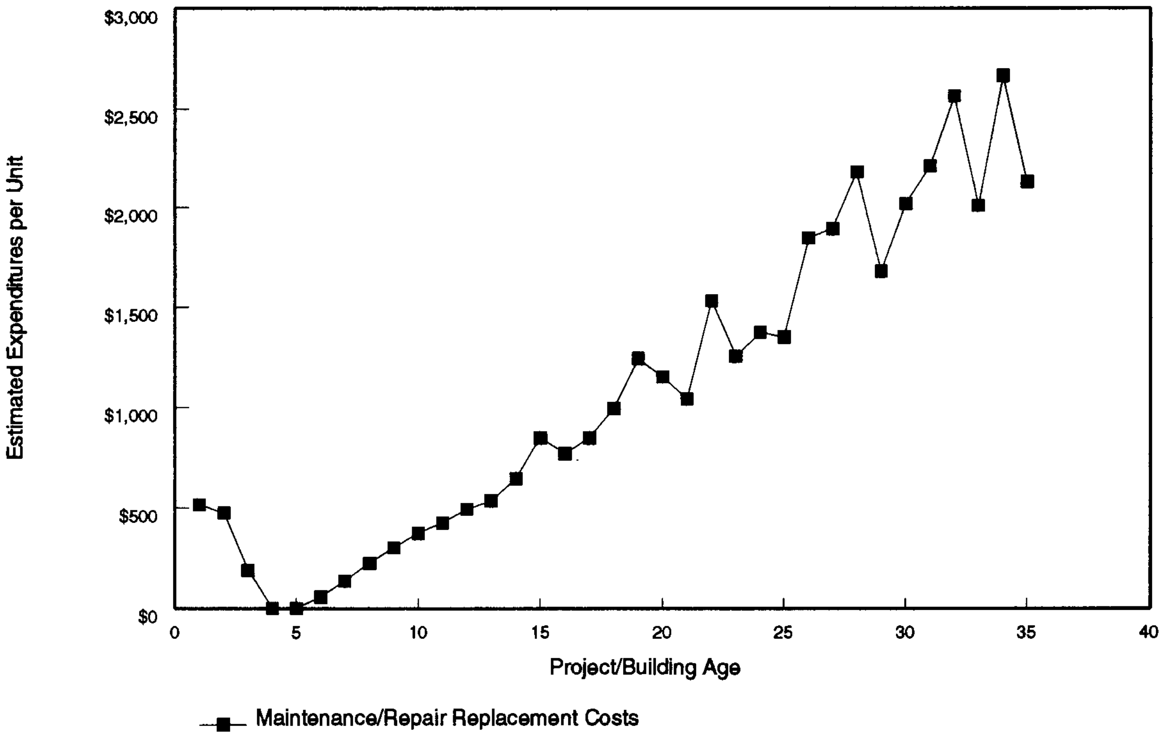
[4] Here and all discussion below, t refers to building age.

[5] The development of policies and procedures are often based upon models of regular and preventative building maintenance and component replacement which in turn, come from maintainability theory (Jardine (1973)). Maintainability theory is extensively grounded in applications of stochastic modelling techniques.

Figure II.1
Hypothetical History of Maintenance/Replacement Expenses--Bathtub Effect with Random Error



Source: Author's simulation using dual Weibull Distributions

has a cost. The authors provide an "optimal" level of investment in the slab, its protective coating and maintenance expenditure minimizing the present value of expenditures, which leads to its replacement just after the century mark. This example also partially illustrates a more general point that maintenance practices can be seen as a balance between time and money allocated to inspection, preventative practices, repair, overhaul (rehabilitation) and replacement strategies. These vary with expectations which, in and of themselves, vary over the life of a machine or building component (Jardine (1973)). Thus, choice among these activities over time may be related to cost effectiveness, given the building component under consideration. Further, component age may affect the expected time and material cost of undertaking a repair, eventually tipping the balance towards overhaul or replacement.

Stochastic and normative models both require the incorporation of life cycle costing techniques, particularly when used for decision making. Realistically, this involves the consideration of stochastic elements relating to prices and costs, including the costs of borrowing and opportunity costs. Thus, the costs of activities over time require discounting based upon a combination of inflation, market related returns and the possible application of an adjustment factor reflecting expectations of internal corporate returns (Ruegg and Marshall (1990)). Irrespective of the type of model used, this involves the adoption of analysis of variability (often referred to as "sensitivity analysis") in expected outcomes and thus, the requirement of some type of stochastic modelling (Ruegg and Marshall (1990, ch. 15)). Within a normative framework, though, the application of life cycle costing involves, initially, the existence of building component input and survival data, the inter-relationships between a myriad of potential trade-offs between design, investment decisions, maintenance and repair and other operating expenditures (utility and fuel use, for example) and estimation of a complex climate of economic uncertainty and technological changes. At a detailed level, this is practically untenable.[6] Treating many of these factors as random elements, and research in identifying a limited number of variables influential to a general, underlying stochastic process of deterioration and renewal, which can be translated into a limited number of classes of building maintenance and replacement expenditures, provides a possible way out of an intractable morass.

Yet here, data limitations constrain the present potential use of stochastic models as a panacea for the development of good practice and procedures. In industrial engineering applications, where large numbers of similar components are often used in controlled processes in mass producing output, comparable data and this assurance of sufficiently stationary processes commonly allow the meaningful fit of probabilistic models. In addition, there is the incentive of considerable economy that can be obtained through the fine tuning of maintenance/replacement procedures. In contrast, within the non-profit housing sector, there is considerable practical understanding of these factors and of potential trade-offs, but seemingly very little systemic understanding. In addition, there is little consistency in the way in which maintenance cost and activity data are reported, let alone analyzed, considerably reducing the potential for generalization.

1. Common Stochastic Models and their Possible Applications

As noted above, reliability theory is a source for a considerable amount of material potentially useful in developing stochastic models related to building maintenance and replacement expenditures. Its source is a wide spectrum of theory from various engineering fields concerned with design, demography and actuarial science. In this section, examples of processes, well used within reliability theory, that may have some relevance to the understanding of how maintenance/repair and replacement costs change over time, are provided.

Simple reliability models usually are characterized by state models--"life" or "survival", and its converse, "death" or "failure". Here, failure can be seen to be roughly analogous to an expenditure of a certain, standard amount to maintain or replace a building component. Aging in these models is seen to be equivalent to exposure to hazard or risk leading to failure. Thus some functional relationship is posed between age and survival or some related variable (for example, age contingent remaining life or expectation of failure) as well as overall performance (for example, average life span, average or variance of failure rates). This functional relationship can be seen to characterize some type of process--in this case resulting from exposure to a hazard. The process is usually stationary--that is, the process itself does not change.

[6] In addition, there have been considerable changes in the nature of building materials in use, as well as relatively little documentation or systematic testing of older materials (McDermott et. al. (1987)). As a result, data requirements often cannot be adequately met.

These models, usually used to characterize life or survival data, are particularly attractive to the common underlying assumption that only major hazards and characteristics of the entity at risk need be incorporated, and that, the incidence of failure (often referred to as "death") is the result of a process subject to a whole series of random and often small influences (termed a "random process"). There are, though, numerous types of "random processes" which can trigger failure. Where a specific type of process can be identified, it can often be used in generating an appropriate probabilistic distribution--indicating, for example, the likelihood of failure over time.

In characterizing "random processes" we can begin with the simplifying assumption that time is the only concern in characterizing failure. Specific processes, with well known functional relationships with the incidence of failure can be generated by making various additional assumptions about the nature of this relationship. For example:

- if failure rates are assumed to be constant over time and failures are also fully a result of random causes not dependent on time, then failures over time will be distributed **negative exponentially** (Elandt-Johnson (1980):

$$f(t) = \mu e^{-\mu t} \tag{2-2}$$

where μ is average occurrence time of a failure.

Such a process might be used to characterize the likelihood of sustaining damage to inappropriately designed hall way or door mouldings in a building where wheel chairs are used. Here, sooner or later, a wheelchair will sufficiently deviate from a usual path to strike a side wall or door way with enough force to cause damage.

- if failure rates may occur randomly over time except near the beginning and end of the process, when failures are more likely, failures over time will be distributed **hyper-exponentially** (Jardine (1973)).

$$f(t) = e^{\frac{R}{a}(1-e^{at})} \tag{2-3}$$

where:

μ is average occurrence time of a failure and
R and a are "shape parameters".

- Certain electrical equipment (lighting equipment for example) which are initially prone to failure due to defects, followed by random failure resulting from power fluctuation or buffeting and which, within relatively short intervals "burn out", have failure rates characterized by the **hyper exponential** distribution.

- If failure rates are exponential, that is either increasing or decreasing at increasing rates over time, failures over time will be **Gompertz distributed** (Elandt-Johnson (1973)).

This distribution is commonly used in modelling human mortality, particularly among adults. In this case, it is presumed that as aging occurs, the likelihood of death will quickly increase. As will be shown below, Gleeson (1981) believes that this distribution may be particularly appropriate to the modelling of residential building lives.

- if it is anticipated that failure rates increase at an increasing rate over time and are a result of the cumulative effect of a large number of small and independent events which can contribute or cause failure), then failures over time will be **normally distributed** (Nelson (1982)):

$$f(t) = \frac{1}{\sigma\sqrt{(2\pi)}} e^{\frac{(-t-\mu)^2}{2\sigma^2}} \qquad \textbf{(2-4)}$$

where:

μ is average occurrence time of a failure and
σ is the variance of occurrence times.

Failure of building components prone to wear and tear such as many floor materials may be normally distributed.

- if the process is the same as above except causative events vary exponentially with time on their effect on failure (i.e. the effect of a hazard near the beginning of a process is negligible, while near the end, it may be catastrophic), then failure over time may be **log-normally distributed**.

Siemes et. al. (1986) use a series of the log-normal distributions to characterize the various factors influencing the deterioration of concrete balconies. In turn, the cumulative effect of these multiple factors is characterized as log normal.

- if it is anticipated that total failure occurs after and as a result of a series of partial failures, then failures may be characterized using a **gamma distribution**:

$$f(r) = \frac{\mu}{\Gamma(a)} (\mu r)^{a-1} e^{-\mu r} \qquad \textbf{(2-5)}$$

where:

μ is an average failure rate and
a is the number of the average number of partial failures before complete failure (O'Connor (1991)).

For example, this distribution may be applicable to the decision to undertake exterior repainting if it is based upon an inspection criterion relating to the visual identification of some level of blistering, peeling and fading.

- if it is anticipated that failure is a result of the failure of a part of a unit where each part is subject to the cumulative effect of small and independent events, then failures over time will be **Weibull distributed** (Nelson (1982):

$$f(t) = (\frac{B}{A^B})\, t^{(B-1)}\, e^{(-\frac{t}{A})^B} \qquad \textbf{(2-6)}$$

where:

B is termed the shape parameter and, as the name suggests, is instrumental in determining the shape of the distribution and
A is termed the scale parameter, and is also termed the "characteristic life". It represents the 63.2nd percentile of the distribution.

Failures of building features such as weight bearing wood, one-piece linoleum flooring and windows that requires replacement when damaged in a single area, may be used to illustrate the Weibull distribution. Martin (1986) used the Weibull distribution in characterizing the life of various paints and coatings.

Three of the distributions noted above, the Gamma, Log-Normal and Weibull, are also frequently used in curve fitting because of the variety of shapes that they take on. Conversely, fitting and portraying an age related mortality process through the use of these distributions can be useful in providing some evidence as to what underlying process might be at play or predominate.[7]

Most engineering applications to stochastic models are limited to the examination of the life characteristics portrayed above and are concerned with elements of the life of relatively closed systems or simple events (a component failure). In contrast, as the last section made clear, buildings are multi-component, complex systems. Each component is prone to age related hazards leading to some type of failure (necessitating repair or replacement) in different ways. While, overall, the system survives for a considerable length of time, the incidence of these failures leads to maintenance/replacement activity which is related to these hazards. In addition, if constant dollar costs can be seen as a random variate related to component maintenance or failure, the costs of repairing/replacing building components themselves vary. The complete characterization of a disaggregate model incorporating all of these factors in a form such as was portrayed in equation 2.1 is extremely difficult to operationalize because of large information requirements, which simply are not fulfilled. Thus, while some of the requirements of a

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[7] A large number of other distributions can be characterized as special cases of each of these distributions. For example, the exponential and normal distribution can be generated by manipulation of the parameters of the Gamma. The normal can, in addition, be generated from the log normal. The difficulty in using these distributions comes in the need for non-linear procedures for fitting empirical data. In most cases, these procedures are iterative search algorithms rather than analytic solutions. These methods are often computationally time consuming and may not provide "best fitting" solutions (see Draper and Smith (1966) for a fuller discussion of this issue).

normative are avoided, the functional form leads to a similar, intractable situation.

One avenue for avoiding these complexities is to treat overall occurrence of maintenance and replacement expenditures as subject to a random process, where deterioration of various component parts are seen as random events. Since it is not clear what manner of aggregate process is at work, this study focuses upon two related tasks:

- the testing of a number of variables which have a significant influence on the magnitude of expenditures over time; and
- the fitting of various functional forms to models, including variables likely having such influences.

The next chapter examines literature which deals with the influences of time and other factors on the costs of activities at this aggregate scale, providing a testable alternative to Equation 2.1.

E. Summary and Conclusions

This chapter begins with an overview of the nature of maintenance and replacement costs. It then moves to the building life literature, which examines normative models of how maintenance and replacement activity change over time. Most of this literature treats time related wear-and-tear and deterioration as important factors in normative modelling. The chapter then introduces a functional model which characterizes maintenance/repair and replacement behaviour as random processes over time.

The emphasis in the latter part of this chapter has been on how relationships between time and the likely occurrence of maintenance/repair replacement costs have been characterized. In the following chapter, empirical analysis drawn primarily from economics and appraisal literature will be brought to bear in the development of a functional form incorporating time and other factors. Here, emphasis shifts to the relationship between age and other variables such as building components, resident characteristics and building maintenance procedures on the overall life and cost of maintaining buildings. Much of this literature, though, is predicated upon behaviour within the private market place, and rarely encompasses issues relevant to the social and/or non-profit housing sectors. The applicability of this literature is further limited because regulation of adequacy and other standards is based upon the enforcement of property standards within the context of the market place machinations.

III. Factors Affecting Levels of Maintenance, Repair and Replacement in the Market Place

It is common to see stochastic modelling used within empirical literature characterizing maintenance behaviour, expectations of expenditures and building lives. Most of this work models the private residential market place, and predicates individual property owner's utility maximizing behaviour. Literature within the building sciences tends to be limited to the effects of physical degradation processes resulting from climate and various corrosive processes, given a set of building structural components. On occasion this literature looks at relations among components. Concern is with the economic optimization of design (Siemes et. al. 1986). In contrast, in the following literature review, emphasis is upon consumer and market behaviour in conjunction with socio-demographic factors, such as resident age and household type.

A. Inter-relationships between Models of Housing Quality and Building Deterioration

1. Application of the Capital Theory of Second Hand Goods

Most economics literature, and related research in the appraisal field tie the effect of non-catastrophic events to a change in a single "value" measure--price--that is, the willingness of a buyer to purchase a home or rental property in a competitive market, and the willingness to undertake some level of maintenance, repair or required replacement. Housing is durable, and is thus thought of as a capital good; as such, housing provides an input to producing a long term flow of goods and services or returns. Changes in price resulting from aging are viewed as reflections of changes in expectations with regard to the expected present and future streams of goods and services produced, using housing during its remaining life. These changes in price are termed depreciation (when price decreases) or appreciation (when price increases). In theories about capital goods, housing as it ages, is often seen in a manner similar to other "second hand goods"--that is capital goods from which value has been previously extracted and which are open to resale. In one common type of formulation, various age related attributes of "unit quality" are linked to the price of housing as an aggregate good (Hall (1971)). This type of formulation has been applied by Margolis (1981), Chinloy (1977) and others as part of the development of a pricing model of housing capital. Housing is thus considered a good containing various levels of housing quality. As it ages, a unit of housing capital depreciates/appreciates because of one of three elements of quality change:

- it deteriorates;
- it becomes obsolete (less productive vis-a-vis new housing capital); and
- there are changes in productivity among other non-housing goods (i.e. other non-housing goods become more attractive).

Theoretically, changes in house prices can be decomposed into these three elements, and over time, compared to "standard unit" of capital. One simple form of this decomposition, characterizing the present level of service is:

$$z(r, t) = \Phi_t b_{r-t} d_r \qquad \textbf{(3-1)}$$

where:	z	is the level of service at time r for a housing unit of age t
	Φ	is an index of deterioration (efficiency decline including wear and tear). The index of deterioration includes consideration of what remains of the original capital, supplementary capital replacements and the flow of non-durable services (short term maintenance).
	b	is an index of obsolescence for a building of age t at time r (often called "embodied technology"). It includes a "vintage effect" or how "well" the building was originally constructed and how well in performs versus buildings built in other eras and
	d	is the effect of present practices and alternative options at time r on the usefulness and cost effectiveness of the building (often called "disembodied" technology and due for example, to changes in maintenance technologies and alternatives).

Here, these three attributes act independently, but cumulatively in defining the good. In other formulations, these elements may interact in more complex ways.

This in turn is related to the market price P of this current level of service through the price of a standardized unit of current building service.

$$P_{r,t} = p' z_{r,t} \qquad \textbf{(3-2)}$$

where:	P is the market value of a unit of a specific unit of housing of age t at time r
and	p is the price of a standard unit of building service at time r

There is a cumulative effect of deterioration, obsolescence and economic circumstances eventually leading to demolition. (The overall price of housing is seen as the sum of the price of present and discounted future levels of service over the remaining life of a capital asset, as well as its discounted salvage value, at the point at which it is demolished). Thus:

$$P(r,t) = p\left(\sum_{s=r}^{N}\left(\frac{1}{1+i}\right)^{s}\Phi_{t+s}b_{r-t+s}d_{t+s} + \left(\frac{1}{1+r}\right)^{N+1}S\right) \qquad \textbf{(3-3)}$$

Where:

P is the market price
p is a market price of a standard unit of housing
N is the expected life of the capital good
i is a future discount rate
S is salvage value.

The discounting factor in this case requires incorporation of an element of risk since many buildings do not reach this stage and are destroyed or demolished as a result of catastrophic economic, social or physical events (bankruptcies, wars, floods, earthquakes, etc.) which are often not insured.

Depreciation reflects the rate at which market price changes. It can be affected by the degree to which maintenance, rehabilitation or modernization is undertaken. It can also be affected by the quality of construction vis-a-vis other buildings or the general quality of building technology available during a given era or "vintage"[8]. In addition, factors well outside the housing sector may influence housing prices, such as the bid price of a standard unit of housing, technological changes in other parts of the economy, future discount rates and even expectations of salvage value. Thus the incentive within a market place to undertake maintenance/repair or replacement or to allow abandonment, conversion, or demolition and salvage, is related to a range of factors outside the realm of internal building economies.

Because of the difficulties of separating the factors influencing price, related to depreciation and the pragmatics of data availability, most analyses of depreciation have used very different concepts. Commonly, the cumulative effects of aging on market price are aggregated in a single term, "gross depreciation" and counterbalanced against expenditures for maintenance/repair and replacement. "Net" depreciation is seen as the difference between the effect of maintenance/rehabilitation expenditures and the effect of aging on housing prices. In most applications using these concepts, a simplifying assumption is used that these expenditures directly translate into price by offsetting the gross effects of depreciation (see for example, Chinloy (1980)).

While this type of model is instructive in allowing the analysis of various factors affecting the level and effects of undertaking maintenance/repair and replacement activities, its use in understanding behaviour within the non-profit sector is limited. The major limitation in its direct application is the inability, within studies to date, of completely decomposing the elements of creating the housing good, as noted in equation 3.1. (Chinloy (1980)). The objective of providing modest housing maintained at "adequate" levels and the inability to move capital to alternative uses through the barriers and restriction of operating agreements, constrain choices about the level of maintenance/repair and replacement activity. In addition, modernization funds allowing betterment through the incorporation of new technologies tend to be quite limited within the sector. As a result, the present ability to estimate Φ (deterioration) and b (obsolescence), given streams of maintenance/repair and replacement expenditures on price, are of limited use.

2. Hedonic Pricing and Building Deterioration

An alternative to treating housing as a single commodity is provided in models based upon

[8] Below it will be seen that "vintage" effects require a broader definition in assessing differences in maintenance and replacement expenditures in Canadian social housing. In that stock, in addition to building technology changing, client type, built form, and policy concerning the availability and use of replacement and maintenance expenditures also markedly changed from era to era.

hedonic pricing. Here, housing is seen as a bundle of differentiable goods, each of which contribute to overall price. Hedonic pricing models potentially allow more diversity and detail in differentiating the housing product and identifying the possible presence of housing sub-markets (for example, housing availability limitations due to discrimination, or housing that is attractive to only segments of a population). Chinloy (1980), Cannaday and Sunderman (1986), and others have used hedonic price equations to attempt to isolate the effect of neighbourhood, site and housing attributes including age, and to use these as building blocks in estimating residential property value. As with the capital theory formulation noted in equation 3.1, most of these assume a cumulative (usually multiplicative) effect of each element of the bundle of goods on utility, and in conjunction with the constraints imposed by individual income and wealth, determine a series of bid prices. Most formulations, as in equation (3.1), assume no interactions among housing goods which affect bid price.[9]

The use of hedonic pricing models which address residential property in the private sector, has a number of disadvantages for those concerned with social housing:

- The objective of social housing providers is restricted to providing housing at a given location at a specified level of adequacy. The option of selling buildings or converting them to other uses is not an alternative, except under some extreme circumstances, nor is the option of providing housing either below or above adequacy standards. As a result, housing may be purchased at a price, at a specific location and/or at a specific time different from that resulting from the behaviour of owners/landlords in the private market.
- It provides adequate housing based upon standards which, in many cases are above those which would be available at a bid price in the market. It is a subsidy program designed to deal with the imperfect capacity of the market to provide housing to low income consumers who would not be able to accumulate sufficient economic resources to pay the price for a socially defined adequate and suitable level of housing and to have sufficient remaining resources to afford adequate levels of other commodities necessary for an adequate overall standard of living.
- Inherent in the selling price of housing and in maintenance/investment expenditures are a number of factors not necessarily relevant in considering non-profit providers. This includes market, neighbourhood, household characteristics, owner expectations, owner financial situation, and dwelling and neighbourhood quality and property value (Mayer (1981), Galster (1987)).
- It is not possible to fully differentiate the effects of obsolescence (which may include the influence of fads and style) from the other factors identified as affecting housing output.

While the wholesale incorporation of market related models is limited, there are some advantages in their use. To some degree, estimates of market price are reflections of the housing quality, including the need for repair and maintenance. These approaches can be used to develop

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[9] Knight and Menchik (1976) provide an extension on this type of model where housing attributes interact conjointly in affecting bid price, allowing the potential of interactions. There are few examples of the application of this model.

indications of the cost in the market place of maintaining/repairing and replacing housing services provided at a specific level or standard. In addition, the effects of factors such as aging, building characteristics and the effects of family/household form on housing adequacy can be estimated, albeit, though the prism of market value.

B. Filtering and the Eventual Deterioration of Building Stock

Considerable literature in urban economics about the behaviour of housing markets has been based upon the premise that all residential buildings deteriorate or become obsolete through an irreversible process and eventually require removal from the stock. Much of this literature coalesced around early theories of "filtering" (see Smith (1964)). These early theories concluded that filtering was a "natural" way in a market economy to provide housing to those with low or moderate incomes. As housing deteriorated with time, it became less attractive to those with higher incomes and thus became within the budgetary reach of others. Inherent in this literature also were interactions with perceived neighbourhood quality and cost. Neighbourhood "quality" included factors such as the proximity and distribution of racial/ethnic groups, the presence of services, and the condition of nearby properties.

Some of this literature directly uses stochastic modelling in estimating the effects of aging. Wolfe (1967) provides an example which can be considered an application of filtering theory.[10] He assumes gradual, irreversible deterioration, with property moving through states ranging from "Good" through to "Unfit" conditions. His model is based upon the assumption that the likelihood of remaining in each state is a constant, and transition between adjacent states occurs randomly over time. The process of deterioration is thus seen as a recursive series of two state models (remaining in a given state of repair or deteriorating to the next "less satisfactory" state). Thus in each state, the distribution of transitions is negatively exponentially distributed with time (see above). Each state, and thus each distribution, is characterized by a different average time of transition.

In addition, transitions to less satisfactory states are seen to be independently related to three other variables--resident tenure, dwelling type (single versus multiple unit residence) and vintage (in this case, reflecting building technology available at the time of construction). Because, as will be shown below, so much of the literature deals with owner occupied dwelling, this first distinction is significant. More important from the context of social housing providers are considerations of unit type and of vintage.[11]

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[10] Wolfe does not, though, refer or directly use filtering theory or terminology in his presentation.

[11] Wolfe differentiates between two periods in modelling vintage effects--buildings constructed prior to and after 1920, and views the stock circa 1939 in indicating major differences in expected life spans. Vintage effects may have been particularly important here because of major technological change occurring after the construction of a considerable amount of pre-1920 stock. In particular, these buildings were often not equipped with amenities considered basic by today's standards (indoor piped water and sewage disposal and electrical wiring) and were often built using building techniques which did not economically allow for upgrading. Sarré et. al. (1989) in the British context and Carver (1954) in the Canadian context, note that housing built during the latter part of the 19th. century were often slated for demolition in the post-war world war II period because of the high cost of rehabilitation,

Wolfe does not characterize the nature of maintenance or replacement activity and thus does not directly indicate anything about annual maintenance or replacement expenditures. Rehabilitation or conversion to other uses is also not modelled or characterized by Wolfe, although, as others have shown, it is a common occurrence (see Baer (1991)). In addition, the differences in the states that Wolfe describes are qualitative, depending upon appraiser assessment.[12]

Figure III.1
Estimated Age of Building Condition Change, San Francisco, 1939

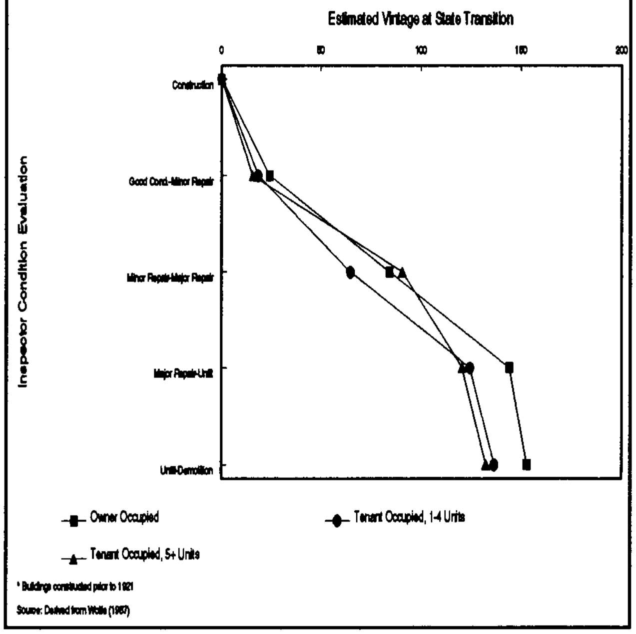

Figure III.1 provides Wolfe's estimates of average age at transition and the estimated effects of tenure and unit type for housing built prior to 1921. It indicates that tenant occupied buildings, particularly when comprised of multiple units, were likely to deteriorate at a faster rate than single household owner occupied dwellings, and consequently the former would be ready for demolition about 20 years earlier than the latter.

Recent literature regarding filtering moves from the idea that it is a universal process of deterioration and income related succession, to concerns with the conditions under which filtering exists. One of a set of factors which may result in filtering is age related maintenance and renovation cost. For filtering to occur, maintenance/rehabilitation may not fully offset the effects of aging. Margolis (1981), for example, outlines a series of market and technological conditions that affect level and type of capital replacement activity and thus lead to "filtering". He sees filtering as an outcome of certain market forces and the production function, as understood by the owner/maintainer. Margolis believes it likely that filtering would occur if:

- there is a shock (for example, a depression removing significant investment capacity/income flow or the development of perception of neighbourhood deterioration in a particular area) resulting in a cessation or significant reduction in replacements of

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especially the incorporation of current technology.

[12] In testing his model, Wolfe used inspection data from a single time period which were gathered the from 1939 Real Property Survey for the city of San Francisco. Recent reviews of inspection data have indicated that they are often subject to considerable variance and inconsistency (see for example, EKOS (1991)). In addition, Wolfe based his empirical tests upon a single "panel" of data. Using panel data to model time series leads to a number of problems. For example, it is impossible to distinguish the effects of vintage from those of aging--are buildings of a certain age in poor condition because they were built poorly or because of the effects of time. While Wolfe reported "good fit", in no way should this be seen as more than a very weak model validation.

building components or interruption of maintenance activities to the point where there are greater economies in completely rebuilding than undertaking massive rehabilitation;

- replacement of capital is subject to diminishing marginal cost (i.e. the overall cost of spending all at once to build new housing is less than the discounted cost of keeping up existing housing through smaller, continuous flows of expenditures); or
- the rate of deterioration/obsolescence increases significantly with building age (i.e. there are real economies in building anew rather than maintaining a building beyond a certain point).

Other literature suggests that obsolescence and level of maintenance factors interact, particularly among landlords who may see lower returns on maintaining a building at a constant, increasingly obsolete level (Mayer (1981)). Galster adds that major capital replacements (rehabilitation) often occur in situ and arrest increasing deterioration/obsolescence rates. With aging, the likelihood increases of a decision to alter or replace--involving either or both replacement of obsolete technology or conversion to multiple units (if size and architecture make this allowable). Thus maintenance/rehabilitation may offset the effects of aging, and units/buildings may appreciate. Baer (1991) sees this as an integral part of the filtering process, with residential buildings often undergoing a series of renovations to accommodate a changing market.

While not directly translatable, this set of ideas suggests a number of maintenance/replace hypotheses relevant to expenditure patterns in social housing, ie. that:

- there is a need to assess age related deterioration and obsolescence rates in evaluating maintenance and replacement decisions;
- there can be "lull before the storm effects": ie. that in some cases, because of budgetary constraints or faulty planning, maintenance/replacement levels may be below optimal levels resulting in requirements for massive spending to offset spending deficits and to compensate for the effects of neglect;
- with aging, the likelihood of undertaking massive work increases with increasing rates and levels of deterioration/obsolescence, and that at that point, function may also change (for example, conversion from seniors housing to a rooming house).

This literature also suggests that under certain, empirically defined circumstances, restricting behaviour to maintenance and replacement of existing stock may not be cost effective in providing adequate, suitable housing. More cost effective alternatives may include redevelopment or conversions.

C. Empirical Studies of the Effect of Aging on Maintenance and Replacement Requirements and Behaviour

Age has had a statistically significant impact on the level and/or expense of maintenance/replacement activity in every study reviewed, where this factor was included. There is, though, no consolidated formulation as to how, exactly, age effects maintenance, repair and replacement behaviour. Studies rather, are concerned with changes over time in:

- net depreciation;
- components of net depreciation (which include gross depreciation offset by maintenance, repair and/or replacement expenditures; and/or
- the incidence and various types of maintenance, repair and or replacement activity.

1. Functional Relationships Between Net Depreciation and Aging
Most related economics and appraisal literature equate net depreciation with price. One emphasis is upon the time related functional form of net depreciation.

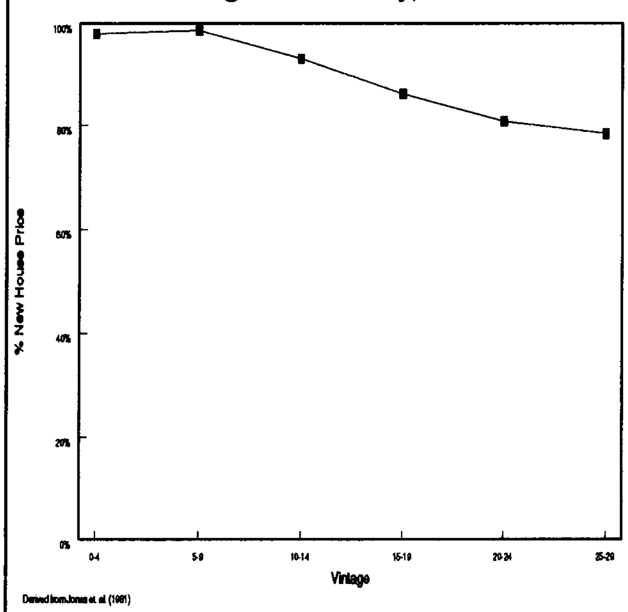
Cannaday and Sunderman (1986) found that historically, most literature in the appraisal area uses standard forms to estimate the effects of age and remaining life in estimating residential building value, and thus, net depreciation. These forms characterized net depreciation linearly, or as a geometric progression, using a fixed proportion of a declining balance as:

$$V_A = V_0\left(1 - \frac{A(A+1)}{L(L+1)}\right) \tag{3.4}$$

where: V_o = New Home Valuation
V_A = Value at Age A
A = Age and
L = Expected Economic Life.

They found in Champagne, Illinois, after isolating the effects of building and neighbourhood attributes and short term market effect, that neither form portrayed the data well. Rather, decreases in single family home sales prices were relatively slow when the buildings were new, but decreases were relatively quick towards the end of the economic life of the dwelling which, on average, occurred near the end of a century of life. Thus, following price over time produces a concave path. Follain and Malpezzi (1980) also found that best fitting net depreciation curves were concave (with value falling less quickly during early years) in their study of selling price data in 35 U.S. cities.

Figure III.2
Estimated Ratio of Selling Price to New Price by Dwelling Age, Single Family Dwellings, Lexington Kentucky, 1978



Jones et. al. (1981) posit a more complex relationship between price and age in the selling prices of single family dwellings in Lexington, Kentucky, although they examined housing which was less than 30 years old. They controlled for the price of land, which tends to appreciate with age, and which they believed counterbalanced the effects of deterioration on house prices. Figure III.2 illustrates that they found that house prices remained relatively stable for the first decade of life and then declined through the next decade at an increasing rate. They conjectured that housing between 10 and 20 years of age tended to incur a flurry of maintenance and replacement requirements which may have been capitalized into selling price. They also found that selling prices declined at a lower rate during the third decade.

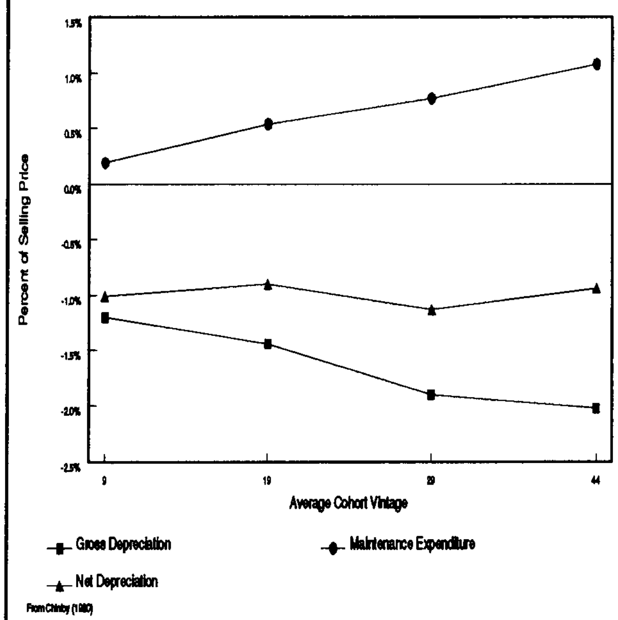
These two examples are illustrative of a dominant theme in this literature--that over time, because of a number of factors, one of which is cumulative deterioration, and the need for repair or replacement of an increasing number of components, house prices tend to decline at an increasing rate, when land prices are removed. Jones et. al. illustrates that this trend is not even over time and that at certain intervals, there may be a coinciding of heavy repair and replacement requirements that accentuate this decline. These studies tend to control for various housing and neighbourhood characteristics (lot size, number of bedrooms, nearby land uses) and fluctuations in selling prices but they do not disaggregate factors directly related to aging.

2. The Components of Net Depreciation

Chinloy (1979) and (1980) is unique in his concern with the role of maintenance expenditures in affecting net depreciation.

His work is particularly pertinent to this study because his concern is with two Canadian cities--St. Catherines and London.[13] Chinloy, in 1974, found that for single family dwellings, both current maintenance expenditures (repairs only) and net depreciation rates increased with age, holding price and other neighbourhood and building characteristics constant. His results are illustrated in Figure III.3 and they indicate that the estimated depreciation, excluding the effects of maintenance, increased from an average of just over 1% of price per year for housing between 5 and 15 years old to 2% for housing more that 35 years old. Current maintenance expenditures rose from .1% of the price for the newest housing to just over 1% for housing over 35 years old. As a result "net depreciation" was positive.

Figure III.3
Estimated Net Effects of Maintenance and Deterioration on Net Depreciation, St. Catherines, 1974



[13] Chinloy's analysis is, like that of Wolfe, subject to the limitations imposed by examining a single panel of data, in this case made available in the 1974 CMHC sponsored Survey of Housing Units (SHU).

Further, Chinloy posits that net depreciation over time was likely to have been geometric--implying a progressively increasing affect on selling price with time.

Chinloy's estimates paint a picture of a steady decline in housing value over time, partly arrested by a gradually increasing flow of maintenance and repair expenditures. But there are limits and a number of conceptual problems in the material that he presents. Chinloy does not provide a disaggregation of other elements which may have contributed to this decline, such as including the anticipated needs in the near future of capital replacements or obsolescence. While Chinloy takes into account surrounding land uses, he does not incorporate the effects of broader elements of relative location, as Jones et. al. suggests, in selling price. Lastly, Chinloy does not allow for interactions between housing characteristics, such as variable quality and vintage effects.

3. The Timing of Various Types of Maintenance and Replacement Activity

A third set of literature examines the reasons for different types of maintenance/repair and replacement activities, primarily in owner occupied dwellings. These behaviours are seen as dependent variables predicted by aging and a number of other neighbourhood, dwelling and household characteristics. The emphasis is placed in this section on specific empirical findings which may be relevant to the social housing context.

Much of this literature is concerned indirectly with filtering--linking disinvestment in housing with physical deterioration in neighbourhood housing stock, rather than positing filtering as a process. Unlike filtering literature, this material excludes considerations of social and neighbourhood change. Cumulative deterioration is seen as one explanatory factor in explaining homeowner maintenance/replacement levels. In contrast, the literature concerned with depreciation, discussed previously, treats a composite of deterioration, obsolescence and relative productivity in assessing market value. There concern is with market value where maintenance/repair and replacement expenditures are offsets, slowing and possibly reversing the process of deterioration and obsolescence captured in the value of depreciation. A strength in this literature is its emphasis upon maintenance/repair activity rather than expenditures, which shifts focus to finer qualitative differences in the nature of this activity.

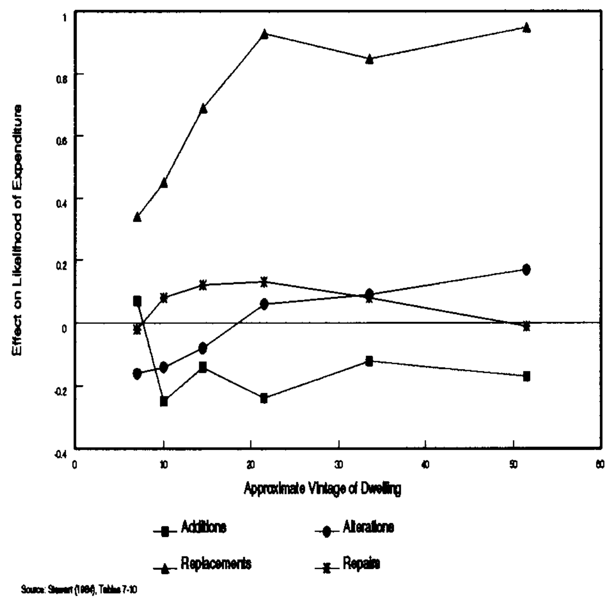
An oft repeated finding is that over time, the likelihood of differing types of activities change, and that, congruent with industrial processes, the costs of undertaking activities tend to increase. Galster (1987), for example, finds that in two U.S. communities, the effect of age on the likelihood of undertaking upkeep behaviour (a combination of short term maintenance and larger, capital replacement) was roughly constant with dwelling age, but that the dollar magnitude of this work increased. Galster also posits that over time, the reduced benefits of maintaining properties also reduces incentives to keep them up in good repair, thus accelerating deterioration and/or increasing the probability of renovation. This is akin to the third rationale for filtering outlined by Margolis (see above).

Results reported by Stewart (1984), who used the U.S. Annual Housing Survey for the years 1974-1977, provide some deeper insights as to why this might be the case. He argues that it is important to differentiate among various maintenance and replacement activities, identifying four separate classes of work:

- structural additions (extra rooms, garages);
- alterations (for example, basement finishing, addition of bathroom to existing facility);
- replacements (for example roof or furnace replacement); and
- repair.

Stewart found that the likelihood of undertaking work over time varies with the type of activity, holding household, neighbourhood and building characteristics constant (See Figure III.4). Age of dwelling had a considerable effect on the likelihood of replacement activity. The effect increased substantially to age 30 and remained high after that. To a much lesser extent, dwelling age also had a positive effect on the likelihood of undertaking alterations. In contrast, the probability of undertaking repair activity peaked among newer housing and tended to level off and remain constant after the first decade. This may be a result of the substitution of replacement activities with increasing dwelling age; that is the likelihood of successfully or satisfactorily undertaking a repair rather than replacing or changing an element of housing infrastructure may decrease. Adding an addition was unlike other activities in that it tended to occur most frequently in new buildings. Shear (1984), using the same data, showed that households with older dwellings were also more likely to undertake multiple alterations and replacements. His results also indicate that those who have recently moved and those that are intending to move tend to undertake alterations and replacements. He found that by removing recent movers and those intending to move, the effects of dwelling age were magnified.

Figure III.4
Impacts of Building Age on the Probability of Various Types of Maintenance Expenditures, U.S. Homeowners, 1975-1977

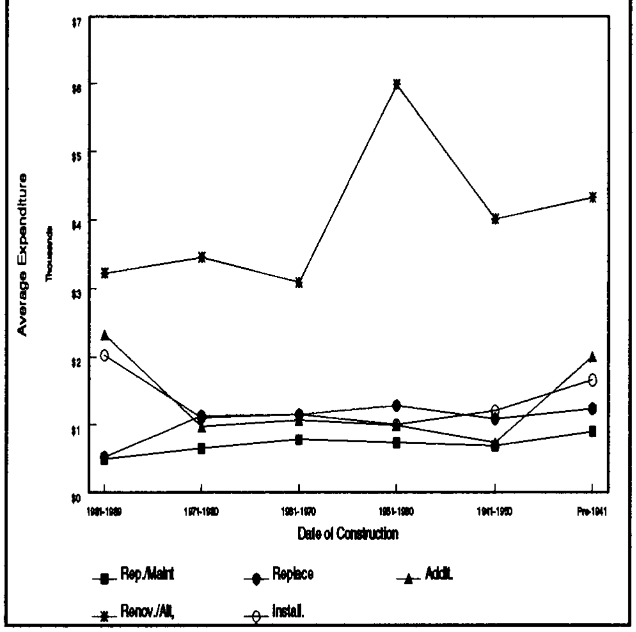


Data on expenditures, rather than the incidence of homeowner repair and renovation activity, are provided in published Canadian sources (for example, Statistics Canada (1991a)). These data provide a rough indication of the average magnitude of activity, rather than its presence. Despite these very different measures, there seems to be some evidence of similar trends in the relationship between aging and repair/replacement activity.[14] Figure III.5 shows the "raw effects"

[14] Statistics Canada's classification of homeowner repair/renovation activity is similar to that of the U.S. Bureau of the Census with one major exception--installations, which involve the incorporation of new equipment is a separate category. In the U.S., this activity forms part of either the renovation or additions categories (Statistics Canada

of aging on average homeowner expenditures in 1989.[15] It indicates that average expenditures on repairs, maintenance and replacement expenditures increase over the first three decades of building life. The magnitude of these expenditures then drops gradually. The U.S. data show similar trends in the incidence of these types of repairs being undertaken. Similarly, expenditures on additions tend to peak in newer Canadian buildings while the likelihood of undertaking this work peaks in the U.S. data. The Canadian expenditure data, in addition, provide a number of additional insights. First and foremost, renovations and alterations dominate in terms of dollar expenditures, making up close to half of Canadian homeowner expenditures. Secondly, renovation and alteration expenditures tend to peak in the third decade. Changes implied by these expenditures may indicate that end of service life can imply obsolescence or changing functional needs leading to more than replacement in kind. Finally, both sets of data indicate that over time, activities and expenditures involving the re-installation of large amounts of new materials, be it replacement or renovation, increasing dominates vis-a-vis repairs and maintenance activities.

Figure III.5
Average Homeowner Maintenance/Replacement Expenditures by Age of Dwelling, and Type of Activity, Canada, 1989



The limited literature in this area, which examines the behaviour of rental property managers, indicates that other factors may come into play in determining the type and range of activity undertaken with aging. Mayer (1981) found that among the rental building operators that he surveyed in San Francisco, the likelihood of undertaking repair was positively related to exterior and facade condition (porches, painting, roof) and negatively related to the presence of major structural/infrastructure problems (electrical system, foundation, condition of plumbing). Since these latter elements tend to have relatively long useful lives, Mayer's findings are congruent with Galster (1987) in indicating that after a certain point, the cumulative effects of deterioration lead to pressures to disinvest. Mayer, though, provides some clues as to where the tie between deterioration and disinvestment is likely to occur with aging.

Evidence here seems to point to a dichotomy between maintenance and repair activity and

(1991a) and Stewart (1984)).

[15] These "raw effects" do not remove the potential correlations between stock aging, demographics, income and recent renovation behaviour upon expenditure levels.

replacement (including modernization). Maintenance and repair activities and expenditures seem to remain constant over time and may actually decrease as buildings age. Replacement activities, involving renovations and alterations and the installation of new equipment, are more age related. There is some evidence that with aging, replacement activity will be substituted for maintenance and repairs. At some point, most likely well on in the aging process, the need for major structural replacements involving large capital infusions may not be met, possibly to the point where either demolition or large scale rehabilitation becomes necessary.

4. Age Effects on Maintenance/Replacement Expenditures in Institutional and Social Housing

A very limited literature has focused upon the inter-relationship between aging and repair and maintenance costs, and on the accumulation of deterioration in social housing stock. The same degree of consensus shown in studies of the private sector does not appear here.

A 30 year study of operating costs in New York City Public Housing by the Rand Institute (Rydell (1970)) does indicate that age was a key element in estimating repair and maintenance costs. Here it was found that real dollar costs increased most quickly over the first few years of operation and then tended to stabilize, increasing at a very slightly decreasing rate. In contrast, though, two earlier studies of military housing in the U.S. (Bagby (1973) and Hartman (1963) found that there was no discernable relationship between building age and maintenance expenditures, over an initial two and a half decade period, for military housing in the Southern United States.

<u>D. Other Factors Influencing Maintenance Requirements and Costs and Activities</u>

While the literature almost universally indicates that aging constitutes a significant contributing factor to changes in maintenance/replacement costs, it is far from the only or the most significant factor in explaining variations in these expenditures, or in building life. Other factors that act to change the absolute magnitude of these costs or the rate at which these costs change posited include location, building and site characteristics, resident characteristics and management practices. Each of these is discussed in more detail below.

1. Location (Exogenous Factors)

a. Climate and Remote Location

Variations in temperature, humidity and solar radiation are most commonly used in the testing of building materials (Nelson (1990)). As noted in the last chapter, Siemes (et. al. 1986) applied a series of log-normal stochastic models to portray the various effects of moisture and temperature on the life of concrete slabs used for balconies. Although there is a tremendous range of climatic conditions in Canada, very little literature exists about their impacts on maintenance and replacement requirements. Among those in the appraisal and economic fields who have developed models of market price and maintenance/replacement behaviours, very few incorporate these variables. One exception is Galster (1987), who finds that the likelihood of having housing with an exterior defect is much higher for all ages of housing in Minneapolis, a northern U.S. city with climatic extremes, than in Wooster, Massachusetts, which is located in a maritime climate. More systematic work on the relationship between climate and maintenance cost has been undertaken by non-profit housing providers in the Netherlands. There, for example, it was found that variations in micro-climates could have significant effects on building maintenance costs (Daman and Botmann (1989)). They found that buildings exposed to the elements, (for example, those on hill sides or structures exposed to prevailing winds) experienced more rapid deterioration of elements of exterior cladding.

CMHC's Public Housing Evaluation indicated that there were substantial regional variations in maintenance/repair and replacement expenditures and needs (CMHC (1990)). Without isolating other factors, it was found that maintenance costs and replacement costs tended to be highest in areas experiencing extremes in temperature (Yukon) and maritime climates (Nova Scotia, New Brunswick, B.C. and Newfoundland and Labrador). Examining the need for major repair in the Rural Native Housing (RNH) program, similar results emerge (CMHC (1992)).[16] In contrast, projects in the Prairie Provinces tended to have lower costs per unit to repair and maintain in the Public Housing portfolio and a lower incidence of repair requirements and housing in need of major repair than the remainder of the country. Finally, CMHC (1987) and Indian and Northern Affairs Canada (INAC (1990)) have noted the relatively short life spans of housing built in northern and remote communities and this has been largely attributed to the effect of climatic extremes on various building components.

b. Population size

De Leeuw (undated) and the HUD evaluation of U.S. Public Housing (Perkins and Will, Inc. (1980)) found that repair/replacement costs and condition were related to urban size.[17] Condition and costs tended to be most marked in large urban areas. Similar relationships were found between project condition and urban size in CMHC's Public Housing evaluation (1990) but only in projects dedicated to family housing. In contrast to the U.S. findings, though, projects in small towns and rural areas tended to have higher repair costs per unit. This was attributed to small project size and the presence of detached/semi-detached dwellings.

The CMHC Rural and Native Housing evaluation found that projects located in remote areas, which tended to be in areas experiencing temperature extremes, were more likely to be in need of repair (CMHC (1992b)). Contributing factors included the difficulties of bringing materials into remote areas and a lack of local maintenance/repair related expertise.

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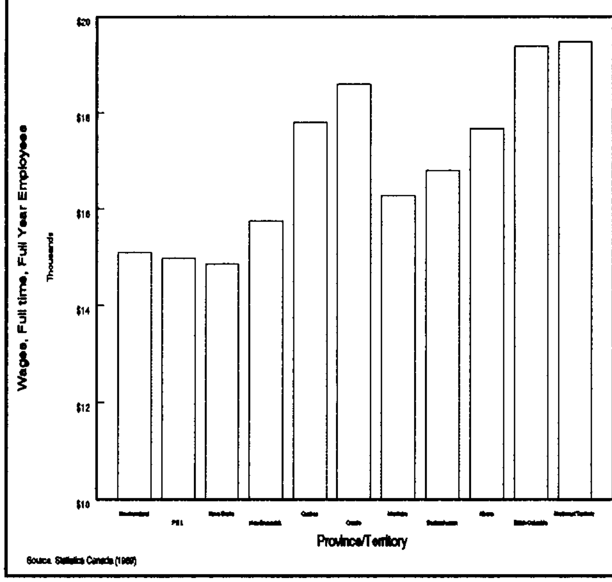
[16] At first glance, these results would seem to be at odds with Galster (1987). It should be noted that Galster is referring only to differences in deterioration of one element of building infrastructure--exterior cladding and that significant differences occurred when a single type--wood was used. In the Canadian context, a reason for the differences in cost may be the relatively frequent use of high maintenance wood exterior cladding in the Maritimes, versus other areas of the country.

[17] Repair needs were determined through inspection by professionals.

No published analogous analysis has been done comparing labour and material costs with urban size. Yet the examination of hourly wages for those employed in property management functions indicates a gradation by province on the basis of proportion of population urbanized (see for example, Figure III.6). Further, the author found significant positive correlation between homeowners' costs when using contract labour to undertake housing repair and renovation, and the proportion of provincial population residing in urban areas in the last 1980's and early 1990's. (Calculated using Statistics Canada (1991a), Table 4).

Figure III.6
Janitorial Wages by Province/Territory and Proportion of Population Urbanized, 1985



In some literature, a strong correlation is noted between the presence of higher levels of atmospheric pollution in more urbanized areas and maintenance or replacement expenditures. Legg (1989) observes that these variations in atmospheric pollution may explain higher costs in maintaining exterior surfaces in large European urban areas. Siemes et. al. (1989) note that the prime source of degradation in concrete balcony surfaces is airborne acidic pollutants, related to urbanization.

2. Building and Site Characteristics

a. Building materials/components

Surprisingly, there is little literature that systematically provides empirical results of the effects of using various types of building materials and components on overall maintenance/repair and replacement requirements and expenditures. A reason for this dearth may be the generally low incidence of outright failure among major building components within the first half century of operation. Legg (1989) found in the Dutch context for example, that major housing components had a mean service life of 84 years. Further, the HUD study of building maintenance requirements of U.S. Public Housing indicated that during the first decades of operation, aging was important to the incidence of deficiencies in only one major building system--the roof (Perkins and Will, Inc. (1980)).

Where there are major variations in maintenance costs, these are often largely offset by other factors, in particular, differences in initial level of investment. In particular, most estimates of floor life in residential buildings indicate a replacement need range from a low of 5 years for low grade carpeting to 50 years for hardwood flooring (see for example, CMHC (undated)) and higher ongoing cleaning costs for carpeting. Yet, offsetting this stream of expenditures is the considerably higher initial investment required in laying a hardwood floor.

There are a number of general statements in the literature based upon the experiences of non-profit providers (for example, see Kapinski (1989) and Legg (1989)). In addition, textbooks on building management and costing manuals routinely provide variations on building life expectancies and time related maintenance costs based on differing material inputs (see for example, Dell'isola and Kirk (1983) and Seeley (1987)). Further, U.S. studies of military housing have found the level of maintenance to be highly related to the type of construction materials (Bagby (1973) and Hartman (1963)). In particular, exterior wood surfaces were found to have the shortest economic lives and to produce the highest maintenance costs, while brick surfaces tended to last longest and have the lowest ongoing maintenance cost. In line with Bagby's findings, Galster (1987) and Varady (1986) indicate that in older owner occupied buildings with exterior clapboard cladding, there was a higher incidence of housing deemed to be in poor repair. Galster also found an interaction with climate in that expenditures for the repair of exterior clapboard siding were higher in the more northerly city (Minneapolis) in the rental housing stock he examined. Finally, De Leeuw's study of maintenance costs in U.S. Public Housing reconfirmed the hypothesis that type of materials was important to long term maintenance costs, but also indicated that maintenance requirements were related to building type (De Leeuw (undated)).

b. Building Type

Throughout the recent guidelines of the Ontario Ministry of Housing (MOH (undated)), there are references to estimates of required maintenance inputs which vary with type of dwelling. For example, they estimate that family townhouses require approximately 25 hours of maintenance work per unit per year while family apartments require 35 hours. These variations are attributed to the greater amount of common space (hallways, laundry rooms etc.) and the presence, in high rises, of elevators, which tend to have life spans of a few decades. Legg (1989) identifies higher relative costs for maintaining detached/semi-detached housing in European non-profit housing.

The HUD evaluation of U.S. Public Housing stock found that there was a correlation between built form and vandalism. Vandalism- related maintenance costs were greatest in high rise buildings, particularly those which housed families in large cities (Perkins and Will, Inc. (1980)). In these situations, safety also tended to be a concern, translating into high rates of turnover and vacancies, thus further exacerbating maintenance and replacement needs. Vandalism tended to be focused at certain locations within the structures, most notably elevators.

The CMHC Public Housing Evaluation (1990), though, indicated a very different pattern (although no attempt was made to remove potential confounding factors). There, high rise buildings tended to have the lowest maintenance and capital costs per unit, while detached, semi- and row housing units tended to have the highest expenditures. Low rise buildings were somewhere in between these ranges.

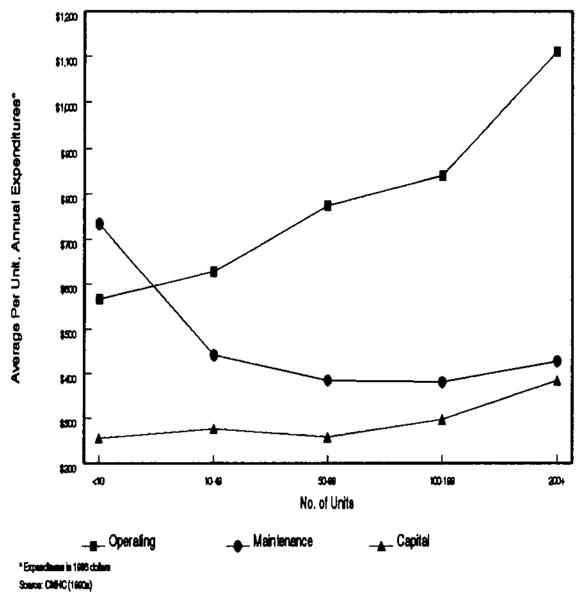
c. Project Size

The HUD evaluation found that there was an interaction between project size (differentiating between projects of over and under 200 units), the presence of high rises, and maintenance need. As discussed above, this was primarily related to issues of vandalism and safety (Perkins and

Will, Inc. (1980)).

The CMHC Public Housing evaluation (1990) may provide some insight into why this might be the case. There it was found that large family projects tended to have higher than average repair and replacement costs while expenditures in large projects occupied solely by seniors tended to have lower than average costs. It may be that economies of scale often linked to large projects are manifest in seniors' projects, while counterbalanced in family projects by design limitations for family living, and increased opportunities for youth related vandalism. Figure III.7, derived from the CMHC Public Housing Evaluation, shows that economies of scale may be evident for maintenance costs. Small projects, (less than 10 units) tended to have the highest maintenance costs per unit and average per unit costs declined markedly from there, levelling off in projects of over 100 units. In contrast, replacement costs per unit tended to increase slightly with project size. Higher operating costs (which include janitorial services and grounds keeping which are often included as maintenance costs) offset savings in maintenance.

Figure III.7
Average Operating, Maintenance and Capital Expenditures by Project Size, Public Housing, 1979-1986



d. Rehabilitation versus New Construction

A theoretical model put for by Gleeson (1984) posits that changes in the useable life of the stock of social housing in the United States are related to the magnitude and type of rehabilitation performed (for example, varying from roof and heating system replacement to wholesale gutting and rehabilitation). Gleeson further indicates in his exposition that rehabilitation does not usually fully reverse the effect of aging. His theoretical argument seems to find some credence in the results of CMHC's evaluation of the co-operative housing stock (CMHC (1992a)). There, the incidence and expected costs of needed major repairs was found to be higher in rehabilitated buildings than in new construction. This difference tended to be accentuated with aging. Thus buildings which had been rehabilitated tended to have higher maintenance costs than newer buildings, and following re-habilitation, the difference between maintenance costs in re-habilitated buildings and newer buildings widen.

3. Resident Characteristics

a. Age of Household Maintainer and the Presence of Children

Discussions with non-profit providers often produce a gradient in the expected level of maintenance/capital expenditure requirements. Special needs housing is often seen to produce the highest costs. Family housing is somewhere in the middle, and seniors housing is perceived to be relatively maintenance free (see, for example, MOH (undated)).

The distinction between the maintenance/replacement expenditure costs for families and seniors is almost universal in the literature (see for example, Legg's (1989) discussion of European social and CMHC's and HUD's evaluations of Public Housing (CMHC (1990a) and Struyk (1980)). One exception is De Leeuw's work on U.S. Public Housing in the late seventies which found that after controlling for unit type, unit size, building age and location, differences due to type of household could not be shown. (De Leeuw, (undated)).[18]

The CMHC Public Housing evaluation explores these differences in some detail. Holding building age, size of unit and number of units constant, the Public Housing Evaluation found that seniors housing tended to have lower repair and replacement costs than family housing. While in older buildings, these differences converged, it was also more likely that family units would be in need of major repair and that substantial expenditures on replacements had occurred in the past.

These differences seem to extend to studies concerning owner occupied housing. Galster (1987) and Boehm and Inlanfeldt (1986) both found that for owner occupied housing in the U.S., the likelihood of undertaking repairs and replacements and the incidence of housing with deficiencies decreased with maintainer age. This was particularly the case in buildings over 60 years of age. Mendelsohn (1977) specifically indicates that similar results are related to the lower incidence of wear and tear among seniors households.[19]

A number of empirical studies show positive relationships between household size, particularly when children are present, and the incidence and cost of household maintenance, repairs and replacements (for example, Shear (1984), Stewart (1984) and Varady (1986)). Shear's results indicate that the incidence of repair and renovation activity tends to be high in larger households containing children. Chinloy notes that, on average, net depreciation tends to increase when household size increases, especially where the additional persons are children. His results also indicate that increases in deterioration are largely offset by increases in maintenance activity in households containing children. Similar results occur in examining maintenance costs and requirements on Indian reserves and in rural and native housing (CMHC (1987), CMHC (1991b)). In this context, larger households generally include greater numbers of children. Accentuating

[18] Results shown later in this report indicate that it is very difficult to control for these factors since they are highly correlated with household type. For example, in the Canadian Public Housing Stock, high rise buildings and bachelor and one bedroom units are very common in buildings dedicated to seniors.
In contrast, row and semi-detached structures, and units with two or more bedrooms are much more common in family projects.

[19] The situation in the ownership market is far from fully analogous. Mendelsohn (1977), for example, indicates that the likelihood of undertaking repairs and alterations may be related to waning physical capacity. He further shows that the costs of these, once undertaken, were, on average, higher for seniors. He postulates that these higher costs were likely the result of a heavier use of trades persons' services, a result of waning physical capacity.

the effects of household size in aboriginal housing are the high levels of crowding.[20] In this context, large household sizes tend to occur in remote areas where unit sizes are small. (Spector (1995)). There, high proportions of the stock have been shown to be in need of major repair (Spector (1995) and average maintenance and replacement costs have been reported to be particularly high (EKOS (1986), CMHC (1987) and CMHC (1991b)).

b. Turnover

Turnover in most cases involves a point where substantial maintenance and replacement activity takes place. The HUD evaluation, for example, provides some empirical data linking maintenance need to the incidence of turnover (Perkins and Will, Inc. (1980)). Primarily, this type of link is found in guides on property management, descriptions of experience and textbooks (see for example, MOH (undated), Kapinski (1989) and Seldon (1987)).

Studies including the effect of either moving or an anticipated move on homeowner maintenance and renovation activity, indicate that these maintenance and replacement actions tend to increase (Shear (1984)). In contrast, with degree of longevity, the incidence of large capital expenditures on additions and alterations tend to decrease. (Galster (1987), Stewart (1984) and Mendelsohn (1977)).

4. Maintenance Regime

a. Timing of Replacement Activity

The timing of renovation activity may be cyclical. Mayer (1981) found in his study of landlords in Berkeley, California, that those who have not undertaken renovations over the past few years were more likely to be considering rehabilitation in the near future. Once initiated, though, replacement activity may span a long period of time, often a few years. Stewart (1984), for example, found that homeowners undertaking additions and alterations in the U.S. were very likely to have reported at least one of these activities in the previous year. These and other results suggest that irrespective of type of housing, expenditures on maintenance and replacement generally tend to increase over time; however, replacement expenditure levels tend to be uneven, often with peaks of high activity and cost, followed by valleys of relative inactivity. In particular, as Gleeson (1984) suggests, a high level of replacement or rehabilitation activity may be followed by an ensuing deep "valley" in maintenance and replacement requirements.

b. Policy and Practice

Policy related factors are significant in determining acceptable levels of maintenance. Bagby found in his study of military housing that policy changes in the accepted level of maintenance was a key variable in explaining variations in expenditure levels. He also found that program parameters were significant in the determination of the size and timing of expenditures. De Leeuw (undated) too reports differences due to maintenance regimes, concomitant with changes

[20] Since the National Occupancy Standard is applied in most non-profit housing, the issue of overcrowding is less likely to be important. Yet the presence of larger families may be a factor in the deterioration of more intensively used common areas and, space requirement for these areas (and subsequent costs such as carpet replacement and painting).

in the applications of minimum standards of adequacy in his study of maintenance costs in U.S. Public Housing. Legg (1989) found a relationship between levels of funding and expenditures in his review of various Dutch and Danish situations.

The CMHC (1990a) evaluation report provides a number of insights concerning the relationship between deferred maintenance and repair activities and budgets for social housing projects. It indicates that a repeated need for high maintenance is most likely in projects where deferral has taken place. It also indicates that the administration and availability of funding were factors in determining the timing and extent of capital replacement. As a result, in some cases, major deficiencies may have resulted from the manner in which capital funding was administered (CMHC (1991)). In addition, though, deferral often took place in buildings where, because of other factors, maintenance and repair costs were already high. Struyk (1980) indicated much more serious problems in the U.S. Public Housing portfolio in the 1970's, due to an uneven flows of capital funding; and continually directing funding towards projects "facing ruin" due to deferrals and other factors, accentuated costs. He felt that more even flows, comprehensive planning and scheduling of capital improvements, combined with the establishment of common standards, could substantially reduce maintenance and replacement expenditures there.

The HUD evaluation of this same portfolio found that specific elements of a maintenance regime also an effect on long term costs. Certain building components--door and window frames and high circulation areas (lobbies, common areas) were more prone to failure and high replacement requirements where there was inadequate ongoing maintenance. In addition, site erosion problems were also found to be related to inadequate maintenance of ground cover (Perkins and Will, Inc. (1980)).

Gleeson (1984) extends the discussion of building deterioration/expected life as an element of policy with regard to U.S. subsidized housing. He suggests that a stochastic model may be appropriate to the estimation of the impact of capital replacement on building life and that this application, as an element of life cycle costing, might be useful as a tool in making decisions concerning rehabilitation versus redevelopment. While not providing estimates of the effect of rehabilitation on expected costs or building life, Gleeson indicates that the adoption of this type of modelling can influence decision making regarding maintenance behaviour.[21]

In the Canadian social housing context, a considerable amount of emphasis has been placed upon policies concerning income and social mix, resident involvement and the availability of various sorts of earmarked funding on long term operating and replacement requirements. For example, the CMHC evaluation of the Co-operative Housing Stock indicated that maintenance costs in this portfolio were lower on a per unit basis than in other types of social housing (CMHC (1991b). It is argued that resident involvement, including volunteer time dedicated to maintenance and sense of community, may be factors contributing to lower cost. Further, the setting of adequate levels of replacement funding has been noted as a means to reduce long term maintenance

[21] There is no evidence that this type of modelling has played a part in replacement/maintenance related policy and practice in the U.S. social housing stock.

requirements and prolonging Canadian social housing stock (CHF (1991)).

5. Other Factors
In addition, there is a wide variation in project requirements. Some buildings and projects are "lemons" while others characteristically require very little cost or maintenance activity. Design deficiencies, past neglect or a range of idiosyncratic circumstances (including, for example, unstable soil conditions) have been reported as factors contributing to the presence of "lemons". For example, a common design deficiency where building residents are made up of persons confined to wheel chairs has been the inadequate provision of re-enforcements to walls, floor boards and doors, leading to substantial and continuing replacement requirement (Public Works Canada (1985)). On the other hand, a very stable tenant base or a strong sense of community have been cited as factors substantially reducing long term maintenance and repair requirements (see for example Perkins and Will, Inc. (1980) and CMHC (1992a)).

E. Building Life and Inventory Change
In much of the material reviewed above, a recurring theme is the estimation of the expected life of residential inventory. Surprisingly, there is no work in the North American context which follows housing inventory through its life. As a result, work concerning the ultimate effects of time and of aging on buildings depend upon either panel or relatively short time series data.

Wolfe (1967), reviewed above, provides an example of the results of using panel data. He applies the assumption of a random but inevitable progression through deterioration states to eventual loss in order to estimate average building life for late 1930's stock in San Francisco. Reflecting differences in vintage related technology, buildings constructed before 1921 are estimated to have an average life of 130 years, and those built between 1921 and 1939, just over 150 years. Wolfe's data do not allow for loss due to demolition or loss due to calamitous events or factors such as further technological change, which could speed obsolescence. As a result, his estimates might be seen as a type of upper bound on expected life.

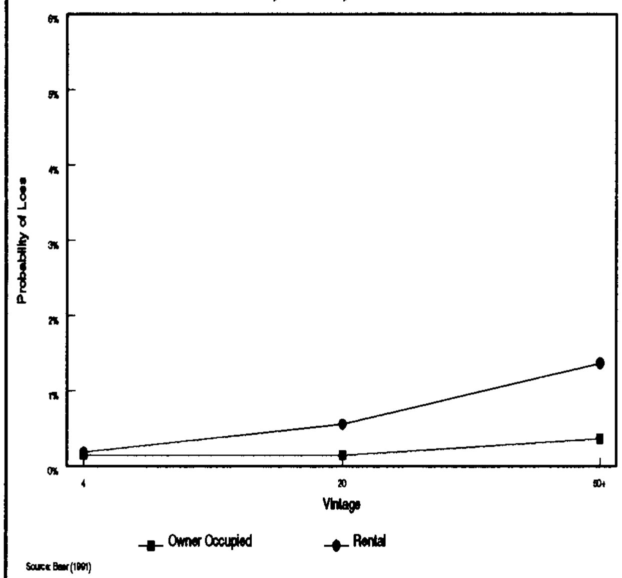
Cannaday and Sunderman (1986) also use panel data and a model which also presumes an inevitable process of economic depreciation, leading, in one way or another, to full loss of value, which is equivocated to loss. As noted above, they presume a process where net depreciation (the difference between the value of building deterioration, obsolescence and maintenance/replacement expenditures) is positive and accelerates over the latter years of building life. Referring to other empirical studies, they calibrate their model of owner occupied housing deterioration to arrive at an estimate of 88 years. Neither this analysis nor that of Wolf is sufficient to differentiate with any reasonable level of certainty between expected lives of between 75 and 100 years.[22]

Baer (1991), using the U.S. census accounting system which inventories the stock of occupied

[22] The Cannaday and Sunderman (1986) model produces fits which improved slightly by incrementing expected life from 75 years through 88 years. At an expected life of over 100 years, the fit produced begins to deteriorate.

dwellings (Components of Inventory Change (CINCH)), provides data on the source of dwelling unit loss and the likelihood of loss during a short time series--1973-1980, for dwellings of various ages and tenure forms. CINCH classifies loss due to demolition, disaster, becoming uninhabitable, conversion to non-residential and "other" (a catch all, including abandonment). Baer's results indicate that conversions to non-residential use and disaster are the major sources of residential inventory loss, particularly for buildings less than 30 years of age. As a result, models based upon deterioration or loss of market value, such as those provided by Wolfe and Cannaday and Sunderman likely overestimate residential building life. Baer's results re-affirm one conclusion of Wolfe's study, that inventory loss rates vary with tenure and that loss is much more likely at earlier stages in rental stock (See Figure III.8). Even so, over the first few decades, the probability of loss from all sources is extremely low among all tenure forms (an average .4% of rented buildings annually and .2% of owner occupied buildings) in stock less than 35 years old.

Figure III.8
Estimated Annual Likelihood of Residential Stock Loss Due to Demolition, Disaster, Being Rendered Uninhabitable or Conversion to Other Use, U.S., 1973-1980



In the Canadian non-profit stock, loss due to conversion and demolition is limited by the inability to convert non-profit housing or the land upon which it is located to other uses during the terms of an operating agreement that spans between 30 and 50 years. In addition, the provision of replacement reserves, subsidies and administrative controls may have the effect of reducing loss due to premature deterioration. Examining annual loss rates through the early 1990's for housing produced under selected non-profit programs where new commitments have not been forthcoming and operating agreements remain in effect, indicates that buildings that are now in their second and third decades of operation are experiencing loss rates of approximately .1%. (derived from CMHC (various)).

Gleeson (1981) and (1985), also use CINCH to indicate that a useful way to view housing inventory is through life tables indicating age dependent mortality rates and expected useful lives. Gleeson develops a mortality or loss model that incorporates losses due to accident, demolition, merger, change in use or deterioration to an unusable state. Without providing arguments concerning why this particular stochastic model might be most appropriate, he adopts the Gompertz distribution as a possible characterization of stock loss.[23] He estimates expected

[23] As noted above, the Gompertz curve is often used to describe human death, particularly during the senior years. Here, it is quite likely that the probability of death among survivors increases with age. Such an hypothesis

structure life in the Southern U.S. and in Indianapolis, Indiana at just under 100 years for one to three unit conventional private owner occupied dwellings.

F. Summary and Conclusions

Because most literature dealing with aging concerns economic and social processes very different from those created through extant Canadian non-profit and social housing programs, these studies offer limited opportunities to extrapolate. In addition, the literature does not provide a uniform characterization of the factors which contribute to maintenance and replacement requirements and expenditures over time.

Literature concerning aging in the private market place has been limited by an inability to separate out the effects of deterioration, obsolescence and competing alternatives for investment, and other expenditures. It is clear, though, that with aging, there is strong tendency for housing to deteriorate - to become obsolete - and for the aggregate of maintenance, repair, alteration and renovation requirements and expenditures to increase. The strongest evidence gathered to date seems to indicate that the manifestations of deterioration tend to become evident at an increasing rate over time. In conjunction with the initial period where modifications and adjustments are quite common, the plotting of maintenance/repair and replacement expenditures needs over time would seem to produce a classic "bath tub" curve. Lastly, over time, there seems to a shift from a relatively constant level of ongoing maintenance and repair activity to a greater emphasis on replacement, renovation and modernization.

There is also evidence that a number of other factors contribute to expenditures on maintenance and replacements. These include climatic and geographical considerations (such as community size and remoteness), household size and composition, turnover, building form, building and unit size, and building materials. In the following chapters, these materials provide a basis for the development of a series of contextual hypotheses concerning variations in maintenance and replacement expenditures in social housing.

In the North American literature, policy related factors such as administration style are also seen as significant in both the determination of funding levels and in defining long term maintenance and replacement requirements. It is quite difficult, and largely outside the scope of this work, to fully develop and test this relationship.

The research reviewed in this chapter is far from comprehensive in its coverage and generally has not had high degrees of success or predictive power in estimating maintenance/replacement

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is reasonable in considering building life but it has not been systematically evaluated. Gleeson's application of the Gompertz curve to empirical data, though, provides inconclusive results. While the Gompertz curve provides a reasonably good fit to stock data for the period 1949-1977 on housing built in the Southern U.S., Gleeson does not compare these results to the application of alternatives. In using demolition and age data for housing stock in Indianapolis, Indiana for 1979 and 1980, he finds that estimating demolitions alone using this distribution produces large error but does out-perform estimates using a negative exponential and linear distribution of residential building lives.

expenditures or requirements. Possibly, this is a result of how maintenance and replacement activities are viewed. Within some streams of economics literature, older housing is treated as another example of a used commodity. Elsewhere, level of maintenance and replacement is are considered as a detail, in conjunction with neighbourhood quality and other, exogenous factors. In the building sciences, the scant attention provided to this subject area may be a reflection of a pre-occupation with the performance of individual building components and systems rather than with the performance of overall building structures.

IV. Characterizing Maintenance Behaviour

This chapter provides a model for estimating variations of maintenance and replacement costs in non-profit housing. The model relates levels of maintenance and replacement expenditures to building age, a number of general building/site characteristics, geography and type of use.

The following section specifies the general form of the model. It is followed by a detailed rationale for hypotheses drawn from this model and open to testing, given available data.[24] These hypotheses are largely drawn from evidence in the literature reviewed in the previous chapter. Unfortunately, the full range of data are not available to allow model testing. A discussion of the nature of untested hypotheses and the implications of "under-specification" on the ability to fully test the model are then discussed.

A. General Model Specification

Results described in the previous chapter suggest that maintenance, repair and replacement costs in social housing are related to a process of aging and renewal (including the effects of deferred maintenance) in conjunction with locational variations, and building and household characteristics. Because of the universal requirements of social housing programs, these expenditures tend to be constrained by:

- budget limitations; and
- the minimization of the discrepancies between building condition and building adequacy (i.e. buildings are in adequate repair, that is to say, not in need of major repair for any major length of time and in compliance with health and safety standards)

Thus:

$$C_A(t)_k = f_k(r-t, r^{\prime}-t, l, u, b, c, w, p(t) + \sum_{i=1}^{r-1} g(C_A(i), b, l, c(i), w(i), p(i))) \qquad (4.1)$$

Where:

$C_A(t)_k$ is the expected sum of maintenance and repair (k=1) and replacement expenditures (k=2) at time t for a mix of housing goods and services s required to sustain a building at time t at an adequate standard

f_k the function relationship between current practices of maintenance and repairs (k=1) and replacements (k= 2); and dwelling condition

t-r Building age, including the effects of aging and vintage (effects of use of past building technologies, general characteristics of quality of construction

[24] Within the literature on homeowner renovation, there is seen to be a negative relationship between regional differences in unit repair/renovation cost and expenditures (i.e. demand for these services is extremely "elastic" or price sensitive (see for example, Boehm and Inlanfeldt (1986)). It is assumed in the hypotheses developed below that social housing expenditures are less price sensitive and that in provinces and areas having higher unit costs, total costs also increase.

	and variations in policy)
t-r′	Building Age is t (or time since age at rehabilitation (r′) if applicable)
l	Location, including the effects of climate, geographic variations in unit costs (including taxation) and urbanization
u	Building and Unit characteristics (unit type, unit sizes, building type
b	Construction characteristics (exterior cladding, heating type, parking facilities, presence of elevator(s), balconies and extensive landscaping, roof type, floor type, building construction type)
c	Resident type (seniors, families, non-senior singles etc.).
w	Tenant practices (such as turnover, variations in wear and tear (due to vandalism, special needs etc.)
p	Institutional characteristics (Program parameters including influence of resident involvement, adequacy, access to and channelling of funding)
g	Past maintenance and replacement practice and situations in producing a building of a given quality

Subject to the following constraints:

$$C_s(t) \cong B(l, b, u, c, p(t)) \quad \text{(4-2)}$$

Where:

$C_S(t)$ is the available resources at time t.

B(l,b,u,c,p(t)) is the program related budget for maintenance, repair and replacements[25]

and

$$|C_s(t) - C_A(t)| \approx 0 \quad \text{(4-3)}$$

Equations (4.2) and (4.3) do not define a best fit, but rather limit possible replacement/repair and replacement strategies constrained by budget and minimum standards. For example, a specific strategy may involve the consideration of future levels of adequacy:

$$MIN|\sum_{i=t+1}^{l} \left(\frac{1}{1+r}\right)^{i} C_s(i) - C_A(i)| \quad \text{(4-4)}$$

where:

l is the expected economic life of the building (which may, in itself be related to maintenance/repair, replacement strategy) and

$$C_A(i) \propto \sum_{j=1}^{i-1} C_s(j) \quad \text{(4-5)}$$

[25] A similar budget constraint is posited in MOH (undated).

i.e. that present and future maintenance is related to past practices.[26]

Equation 4.1 seems at first glance to be fundamentally different from the equation 2.6, where cost was related simply to stochastic elements of building component life. Equation 4.1 sets out a series of conditions which are hypothesized to be influential in affecting expected cost due to repair and replacement. Expected cost is thus a function of the accumulated effect of the presence/absence of gross variations in major building systems and the presence of factors having various impacts upon wear and tear and condition at a point in time. Broadly, the cumulative effects of these conditions are changes in the likelihood of repairs and replacements, as represented in equation 2.6. Yet there are substantial differences in equations 4.1 and 2.6. Added to equation 4.1 is a qualitative standard of "adequacy", defined in terms of present and past practice and policy--acknowledging a need for judgement in the evaluation that a component has failed sufficiently to warrant repair. Further, practices and policies may include provisions for inspection and preventative maintenance.

As noted above, data are not available for a number of these factors, which directly affects maintenance and replacement expenditures. As a result, the model tested in the following chapters is restricted to:

$$C_s(t)_k = f(r-t, r'-t, 1, b, u, c, p(t)) + g(C_s(t-1)_k) \tag{4-6}$$

In the following section, the function form and details of the variables making up equation (4.6) are described in detail, followed by a discussion of the implications of under-specification.

B. Detailed Specification of Hypotheses and Rationales

The range of hypotheses to be tested are summarized in Table IV.1 and dealt with below in detail.

1. Building Age

* **Constant dollar maintenance and replacement expenditures are expected to increase with building age (or age since rehabilitation), following an initial adjustment period, where costs remain relatively constant or decline slightly.**

The products of most new construction or rehabilitation are hypothesized to have high failure

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[26] A significant factor influencing available budgets for maintenance and replacements is the gradual decline in the financing costs of initial construction. Most social housing, for example, is fully mortgaged at the onset and faces a long amortization period (of up to fifty years). Amortization is typically based upon equal nominal payments. Over this period, the effects of inflation considerably reduce present values of these payments, potentially leaving room for larger commitments to maintenance and replacements.

rates (often referred to as the "infant mortality syndrome".[27]) Taking into account the findings of Stewart (1984) and similar reflections in Canadian homeowner expenditure data (Statistics Canada (1991a), additions and modifications may also be undertaken to fine tune the "fit" between the building and its occupants. After a fall off in the first few years of operation,

Table IV.1
Summary of Building Characteristics Available for Model Testing and Data Sources

Characteristic	**Notes and Specifics**
Dependent Variables: Yearly Expenditures Per Unit since IAD[28] data on:	
Maintenance	Often Referred to as "recurring maintenance"
Replacement	Referred to as capital, "non-recurring", Modernization, Improvement and/or Renovation cost
Independent Variables:	
Building Age, Presence of Rehabilitation, Original Age	* Age or Years since rehabilitation (for rehab. buildings) * Age or Years since construction * Original Age (for rehab. buildings)
Building Location	* Province * Population of urban area/community * Location in a northern/remote area
Project and Unit Characteristics	* Total number of units * Types of unit (apartments, row etc.) * Average number of bedrooms
Household Type	* Household Form (i.e. seniors, families, etc.)
Institutional Characteristics	* Program built under * Provider type (housing authority, co-op etc.)
Building Characteristics	* Construction type * Exterior cladding * Roof type * Heating type (forced air, hot water etc.) * Heating fuel * Presence of balconies * Presence of elevators * Predominant unit floor covering * Presence, extent of landscaping * Presence/type of parking

[27] In some cases cost may be amplified by including additional minor capital items during the initial stages of operation not handled in capital budgets. This may include cleaning and maintenance tools and equipment.

[28] IAD or Interest Adjustment Date is the date at which a non-profit social housing project moves from construction phase to co-operation. Often, projects begin operations prior to this date. Typically, a period of partial use follows this date as buildings are gradually filled by occupants.

periodic maintenance activities tend to replace these initial failure costs[29], in conjunction with the onset of random early failures.[30] With age, more periodic maintenance may be required in conjunction with a significantly increasing failure rate for smaller elements of infrastructure (primarily among mechanical devices such as valves, taps, thermostats, furnace motors and elevators). Cumulatively, these translate into a gradual upturn in maintenance costs and initially, a more moderate initial upturn in replacement costs. Slowly, replacement costs overtake and eventually come to dominate maintenance costs as sources of expenditure. Thus two process may be at work--initial failure due to design/manufacture flaws followed by a continual process of deterioration, upkeep and eventual, dominated by wear out.

Unfortunately, the sources of data available, which are property manager costs, likely do not capture large proportions of initial "infant mortality" since in many cases, these failures fall under warranty and their costs are encumbered by suppliers (MOH (undated)). As a result, data are hypothesized to reflect a relatively flat period of expenditure, eventually giving way to the effect of time.

The rates of change maintenance and replacement expenditures over time are thus characterized:

$$\frac{dC_s(t)_k}{d(t)} \cong 0. \tag{4.7}$$

Over the first decade or so of operations.

$$\frac{dC_s(t)_k}{d(t)} \rangle 0 \tag{4.8}$$

over remaining building life.

Just after the first decade,

$$\frac{dC_s(t)_1}{d(t)} \rangle \frac{dc_s(t)_2}{d(t)}. \tag{4.9}$$

but, over remaining life,

$$\frac{d''C_s(t)_1}{d(t)} \langle \frac{d''c_s(t)_2}{d(t)}. \tag{4.10}$$

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29 For example, carpet replacement, painting and caulking become significant replacement costs in and around the fifth year.

30 Examples of such rare occurrences might be the emergence of stress cracking in concrete structures experiencing settling or shingle adherence failure due to the cumulative stress of multiple high wind storms.

In reliability theory, this would be seen as a type competing hazards model, (each process being a competitive source of hazard leading failure) (Nelson (1990), ch. 7). The hazard function (the relationship between failure rate or, in this case, expenditure level and time) is characterized by the classic bathtub curve effect. Given the discussion of stochastic models in chapter II, a building which is a complex, multi-component form, will have multiple competing sources of failure. Holding other factors constant, the effects of age on expenditures may have two competing causative agents or hazards. Initially, the process relating to the incidence of defects leading to failure, may not be strictly dependent upon wear and tear but rather on the severity of initial defects. Such a process might be characterized by an exponential distribution of failures. The second factor, age related process, is at first glance more difficult to characterize. In chapter II, each of the stochastic models described might be appropriate to a process of deterioration and failure of a class of building characteristics. However, it is not strictly failure that is being characterized but the incidence of costs relating to failure. In essence, costs might be appropriately generated through a process of failure of weakest elements--characterized by the Weibull distribution.

Thus a competing hazards model of nominal dollar maintenance and replacement costs is hypothesized. It is initially characterized by a initial hazard function which is quickly damped (a process generating an exponential probability density function). Much of the effect of this process is not reflected in operating costs, especially during early operation because of the presence of new product warranties. Over time, an initially flat but very gradually increasing likelihood of failure due to a hazard is hypothesized to be a reflection of a Weibull process.

This hypothesis is related to the underlying assumption that social housing stock is maintained at or above a relatively constant level of quality--i.e. that it remains "adequate" over time. Another way to view this is by presuming that over building life, deterioration and obsolescence are ongoing and increasingly significant processes[31] which are offset by increasing but always sufficient expenditures.[32]

Expenditures counteracting the effect of time related deterioration are in turn amplified or damped as a result of interaction with a number of factors. Within the world of reliability theory, the effect of such factors is tested under controlled conditions and their effects are modelled as a stochastic process. In this case, a multivariate model is postulated, characterizing a general form for the aging process and introducing a series of amplification/damping parameters relating the effects of variations in building form, environment, household and management

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[31] This is in line, particularly, with Chinloy's findings with regard to owner occupied buildings (Chinloy (various), (see above)).

[32] In a broad sense, this is in line with the findings of the CMHC Evaluations of Public and Co-operative Housing which indicate that the great majority of social housing stock, irrespective of age is at or above "adequacy" standards (CMHC (1990) and CMHC (1992a)). Major exceptions occur in housing built in northern and remote areas and on-reserve (CMHC (1987) and CMHC (1992b)).

characteristics.

* **Vintage effects will effect both initial levels of replacement and maintenance expenditures and the rate of change and direction of these expenditures over time.**
A number of these factors affecting maintenance and replacement expenditures may be simultaneously be present at similar levels at the same period or "vintage". As well other "vintage" related factors may come into play. During the history of social housing in Canada, there have been considerable changes in building technology and variations in household for whom social housing has been targeted, differences in preferred location and built form and policy concerning the magnitude and direction of funds available, particularly in the area of replacement expenditures.

Because of the availability of time series data for buildings constructed during differing eras, analysis includes the application of a method to separate vintage related differences in aging, and an assessment of the significance of vintage effects.

In addition, "vintage" and age are expected to interact in influences expenditures related to rehabilitated dwellings. Because of older building technology and greater difficulty of finding and replacing materials, rehabilitated buildings are hypothesized to have higher than average maintenance costs. Further, because in many cases, building components which are not replaced at the point of rehabilitation have aged and are closer to the end of their economic lives. Thus, replacement and maintenance costs are expected to be higher in these projects (see Gleeson (1984)and CMHC (1992a)).

2. Building Location

* **Maintenance and replacement cost are expected to reflect broad differences in environmental and economic conditions (characterized by province).**[33]
There are a number of factors which in the aggregate, are seen to influence replacement and maintenance costs:

- Temperature extremes in the Territories and in remote areas will lead to higher than average maintenance and replacement requirements. In these areas, the high costs of transporting materials and labour costs may accentuate the costs of undertaking these activities (see for example, CMHC (1992)).

- Higher labour costs in the highly urbanized provinces of Ontario, British Columbia, Alberta, Quebec will tend to lead to higher maintenance and repair unit costs in these provinces.

- The common use of wood exterior cladding in conjunction with high humidity levels in areas on the east and west coasts may contribute to higher repair and replacement costs

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[33] There have been variations in the size of differences in sales tax and wages rates/salaries over time. The rank order of these, though, has not dramatically changed since the early 70's.

in these provinces.[34]

- High sales taxes in the Atlantic provinces (in excess of 10% presently) and the absence of sales taxes in Alberta will influence the unit cost of materials.

The resultant gradation is shown in Table IV.2:

Table IV.2
Hypotheses concerning the Effect of Environmental and Cost Factors on Maintenance/Repair Expenditure Differences at the Provincial Level

Maintenance/ Replacement Costs	Province/Region	Cost Factor
High	Yukon and Northwest Territories	Very High Labour Costs/High Material Costs/Remote Location Climatic Extremes
|	Ontario	Very High Labour Costs
|	Newfoundland and Labrador	Unfavourable and Extremes in Climate/Wood Exteriors/High Sales Tax/
|	Nova Scotia, P.E.I., New Brunswick	Unfavourable Climate/Wood Exteriors/High Sales Tax
|	Quebec	High Sales Tax/High Labour Costs/Moderate Climate
|	British Columbia	High Labour Costs/Humid Climate/Wood Materials
Low	Alberta	High Labour Costs, Favourable climate, No sales tax
	Manitoba, Saskatchewan	Low Labour Costs, Favourable climate

* **Maintenance, repair and replacement costs are expected to be related to community size.**
Environmental conditions, in particular the higher levels of air borne pollutants damaging to building surfaces, will contribute to a higher incidence of maintenance and repair activity (for example painting) and replacement expenditures (exterior surfaces and areas) as population size increases (see for example, Siemes et. al. 1986 and Christer (1976), Daman and Botman (1989). Higher labour unit costs will also positively influence maintenance and replacement costs in larger urban areas (see, for example, Legg (1992)).

In addition, community size has been seen as a factor in the incidence of vandalism and neglect (Perkins and Wills, Inc. (1980)). Some experiences in the Public Housing stock indicate that family projects in major urban areas are more prone to higher maintenance/repair and replacement expenditures (CMHC (1990a)).

* **Remote projects are expected to experience higher maintenance costs.**
Higher maintenance and repair costs are a reflection of both the frequent and costly

[34] Galster (1987) indicates this result in the U.S. context.

repairs/replacements associated with the effects of climatic extremes and the higher transportation costs in remote areas (CMHC (1992).

Northern and remote projects are located outside of major population centres (defined as those with an urban/community population of under 10,000) in the area delineated by the Royal Commission on Aboriginal People as the mid-north or far-north.[35] The mid-north and far-north includes Labrador and roughly the northern third of the provinces to the west of New Brunswick, the Northwest and Yukon Territories.

3. Project and Unit Characteristics

* **Maintenance and replacement costs will be related to the economics or various unit types**

Projects comprised of a significant proportion of hostels are expected to have much higher maintenance and replacement costs. Unit maintenance, often undertaken in other cases in tenants' living spaces (cleaning, janitorial activity) will often be performed by paid staff. Constant turnover and the presence of persons who may cause additional wear and tear are expected to positively influence maintenance, repair and replacement costs.

Single detached units are expected to have higher than average maintenance and replacement costs. The dispersed nature of single detached housing should affect the travel costs required in maintaining this type of unit. Legg (1989) found that in the European context, that high proportions of exterior wall and roof space, separate heating units and larger landscaped and/or parking areas, should contribute to higher than average costs in this type of unit.[36]

Apartments are expected to have lower than average maintenance and repair requirements.[37] The large amount of shared common areas and facilities and small per unit amounts of exposed exterior wall/ceiling space should produce "economies of scale" in this type of unit. (Note: the presence of high cost elevators and parking facilities are treated separately below).

Finally, duplexes, triplexes, semi-detached and row housing are expected to have similar, average maintenance costs and repair requirements. These types of units have characteristics which lie between the extremes of apartment and single detached housing.

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[35] Statistics Canada, Indian and Northern Affairs and others concerned primarily with aboriginal issues have wrestled with the issues of what, in Canada, should be defined as Northern and Remote. Other categorizations are reviewed in Armstrong (1994).

[36] CMHC (1990) provides some evidence that costs in this type of dwelling are higher per unit. In contrast, Wolfe (1967) estimates a slower rate of deterioration in this type of rental accommodation (see above).

[37] In most analyses, a distinction is made between low and high rise buildings. This distinction was not available in existent data. As a result, high rise and low rise buildings are distinguished in the limited number of cases where data on the presence of an elevator were obtained. These hypotheses also distinguish between linked housing, which largely have separate entrances (rows, duplexes, triplexes, stacks etc.) and those with common access areas (hallways).

The resultant gradation is shown in Table IV.3.

Table IV.3
Hypotheses concerning the Effect of Unit Type on Maintenance/Repair Expenditure Differences

Maintenance/ Replacement Costs	Type of Unit	Cost Factor
High	Hostel	High cost of intensive use and high levels of turnover
		Semi-Detached	High cost of travel, large areas of landscaping, exterior wall surface
		Duplexes, Triplexes, Semi-Detached	
Low	Apartments	Small exterior surface and landscaping area, low travel costs

* **Large projects are expected to experience economies of scale.**

It is expected that all else being equal, projects which have maintenance staff on location (reducing travel times) and projects where replacements and major maintenance can be undertaken on a large scale when required, will reduce costs. Issues pertaining to increased costs due to vandalism in large projects are ascribed to the high incidence of these projects in large urban areas and the high proportion of these projects which are family housing.[38]

* **Maintenance and replacement costs are expected to be related to average unit size, reflected in bedroom count.**

Maintenance and replacement costs are expected to be related to unit size, with larger units costing more to maintain or repair (i.e. large surface areas to paint or requiring carpet/flooring replacement). This is in line with the results of applying depreciation models to owner occupied dwellings (see Jones et. al. (1981) and Chinloy (1980).

4. Household Type is expected to influence Maintenance and replacement costs.

Seniors projects are expected to have lower maintenance and replacement requirements than are family projects, due to differences in wear and tear and absence of some equipment with short service lives (for example, play structures and children's recreation areas). As noted above, most studies in the area have noted that maintenance costs increase considerably where children are

[38] There has been some discussion in the literature of the relationship between project scale and breakdown of "community identification" (see for example, Wekerle (1988)). Smaller projects or communities are seen to be less likely to experience tenant neglect and vandalism.

present (see Shear (1984), Stewart (1986), Varady (1986)).[39]

5. Maintenance and replacement expenditures are expected to vary by institutional characteristics such as housing program and type of provider.

* **Co-op maintenance and replacement expenditures are expected to be lower than in other non-profits.**

The use of volunteer labour in the co-op programs should lead to relatively lower maintenance expenditures.[40] The CMHC evaluation of co-operative housing provides some evidence that this may be the case (CMHC 1991b).

* **Community based non-profits (Built under 15.1 and 34.18 of the old National Housing Act) are expected to have lower replacement expenditures and higher maintenance expenditures than other non-profits on average, holding age constant**

The limited replacement reserve provisions of the community based private non-profit program will have a restricting effect on replacement expenditures. As a result, in these non-profits, maintenance expenses are expected to be higher than average while replacement expenditures will tend to be lower. Given a potential lack of flexibility in determining optimal levels of each, it is expected that overall expenditures will be higher, all else being equal, than in later programs.

* **Public Housing and Municipal Non-Profits are expected to have higher maintenance and replacement costs than other non-profits, on average.**

High administrative and labour costs in Public Housing and municipal non-profits may result in higher than average maintenance/repair expenditures.

6. Maintenance and replacement expenditures are expected to be related to general building characteristics:

* **Units in wood frame/solid masonry buildings (primarily low rise buildings) are expected to have higher replacement expenditures than concrete/steel frame buildings. Replacements directly related to frame type are expected to be extremely rare.**

Construction costs of concrete/steel frame buildings tend to be higher than those of wood frame/masonry construction. The former construction type is used primarily in larger multi-unit buildings. In either case, the likelihood of a failure directly related to frame type is extremely rare. Still, frame type provides a surrogate for a number of other building characteristics, which are also related to building size, including, for example, type of exterior cladding, and air

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[39] There are very few non-profits which provide permanent (non-hostel) housing exclusively for non-elderly singles in the federal non-profit portfolio so results are likely to be inconclusive for this household type).

[40] Lower expenditures may not necessarily represent lower costs. Often in co-operative housing projects, a requirement of membership is the dedication of volunteer time to maintenance tasks, thus utilizing resources which are not reflected in expenditure patterns. It is also expected that the commitment of co-op members to the maintenance of their housing will have some influence on replacement requirements.

ventilation system. In many cases, the expected life of building components associated with wood frame construction are lower than those associated with concrete/steel frame buildings. As a result, it is expected that these buildings will have slightly higher levels of replacement expenditures during the first few decades of operation.[41]

* **Units in buildings with wood exterior cladding are expected to have higher than average maintenance and replacement expenditures. Those with brick exterior cladding are expected to have lower than average maintenance and replacement expenditures.**

Buildings with wood exterior cladding require painting on a cycle of five to eight years, on average (CMHC (undated) and Dell'isola, and Kirk (1983)). In addition, wood surfaces are prone to deterioration at a much faster rate than many other materials. Higher costs in wood exterior buildings, further, were found consistently in Galster (1987). Aluminum and other metallic sidings are prone to damage and, depending upon the paint adhesion process, eventual paint chipping. Dell'isola and Kirk (1983) found that aluminum exhibited a considerably longer life and lower maintenance costs than for wood, but still indicate a much shorter life/higher cost than for brick. Stucco, while extremely resilient, requires periodic painting.

* **Flat tar and gravel roofs will positively affect replacement expenditures than those with sloped/shingle roofs.**

This hypothesis is related to two factors--flat roofs tend to have shorter expected lives before requiring rehabilitation (CMHC (undated) and the cost of rehabilitation is considerably higher per foot for flat tar roof than for shingle replacements.[42] Roof related replacement costs tend to make up a large proportion of replacement requirements in the first decades of most residential buildings (see for example, Perkins and Will Inc. (1980)).

* **Elevators will have a positive impact on maintenance and replacement costs.**

Constant elevator inspection and preventative maintenance create a considerable additional cost. In addition, the expected life of an elevator unit is relatively short (estimated to be just over two decades). Recently, for example, in the province of Ontario, elevator replacement requirements have been exacerbated by changing safety standards, accelerating technological obsolescence (MOH (undated)).

* **Balconies will have a positive impact on replacement costs, particularly among older buildings.**

As noted above, balconies are prone to considerable stress and their high degree of exposure and horizontal surface lead to considerable water and other chemical related weathering (Siemes et. al. (1986)). As a result, it is common for balconies to require repairs in and around the second

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[41] At the same time, failure of building components in concrete/steel frame buildings leading to replacement tend to be much more expensive.

[42] This relationship may be confounded by the predominance of flat roofs in apartment buildings and of sloped roofs in smaller structures.

or third decade of building life (see for example, CMHC (undated).

* **Significant exterior landscaping will positively influence maintenance costs.**[43]
Landscaping can lead to lead to a considerable ongoing expense. Perkins and Will Inc. (1980), for example, found that extensive landscaping could contribute to significant premature capital replacement.

* **Units with carpeted floors are expected to have more frequent, and overall, higher replacement expenditures than those with linoleum/tile. All else being equal, those with hardwood/parquet flooring are expected to have lower than average replacement expenditures.**
These hypotheses are tied to life data available from a number of sources (including CMHC (undated)). Average life of carpeting has been cited as from 5-8 years; linoleum/tile as between 15-20 and hardwood parquet as approximately 3 decades.

* **Units in buildings with interior parking facilities are expected to have higher than average maintenance/replacement costs. Units in buildings providing no parking are expected to have lower than average maintenance/repair costs.**
Interior parking creates a number of maintenance requirements including, for example, the painting of interior walls and the maintenance of lighting and ventilation systems. In contrast, exterior parking surfaces are prone to deterioration due to the effects of weather.

* **Electric baseboard heated units are expected to have lower than average maintenance/replacement expenses. Units heated through water circulation systems fuelled by gas or oil are expected to have higher than average replacement expenses.**
Electric baseboard heating systems tend to be relatively simple, containing few working parts. Further, these parts tend to be long lasting and are relatively easy to service. The addition of other systems to create and regulate heat circulation increase the number of elements, and complexity of the system tends to increase the likelihood of failure and the cost of repair. Water circulation systems, fuelled by gas or oil, tend to be the most intricate and complex of heating systems.

* **Per Unit current year replacement expenditures and maintenance will be correlated with the past year expenditures. Present year expenditures on maintenance and replacements will be positively correlated.**
Large scale capital projects, by their nature, tend to cover long time periods, often spanning multiple years. Stewart (1986), for example, found that it was quite common for homeowners to stretch renovation tasks over long time periods. Given past restrictions in the capacity to draw from some replacement funding (for example, Public Housing Modernization and Improvement

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[43] In a number of accounting formats, landscaping costs are not considered as maintenance costs, but are, rather, part of "operating costs". The general impact of this and other accounting issues will be discussed in the following chapter.

Funds), in many circumstances, these constraints would have required multi-year funding.

This correlation may also be a reflection of the presence of construction/design related deficiencies which can lead to a string of expenditures (the "lemon effect" discussed above). In these cases, both maintenance and replacement requirements may be affected.[44]

C. Other Factors Influencing Maintenance and Replacement Costs

There are a number of factors which likely influence maintenance/repair and replacement costs for which data are unavailable, or which cannot be segregated from other elements of existing data. As a result, the model described above will likely produce biased results. That is, "the estimated regression co-efficient will be biased estimates of the "true" co-efficient, the extent of the biases depending on the correlations between the included and excluded variables and the population co-efficients of the excluded variables" (Johnston (1972), pp. 169). These are reviewed below.

1. Tenant Practices

*** Special Needs**

Maintenance and Replacement costs may be related to the special needs of residents. There may be an interaction between building design and special needs. For example, wheelchairs can produce gradual but considerable damage to conventional mouldings, walls, doors and some floor coverings. Without re-enforcement and modifications of the lower parts of doors (usually the addition of kick plates) and the addition and re-enforcement of wall mouldings and railings, considerable additional maintenance costs can be generated in buildings with wheelchair dependent residents. In addition, equipment and maintenance requirements may be necessary to meet special needs. For example, the maintenance and repair of air filtering devices may be required for those with environmental sensitivities, and thus additional funds must be allocated (CMHC (1991), Public Works Canada (1985)).

*** Turnover**

At the point of resident turnover, it is common to undertake unit maintenance (Kapinski (1989), Seldon (1987). A large proportion of providers, for example, do cosmetic repair and painting each time there is a move-out. This may be complemented or replaced by the activity of new tenants who may be allocated resources (paint and brushes, etc.) for alterations upon move-in. As a result, variations in turnover rate may be related to maintenance/capital replacement expenditures.

Chronic turnovers and high vacancies may have additional impacts on maintenance and capital replacement. First and most obviously, the impact of turnovers/vacancies upon budgets may lead to restrictions, deferral and the curtailing of required work. Scarce resources may be allocated to tasks increasing the immediate attractiveness of buildings and units such as painting and

[44] The relations between capital and replacement expenditures are complex. There is no capacity at this level of analysis to make any inferences about subtleties such as the effects of deferred maintenance or to isolate trade-offs between materials and design during construction.

repairing surfaces (see for example, Mayer (1981)). Conversely, where budgeting is undertaken on a portfolio basis and a small number of buildings within the portfolio are experiencing this difficulty, a reaction to chronic turnover and vacancies may be the revamping of facilities, leading to increases in these budget items.

* **Vandalism and Neglect**

There are considerable variations in the incidence of vandalism among non-profits. Some of this variation may be captured through the use of surrogates included in the model[45]. One of the distinctions between family housing and seniors housing in the evaluation of Public Housing was the significantly higher proportion of respondents who perceived vandalism as an issue in family projects (CMHC (1990). The U.S. evaluation of Public Housing indicated a correspondence between community size and project size with the incidence of vandalism. Conversely one of the arguments for co-operative housing is that resident commitment to the upkeep and care of common areas is related to "a feeling of ownership and control", which in turn is related to the lower incidence of vandalism, and an absence of "neglect"[46]. Some qualitative evidence was gathered in this regard in CMHC's co-op evaluation (CMHC (1992a).

The impacts and incidence of vandalism/neglect may vary as a result of design. Design which encourages high visibility and defines "private"/"semi-public" space has been seen to affect the incidence and, thus the cost of vandalism/neglect. Lastly, the use of surfaces and designs which are resistant to damage/defacement or easy to clean/repair can be a response which influences maintenance/repair costs.

While factors correlated with level of vandalism such as household type, urban size, project size and program type are included in this analysis, this factor is not fully characterized in the model.

2. Past and Present Practices regarding quality of maintenance and materials

Very little data are available concerning the present quality of social housing stock. The evaluation of Public Housing by CMHC indicated that deferred maintenance and modernization were prime concerns and that the funds required to sustain or bring buildings to a standard of adequacy were equivalent to more than 1.8 years of present maintenance expenditures. The co-operative evaluation, concerned with a much newer housing stock, indicated that expenditures roughly equal to 1.6 years of present maintenance expenditures and replacement contributions were needed to sustain or bring co-op stock to a standard of adequacy (derived from CMHC (1990) and (1992a)).

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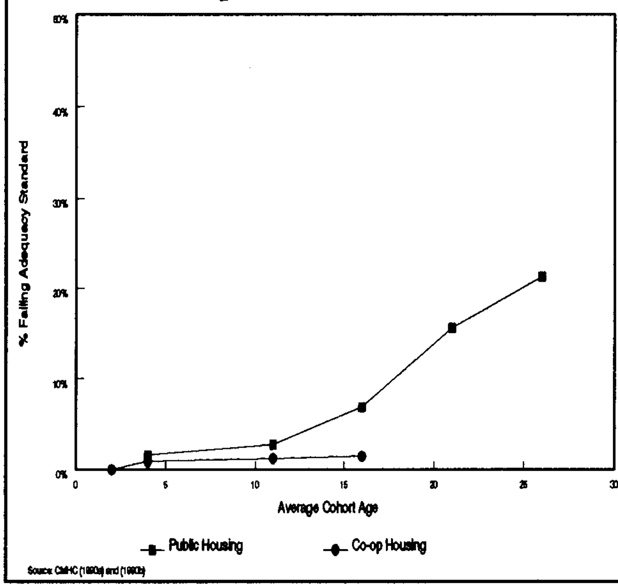
[45] These, to some degree may act as surrogates or, as is commonly termed in the literature, as "instrumental" variables.

[46] By neglect is meant a lack of minor remedial action which might avoid maintenance and repair activities. Neglect can involve not picking up garbage in common areas, failure to report damage or not undertaking small acts which could avoid damage or cost (securing leaking taps or closing/securing doors leading to common areas prone to vandalism etc.)

Both evaluations indicated that maintenance and replacements were provided to a sufficient degree to allow the vast majority of units to be assessed as being in good repair.

While estimates are available concerning overall shortfalls and deferrals in maintenance within the co-operative and Public Housing stock, small sample sizes make it impractical to develop sufficiently reliable estimates at the project level.[47] As a result, there is no indication of the relative efficacy of the maintenance regimes in providing adequate housing. This issue is of particular significance because both the co-op and Public Housing evaluations indicate that the proportion of housing not in adequate condition varies directly with age (See Figure IV.1). As a result, it may be that in these and other programs, deferred maintenance may be a critical issue and that using actual expenditure data characterizes behaviour which is not sufficient to sustain a constant standard of adequate housing.

Figure IV.1
Proportion of Units Failing CMHC Evaluation Condition Rating by Age, Public Housing and Co-operative Evaluation



The effects of deferred maintenance are difficult to assess. There may be and continue to be inadequate maintenance, so that some projects may be continually reporting lower than required maintenance. There may also be higher maintenance and replacement requirements due to past deferrals.

In addition deficiencies may relate to a combination of expenditure levels and other factors, which are also not captured in the specified model. These may include:

- original structural design (an aspect of vintage);
- the quality of workmanship, or materials used during construction;
- the quality of repairs or maintenance or related materials;
- diagnosing of maintenance and repair related problems;
- the timeliness of undertaking repairs or replacements; and
- value obtained for money spent on repairs or replacements.

Further, remedies to maintenance problems vary both in their short and long term cost

[47] In both the co-operative and Public Housing evaluations, individual units and common areas were sampled from a wide range of projects. This allowed the development of inferences for portfolios as a whole found in CMHC (1990) and (1992a) but providing insufficient sample size at the project level to make inferences about individual projects.

implications and they are made within the constraints of short term budgetary and administrative concerns. Accounting concerns noted in the next chapter have a considerable amount to do with the decisions of maintenance management as to what is good practice, and who is working within the framework imposed by accounting and budgetary limitations.

D. Summary

This chapter began with a theoretical model characterizing the composite of factors which have been seen in the literature and elsewhere to influence maintenance and replacement requirements and expenditures. These include the effects of time, variations in location, building and construction characteristics, tenant type and behaviour, and past practices. A wide range of testable hypotheses were posited corresponding to the majority of these factors' influences upon maintenance and replacement expenditures. Unfortunately, data are not available concerning some of these factors. These include tenant behaviour (ie. turnover, level of vandalism, and the presence of special need which all influence wear and tear) and past and present maintenance and/or replacement practices. These data limitations restrict the capacity to fully specify this model and may have some implications on the quality of the estimates developed in the analysis which follows. In the next chapter, discussion turns more fully to the nature and limitations of the data.

V. Data Sources, Quality and Description

This chapter describes the data used to test the hypotheses described in the last chapter, concerning how maintenance and replacement expenditures vary in Canada's social housing stock. The various data sources are described, and analysis is undertaken of the appropriateness of the data to the task at hand. The questions in this regard include:

- the degree to which the characteristics of the housing stock included are similar to that of the universe of Canadian social housing stock
- known errors in the data and the appropriateness of the data to the task at hand.

As will be seen, there is likely a high level of confounding because of inconsistent classification and measurement rules of the expenditure data which forms the basis of the analysis which follows.

The data used in this analysis include time series of expenditures. These data are influenced by inflation. As a result, to make comparisons in expenditure patterns over time, a de-indexing mechanism is required. The last section of this chapter discusses the mechanism used and the rationale for its choice.

A. The Population and Sample Universe

The population universe chosen for analysis is the public and non-profit rental and co-operative social housing stock operating in 1992. In addition, because concern is with changes in expenditures over time, projects are included which began operation prior to 1991. The population universe also excludes projects on-reserve and in some aboriginal communities which are administered for or on behalf of Indian and Northern Affairs Canada because of complexities ranging from tenure form to administration and record keeping. There are no sources which provide a full inventory of this population universe. Using inventories of federal and provincial portfolios, and other sources, it is estimated that the universe contains between 610,000 and 620,000 units.

The sample universe included off-reserve public and non-profit rental and co-operative housing projects administered partially or fully by CMHC in 1992 and which had operated prior to 1991.[48] As a result, projects administered by provincial agencies without federal partnership, exclusively by non-profit organizations or those receiving funding exclusively from other federal departments, were excluded. The sample universe at the end of 1992 is estimated to have contained approximately 557,000 units (derived from Tables 67 and 68, CMHC (various, 1991 and 1992 editions)).

B. Data and Data sources

[48] Excluded from this group are rent supplement units for which subsidy payments are administered by local Public Housing authorities but which are maintained by private sector housing managers.

A data dictionary is provided as Table V.1 which describes the characteristics included, and indicates their sources. In total, there are 23 characteristics of CMHC administered social housing stock derived from five sources. In some cases, identical variables were available from more than one source. Where discrepancies in the data collected from various sources occurred, resolution mechanisms were implemented and these are also discussed below.

Table V.1
DATA DICTIONARY

No.	Variable Name	Categories/Description	Source [46]
1.1	PROJECT AGE	Defined as the number of years since the Interest Adjustment Date (IAD), the approximate point at which a project began operation as social housing. Where the project included multiple buildings, the number of years from the mid point between the earliest and latest IAD date is used as a surrogate. For rehabilitated projects, this date represents the point of conversion for operation as social housing.	1
1.2	BUILDING REHABILITATED		2
1.3	ORIGINAL BUILDING AGE, WHERE REHABILITATED	Note: Insufficient data were available concerning original building age and no analysis of this variable was possible	2
2.1	PROVINCE	1. Newfoundland and Labrador 2. P.E.I. 3. Nova Scotia 4. New Brunswick 5. Québec 6. Ontario 7. Manitoba 8. Saskatchewan 9. Alberta 10. British Columbia 11. Yukon and Northwest Territories	1,5
2.2	POPULATION SIZE	1991 CENSUS POPULATION OF: 1. Urban Area 2. Community (for small urban places) 3. Township/Census Subdivision for Rural Areas (those not included in 1. or 2. above)	5
2.3	REMOTE AREA	Location in northern or remote area, (as defined by the Royal Commission on Aboriginal people), off major provincial highway and within a community, township or census subdivision with a population of less than 5,000	5
3.1	NUMBER OF UNITS	Project Count of Residential Units	1,2,4
3.2	BEDROOM COUNT (COUNT BY NUMBER OF BEDROOMS IN PROJECT)	1. Bachelor, bed 2. 1 Bedroom 3. 2 Bedrooms 4. 3+ Bedrooms (unspecified) 5. 3 Bedrooms 6. 4 Bedrooms 7. 5 Bedrooms	1,2

Table V.1 DATA DICTIONARY			
No.	Variable Name	Categories/Description	Source [46]
3.3	TYPE OF UNIT (COUNT BY UNIT TYPE IN PROJECT)	1. Apartment 2. Duplex 3. Hostel/Special Unit 4. Row House 5. Semi-detached 6. Single Detached 7. Stacked Townhouse 8. Triplex	1,2,4
4.	HOUSEHOLD TYPE	1. Family 2. Seniors only 3. Family and seniors 4. Singles only 5. Special needs	2,3,4
5.1	PROGRAM	1. Sect. 26: Limited Dividend, Municipal or Private 2. Sect. 27 and 61: Community Sponsored Non-profit/Co-op 3. Sect. 95 Unilateral CMHC Non-profit Programs 4. Sect. 79, 81/82: Public Housing Programs 5. Post-1986 Federal Provincial Agreements	1,2
5.2	PROVIDER TYPE	1. Housing Authority 2. Municipality 3. Private non-profit 4. Co-op 5. Aboriginal	1
6.1	CONSTRUCTION TYPE	1. Concrete frame 2. Factory assembled 3. Masonry 4. Modular 5. Steel frame 6. Wood frame	1,2
6.2	EXTERIOR CLADDING	1. Brick/brick veneer 2. Aluminum siding 3. Wood siding 4. Stucco 5. Concrete, concrete block 6. Mixed, wood/stucco 7. Mixed, brick/aluminum 8. Mixed, brick/wood	2
6.3	ROOF TYPE	1. SLOPED/SHINGLE 2. FLAT TAR & GRAVEL 3. FLAT STEEL 4. OTHER	2
6.4a	TYPE OF HEATING SYSTEM	1. Forced air 2. Water 3. Base board	2
6.4b	TYPE OF HEATING FUEL	1. oil 2. Wood 3. Electric 4. Gas 5. Mixed, oil/wood 6. Coal	1,2

Table V.1 DATA DICTIONARY			
No.	Variable Name	Categories/Description	Source [46]
6.5	ELEVATOR(S) PRESENT		2
6.6	BALCONY(IES) PRESENT		2
6.7	PREDOMINANT FLOOR COVER (UNIT INTERIORS)	1. Carpet 2. Linoleum 3. Tile 4. Hardwood 5. Vinyl/tile & carpet	2
6.8	SIGNIFICANT LANDSCAPING PRESENT		2
6.9	TYPE OF PARKING FACILITY	1. None 2. Exterior lot 3. Garage, underground 4. Garage at grade, interior 5. Separate garage 6. Carport 7. Mixed separate garage & carport 8. Mixed, garage, underground & separate 9. Mixed, exterior lot & carports	2
0.1	EXPENDITURES IN NOMINAL DOLLARS ON REPLACEMENTS	For each year available for the period 1973 until 1992	1,2,3,4
0.2	EXPENDITURES IN NOMINAL DOLLARS ON MAINTENANCE	For each year available for the period 1973 until 1992	1,2,3,4

1. CMHC'S Administrative Data Base (AGRSHRX)[49]

These data are administered and maintained by the Property Planning and Administration Division of CMHC (PPAD). The administrative data base, AGRSHRX contains partially verified expenditure information and some building characteristics. The source of maintenance costs and replacement expenditures is a yearly submission required of housing providers, CMHC Form 1323. Additional building related characteristics were linked from a second CMHC data base (AGRSHAG) which contains project information (date of completion, location, program, type of provider, number of units, unit type, building and heating type) collected at project completion.[50] In total, these two data bases contain data on well over 20,000 social housing projects in Canada.

Although CMHC requires financial information from the non-profits receiving subsidies or involved in CMHC programs, not all of this information has been converted to computer readable form and a considerable amount of this material has been archived and is difficult to access. As a result, financial data for a limited number of projects and for the period prior to 1986 were not

[49] Source numbers listed in Table V.1 correspond with section numbers below.

[50] In some cases, projects had changed considerably since inception. This created a source of error in the analysis which follows. For example, a number of projects in the Ottawa region were known to have converted from electric heating to gas and in a number of cases, the number of units available for rental had changed and the units had been modified to perform different functions.

available from this source. Further, a considerable number of projects did not contain full financial data for period 1986-1991 and were missing other, project related characteristics.

For the purposes of this study, further projects were excluded where:

- there was less than ten months of expense data on file, as of March 1994;
- there was a considerable amount of missing information about the project (no start date, etc.);[51]
- records concerning single projects or multiple projects had been completed over a span of more than 2.5 years (introducing a maximum error in completion date of less than 15 months); or
- cost information available referred to a portfolio which represented a geographically dispersed set of projects.

To assure confidentiality, the names and addresses of projects and of managers were not included in this data base nor were they made available in the material provided by CMHC.

2. Survey of Sample of Housing Providers

A total of 31 providers agreed to participate in a survey of non-profit providers, each of whom managed multiple projects. Of these, 21 surveys were eventually completed. The survey, included as Appendix B, requested information for buildings in each project. Included were attributes of the building and grounds (for example, type of roof, unit floor covering, exterior cladding, type of parking facility, presence of landscaping or elevator). Information from the survey was used to supplement, modify or create project records for 4%, or 521 projects included in the sample.

These data were linked to the AGRSHRX file created, where possible, using matching common fields. These fields included IAD date, city, CMHC account number (available from some providers) and direct matches of unit count, maintenance and/or capital expenditures. Where multiple provider building records available referred to a single CMHC record, this information was aggregated.[52] Project information in some cases was at odds with that of the corresponding CMHC data. Where this was the case, data provided by respondents was substituted.[53]

Despite a sampling design which initially attempted to avoid these biases, the provider sample is different from those included from the CMHC data base in two ways:

- Responses were provided from only 4 provinces: Nova Scotia, Ontario, Alberta

[51] Where additional expense or other data were available from other sources (see below), CMHC data were merged and retained.

[52] Where it was evident that the information provided by CMHC referred to too diverse a portfolio, respondent data was substituted or, where this was possible, project information was removed.

[53] In most cases, discrepancies involved slight differences in unit counts, unit types and maintenance/replacement expenses.

and British Columbia.

- Project sizes on average were larger. Responses were from managers whose projects averaged 71 units, in contrast to 38 units in the CMHC data base.

As a result, a number of possible estimation biases may have been introduced.[54]

3. Data from the 1990 CMHC Public Housing Evaluation

The CMHC evaluation division had available AGRSHRX data collected from the period 1979-1986 for Public Housing. In addition, where data were missing or unavailable from this source, supplemental requests had been made to the provinces to create a relatively complete base of data for this period. These data augmented records for approximately 19% of Public Housing projects included in the data base.

The Public Housing evaluation data included information on maintenance and replacement expenditures, household type, building type and heating fuel. Information on building type and heating fuel from this source was used where information was missing in the CMHC administrative data base.

The maintenance and replacement expenditure data available in the Evaluation Division data base were not fully compatible with post 1985 records. A number of replacement and maintenance areas were classified as "Operations", and as a result, expenditures reported under these categories tended to be lower. For example, replacements involving grounds versus buildings (i.e. landscaping, exterior parking lots) were classified as operations. In the Ontario Public Housing portfolio, more detailed accounting information was available (see section 4, below). Overall, in Ontario, the effect of using these data was the understating of maintenance expenditures by 3% and replacement expenditures by 7%, when compared to data reported in the CMHC administrative data base. Similar results were obtained (7% and 4% respectively), when comparisons were made on a small number of non-Ontario projects containing 1986 AGRSHRX records and Evaluation division records.

4. Ontario "Blue Books" (Ontario Housing Corporation Annual Budgets)

The Ontario government has published annual budget books through the provincial Ministry of Housing since 1974 on behalf of the Ontario Housing Corporation, providing past year financial data, estimated current year performance and future year budget projections on a project by project basis for that province's Public Housing Stock (OHC (various)). They also include information on number of units, household type and predominant unit type.

Financial data included in the Blue books generally "match" data available in the CMHC

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[54] For example, responses from one province included a large proportion of all rehabilitated buildings, and from another, all projects were very large. The effect of rehabilitation or large size on costs may not have been adequately distinguished in these cases from other, geographically specific factors such as client type or differences in labour costs.

administrative data base.[55] These data were used to supplement incomplete information on AGRSHRX for the period 1986-1992, to create a series stretching from 1974 to 1979 and were substituted, on a limited basis for the data provided by the CMHC Evaluation Branch for the period 1979-1985.[56]

Projects records were merged on the basis of common identification numbers, or where this was not possible, on location, start date and unit count. Data on number and type of unit and household type were used to fill in data holes from other sources where these appeared. In some cases, Blue Book or AGRSHRX records refer to differing numbers of units and projects. Where this was the case, project records were merged to create a single, fully compatible record, unless the merged record included too diverse a mixture of projects or buildings.

This source was used to create or modify records for 1211 Public Housing projects, (9% of the total sample projects). Time series of maintenance and replacement expenditures were created that included up to 20 years of expenditures.[57]

5. 1991 Census

Two variables, area population size and location in a remote area, were derived from the 1991 census, based upon the location indicated on AGRSHRX. Where places were not located in urban areas, the populations of the surrounding non-incorporated place or census subdivision were used.[58] Where location names were no longer being used, reference was made to various place name publications and past dated maps to link these places to current locations and the latter's 1991 populations were then used. All records contain city population and remote area designations derived from these sources.

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[55] This was not universally the case. In a very few cases, the administrative data base appears to contain typographical errors. More significantly, for the period 1990 - 1991, the administrative data base appears to contain present year estimates from the Blue Books rather than past year "actuals". Finally, there were differences in unit counts, almost always of a magnitude of 3 or fewer units. In these cases, Blue Book counts, based upon more current information, were substituted.

[56] In 1991, Blue Books switched from reporting past year expenditures (i.e. 1990) to current year expenditures (1991). As a result, 1990 actuals were not available from this source. Further, because of budget limitations, a very limited amount of Blue Book reported expenditures for corresponding CMHC Evaluation Branch data.

[57] A minority of Blue Book records (representing 6% of total unit) were excluded because of changes over time in the projects included could not be unambiguously resolved. Usually this involve buildings which shifted among reporting centres, due to re-organization. Most of these were located in Metropolitan Toronto.

[58] The use of census subdivision leads to a problem in some parts of the country, especially rural Nova Scotia. In particular, some census subdivisions in Nova Scotia contain relatively large populations, although projects are sometimes located in small, relatively remote locales. Where this was clearly the case, an arbitrary, small population (250) was substituted.

C. Data Quality

1. Variations in Classifying Replacement and Maintenance Costs

Of considerable significance to this study is the accuracy and consistency of the expenditure data collected. For the numerous reasons outlined below, there is likely a high level of "error" inherent in this base. A major source of error is inconsistency in the definition of what is a maintenance or replacement expenditure. This springs from variations in the accounting practices and systems. In addition, these practices and systems at least partly reflect strategies to deal with program, and resultant budgetary restrictions. Each of these is discussed below.

i. Inconsistencies in allocating expenses to maintenance/repair versus replacement

Theoretically, the costs of maintaining buildings are captured at an aggregate level as either operating or capital expenditures. Operating expenses are usually seen as relating to daily upkeep and to the undertaking of activities that require intermittent repetition (cleaning, snow removal etc.) or which involve replacement or repair of parts of building infrastructure or equipment (ie. changing locks, repairing a leak in a roof). Capital expenditures involve replacements, repairs and upgrades of identifiable large elements of building infrastructure or equipment (for example, a roof, balcony, floor etc.). The results of this activity endure for a significant amount of time (usually multiple years). Yet in practice, it is difficult to distinguish these costs.

One criterion that is often added in distinguishing maintenance and replacement costs is magnitude of cost. In some cases, a minimum rule relating to cost or effort is adopted in differentiating between capital and operational activities. In some organizations project cost, (typically $500 or $1000) acts as a threshold in determining what may be capitalized. In other circumstances, certain activities are defined arbitrarily as repairs. For example, a door replacement is often a maintenance expense, although, theoretically it could be seen as capital. Some operations capitalize outside door but not interior door replacement, because of differences in the amount of effort and cost involved.

The boundary between maintenance and replacement activity is thus fuzzy and this fuzziness may be accentuated by historical practice, legislative fiat or convenience. For example, most accounting schemes and CMHC operating agreement requirements include painting as a repair item, although its effects are often enduring (often lasting up to a decade) and involve a significant upgrade. Here, too, there is an exception, where painting is part of a larger, capital project.

On the other hand, at first glance, the use of the portfolio administered by CMHC has the advantage of a fixed set of rules of what it considers to be eligible for funding from various capital funds. In addition, it sometimes requires an approval procedure, largely utilizing these rules, (although often only where expenditures are above a certain minimum amount).

Yet even here, the rules imposed have not been hard and fast, and may themselves influence accounting and the type of work undertaken. For example, within some programs, carpet replacement has, in recent years, moved from an operating expenditure and has become eligible as a capital expenditure. In addition, questions have arisen as to the capacity to use replacement

reserves for certain items which were considered by CMHC staff as beyond "standard". For example, modest accommodation has on occasion been seen to exclude items such as calling facilities at apartment entrances or items required by certain provinces for safety reasons. As a result, capital expenditures for these items may or may not be funded through the use of a capital fund at all or may be funded through a less stringently reviewed maintenance budget.
Further, the approval process itself can place a barrier on the use of these funds, since it is often slow. Maintenance accounts thus become an attractive alternative, particularly where exigencies are pressing.

More generally, budgetary and operational considerations affect decisions as to whether to capitalize or expense maintenance expenditures. These considerations may include present levels of available reserve funding and/or situations where work can be pragmatically undertaken in small pieces. During the early years of a project, where replacement fund contributions involve self funding and it is not possible to obtain additional funding, the option of a major capital replacement may not be chosen simply because the funding is not in place.[59] In addition, maintenance strategies often involve trade-offs between repairs and capital replacements/improvements. These trade-offs include decisions as to what to do, and when and how to do it.

Operational exigencies may be a factor in the determination of what is a maintenance or a replacement expenditure. For example, a single capital project may often include a number of items than in isolation would be considered as repairs. It is quite typical to see a number of capital replacements at a single juncture, possibly involving a multi-year commitment. This results in expenditure "spikes", where replacement levels are low for long periods, then very high, then low again. Expenditures reflect replacement of building components at various stages of useful life, and thus do not directly mirror the effects of age related problems and other types of deterioration.

ii. No consistent data aggregation "level"

In some cases, data refer to single buildings, while in others, projects may contain numerous buildings and in still others, reporting is provided at the portfolio level, involving multiple projects. As a result, for example, buildings became available for use over an extended time period and these buildings include a wide range of structural and use characteristics. To partially deal with this problem, records were excluded where building start-up dates were more than 2.5 years apart or where single project records referred to buildings in multiple locales.

More significant, though, are resultant problems in the linking of cost to work done. When activities are undertaken at a portfolio level, it is common for an allocation mechanism to be

[59] In addition, a patchwork of programs have been in place which encouraged or discouraged certain types of expenditures. For example, for a short period, RRAP and sundry provincial program funding became available to non-profits for capital repairs. In conjunction with restrictions to Section 95 funding for rehabilitation projects, it may have been attractive in some cases to take on buildings which required replacement expenditures early in project life.

adopted. Allocation processes remove the capacity to accurately attribute cost to work undertaken. Typically, administrative costs, small tools and materials are allocated. Allocation methods can be quite diverse and may include per job overheads or straight, per unit allocations. Further, a criterion that can be used in cost allocation is the respect of budget constraints, often imposed at a project or departmental level. A maintenance co-ordinator faced with a necessary repair and insufficient budget in the appropriate account may change the definition of the activities undertaken to better fit these exigencies. Finally, allocation mechanisms are particularly common in large organizations where costs and budgeting are often accounted for on an "activity centres level" rather than a "cost centre level". For example, maintenance departments may develop overall budgets for painting or roofing and allocate common costs for these activities to projects where work is done, and in some cases, to entire portfolios. "Cost centre" level accounting and budgeting, in contrast, attribute budgets and work to be undertaken where the cost is encumbered (in this case, the project).

iii. Difficulties in identifying and classifying maintenance/repair or replacement activities

In many organizations, the role of employees may span different areas of property management. In these circumstances, it becomes quite difficult to attribute activity and cost to maintenance or capital cost categories. For example, in small non-profits, a single coordinator can be responsible for renting, day to day upkeep and member/tenant relations. Thus, it may be difficult or inappropriate to apportion time to various budget elements. In medium size operations, the administration of maintenance activities may fall under the responsibility or accounting categories of general administration. More generally, it may be difficult or impossible to fully and adequately cost capital improvements or replacements. For example, it is common for administrative overhead to occur in managing capital expenditures but it is difficult to attribute these to capital projects outside of very large corporations. This type of overhead has often been disallowed in claims to some CMHC regional offices for replacement funding, and thus expenses remain as part of general maintenance account.

iv. Variations in Accounting Rules

There are no hard and fast rules used throughout the non-profit sector in attributing costs to maintenance, repair and replacement categories. For example, at one extreme, some non-profits may choose to use functional, or cost centre based accounting classifications, while others may organize their accounts around activities or the responsibilities of departments or responsibility centres (see Moriarity and Allen (1991)). For example, it is quite common to use "contracted work" as a category or to develop single, broad classifications entitled "labour costs" or "transportation costs". For the purpose of providing functional classifications, these expense data may be allocated, rather than attributed in some cases. There is no guarantee that allocations will be made to maintenance or as to how these allocations are made.

Also significant are inconsistencies in how certain activities are allocated. For example, in data appearing in the CMHC administrative data base and the data base created by CMHC evaluation division and submitted by the Ontario Housing Corporation (OHC), categories allocated to Modernization and Improvement (termed Replacements here), Maintenance and Operation (considered here as utilities) change over time. For example, in OHC accounting classifications (prior to 1981), no differentiation is made of equipment purchased for maintenance purposes versus equipment purchased as part of longer term replacements. In total, these expenses were attributed to capital. After 1981, the appropriate split is made, shifting approximately 2% of expenditures. Also, between 1979 and 1986, the CMHC evaluation data base attributes all maintenance of grounds (including landscaping), waste removal and sundry materials and services, to operations. Records collected from a sample of non-profits for the period beginning in 1987 shows that expenses for these same activities are contained in the maintenance category. The shifting of these accounts influence maintenance related expenditures by approximately 15% for this portfolio. For selected years (the years 1979 to 1981) Ontario accounting allowed capital projects related to grounds to be isolated. In the CMHC data base, these were removed, reducing reported capital expenditures by approximately 3%[60]

v. Capturing Required Activity Using Expenditure Data

The use of expenditure data provides an indication of work undertaken, not of work necessary. This is why in the expenditure model formulation provided in Chapter IV, a budget constraint term is included. Still, the Public Housing and Co-operative Housing Evaluations provide some indication of the magnitude of deferred, but required work.[61] In the Public Housing evaluation it was estimated that an average of $1,815 (inflated to 1992 dollars) was required to bring Public Housing units to a standard which met CMHC defined minimum building standards in 1988. At that point in time, the average age of the portfolio was just under 13 years. This represents just under 2 years of average replacement/maintenance per unit expenditures for Public Housing projects or approximately a sixth of total annual expenditures during the average life of projects in the Public Housing portfolio. In the co-operative housing portfolio, $1,150 was required to meet CMHC standards in 1990. Given an average expenditure on maintenance and replacements of approximately $700, and an average age of 9 years, this represents approximately 1.5 years of budgeted expenditures or, again, a sixth of average annual expenditures. Thus, in both portfolios, there is weak evidence indicating that expenditure levels have not been totally sufficient to assure that adequacy standards have been maintained in all units.

Finally, expenditure data are far from perfect mechanisms for capturing maintenance/replacement activities. For example, expenditure data also do not provide any indication of value for money--that this the effectiveness of expenditures in reaching ascribed maintenance standards (Moriarity and Allen (1991)). In addition, a significant amount of maintenance activity in the co-operative housing portfolio is undertaken using volunteer labour.

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[60] The determination that this problem exists was through the comparison of 15 projects for which Ontario Public Housing Blue Book and Evaluation Division data were both collected for the period 1979-1986. Estimates of the impacts were made by averaging the proportions of expenditures accounted for by these accounts for a sample of regional totals for the years 1978 and 1986.

[61] Estimates of the costs of deferred work are difficult to develop. First, work done in a timely fashion often leads to differing expenditures than does maintenance and replacements required due to deferral. Secondly, an inspection undertaken at any given point in time does not reflect upon work planned and budgeted for. The estimates provided below are then at best, indications of the magnitude of deferred maintenance or repair activities.

2. Cross Verification of Sources and Error Resolution

Verification of a sample of data was possible where overlaps existed between the provider samples, the Ontario Blue Books and the CMHC data base. It was found that:

- Inconsistencies of over .5% in financial data caused by data entry errors were rare (well under .1%).[62]
- That financial data for OHC Public Housing characterized as maintenance in the CMHC AGRSHRX data base and CMHC evaluation division data set were not defined using the same accounts. CMHC evaluation maintenance financial data excluded the following: grounds, miscellaneous, social and recreation, security and waste removal. Replacement expenditures excluded grounds for the period 1979-1982.[63]
- For the year 1980 and in some cases, 1979, CMHC evaluation division data for OHC Public Housing did not correspond. In many cases, capital replacement financial data were combined with maintenance data and, accounts removed from the maintenance accounts in other years were also removed from the capital account.
- For the years 1991 and 1992, CMHC AGRSHRX expenditure data included some budget estimates rather than actual expenditures reported in OHC Blue Books.

Where inconsistencies occurred, data from source materials (OHC Blue Books or financial statements from sampled providers) were substituted for CMHC Evaluation data and AGRSHRX. In doing so, there is a danger of introducing errors identified and resolved through CMHC verification procedures.

D. De-indexing Method

This study focuses upon time series data of maintenance/repair and replacement costs, rather than either using panel data or short time series. These time series stretch over a period of up to 20 years. In order to isolate the effects of aging and other factors on building life from changes in input prices, it is necessary to create a series of consistent cost estimates over a period of considerable inflation.

Unfortunately, there are no inflation indices which are directly applicable to plotting price changes in this sector and there has been relatively little concern with this issue in the literature examined.

In the absence of existing research, a series of experiments were undertaken using a number of price indices which may correspond to price changes in these areas using six indices:

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[62] There were consist, though inconsequential, small random rounding errors in the last digit of CMHC AGRSHRX data of between $1 and $3.

[63] In 1983, non-recurring cost categories were merged in Ontario Blue Books making it impossible to exclude capital work on grounds. Between 1982 and 1983, CMHC Evaluation Branch data indicated average reported expenditures of approximately 15% in this portfolio. Tracking sample projects in Eastern Ontario indicates that this is the combined effect of inclusion of this cost and inflation.

- Homeowner's maintenance, repair and replacements component of the Consumer Price Index (CPI) for Canada (See Statistics Canada, (various), 1993 edition)
- Homeowner's maintenance, repair and replacements component for the provinces.[64]

It was believed that because such a large element of maintenance/repair and replacement activity includes the purchase of materials or contract labour for both owner occupied and rental buildings, the Homeowner's maintenance, repair and replacements component of the Consumer Price Index (CPI) index would likely be most appropriate. In addition, regional variations in this component would allow for regionally sensitive differences due to wage rates and other factors.

- Rental Construction component of the Construction Price Index for Canada (See Statistics Canada (1989));[65] and
- Rental Construction component of the Construction Price Index for large CMA's.[66]

An available alternative was the rental construction component of the construction price index. The advantage of this series is the close relationship between major repairs and replacements and construction costs, since in many activity cases the same trades people and materials are used. Unfortunately, though, cost structures in this industry are more highly tied to regional variations in overall new construction demand. In addition, the availability of regional data are relatively recent and tied to a very limited set of large CMA's.

- Canada (CPI); and
- Provincial and CMA CPI[67]

Because of the availability of series data at the CMA, provincial and Canadian level, the overall CPI was also fit to the empirical cost data. It allows the use of relatively consistent, regionally sensitive data for the entire time series. Should more refined indices not yield significantly higher correlations, then this data would be prescribed for controlling for price variations in the maintenance/repair and replacement series.

These indices were regressed against series of average expenditures for projects which contained at least 15 years of data stretching over the period 1973-1992. These series were only available for Public Housing in Ontario and included averages based upon a total of 750 projects. As a result, only Ontario and national based measures were used.

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[64] The Homeowner component of the CPI was reported beginning in 1979.

[65] The Construction Price Index began in 1981.

[66] Provincial series of homeowner's maintenance, repairs and replacements began to be produced in 1980. There are no provincial Rental building construction provincial series, so CMA series were substituted. CMA series are relatively recent and began in 1983.

[67] Reporting of provincial CPI began in 1979.

Table V.2 shows the results for the series estimated for the period 1973-1992[68]:

Table V.2 Results of Regressing Average Maintenance and Replacement Expenditure Data with Price Index Series		
Price Index Series	Maintenance Series, Adjusted R^2	Replacement Series, Adjusted R^2
Canada CPI	.646	.354
Ontario CPI	.651	.363
Canada, Homeowner's Repair and Replacement Component of the CPI	.597	.326
Ontario, Homeowner's Repair and Replacement Component of the CPI	.598	.336
Canada, New Apartment Construction Price Index	.647	.366
Ontario (Toronto and Ottawa only), New Apartment Construction Price Index	.644	.369

These results show that there is very little to choose from among Ontario CPI and the New Apartment Construction Price indices.[69] Examining the residuals generated in fitting these two series indicates that the relatively good performance of the New Apartment Price Index in the maintenance series, is enhanced by a correspondence between the accounting variation in the CMHC Public Housing series which led to an artificial depression in these data and a depression in the New Construction index associated with the recession in the period 1982-1984. **As a result, in the time series analysis, Provincial CPI's are used to deflate all expenditure series and estimates.**

C. Data/Sample Characteristics

Of the sample universe available, some data were initially extracted from AGRSHRX concerning approximately 539,225 units, or 97% of the sample universe. A sufficient amount of data was available to utilize information for projects containing 504,895 units or 91% of the sample

[68] To examine the effects of splining CPI data to these other series, five series of regressions were performed to determine which series might be most appropriate in de-trending the maintenance and replacement series:

All series, 1983-1992;
Ontario and Canada CPI series, 1979-1992;
Canada CPI series, 1973-1992;
Ontario CPI series with splined Canada CPI data for the period 1973-1978; and
Canada and Ontario Apartment component of construction price index with a spline using Canada CPI for the period 1973-1992.

The results for regressions using the 1973-1992 series only are reported here. Differences in goodness of fit are somewhat narrower than those found using the shorter series because of the use of common data elements, but the monotonic order of the "goodness of fit measure" R^2 was the same.

[69] These results cannot be distinguished with any reasonable level of confidence.

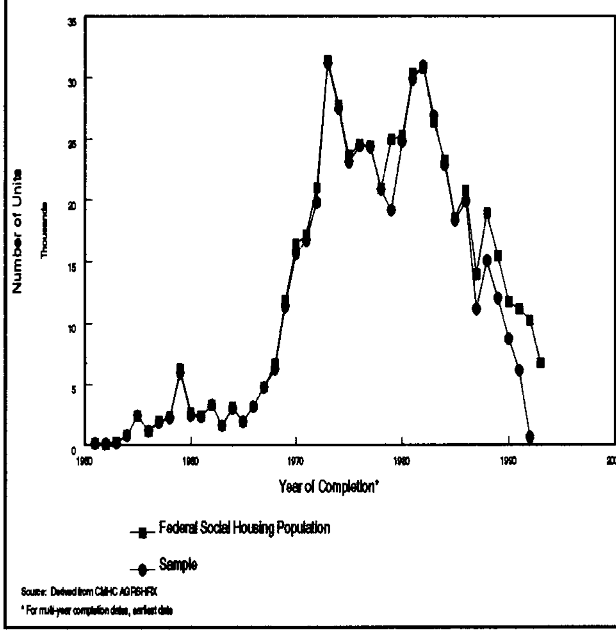
universe.[70] These units are contained in 13,223 projects.[71]

There are, though, numerous "holes" in maintenance/replacement expenditures and only a minority of observations contain a full range of building characteristics. The discussion which follows provides an overview of the building and occupant characteristics of the projects sampled, and outlines where these holes exist and the implications that these have in the analysis which follows. Included in this discussion are comparisons, where corresponding data are available, with distributions of corresponding characteristics in the sample universe.

1. Building Age, Presence of Rehabilitation

Social housing stock has been an element of the Canadian housing mosaic in some manner, shape or form since the advent of the first entrepreneurial and self-help schemes of the 1930's. Figure V.1 shows the date at which administration of projects began for the sample universe and the sample.

Figure V.1
Year of Completion, Non-Profit Units in AGRSHRX Federal Social Housing Data Base and Projects included in Data Base



The first relatively large scale development occurred in the late 1950's following the adoption by some provincial governments of federally proposed cost sharing schemes for the construction of Public Housing and the introduction and expansion of private sector and municipal housing corporation limited dividend housing. With revisions to the National Housing Act during the 1970's, which expanded the eligibility for community and municipal non-profits and modified provisions for Public Housing, the supply of non-profit housing expanded considerably. The downturn of completions in the latter part of the 1980's reflects firstly the culmination of most new development in the Public Housing programs, followed by the gradual contraction in the availability and scope of federal funding for new non-profit initiatives, and culminates in complete withdrawal in 1992. Figure V.1 demonstrates these trends in that it shows that the majority of projects and stock came on stream between 10 and 25 years ago.

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[70] This represent approximately 82% of the estimated population universe.

[71] The vast majority of these records were at least partially developed from the AGRSHRX data base. A small number were added from other sources. In these cases, insufficient information was available in the AGRSHRX data base to allow for a certain match and other sources provided a sufficiently rich base of information to create an additional record.

Figure V.1 also indicates that the sample tends to exclude a large proportion of recently completed projects and projects completed in the early 1980's. Since a primary concern of this research is the examination of histories of maintenance and reserve expenditures, exclusion of recent projects is expected to have negligible effects.[72]

These data do not distinguish between new construction and rehabilitated stock. Data concerning whether or not the stock was rehabilitated and the age at rehabilitation were collected in the survey of housing providers. Unfortunately, very few of the respondents had rehabilitated stock and in some cases, this information was not available to respondents. In total, these data were provided by respondents concerning 1.8% of projects (231 projects and 13,927 units), of which only 50 projects were rehabilitated. In addition, original age was available from respondents for only 7 of these projects (367 units). While limited inferences can be made concerning the effects of new construction versus rehabilitation based on these data, insufficient data were available to provide information on the effects of original age on maintenance/repair and replacement expenditures.

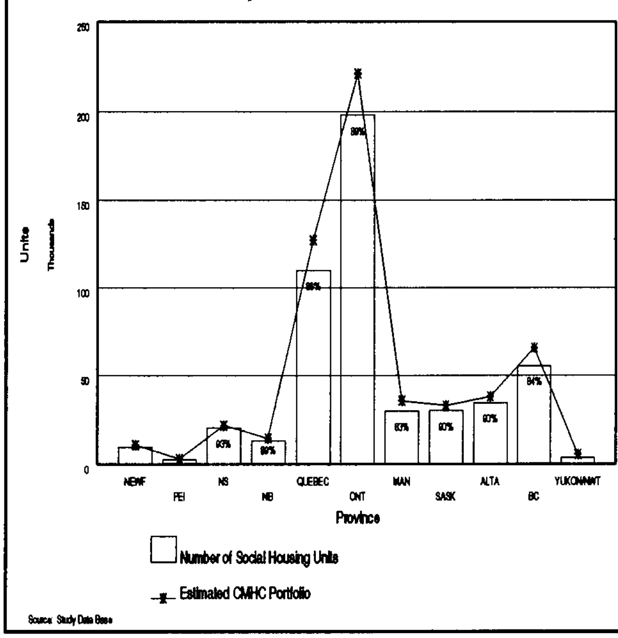
2. Project Location

There are three aspects of project location hypothesized to affect maintenance/repair and replacement costs:

- Region (as characterized by Province)
- Population Size of surrounding area
- Location in a remote area

Figure V.2 indicates that the distribution of sampled social housing units follows the overall distribution of CMHC portfolio in the country.[73] With the exception of the Territories where just over two thirds of units are included, between 83% and 99% of the sample universe are included. The high rate of exclusion in the Northwest Territories is due to a large proportion of projects located in different locales being administered as single portfolios. A large proportion of the

Figure V.2
Distribution of Data Base Projects by Provincial/Territorial Location



[72] Recent projects were primarily excluded because insufficient financial data were available. The reason for excluding projects coming into operation in the early 1980's and for a stream of later projects was the aggregation of financial data in AGRSHRX concerning multiple buildings, often in very disparate locations. A large proportion of these projects were undertaken under the Rural and Native Housing Program.

[73] Comparisons are made at the unit level rather than at the project level because data are not available concerning the sample universe at the project level.

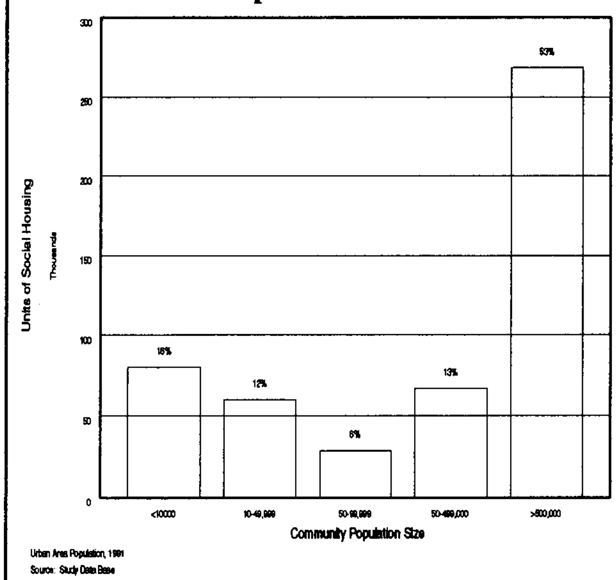
units excluded in British Columbia, Alberta and Ontario occurred because of missing financial information. Overall, Figure V.2 indicates that at the provincial level, the very large proportion of the sample universe included allows for strong inferences.

More generally, social housing projects administered by CMHC tend to be relatively concentrated geographically on the basis of the level of provincial participation over the years, and are a reflection more recently and to a much more modest extent, of the impacts of the application of a needs model. Overall, these social housing units make up approximately 6% of all off-reserve stock. Across the country, these federally administered units are relatively concentrated in the Territories (21%), Manitoba (9%) and Saskatchewan (9%), and this stock makes up a relatively small proportion of Alberta's stock (4%).

Figure V.3 indicates that the stock sampled is concentrated in large urban and small, rural areas--53% of the stock was located in areas with populations over 500,000 and 18% of the stock in areas with populations of less than 10,000. This very closely matches the overall distribution of occupied private non-farm dwellings. This is despite a relatively large proportion of the projects excluded projects due to data considerations being located in large urban and remote areas.

In total, 544 projects or 1% of the sample were located in remote areas. The majority of these projects were located in Québec, the Territories and the northern parts of the western provinces.[74]

Figure V.3
Location of Data Base Projects by Community Population Size



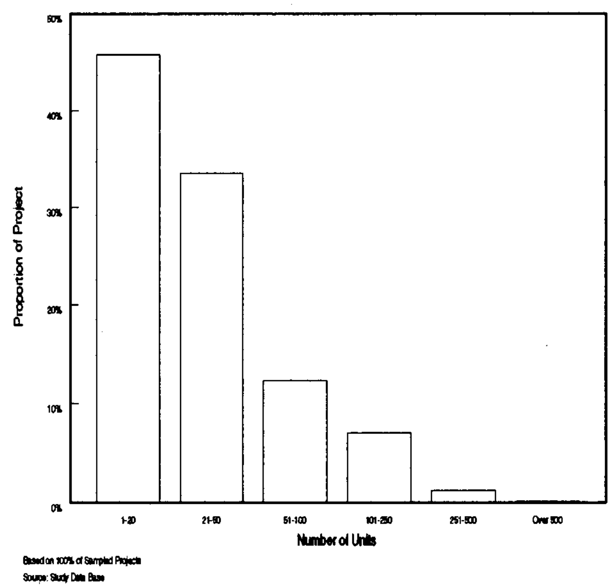
3. Project and Unit Characteristics

Social housing projects cover a wide gamut of project and unit types and building forms. There are, though, some universals in characterizing the stock. The housing is designed and maintained according to standards which generally assure that it is modest, has a basic set of amenities and is maintainable at a minimum set of standards considered as generally adequate. The projects generally do not contain amenities which are considered to be luxuries, such as central air conditioning, swimming pools, health clubs etc.) Further, construction costs have been constrained (for example by Maximum Unit Prices).

[74] Exclusion of on-reserve housing considerably reduces the number of projects drawn from remote locations in Northern Ontario, the Prairies and British Columbia.

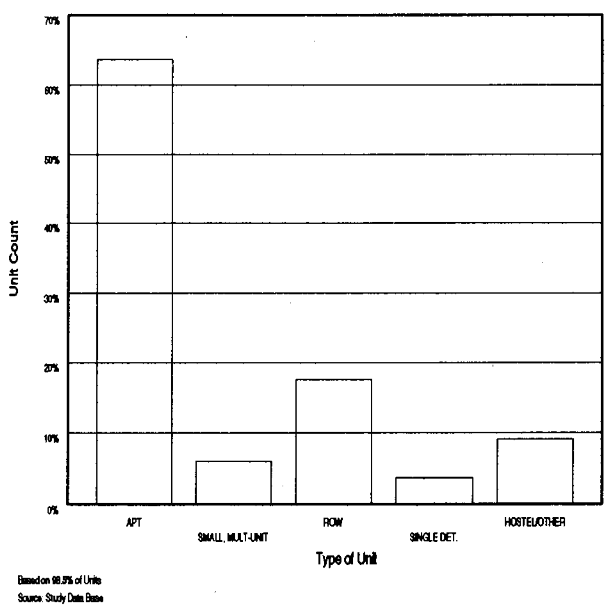
The average social housing project in the data base contains 38 units. Figure V.4, indicates that there are a great many small projects in the overall portfolio, and a small number of very large projects-- 47% of projects include 20 units or less, another third contain between 21 and 50 units, 12% were between 51 and 100 units, and less than 1% contain more than 250 units. Large projects are, for the most part in large CMA's and the great majority were produced under the Public Housing programs more than two decades ago (CMHC (1990)).

Figure V.4
Distribution of Projects by Size



As in other rental stock, apartment units predominate, making up 48% or 242,330 units (See Figure V.5). Apartments are located in projects which, on average, are larger than the norm (46 units). At the other end of the spectrum single detached and small multi-unit buildings (duplexes, triplexes, semi-detached units etc.) make up a smaller part of the stock, 26% are located in projects which are small (averaging less than 16 units). Further, these projects are relatively concentrated in smaller urban and rural areas. Row housing, which makes up 15% of the stock, tends to occur in projects which fall somewhere in the middle (averaging 38 units). Hostel units/beds make up 10% of the stock but tend to be found in projects which, on average, have a high unit counts (52 units).[75] Hostel units/beds are present in a small proportion (4%) of projects. In comparison to the rental stock as a whole, the social housing stock is made up of a larger proportion of apartment and row housing and a much smaller proportion of single detached and small, multi-unit buildings (comparison derived using Statistics Canada (undated)).

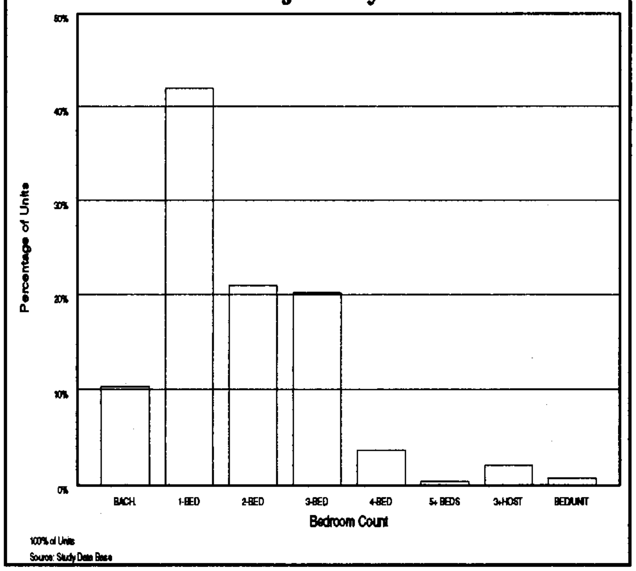
Figure V.5
Distribution of Unit Types



[75] Unit counts in hostels are not strictly comparable to that of other project types because in many cases, these projects are rooming or dormitory like settings with shared and/or collective areas (bathrooms, kitchens, common rooms).

The stock is primarily made up of one bedroom units (42%). Two bedroom units make up an additional 21% and three bedrooms, 20%. (See Figure V.6). Bachelors units make up an additional 10%. Units with four or more bedrooms are relatively rare (3% of the stock), as are bachelor/beds in hostels (3%). Bachelors and one bedrooms tend to be found in larger buildings (averaging over 50 units). Projects with two or three bedrooms tend to be located in projects just under the 38 unit average (30 units). Units with four or more bedrooms tend to be found in very small projects (less than 15 units), while hostel units are, as expected, found in larger projects (over 60 units).[76]

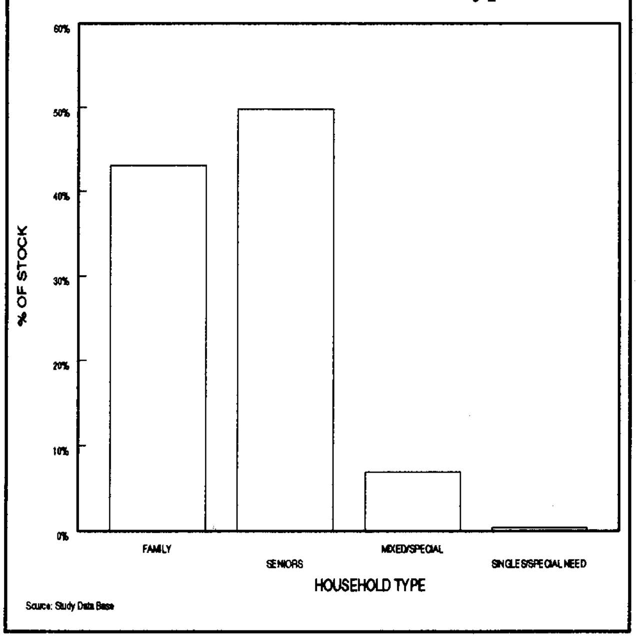
Figure V.6
Distribution of Projects by Bedroom Count



4. Household Type and Resident Characteristics

Data on household type were available for Public Housing projects and a small number of non-profit projects surveyed. These sources allowed the identification of household form for 35% of the projects sampled (4,652). Figure V.7 shows the household type breakdown of these units, and indicates that a large proportion of projects for which this information is available are seniors only buildings. Since a larger component of Public Housing projects was constructed specifically for seniors, these data do not accurately reflect household type composition in the overall portfolio. Figure V.7 also shows a very small number of projects containing these data contain singles or those with special needs. This again is a off shoot of the historical evolution of social housing programs. Social housing for non-elderly singles is relatively rare and more generally, makes up a significant proportion of projects built in the post 1986 era,

Figure V.7
Distribution of Household Types



[76] The discrepancy between the number of hostel/other units and units size being described in terms of being hostel/bed units is explained by the considerable number of hostel units where separate bedrooms are provided (primarily one bedroom units).

following the end of new Public Housing commitments.

The implications of this bias are likely not major in distinguishing family from seniors housing, since sample sizes where this distinction is provided are sufficiently large. There may, though, be an interaction which cannot be fully identified between Public Housing and household type in terms of maintenance costs. For example, there is some weak evidence in the co-op and Public Housing evaluations suggesting that family housing in co-ops may be less prone to vandalism and neglect than other types of social housing. In this analysis, this effect cannot, therefore, be fully identified.

5. Institutional Characteristics

Table V.3 indicates that the largest group of projects included is Public Housing (35%). The vast majority of these projects were completed between 1951 and 1986, with peaks occurring through the 1970's. Approximately 27% of the sample is composed of private non-profits.[77] The participation of municipalities or municipal housing corporations spans the full period of social housing provision. Operating agreements between CMHC and these providers have ended for a limited number of these (constructed before 1958) and, as a result, CMHC administrative data

Table V.3
Provider Type and Program for Projects Included in Sample

Type	Housing Authority	Municipal	Private	Co-op	Inuit/ Aboriginal	Total	Approximate Range of IAD Dates[78]
Limited Dividend		591	298			889	Pre-1972
Public Housing	4605					4,605	1951-1983
Community Sponsored			756	183		939	1972-1979
Section 95		1407	1620	1506	114	4,647	1978-1986
Federal/Provincial		826	871	79	367	2,143	Post 1985
Total Average Unit Size	4,605 (44)	2,825 (50)	3,544 (27)	1,768 (32)	481 (14)	13,223	

for some of these are no longer available. Municipal providers make up just under 21% of the sample, and also span the entire period. With a very minor exception, the 13% of the sample made up of co-ops began as an element of the federally sponsored non-profit portfolio after 1972, with the vast majority being built after 1978. The portfolio directly operated by Inuit/Aboriginal

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[77] With the community sponsored stream, data available did not allow the distinction between municipal, private and a very small number of co-op units. As a result, the proportion of private non-profits are overstated since a large proportion of projects built under this program were constructed by municipalities.

[78] A number of projects were completed well after the termination of new commitments in each of the earlier programs. For example, a limited number of completions of the community sponsored projects occurred as late as 1982. Further, there were a limited number of new commitments in the Public Housing Program in the post 1982 period especially in the Northwest Territories (CMHC (1990) and (various)).

persons makes up the remaining 4% of the sample. Projects in the public and municipal portfolios tend to be larger and thus make up larger parts of the over unit portfolio (Public Housing (40%) and municipal (28%)).

The sample over-represents Public Housing since the majority of cases where cost information was not fully available were for projects completed in the post 1985 period (just over 50%) and for Limited Dividend projects where operating agreements with CMHC have ended. Because a significant amount of rural/aboriginal housing was constructed through the on-reserve program, excluded from the sample, these projects are also under-represented. The evidence provided in Table V.3 indicates that the implications of exclusion biases are probably not major, since there are large sample sizes for each portfolio.

6. Building Characteristics

i. Construction Type

Construction type data were available for 64% of projects included. The vast majority of these projects are constructed using wood frame (82%). Approximately 8% of the sample was constructed using concrete/steel frames and 9% used a masonry frame. Given the general use of concrete/steel frame as a method for constructing large buildings, it is not surprising to find a large average unit count in these buildings (103 units), in contrast to 26 units in projects reporting the use of wood frame construction. As a result, a much smaller proportion of units (59%) was found in projects constructed of wood while 24% were in projects constructed using concrete frames. Masonry construction projects have an average size just above the average of 38 units. Further, as would be expected, apartments are relatively concentrated in buildings using concrete/steel construction, while street oriented housing (detached, semi-detached, row etc.) are predominately wood frame.

ii. Exterior Cladding

Exterior cladding was identified in the non-profit survey for 1.8% of projects. The dominant exterior cladding was brick or concrete (48% of projects). Less durable wood siding made up 16% of exteriors. Metal siding was the exterior cladding for 12% of units, and those finished with stucco comprised 6% of the stock sampled. A total of 16% used combinations of brick, wood and stucco. Brick or concrete tended to be used in larger projects (averaging an estimated 85 units), while other cladding was more dominant in smaller projects (all averaging around 40 units).

iii. Roof Type

Among those projects identifying roof types, (1.9% of all projects), the majority have shingled, sloped roofs (62%). These projects tend to be small (averaging 29 units). In contrast, among the 37% of sampled projects with flat tar/gravel roofs, average unit size was 112 units.[79]

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[79] Unless otherwise reported, the response pattern for each of these variables allows a sufficient sample size for each major building characteristic to adequately make inferences concerning large impacts on maintenance/repair and replacement expenditures. For example, the sample contained more than 40 projects reporting wood exterior cladding and 80 projects reporting flat tar/gravel roofs.

iv. Heating

Of the 2.1% of the sample responding, the majority (60%) had forced air heating. Baseboard heating was found in 28% of the projects and water in 12%. Projects heating by water systems tended to be larger (averaging 97 units). Baseboard heating was found in projects which, on average, were slightly smaller (83 units), and projects using forced air averaged 55 units.

Among the 37% of projects reporting fuel type, the majority were electrically heated (56%). Almost all of the remaining projects were heated by gas or oil (43%). Less than 1% were heated using wood, wood with gas or oil, or solar heat. Too few projects using the less common fuel types were included in the sample (in each of the above cases, numbering less than 20) to allow inferences to be made with any reasonable level of confidence. Oil and gas tended to be found in larger projects (averaging 43 units) than those with electricity (32 units). Projects using less common fuel types tended to be small (averaging 9 units).

v. Presence of Elevator

Of the 2.3% of projects reporting, approximately 26% or 79 buildings had elevators. These, as would be expected, are in larger projects (averaging 150 units in contrast to an average of 38 units for those without).

vi. Balconies

Among the 1.9% of projects reporting, a slightly higher percentage (28%) had balconies. The average size of projects with balconies was 106 units.

vii. Floor Coverings

Among the 1.6% of projects reporting, the majority reported carpeting as the dominant unit flooring (55%). A slightly smaller proportion reported the use of more durable, but less aesthetically satisfying linoleum or tile (41%). Only 3% reported wood as the dominant floor covering, although this was usually a component in the 3% who reported mixes of floor coverings in their units. Carpeting and wood tend to be used in smaller projects (averaging 34 units) while tile/linoleum dominated in larger projects (averaging 119 units).

viii. Exterior Landscaping Facilities

The majority of the 1.4% reporting, (72% or 137 of 179 projects) indicated that there was a significant amount of landscaping on the grounds included in their project. These projects tended to be larger (averaging 88 units, in contrast to 37 unit projects where no significant landscaping was present).

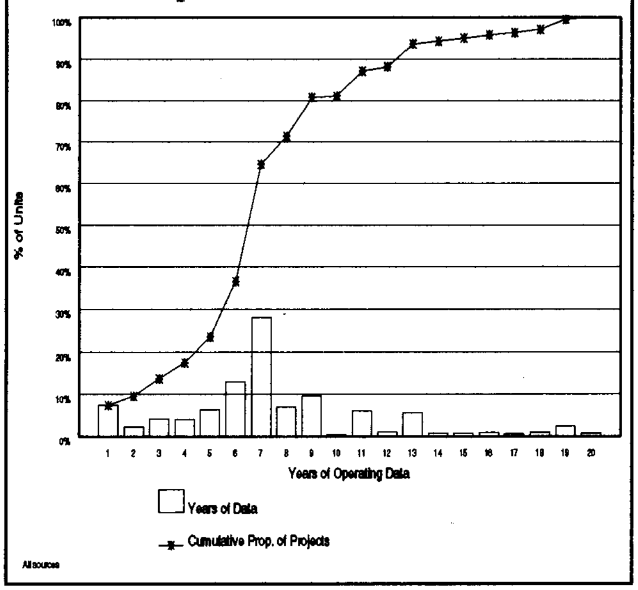
ix. Parking Facilities

Within those responding (1.8%), 85% of projects (199) had exterior parking lots. Relatively few had either interior garages (underground or at surface 8% or 19) or separate garages and/or carports 8% or 18). Projects with interior lots tended to be larger (averaging 94 units) and those with separate garages and/or carports tended to be relatively small (38 units). Unfortunately, too few observations were available to allow strong inferences to be made about the effect of interior lots or garages/carports on cost.

A number of building characteristics are strongly correlated with project size, for example, construction type, presence of elevators and balconies. Respondents were not directly asked if their projects contained "high rise" structures. Yet there were many buildings which fit this form--containing, for example, apartments, elevators, concrete/steel construction, and/or balconies. The high concordance of a number of these combinations will be seen in the next chapters to have produced multicollinearity problems, making it difficult to isolate the effect of some of these characteristics on costs. These multicollinearity problems are worsened by the presence of small numbers of responses concerning various building attributes. Further, a number of respondents had multiple, similar buildings--so that it is difficult to distinguish the potential effects of management style rather than building characteristics.

D. Replacement and Maintenance Expenditures

Figure V.8
Distribution of Years of Maintenance Expenditure Data Available



Up to 20 years of annual maintenance and replacement expenditures were available for the projects included in this data base, spanning the period between 1973 and 1992. Figure V.8 shows a count of the lengths of maintenance cost series. On average, just under 8 years of operating results were reported. Over 75% of the series reported contain at least 5 years of data.[80]

Series of over 7 years were only available for Public Housing stock and a single non-profit provider. Series of over 13 years were only available for Ontario Public Housing stock. Other series from private non-profit and co-op sources begin, at the earliest in 1985.

Figure V.9 indicates considerable variations across time in data captured. For the period 1973-1978, the Ontario Public Housing stock data represent 20% of projects operating in the country at that time. Data coverage during the period 1979-1986 is extended to include the national Public Housing stock. With the completion of larger and larger numbers of non-profit projects during this time, the Public Housing portfolio slips from just over 60% of the total to under half. With the inclusion of non-profit data in 1986 in conjunction with Public Housing evaluation data, the proportion of projects with financial data substantially increases. In the post 1986 period, especially in the 1987-1990 period and the end of the evaluation study time period, there are considerable gaps in Public Housing reporting to

[80] There is no capacity to differentiate between missing data and null maintenance/replacement cost expenditures. It is relatively rare for a project to experience no maintenance costs over a year, but it is common for no replacements to occur. As a result, it is assumed that data are missing where a $0 maintenance cost is provided, and that corresponding replacement expenditures are also not present.

CMHC, creating data base gaps outside of Ontario. During this period, report levels increase mostly as a reflection of other programs playing a more and more dominant role in the makeup of the stock. By 1992, data are captured from all sources for well over 80% of the portfolio.

Figure V.9
Percentage of Expenditure Data Available by Year of Operation

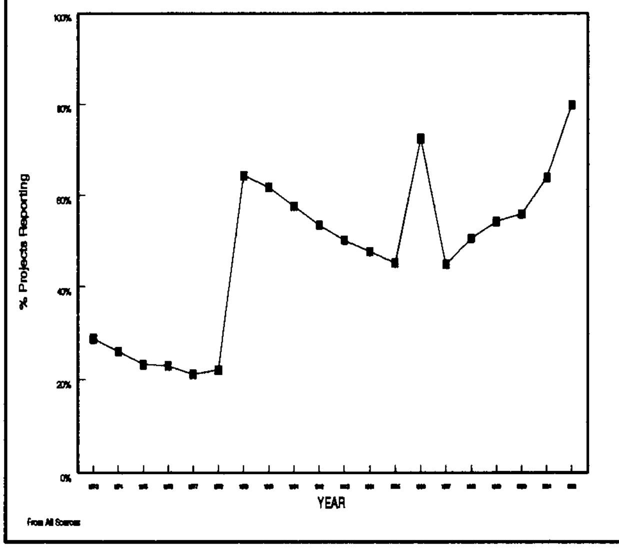
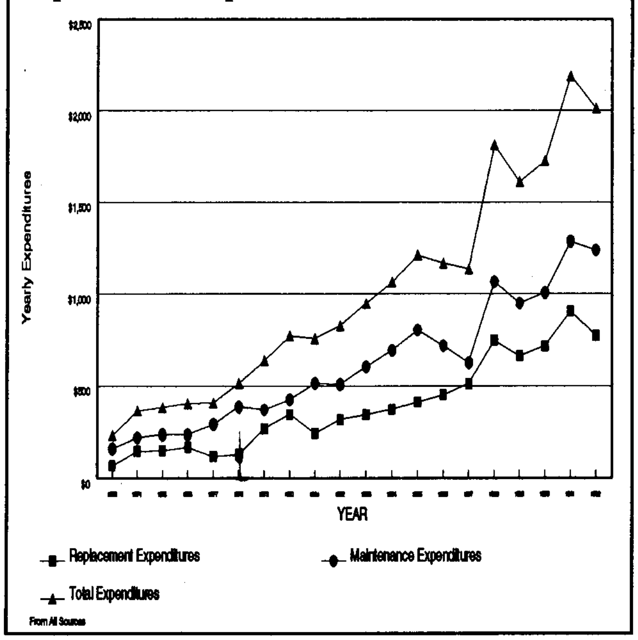


Figure V.10 indicates how average nominal dollar expenditures per unit, on maintenance and replacement, changed over the period 1979-1992. It shows that throughout this period, expenditures on maintenance/repair were larger than those on capital. Further, the proportion of total expenditures made up of maintenance has remained relatively constant over time.

In both cases, expenditures in nominal dollars have increased. The rate of increase, though, is very different from that of inflation. During the early part of the decade, expenditure growth was slow compared to the CPI. As the decade proceeded, the reverse would seem to be true. A number of factors influenced these expenditure patterns, as will be seen in the next chapter. At this point, though, it is important to note that during the initial part of this period, the number of new completions was considerable, and the relatively low maintenance and repair requirements of this stock go a considerable way in explaining the low rate of expenditure increase in both of these categories. During the latter part of the 80's and the 90's, though, the reverse has been the case--there has been very little incremental stock and the stock has, thus, aged overall. As a result, a considerable amount of the stock has remained "young" (arbitrarily defined here as less than 10 years of age) and the majority of the stock has moved into middle age (11-25 years). During this period, the gradual increase of replacement requirements begins to become noticeable.

Figure V.10
Average Per Unit Maintenance and Replacement Expenditures in Nominal Dollars



These relationships are better characterized in Table V.4 which both removes the effects of outliers (see Chapter VI below) and provides 1992 constant dollar expenditures. It summarizes the source, sample size, average age and average maintenance and replacement expenditures.

Table V.4
Summary Characteristics of Replacement and Maintenance Expenditure Data

Year	Average Replacement Expenditures*	Average Maintenance Expenditures*	Average Age	N	Data Available from:
73	$236	$583	5	441	Ontario Public Housing Only
74	$448	$676	5	506	
75	$392	$696	6	553	
76	$461	$645	6	658	
77	$302	$737	6	730	
78	$299	$903	7	887	
79	$194	$718	6	2,991	All Public Housing
80	$198	$768	6	3,224	
81	$463	$551	7	3,450	
82	$291	$636	7	3,840	
83	$338	$630	8	4,063	
84	$335	$663	9	4,202	
85	$321	$689	10	4,287	All Public Housing and Small Sample of Non-Profits
86	$252	$553	9	7,356	All Public Housing and Large Sample of Non-Profits
87	$108	$567	8	4,814	Non-Profits and Eastern Ontario Public Housing
88	$277	$618	10	5,960	Non-Profits and Ontario Public Housing
89	$258	$673	10	6,504	
90	$240	$672	11	7,185	
91	$302	$750	11	8,201	Entire Portfolio, 1991 includes only some non-Ontario Public Housing
92	$345	$673	12	10,363	

* All expenditures have been inflated using Provincial CPI's to 1992 nominal dollars

For the period 1973-1978, where the data available are restricted to the Ontario Public Housing portfolio, a considerable amount of new construction was occurring in this portfolio and almost no units were being removed. Table V.4 shows that, as a result:

- the average age of the portfolio increases only by two years over the five years of this study period;
- the universe, and the resultant data available increases. In 1973, 441 projects were included in the analysis, in 1978 there are 887 projects, an increase of just over 100%.

Constant dollar replacement expenditures during this period ranged from between $236 and $461 per unit and for maintenance, between $583 and $903. Average replacement expenditures on a year to year basis show very little pattern when viewed as a time series. In contrast, average maintenance expenditures seemed to be gradually increasing.[81]

For the period 1979-1985, the data available are predominantly from the entire Canadian Public Housing portfolio. The 1985 data include a significant but small amount of data provided by non-profits. The number of projects included increases considerably with the enlargement of scope from 887 projects in 1978 to 2,991 in 1979. Because Ontario was one of the original participants in the non-profit program, the introduction of other provincial data in 1979 reduce average age from 7 to 6 years. In some cases, data for the early years of this period are not available. In addition, during this period, some new Public Housing was completed, and almost no projects were removed. The effect of these factors and the small amount of non-profit housing available in 1985, was an steady increase in data set size to 4,287 projects, 43% larger than the 1979 portfolio. The effect of portfolio growth was an increase of average age from 4 years to 10 years during this 7 year period.

Constant dollar replacement expenditures ranged widely during this period, from between $194 and $463. Maintenance expenditures varied from a low of $551 to a high of $768. Average replacement expenditures seem to show a gradual increase while little pattern is evident in maintenance expenditures. An evident dip between 1978 and 1979 in expenditures can largely be attributed to differences in accounting rules in expenditures attributable to maintenance and operations. Within the Ontario portfolio, the CMHC evaluation data base classification system shifted approximately 15% of expenditures on capital and maintenance in 1979 and 1980 to operations. In 1981, when replacement expenditures ceased to be differentiated in a manner which allowed this shift in Ontario, these expenditures remained in the replacement account. At that point, replacement expenditures adhere more closely to the Ontario pattern for the period 1973 to 1978.

The sample for the year 1986 includes a variety of Public Housing and a large number of non-profit housing projects. The year 1986 represents the beginning point of a considerable number of records held by CMHC in their Administrative Data Base. The data examined thus increases 7,356 projects, - 72% larger than in 1985. While Public Housing had largely been phased out in the in late 1970's and 1980's, non-profit housing starts had considerably increased. As a result, with the inclusion of the non-profit base, average age decreased in the 1986 data. More significantly, average expenditures on replacements and maintenance both considerably decreased,

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[81] The dip in replacement expenditures in 1977 and the concurrent increase may be related accounting changes that occurred in that year.

by approximately 20% to $252 and $553. Expenditures reported in non-profit housing are during this and latter periods, consistently lower than those for Public Housing.

The incidence of reporting of independent variables is highly related to the Public Housing/non-profit distinction. In the Public Housing stock, a relatively small amount of data is available concerning the presence of various building characteristics or of rehabilitation versus new construction. In contrast, the distinction between family, seniors and mixed housing is universally available here, and only available for a small sample of projects outside this portfolio. Generally, with the inclusion of sizeable amounts of non-profit stock in 1986, the availability of building characteristics substantially increases the ability to test a wider range of hypotheses.

The Public Housing evaluation data ended in 1986 and only a limited amount of 1987 data were available from the province of Ontario. Prior to 1991, no Public Housing expenditure data available from the CMHC administrative data. As a result, the data set size for 1987 fell considerably, to 4,814 projects. Average age of project included here fell to 8 years, reflecting, again, the relative youth of the non-profit portfolio and more significantly, the much lower reported expenditure levels on replacements in the non-profit sector. These dip to $108 per unit. Maintenance expenditures reported are relatively constant at $567.

Between 1988 and 1990, sample size increased for three reasons:

- full Ontario Public Housing data were available for these years;
- data were available for larger and larger proportions of the non-profit housing stock from the CMHC administrative data base; and
- there was a limited amount of new construction in the post 1986 programs.

With the full inclusion of Ontario Public Housing data in 1988, the data set grew by 24% to 5,960 projects from 1987 levels. The much higher average age of this portfolio led to an increase of 2 years in overall average age. Between the three reporting years of 1988 and 1990, projects with replacement/expenditure data increased to 7185, - roughly 26% over 1988 levels. During this period, average age increased by 2 years, reflecting the relatively minor contribution of new additions to the stock. The primary contributing factor in the increasing size of the data set, was then, the greater numbers of projects reporting to the CMHC administrative data base.

The higher incidence of replacement expenditures reported in Public Housing was the primary factor that led to a considerable increase of 247% in these expenditures. Maintenance costs also increased to $618. During this period, average expenditures on replacements decreased from $277 to $240 reflecting, possibly, the increasing proportion of non-profit projects making up the data set. Maintenance costs increased to $673 in 1990.

In 1991 and 1992, an increasing amount of data was available and used from the CMHC administrative data base, primarily from non-Ontario Public Housing. In 1991, the size of the data set increases by 14% over 1990 levels to 8,201 projects, and 1992, by 26% over 1991 to 10,363. The 1992 data set represents approximately 73% of all projects administered by CMHC. During this period, the average age of the portfolio increases from 11 to 12 years, reflecting the increasingly small contribution of new additions. The effect of losses to the portfolio remain minuscule.

Average replacement costs increase to $302 and then to $345, reflecting the inclusion of additional Public Housing units. Maintenance costs increase to $750 and then decline to $673.

G. Summary and Conclusions

The five data sources described have been used to generate, in most cases, a sufficient large sample to allow for the testing of hypotheses described in the last chapter. There are though, difficulties in using these data for this purpose. Data concerning building characteristics, because of small size and bias in response pattern are weakest in allowing inference testing. Further, there is likely a high level of correlation between building attributes and other provider characteristics. More troubling is the influence of differing accounting practices and inconsistencies in the development of maintenance and replacement expenditure data.

The expenditure data utilized in this report, like all financial data, are prone to the effects of inflation. A series of indices were fit to expenditure times series in order to create constant dollar cost estimates. Provincial CPI tended to outperform other cost indices in estimating variations in expenditure patterns over time and thus was chosen to produce de-indexed cost estimates.

As will be shown in the next chapter, these data problems are sufficient to reduce estimates of the potential effectiveness of the model hypothesized. Yet, it will be shown that the data and trends would seem to be sufficiently robust to indicate that the factors noted have significance in the determination of long term trends in maintenance, repair and replacement expenditures.

VI. Statistical Issues and Methodology

In chapter IV, series of hypotheses were posited which potentially describe reasons for differences in maintenance and replacement costs over time, given differing building structures, household types and climatic conditions. This can be seen as a type of structural model, which, in conjunction with other less significant factors (characterized as "error"), can be used to predict magnitudes and changes in these expenditures.

The primary focus of this chapter is the description of analytical procedures utilized in testing hypotheses concerning the effects of time, aging, building form and characteristics and household type on maintenance and replacement costs.

These research questions are addressed through the use of analysis of variance/covariance techniques. Included here are simple ANOVA, multivariate MANOVA, MANOVA with repeated measures and experiments with non-linear regression.

In order to apply these various methodologies, a number of statistical issues first require consideration:

- Do the data sufficiently meet the assumptions required in testing hypotheses using well established statistical methodology, and if not, how should the data be transformed to allow for model testing?
- Were independent variables sufficiently different to allow their effects to be distinguished (multicollinearity)?
- What methods best address the significant number of gaps in this data base?

These issues arise due to the nature of the data available.

A. Statistical Issues

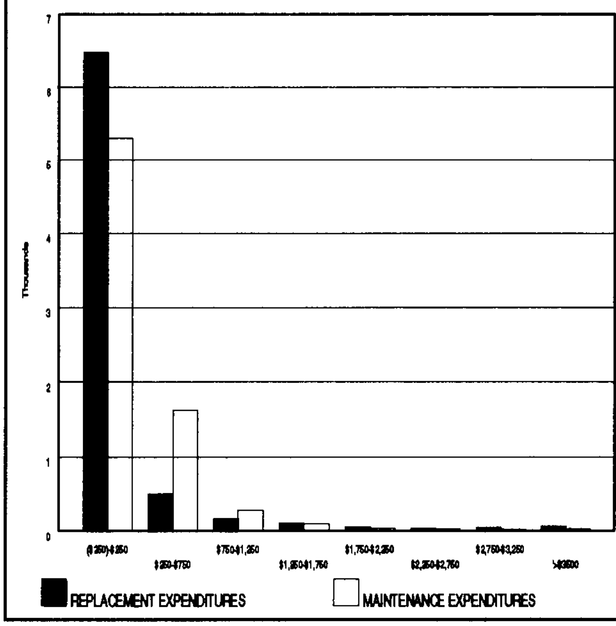
1. Meeting the assumptions required for Hypotheses Testing: The Presence of Outliers and Non-normal Data Distributions

The effective utilization of Analysis of Variance/covariance models to test hypothesis is predicated upon certain assumptions about both dependent and independent variables.

In a number of cases, these assumptions were severely violated. Thus:

- Replacement expenditures is not normal distributed. Figure VI.1 provides histograms characterizing replacement expenditures in 1986--a year where data are available for a large number of projects. The majority of projects in the CMHC portfolio had expenditures of less than $250 (1986 $'s) per unit, and of these, the great majority reported no expenditure. A significant plurality of projects did not undertake replacement activities in any given year, and a small number reported very large expenditures. This is especially the case in years where a large number of projects were relatively new. Experiments in fitting theoretical distributions to the aggregate distribution of replacement expenditures indicate that the exponential distribution provides a better fit, indicating that replacement expenditures are relatively rare events. In addition, there are a few projects which report very large expenditures--3 of over $10,000 per unit, indicating the potential of rare catastrophic events.

Figure VI.1
Distribution of Maintenance and Replacement Expenditures in Nominal Dollars, 1986



- Maintenance costs too are not normally distributed, although they are much "closer" than are replacement expenditures. The distribution of maintenance expenditures shown in Figure VI.1 is close to a theoretical Chi-square--or "truncated normal" distribution (where mean expenditures are close to zero and the possibility of negative expenditures are very low). Further, Figure VI.1 shows that a result which repeats itself in other annual distributions--extreme outliers are less common in maintenance expenditures, and further, when these do occur, they are considerably less likely to produce extreme values.
- A number of independent continuous variables are also not normally distributed, or could not be easily transformed into variables which were normally distributed. For example, most projects contained either one or two types of units--for example, a combination of apartments and/or row housing. The distribution of the proportions of unit types tended to have a reverse "J" shape, with many projects having a single unit type or a predominant unit type, and a second, less frequent type.
- Variances of expenditures across nominal variables and across ranges of continuous variables were often quite different. For example, the wide range of circumstances in Ontario led to relatively high ranges in maintenance/expenditure patterns there, in contrast to the situation in smaller provinces, such as Nova Scotia. This problem was exacerbated by very large "holes" in reporting for a number of independent variables.
- Sources of error included variance in accounting practices and thus major sources of error were not randomly distributed. For example, major providers use the same accounting schemes for a large number of projects and thus produce similar "errors" for all of these projects.

In some cases, remedial action was possible to reduce the magnitude of these problems:

"Extreme outliers" exhibiting either very large replacement or maintenance costs (arbitrarily defined as lying more than 8 standard deviations from the mean) or large negative expenditures (arbitrarily defined as exceeding $500 in 1992 dollars) were excluded from analysis. In total of 219 projects were excluded from an annual analysis because of extremely high or low reported maintenance or replacement expenditures. In most cases (81%), a single year of data was excluded. A maximum of .2% of observations for any given year.[82]

These projects were more likely to:

- be small, 74% had 20 units or less in contrast to 47% of the overall sample;
- be from the Public Housing Portfolio from Ontario (47% in contrast to 20% of all projects) the Northwest Territories (14% in contrast to 1%) or Saskatchewan (9% versus 6%)
- be located in remote locales (14% in contrast to 1% of all project), especially in the Northwest Territories
- be replacement rather than maintenance expenditures (68%).

A small minority of these expenditures were negative (6%). These likely represent cost recoveries, from other sources including tenants or grants or the reversal of an overestimated accrued cost. Almost all of these (85%) were reported in the Ontario Public Housing Portfolio.

It is not surprising that a large proportion of expenditure "outliers" are found in small projects, often in remote areas, and more commonly involve replacement expenditures. It would seem that these expenditures often consist of large capital outlays involving a limited number of units and the failure of a major building components. In remote areas, expenditures are often magnified by high costs in transporting material, equipment and skilled labour. In the Public Housing portfolios, where the funds for non-recurring costs are often pooled, the capacity to fund these types of expenditures is greater.[83]

In addition, to take into account a large amount of skew in the population of places within which social housing is located, the logarithm of urban/rural area population rather than population was used in testing for the effect of population size on expenditure patterns.

Still, heavy reliance is placed upon the robustness of the models utilized to the normalcy assumption violation. Luckily, given the distribution which characterizes maintenance and replacement expenditures, considerable evidence exists in the literature that with the removal of outliers, the model utilized here are very likely sufficiently robust to provide meaningful result (Bray and Maxwell (1990)).

2. Multicollinearity

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[82] A sample of models were tested using a range of threshold levels for excluding outliers. The choice of 8 standard deviations was made based upon an assessment of the degree to which changes occurred in which variables which were seen to have significant impacts upon expenditures and on the magnitudes of associated co-efficients. Constraining the sample to exclude a higher number of extreme values had little impact, except with regard to the set of observations located in northern and remove areas. Resetting the threshold for outliers to 7 and 6 standard deviations had the impact of severely depleting these cases when maintenance costs were considered..

[83] It may also be that a small number of projects are not included in this data base because of abandonment due to failure of a building or its components, making replacement uneconomic.

There are a number of strong relationships among the independent variables included in the models postulated above and these tend to confound the univariate comparisons reported below. For example, seniors housing include a predominant number of bachelor, one and two bedroom units. Housing designed for families tended to include predominantly two or more bedroom units. Similarly, larger proportions of housing designed for families have been detached, semi-detached or row. These house forms were, in turn more likely to have been built using wood frame construction techniques.

In addition, where the relationships among independent variables are strong, it becomes increasingly difficult to differentiate their effects in multivariate models. In these models, the unique effect of each independent variable is estimated, after estimating the effects attributable to other independent variables and this is related to the dependent variable. Where the correlation among independent variables is high (where there are high levels of "multicollinearity"), residual, unique effects are prone to error and they are increasingly subject to existing measurement error. Estimates of these effects are increasingly biased (they tend to be negatively correlated with each other). Thus, the likelihood of spurious results increases (Johnston (1972)).

As a result, an analysis was undertaken to determine whether or not there were strong, common inter-relationships (multicollinearity) among sets of independent variables. First, correspondence measures (squared correlation co-efficients for continuous and Kendall Tau statistics (for ordinal/nominal data (see Hollander and Wolfe (1973)) were calculated for each pair of independent variables. To determine the major sources of multicollinearity among continuous and nominal variables, summary variables, called principal components, were derived from the correlation matrix using a factor analysis procedure.[84] A strong inter-relationship was seen to exist where communalities of over 85% existed, that is where over 85% of the variance of an independent variable could be replicated using a single or linear combination of other independent variables, or where an underlying factor could be constructed, using the pool of common variance among independent variables which had squared factor loadings which exceeded 85% for at least two independent variables.[85]

The analysis indicated that there were five "clusters" of interdependent variables:

- Presence of an elevator, balcony and electric heating were very strongly inter-linked. Buildings with elevators, balconies and baseboard heating were also more likely to be built using steel or concrete frame construction and have a flat/tar roof.
- Apartments and row housing were rarely mixed and apartments tended to have fewer bedrooms.

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[84] Principal components were first determined using the pool of variance common to the independent variables (squared correlation co-efficients were used along the diagonal of their correlation matrix). These components were then rotated using a oblimin technique which maximizes within factor correlations while allowing correlations between factors. (Mulaik (1972), SPSS (1988))

[85] Analyses were also repeated for each of the twenty years of the time series where concomitant expenditure data were available. This was done in order to examine the possible impacts of correlations which are conditional upon the use of varying "frames" and to conversely test the intransitivity of underlying factors.

- Larger units were also highly correlated with the presence of detached dwellings.
- Larger projects were strongly correlated with size of urban area.
- A considerable amount of housing was still earmarked as seniors or family housing. During the early years of Public Housing, unit size (number of rooms) and presence of apartments was highly correlated with client type (i.e. seniors units tended to make up much of the bachelor and one bedroom stock.) The correlation between seniors/family housing and apartments/bachelors decreased slowly in the 1980s, followed slightly more slowly by a decrease in the correlation with unit size. With the inclusion of non-profit housing available for the post 86 period, this linkage is considerably weakened. Further, in the Ontario Public Housing stock for the period 1973-1978, seniors and detached housing were related to project age--these being features of relatively newer projects.

The analysis further indicated that these factors were not strongly inter-related. These correlations either follow common sense or are congruent with reports in the literature concerning the history and evolution of the social housing stock.[86]

Where squared correlations were very high, and groups of independent variables were clustered in single factors, a single representative variable was chosen for subsequent, multivariate analyses.[87]

As a result of this analysis, only the variable with the highest simple correlation co-efficient with replacement and maintenance expenditure, was selected as an independent variable from among the following:

- In data series prior to 1979, presence of Families, Presence of Seniors, Percentage Apartments and Average Number of Rooms (size);
- In data series between 1980 and 1985, Presence of Families, Presence of Seniors and Average Number of Rooms (size); and
- In all data series, presence of elevators, balcony and type of heating system.

3. Dealing with Missing Data

Missing data were handled through two standard procedures. In the exercise involving simple analysis of variance, observations with missing nominal data were treated as belonging to a

[86] Sewell (1994) links project size and population size, the separation of seniors and non-seniors, particularly in Public Housing, and the presence of seniors in apartments.

[87] Two other procedures for removing the effect of multicollinearity were also utilized. First, forward and backward stepwise regression procedures were used. Variables were included/excluded based upon a minimum estimated unique variance and contribution to explanation of the dependent variable. It was found, using these techniques, that a number of alternative models produced indistinguishable levels of explanatory power. Secondly, "Characteristic" new variables were developed using factor analysis. These variables were primarily based upon linear combinations of highly correlated independent variables. These produced results in subsequent analyses which were statistically indistinguishable from the use of surrogate variables, (comparatively, fits were generally slightly poorer).

separate group. Where multivariate analysis of variance models were used, means were assigned where nominal data were missing, based upon average for cases with similar characteristics. Where variables were continuous, estimated simple correlations were substituted. Partial correlations were then based upon these estimates.

As noted above, data available on building characteristics and user groups were not universally available, and, as noted in the last chapter, may, because of sampling, have introduced correlations among independent variables not evident in the population at large. This was especially important in the use of detailed building characteristics, where only a small sample of providers gave information, often concerning a number of projects. For example, it was typical of two large providers to use linoleum flooring in elevatored buildings. Thus, it is likely that the methods used for dealing with missing data introduced some bias in the results reported below. In the example above, the estimated effect of linoleum flooring on cost cannot likely be distinguished from location in an elevatored building.

B. Methodology

Four distinct but inter-related types of analyses were undertaken of the replacement and maintenance cost data. A univariate model was initially examined between all of the independent variables and the operating costs for each of the twenty years of data available. Next, for each year, a multivariate model was posited. Variables which, with a high level of confidence (99%), were seen to likely be related to expenditures, based upon the univariate model, were included. Thirdly, expenditure time series of operating expenditures were examined. Finally, a repeated measures multivariate analysis of various models was used for data where series were complete for limited time periods.

These analyses were undertaken to address the following questions:

- Are there possible strong and simple relationships that appear to exist between expenditure patterns and the range of independent characteristics posited, including age of building, type of household, geographical location program and replacement and maintenance expenditures?

- On a year to year basis, can a multivariate model adequately characterize replacement and maintenance expenditure patterns? Do these models change over time?

- Should replacement and maintenance expenditure patterns best be treated independently, or are there strong lagged or simultaneous relationships?

- Can a multivariate model be used to characterize the simultaneous effect of time and other characteristics on replacement and maintenance expenditures?

- What type of pattern best portrays constant dollar maintenance and replacement expenditure patterns over time? Can this be linked to a particular type of stochastic process?

In the following sections, the methodologies used to address each of these questions is summarized.

1. Univariate Relationships

A considerable amount has been published indicating the expected magnitudes of some of these relationships at a very disaggregated level. Included here are yearly trade publications indicating the approximate costs of various types of repairs and data on the expected lives of various building components (see for example, Dell'isola and Kirk (1983)). Very little, though, exists in published form providing estimates over time of costs given general differences in building form. A first step in this analysis is the determination of whether or not significant differences exist which may be attributable to a wider range elements of general building characteristics, use pattern, location and aging.

For each calendar year for which maintenance and replacement expenditure data were available, and for each independent variable, a simple one way analysis of variance (ANOVA) or simple correlation was used to test the hypothesis that differences exist due to that factor in maintenance costs and replacement expenditures.

The ANOVA/correlation procedure was also used as a type screening mechanism, filtering out from further analysis hypothesized relationships which were indistinguishable from background noise.

Generally, to address the potential for spurious relationships tied to the uneven distribution of error and potential sampling problems, a very high level of confidence was chosen for rejection of null hypotheses.[88] Where the null hypothesis that a relationship existed in the expected direction could not be rejected with 99% confidence, the independent variable was not used in subsequent analysis. In addition, in parallel with simple parametric correlation and difference of means tests, non-parametric tests were also administered.

The results of these univariate tests are reported in the next chapter. In some cases ANOVA tested the effect of multiple, distinguishing categories (Province, Program, Building Type etc.). Here, expected relationships were characterized as rank order relationships. Scheffé statistics were used to test for differences among groups (see Dunn and Clark (1987), ch. 5) and tests of correspondence with the hypothesized rank ordering (see Chapter IV) were performed using the non-parametric Kendal Tau statistic.

[88] The use of one way ANOVA as a preliminary filtering mechanism can eliminate the discovery of complex relationships among independent and dependent variables or those which are masked because of high levels of correlation between a set of independent variables. In addition to one way ANOVA, step wise regression models were tested where various independent variables were "forced" and residual relationships were then examined. In no case did variables eliminated through one-way ANOVAs exhibit more subtle inter-relationships or relationships hidden by high levels of multicollinearity. As was seen above, though, in other circumstances, multicollinearity is a considerable problem.

2. Multivariate Analysis of Variance and Covariance

Where independent variables were shown to produce significant effects upon expenditures and were also not excluded because of high levels of multicollinearity, they were then used in multivariate analyses of variances and covariance[89].

Separate series of replacement and maintenance expenditures were again run for each year that these data were available. This strategy had a number of advantages, given the aims of the study:

- because data were not available for all projects for all years, in effect, hypotheses were tested on slightly differing samples. Thus tests could be applied measuring the consistency in the magnitude and direction of co-efficients.
- since it was hypothesized that over time, as the oldest age of buildings in portfolio increased, the effects of aging would increase more than linearly on both maintenance and replacement expenditures, the relative magnitude of the age co-efficient could be examined.
- since the data were prone to error due to the adoption of differences in accounting rules over time, separate analyses would allow for the holding of this factor constant and the estimation of the effect of known changes in practices.

Lastly, repeated measure analysis of covariance was utilized, allowing the incorporation of simultaneous effect of time and other factors (Girden (1992) and Dunn and Clark (1987)). In this context, repeated measures MANOVA estimates the effects of time and interactions between time and other factors (for example, being in a seniors or family project) on a set of maintenance and replacement expenditures spanning a number of years. The nature of the differences or "contrasts" over time can also be specified. In this context, a orthogonal polynomial was fit to these contrasts. The advantage of fitting polynomials is that curves of differing complexity (related to the "order" of the polynomial) can be fit, potentially providing some evidence of the appropriateness of an underlying process as well as changes in expenditure patterns during a particular era (Dunn and Clark (1987)).

Three shorter series were developed using observations for projects operating during the full period of each of three eras:

- Ontario Public Housing Projects operating for the entire period 1973-1978 (390 projects);
- Public Housing Projects for the entire period 1979-1986 where only National Public

[89] In addition, experiments were undertaken using simultaneous and conjoint models. In the first case, it was assumed that expenditures on replacements and maintenance interacted simultaneously. In the second, it was assumed that independent variables affected a combination of unique and shared components of replacement and maintenance costs. Simple correlations between expenditures on maintenance and replacements were, for most years significantly different from 0 with 99% confidence, but were not very high. When applied, the simultaneous and conjoint effects of expenditures contributed very little to the overall explanatory power of the simpler model and introduced large multicollinearity problems. To account for these and lagged effects, additional independent variables (present and past year expenditures) were introduced. In Chapter VIII only these effects are discussed.

Housing data were available (2,471 projects); and

- Non-profit projects operating during the period 1986-1992 (1,612 projects)

In each case, Provincial CPI's was utilized to transform replacement and maintenance expenditures to 1992 constant dollars.

3. Time Series Analyses--Expenditure Histories of Single Projects and Projects Built at Different Times

Series of longitudinal data of up to 20 years were available allowing, with a sufficient number of degrees of freedom for meaningful testing, the fitting of curves reflecting what is believed to be an underlying process. The examination of individual time series allows the focusing upon a single element--time, in the estimation of maintenance and replacement expenditures. Before undertaking this analysis, the expenditure data, which was available in nominal dollars, were converted to a constant dollar series using the Ontario CPI (see Chapter VI). To ease in interpretation, results are reported using dollars which had been inflated to the last year for which data were available--1992.

The time series models discussed above primarily require the fitting of two or three parameters. In addition, though, the use of nonlinear relationships substantially increase the potential to fit the data. Using a short time series has two marked disadvantages which are accentuated when curvilinear rather than linear functions are fit:

- As the number of parameters to be fit increases, degrees of freedom decrease and irrespective of the model, fit substantially improves; and
- Since the data is prone to considerable error, the likelihood of an outlier is high and the effect of outliers on the parameters fits increases as the degrees of freedom decrease.

Table VI.2
Time Series Utilized Showing Length of Series in Years

Time Series Length (in Years)	Number of Series
20	84
19	319
18	105
17	72
16	100
15	88
Total	768

Only time series which contained at least 15 years of data were utilized. This represents a relatively small fraction, 6% or 768 of the projects in the data base. These projects are limited to Public Housing stock in Ontario. Table VI.2 provides a summary of the number of data series utilized by time series length.

Using non-linear regression, Maintenance and Replacement expenditures were regressed against time using various linear and non-linear forms (see Norusis/SPSS Limited (1992):

- a simple linear function;
- a second degree polynomial indicating an initial decline in expenditures followed by an increasing large increase;
- a third degree polynomial characterizing an initial decline, followed by a damped increase in expenditure (and possibly indicating a late surge and lull;
- Exponential function;
- Compounding function (substitute for Gamma);
- Power Function (substitute for Gompertz);
- Log Normal; and
- Weibull distribution characterizing a range of different types of extreme value impacts.

As noted in Chapter II, close fits between the exponential, log normal and Weibull distributions may be indicative of a dominant stochastic process. Compounding and Power functions are provided as surrogates for the Gompertz and Gamma distributions, substituting multiplicative effects of time on failure.[90] Further, a second degree polynomial can be used to characterize the bath-tub effect.

In addition, series were aggregated by combining all projects with the same starting years and same series of available data. In creating these aggregations, individual projects were weighted on the basis of number of housing units, and a second series was included where each project remained unweighted. This aggregate analysis was done to remove the effect of wide variations in expenditure patterns among projects to allow for the consideration of which distribution best fit data where differences in vintage was removed, and to examine the effects of aging among groups of buildings which differed only on the basis of vintage.

C. Simulations

Using the results obtained in Chapter VII, six sets of simulated histories were developed. Each of these building histories is based upon "stereotypical" projects. These stereotypes were developed by clustering projects on the basis of similarity of characteristics, using an hierarchical clustering algorithm (Everitt (1974) and SPSS (1990)). Stereotypical projects are defined where a large number of projects have very similar characteristics (heating, location, size etc.) and expenditure patterns. The simulations estimate changes in expenditure patterns over time using MANOVA estimated parameters random variations. Random variables were assumed normally

[90] This choice was made because efficient curve fitting algorithms were available (SPSS (1988) for these distributions and with a maximum of 20 observations, it is impossible to distinguish the fitting of these multiplicative distributions from the results of fitting Gamma and Gompertz curves. Extensive experiments using the available non-linear regression heuristic were both time consuming and never produced significantly better fitting different results.

distributed about the estimated parameters with standard errors equated to average parameter standard errors.

Finally, for replacement expenditures, these simulated results are compared to funding available for these projects under scenarios reflecting differing program funding formulations.

D. Summary

1. Statistical Issues

The data base has a number of characteristics which may limit the efficacy of using commonly available statistical methodology.

The dependent variables (maintenance and replacement costs) are not normally distributed and this is also the case for a number of continuous independent variables. The common statistical procedures used here presume some degree of "normalcy" in testing for relationships, although, it has been shown that unless violations of this assumption are extreme, these procedures tend to be robust. A major factor influencing the efficacy of the methodologies used is the presence of extreme outliers. These are projects where maintenance and/or expenditure levels are extremely high or low. A limited number of these extreme outliers were removed from the data base prior to analysis. The effects of more stringent rules for the exclusion of outliers were examined but were seen to be minimal.

Several independent variables are highly correlated. As a result, the effects of these variables cannot be differentiated. To deal with this problem, single variables out of these clusters were selected for inclusion out of identified clusters of correlated variables.

Some of these correlations and potential interactions between independent and dependent variables may be due to biases introduced in the sample survey which provided a number of building characteristics for a very limited number of providers. It is thus impossible to differentiate between the practices of these limited number of providers and their attributes (location, building type etc.) from other effects.

2. Methodology

The results discussed in the next chapter characterize relationships affecting maintenance and replacement costs in a number of ways. First, the simple interaction between the various independent variables and expenditures is assessed. Then, the interaction between time and other factors over time is viewed, where reasonable size blocks of expenditure data are available over multiple years. Finally, the effect of time on expenditures over time is examined in isolation for a small set of projects where expenditure data are available for most or all of the twenty year span between 1973 and 1992.

In Chapter VIII, the results of these exercises are applied to a simulation exercise for a limited number of "stereotypical" projects and for replacement expenditures. These are contrasted with the estimated availability of funds under differing program scenarios. Assumptions used and simulation methodology adopted are left are to that chapter.

VII. Relationships between Project Characteristics and Maintenance/Replacement Expenditures

This chapter begins with the results of the simple analyses of direct relationships between social housing characteristics and maintenance and replacement expenditures. Attention then turns to multivariate modelling. For each of the twenty years for which expenditure data are available, a multivariate analysis of covariance is undertaken. These results are separately discussed for three eras--1973-1978 where only Ontario Public Housing expenditures are available, 1979-1985 where Public Housing data for the entire country are provided and the post 1985 period where data are included for an entire range of federally funded non-profits. Complementing these analyses are the examination of projects where full blocks of expenditure data are available. A repeated measure analysis of covariance model is fit to replacement and maintenance expenditures is fit to data available for each of these three eras. This analysis is used to estimate the combined effects of time and other factors during each of these periods. Here, non-linear effects of time are examined through the fitting of a polynomial to contrasts (differences) in constant dollar replace/maintenance expenditures over these eras.

The chapter concludes with an analysis of time series of expenditures for a limited set of Ontario Public Housing projects where longer series are available. For individual buildings and groups of similar buildings, a series of non-linear functions are fit which correspond to various stochastic expenditure models.

All results are reported in estimated 1992 constant dollar. To remove the effects of regional variations in inflation over this period, all expenditures were inflated using provincially specific CPI series. Further, only results which, with 99% confidence, reject the null hypothesis that there is no relationship between the expenditures and an independent variable, are reported.

A. Analysis of Single Year Data

1. Characteristics of the Dependent and Independent Variables in the Single Year Analyses

As a preliminary step, measures of associated were calculated between levels of replacement and maintenance expenditures for each of the twenty years of data available and the range of independent variables described in Chapter V. For independent continuous variables, a test of association was based upon simple correlation co-efficients, where independent variables were categorical, and simple one way analysis of variance (ANOVA) was used.[91] The hypotheses tested (see Chapter V), along with a summary of results are provided below.

These results do not take into account the considerable degree of interaction among independent variables discussed in Chapter VII, and as a result, should be viewed with caution. They do provide some broad insights into the nature of inter-relationships between maintenance and

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[91] As noted above, because of severe violations of normality assumptions, a corresponding non-parametric test of association was employed, Kendal Tau, which uses the rank order to both independent and dependent variables was also used, since inferences based upon this statistic do not depend upon the normalcy assumption. The results produced were extremely similar.

replacement costs and project characteristics.

a. Building Age and Presence of Rehabilitation:
In all twenty analyses, age was significantly correlated with replacement expenditures with 99% confidence (See Table VII.1). In 19 analyses, age was significantly correlated with maintenance expenditures. Examining the size of the correlation co-efficients, the simple effect of age tended to be more important, and more consistent in affecting expenditures of replacements than maintenance (Table VII.2). On average, approximately 8% of the variance in replacement costs could be explained using a simple linear model using age and 6% of variance in maintenance costs. In addition, over time, replacement cost simple regressions consistently yielded results which indicated that between 5-15% of the variance in replacement costs could be characterized by a linear equation, simply using project age. Results using maintenance expenditures were less consistent.

Table VII.1
Results of Fitting a Simple Relationships Between Building Age/Presence of Rehabilitation and Maintenance/Replacement Expenditures

			% Co-efficients Significant with 99% Confidence/in Predicted Direction			
			Replacement		Maintenance	
Characteristic	Years Data Available	Average Sample Size	Expected Co-eff.	% Sig./Correct Direction	Expected Co-eff.	% Sig./Correct Direction.
Building Age	20	3956	(+)	100%	(+)	95%
Building Rehabilitated	7	205	(+) (-)	14% 43%	(+)	100%

Table VII.2
Proportion of the Total Variance Explained by Fitting a Simple Relationships Between Building Age/Presence of Rehabilitation and Maintenance/Replacement Expenditures

Proportion of Variance Explained (R^2)	% of Analyses	
	Replacement	Maintenance
0-4.9%	20%	60%
5-9.9%	20%	10%
10-14.9%	45%	5%
15-19.9%	5%	15%
20-24.9%	0%	10%

In examining the effect of rehabilitated versus new construction, sufficient data were only available for projects reporting maintenance and replacement expenditures over the period 1986-1992. Further, these data were only available for a small number of non-profit projects. These projects were primarily municipal and private non-profits and co-ops.

Still, there is a clear and consistent relationship between rehabilitation and the magnitude of maintenance costs, as Table VII.1 indicates. Over the entire period, 1986-1992, the group of projects which had been rehabilitated reported significantly higher maintenance expenditures than projects that were newly constructed.

Replacement expenditures patterns are, at first glance, less clear. Over this period, once replacement costs were significantly higher in rehabilitated buildings in one instance, and three times, they were significantly lower. Projects identified as rehabilitated projects in the sample tended to be relatively new additions to the stock in comparison to new construction. Age may be significant in understanding why in 1986, rehabilitation expenditures reported were significantly lower, and the null hypothesis that there was no difference could not be rejected for the period 1987-1989. As the time since rehabilitation progressed, these projects seem to exhibit higher replacement requirements. Thus, during the period 1990-1992 costs were significantly higher in rehabilitated projects.

2. Building Location

i. Province/Territory

The overall effect of difference by province was significantly different from zero with 99% confidence in each of the 14 analyses where these data were available (the period 1979-1992). Rankings, though, did not corresponded with 99% confidence with the hypothesized order (see chapter V), using the non-parametric Spearman Rank order correlation co-efficient (rho). The estimated squared rho was positive (i.e. indicating that the rank orders were, generally, in the same direction) but low, .04 for replacement expenditures and .18 for maintenance.

Examining data by province indicates that significant variations may have been a result of problems in reporting. Particularly, replacement expenditures in series for Newfoundland and Labrador, Prince Edward Island and the Territories were much lower than expected. In each of these cases, large proportions of these series showed no expenditure, while corresponding maintenance series were ranked higher than expected. In Ontario, the ranking of average maintenance costs was lower than expected, likely a result of the removal of cost categories in the CMHC Public Housing evaluation data base.

Further, examining within-province variances consistently leads to results which seriously violate an assumption required for hypothesis testing--homoscedasticity. In utilizing hypothesis testing in simple analysis of variance, it is assumed that within group distributions of expenditures are normal and their variances are the same (Dunn and Clark (1987)). For example, in northern and remote areas, it will be seen that expenditures for maintenance tend to increase quickly over time leading to considerable larger variations in expenditures in these provinces between new and older projects than in other parts of the country. As a result, using the Levene test which examines similarity of within group variance, consistently indicated failure of this assumption (SPSS (1988a)). Results in this regard, then are highly dependent upon the robustness of the ANOVA test.

Table VII.3 indicates that there is no dominant pattern in the relative size of replacement expenditures over time among the provinces and territories. Yet, as was expected, replacement expenditures in Ontario were consistently above the norm. Unexpectedly, Saskatchewan also tended to be higher, although expenditure levels were well below those of Ontario. Expenditures in Québec and Alberta, as predicted, were consistently below the norm. Partly because of difference in reporting, there were sizeable fluctuations over time in the expenditure patterns reported in five provinces/territories--Newfoundland and Labrador, Prince Edward Island, the Territories, Manitoba and New Brunswick.

Table VII.3
Simple Relationships Between Building Location and Maintenance/Replacement Expenditures

			% Co-efficients Significant with 99% Confidence/in Predicted Direction			
			Replacement		Maintenance	
Characteristic	Years Data Available	Average Sample Size	Expected Mean Co-eff. Sign/Ranking	Mean Rankings % Sig./Correct Direction	Expected Mean Co-eff. Sign/Ranking	Mean Rankings % Sig./Correct Direction
Province/Territory	14	5382		100%		100%
Newfoundland/Labrador			3	7*	3	2
Prince Edward Island			5	9*	5	3
Nova Scotia			5	6	5	8
New Brunswick			5	3	5	4
Québec			8	11	8	11
Ontario			2	1	2	9*
Manitoba			11	8	11	6*
Saskatchewan			11	2*	11	10
Alberta			10	10	10	5*
B.C.			9	4*	9	7
Territories			1	5*	1	1
Remote Area	20	3956	(+)	40%	(+)	70%
Population Size (log)	20	3956	(+)	80%	(+)	45%

* indicates average rankings departed from expected rankings by more than 3 places.

Over the years, maintenance expenditure patterns were clearer and more consistent. As was expected, expenditures in the Territories were considerably above the norm and expenditure levels in the provinces of Newfoundland and Labrador and Prince Edward Island consistently ranked above those of other provinces. At the other end of the spectrum, expenditure levels in Saskatchewan and Québec were well below the norm. Fluctuations in expenditure levels were considerably less in this series. The introduction of non-profit data in 1986 and subsequent series led to significant shifts in the average provincial data of three provinces--Ontario, New Brunswick and British Columbia. This may be a reflection of considerable differences in characteristics such as project age and type of clientele in Public Housing and other portfolios in these provinces.

ii. Population

The simple effect of the logarithm of population on both replacement and maintenance costs is clear. In both cases, simple correlation co-efficients were significant for the majority of series (65% of replacement series and 80% of maintenance series). Yet the direction of the relationship shifted. Among the early series, consisting solely of Public Housing in Ontario, population size has an unambiguously positive relationship with respect to maintenance and is only weakly related to replacement expenditures. With the introduction of data from other provinces and programs, considerable fluctuations occur. As will be seen in the multivariate analyses, there is considerable interaction with these and other variables.

iii. Location in a Remote Area

In the majority of series, the effect of remote area on maintenance (70%) expenditures was both significant and in the correct direction. The majority of series where this variable was not significant contained small numbers of projects located in remote areas. The effect of location in a remote area on replacement expenditures was less clear cut. In only 8 of 20 series could the null hypothesis be rejected with 99% confidence. A major contributing factor is the low reporting of replacement expenditures in the Territories (see above).

3. Project and Unit Characteristics

Table VII.4
Simple Relationships Between Project and Unit Characteristics and Maintenance/Replacement Expenditures

Characteristics			**% Co-efficients Significant with 99% Confidence/in Predicted Direction**			
			Replacement		**Maintenance**	
Dependent Variables	Years Data Available	Average Sample Size	Expected Co-eff. Sign/Ranking	% Sig./Correct Direction	Expected Co-eff. Sign/Ranking	% Sig./Correct Direction
Number of Units	20	3956	(-) (+)	5% 55%	(-) (+)	30% 20%
Type of Units:	20	3956				
% Apartments			(-) (5)	95% (5)	(-)(5)	100% (5)
% Semi- Detached, Duplex, Triplex			(+) (3)	20% (3)	(+) (3)	40% (4)
% Row			(+) (4)	65% (2)	(+)(4)	75% (2)
% Detached			(++) (1)	65% (1)	(++) (1)	95% (1)
% Hostel			(+) (2)	(+) 20% (-) 35% (3)	(+)(2)	(+)(35%) (-) (10%) (3)
Mean # of Bedrooms	20	3956	(+)	100%	(+)	100%

i. Number of Units (Average Project Size)

It was postulated that total number of units would, because of economies of scale have a negative impact upon replacement and maintenance costs. Univariate results for maintenance costs were ambiguous, showing significant relationships in 50% of the series, but almost randomly changing direction. Results for replacement costs were less ambiguous, but in the opposite direction. Large projects, in 55% of the series tended to have higher than average replacement expenditures on a per unit basis than small projects. As will be shown later, this variable was highly correlated with community population size, presence of an elevator balconies, and presence of apartments.

ii. Types of Units

It was postulated that there would be significantly lower replacement and maintenance requirements in projects with high proportions of apartment structures and much higher costs in detached buildings. The costs of other built forms, semi-detached, duplex, triplex and row housing would lie somewhere in between, with a gradation of high to low for semi-detached, duplex/triplex structures and rows units.

Hostels, because of high intensity and special use would tend to have high replacement and maintenance per unit expenditures. These tendencies would be somewhat offset, because hostels tended to have relatively large numbers of units, allowing for some economies of scale. In addition, hostel units tend to be small and facilities are shared in many cases, further reducing costs on a per unit basis. The degree and magnitude of these offsets are unknown. Projects containing hostels, were though, postulated to have relatively high costs.

Table VII.4 shows that apartment per unit replacement and expenditure costs were considerably lower than that of other built forms. Further, replacement costs were lowest for apartments in all of the series, and either lowest or second lowest for the maintenance costs series.

Maintenance costs for detached housing were significantly higher in 95% of the series than were other projects, while replacement costs were significantly higher in 65% of the series. Further, average replacement and maintenance costs in these projects were consistently ranked first or second.

A wider gap emerged between row and semi-detached housing than was expected. Costs for projects with row housing were much closer to those with detached structures, while semi-detached/duplex/triplex structures had costs which were closer to those of apartments.

Lastly, average costs for projects containing hostel units tended to have both replacement and maintenance costs which lay in the centre. At the same time, a significant number of these projects had extremely high costs per unit.

iii. Average Number of Bedrooms (Average Unit Size)

In each year of the analysis, unit size was strongly and positively associated with both replacement and maintenance costs. This characteristic consistently explains between 1% and

3% of the total variance in replacement expenditures. Its explanatory power in explaining maintenance expenditures is considerably higher, especially for the pre-1986 series which exclusively contain Public Housing data, where a simple linear equation using average number of bedrooms "explains" approximately 19% of the variance. For post-86 data the average R^2 shrinks to 3%.

Average number of bedrooms, as indicated in the last chapter, was highly correlated with other unit and household type characteristics. Pre-1986 unit size is highly correlated with the distinction between family and senior targeted Public Housing, and universally positively correlated with percentage apartments and negatively with percentage detached.

4. Household Type

Projects identified in the data base as senior, family or mixed housing were included primarily in the Public Housing stock.

Housing which was either exclusively seniors or mixed seniors/family tended over the 20 year series to consistently report lower levels of replacement and maintenance expenditures. As will be seen in the following section, however, this result should be treated with caution since seniors housings was highly correlated with a number of other factors which also were coincident with lower replacement and maintenance expenditures,
including proportion apartments and average size of units.

Table VII.5
Simple Relationship Between Household Type and Maintenance/Replacement Expenditures

			% Co-efficients Significant with 99% Confidence/In Predicted Direction			
			Replacement		Maintenance	
Characteristic	Years of Data Available	Average Sample Size	Expected Co-efficient	% Significant Correct Direction	Expected Co-efficient	% Significant Correct Direction
Household Type--Seniors	20	4,652	(-)	95%	(-)	100%

5. Institutional Characteristics

i. Program

It was postulated that there would be two effects of program on replacement and maintenance expenditures. Firstly, because programs spanned differing time periods, expenditures would roughly correspond to program age. Thus, Public and Limited Dividend projects would most likely exhibit high expenditure levels, followed by the Community Based, section 95 and lastly Post 1986 projects. The second effect would primarily be seen in expenditures on replacement and interaction with maintenance. Provision for replacements tended to be much more limited in earlier programs. As result, replacement expenditures would tend to be reduced, and maintenance expenditures increased in the three early programs, Public Housing, limited dividend and community based programs vis-a-vis Section 95 and Post-86 projects.

Age of program seemed to dominate as a factor in replacement expenditures and tended to be much higher in building constructed under the various Public Housing provisions. Expenditures in the community based and limited dividend projects were similar. Lowest levels of expenditures were found in the Section 95 and Post-86 projects.

Table VII.6
Simple Relationships Between Institutional Variables and Maintenance/Replacement Expenditures

			% Co-efficients Significant with 99% Confidence/in Predicted Direction			
			Replacement		Maintenance	
Characteristics	Years Data Available	Average Sample Size	Expected Co-eff. Sign/Ranking	% Sig./Correct Direction	Expected Co-eff. Sign/Ranking	% Sig./Correct Direction
Institutional Variables						
Program	7	7201		100%		100%
Public Housing	7		1	1	1	4
Limited Dividend	7		2	3	2	3
Community Sponsored	7		3	2	3	1
NHA 95	7		4	4	4	5
Post 86	5		5	5	5	2
Provider		7201		100%		100%
Private Non-Profit	7		3	4	3	2
LHA/Munic.	7		1	1	1	3
Aboriginal	7		2	2	2	1

While differences among programs in maintenance expenditures consistently appeared, and tests of these differences consistently were significant with 99% confidence, the magnitude and direction of these differences changed considerably from year to year. Unexpectedly, Community based, Post 86 programs and Limited Dividend Expenditures tended to be high in comparison to Public and Section 95 housing.

ii. Provider Type

It was expected that the voluntary labour undertaken by co-op members would have some impact upon maintenance, and possibly replacement expenditures. Conversely, municipal and Public Housing administered by Local Housing authorities would have higher than average labour costs, as would the costs for Aboriginal housing located in areas where the costs of materials and skilled labour were particularly high. Scheffé tests of between-group differences indicated, generally significant differences among provider types and these differences for the most part corresponded to the hypothesized ordering. The only major departure came in the lower expected maintenance costs in housing administered by Local Housing Authorities and municipalities. As will be seen below, this may be a reflection of the dedication of considerable resources in recent years to replacement expenditures.

6. Building Characteristics

Table VII.7 summarizes the estimated univariate relationships between building characteristics, and maintenance and replacement expenditures. The majority of building characteristics were available for buildings in the non-profit sector, expenditures were available in the post 1985 period, and most were obtained from the small sample of non-profits survey respondents (See Chapter V).

i. Construction Type

Construction type is highly correlated with building form. Wood frame construction is predominantly used in the construction of detached and semi-detached/duplex built forms, concrete and steel frame in high rise apartments. As a result, it is difficult to differentiate the use of construction type from built form. Two general trends are, though, evident in Table VII.7. First, dwellings built using wood frame construction tended to be more expensive to maintain and were somewhat more prone to replacement expenditures than was other housing. These dwelling units, though, were considerably more likely to be detached, semi-detached or row housing and to house families. As a result, it is not possible using these data to isolate the effects of wood frame construction from other elements of building form and use.

Secondly, buildings using masonry construction, tended also to be buildings experiencing high maintenance costs.[92]

ii. Exterior Cladding

Over the period 1986-1992, where there was a sufficient number of data to allow for inference testing, exterior cladding, for the most part, did not explain significant differences in the distribution of maintenance or replacement expenditures. Where there were significant differences, there were no significantly large or consistent differences between pairs of cladding types. Lastly, the hypothesized rank order of average expenditures on maintenance and replacement costs did not correspond to the empirical data. Buildings with wood and stucco exterior cladding tended to have lower maintenance and replacement costs than those with brick exteriors.

iii. Roof Type

It was postulated that buildings with flat, tar roofs would, on average, require significantly higher levels of maintenance than those with sloped, shingled roofs. The relatively small significance of roofing costs in conjunction with the relatively small proportion of the sample for which these data were available, reduces the likelihood of rejecting the null hypothesis that there is no difference. Further, projects with flat roof construction also tend to include a considerable

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92 Expenditure data were only available for buildings identified as having been constructed using masonry construction for the 7 years between 1986 and 1992.

number of apartments, where costs are relatively low. Roof type could be seen to differentiate only 1 year of replacement expenditures and 2 years of maintenance series. In each case, buildings with flat roofs had higher average maintenance/expenditures as expected.

Table VII.7
Simple Relationships Between Building Characteristics and Maintenance/Replacement Expenditures

			% Co-efficients Significant with 99% Confidence/in Predicted Direction			
			Replacement		Maintenance	
Characteristics	Years of Data Available	Average Sample Size	Expected Co-eff. Sign/Ranking	% Significant, Correct Sign/ Mean Ranking	Expected Co-eff. Sign/Ranking	% Significant, Correct Sign/ Mean Ranking
Construction Type	20	1926	Concrete/Steel Frame (-)	0%	Concrete/Steel Frame (-)	0%
			Wood Frame (+)	25%	Wood Frame (+)	45%
			Masonry (+)	86%	Masonry (+)	86%
Exterior Cladding	7	205		29%		14%
			Wood (1)	4	Wood (1)	5
			Aluminum (3)	3	Aluminum (3)	2
			Mixed (3)	1	Mixed (3)	3
			Stucco (4)	5	Stucco (4)	4
			Brick (5)	2	Brick (5)	1
Roof Type	20	121	Flat (+)	5%	Flat (+)	10%
Heating Type	7	111	Baseboard (-)	0%	Baseboard (-)	70%
Heating Fuel	20	1564	Electric (-)	60%	Electric (-)	100%
			Wood/Coal (+)	10%	Wood/Coal (+)	10%
Presence of Balconies	20	120	(-)	10%	(-)	45%
Elevator	20	141	(-)	15%	(-)	55%
Flooring	7	182	Lino./Tile (+)	86%	Carpet (+)	0%
Significant Landscaping	20	115	(+)	0%	(+)	0%
Parking	7	199		0%		43%
			Exterior Lot (1)	2	Exterior Lot (1)	3
			Separate Struct. (2)	2	Separate Struct (2)	1
			Mixed (2)	2	Mixed (3)	4
			Exterior Lot (4)	2	Exterior Lot (4)	2

iv. Heating/Fuel Type

Heating system data were available for a small sample of projects, while heating fuel type was more commonly available. Both series were strongly related to maintenance expenditures. Projects with electric, primarily baseboard heating systems, tended to report lower maintenance costs than those with oil/gas furnaces (usually forced air or water).

A weaker generality is that systems using wood or coal seemed to experience higher maintenance and replacement expenditures. Because the sample sizes for these projects were small, the differences were significant, using the Scheffé test in only two or twenty series. In addition, these systems were also largely co-incident with remote locations, which, as noted above, was a much stronger factor in explaining higher maintenance and replacement costs.

v. Presence of Balconies

It was initially postulated that the presence of balconies would provide a significant additional expenditure requirement. Balconies, though, tend to be present in larger projects, many of which are largely made up of apartments, and as a result, per unit expenditures, as is the case where elevators are present (see below), are relatively low. For 10% of replacement and 45% of maintenance series, buildings with balconies had significantly lower per unit expenditures.

vi. Presence of Elevator(s)

Projects with elevatored buildings tend to have lower average maintenance costs (in 11 of 20 years of data), and on occasion, lower average replacement costs (3 of 20 years of data) than other projects. As with the presence of balconies, while the costs of elevator maintenance and replacement tend to be high, these facilities tend to be located in high rise buildings, containing apartments. The effect of economies of scale in these buildings seem to overshadow higher mechanical expenses.

vii. Unit Floor Covering

Sample sizes were large enough to test differences between buildings where units were carpeted versus buildings where units contained either tile or linoleum. It was expected that buildings with carpeting would experience significantly higher replacement and maintenance expenditures. Results for maintenance costs are in the expected direction and are relatively strong. Replacement costs results though, point in the opposite direction, indicating lower than expected replacement costs. It may be that carpet replacements and repairs tend to be smaller and be treated more frequently as maintenance expenditures than expenditures on other types of flooring.

viii. Site Characteristics--Landscaping and Parking

The presence/absence of significant amounts of landscaping, available for a small sample over the entire twenty year period did not have a discernable impact upon replacement or maintenance costs using the chosen confidence level in any year.

Type of parking, available for a small sample for the period 1986-1992 also had no significant impact on replacement expenditures during that time. There are, though, significant differences in maintenance expenditures in 3 of 7 series. In each of these series, tests of differences between pairs of alternatives indicated that buildings with either only interior parking, or only parking contained in separate structures, had significantly higher maintenance expenditures than those with only exterior lots. The high costs of buildings with separate structures are likely related to a significant number which are detached/semi-detached buildings with separate garages. Still, these results may point to the net higher costs of maintaining interior structures.

B. Multivariate Analysis of Variance and Covariance

Multivariate analysis was undertaken using single years of replacement and maintenance expenditures. Independent variables were included where, using univariate ANOVA results, the null hypothesis that there was a relationship with the dependent variable was rejected with 99% confidence. In addition, the relationship was evaluated between present expenditures and both past year maintenance and replacement expenditures.[93]

Because there are considerable differences in the samples over time, analysis is broken into three parts. First, results for the period 1973-1978 are discussed. These results include data solely for Ontario Public Housing. Next, attention turns to results which cover the period 1979-1985, which predominantly are made up of national representation of Public Housing. Finally, the 1986-1992 results are discussed. These data cover the entire range of non-profit providers.

1. The Period 1973-1978--Ontario Public Housing

An insufficient numbers of observations were available to utilize a number of independent variables, including type of floor covering, exterior cladding, type of parking, and rehabilitated properties. In addition, there were also inadequate observations to include masonry and factory/prefabricated construction methods in differentiating construction type. Results of replacement expenditure analyses are shown in Table VII.8 and VII.9. Results of Maintenance analysis are shown in Table VII.10 and VII.11.

a. Replacement Expenditures

Most of the portfolio was built during or shortly before this era. As would be expected, relatively few projects reported substantial modernization and improvement expenditures. Since there were so many null and minimal expenditures, the explanatory power of any model used to estimate variance is relatively limited. Thus, an average of only 15% of the variance in replacement expenditures was explained by the best fitting replacement expenditure models during this period. In contrast, the models used to estimate maintenance expenditures explained an estimated 39% of the variance of these expenditures. These relatively weak relationships made it extremely difficult to differentiate between independent variables which were highly correlated, and which often were available for relatively small subgroups. As a result, a number of competing models provided fits which were at best, marginally, distinguishable. For example, it was relatively difficult to distinguish between the effects of population size and project size in a number of models, since the two tended to be interchangeable, and because of collinearity, tended to have relatively small independent effects.

[93] In addition as noted above, present year and past year expenditures were included as independent variables. This choice was made because significant but small correlations only existed between maintenance and replacement expenditures in the current year and between expenditures in both categories, lagged a single year. Examining autocorrelations of more than a year indicated a sharp damping of correlations.

Table VII.8 shows two strong, distinct and repeated results:

Table VII.8 Estimated Effects of Building and Household Characteristics on Replacement Expenditures, 1973-1978[94]											
		EFFECT OF:									
Yr.	R^2	Constant	Age	Remote	Family	Log Population	% Detached	% Row	% Hostel	No Elevator	Past Yr. Expend.
73	33%	-72	12	NS	54	NS	NS	NS	NS	NS	NS
74	8%	1849	25	457	NS	-59	NS	232	NS	NS	-.033
75	9%	1829	38	369	NS	-32	NS	NS	NS	NS	NS
76	8%	1534	33	NS	82	-25	NS	296	NS	177	NS
77	10%	968	30	NS	51	NS	183	NS	NS	91	NS
78	18%	611	28	NS	84	28	NS	NS	548	NS	NS

- Building age was a consistent factor positively influencing replacement expenditures. The estimated linear effect of a year of building age on replacement expenditures per unit varies from a low of $13 per year in 1973 to $38 in 1975. With the exception of the 1973 result, most estimates were in the $30 range per unit per year of age.
- Family housing (which also tend to be larger, non-apartment units), tend to encumber larger replacement expenditures than does seniors housing in four of six years, the cost of replacements in family housing ranged from $51 to $84 more per unit per year more than for seniors housing.

It also provides three less consistent results:

- The effect of population size of surrounding community was ambiguous. Projects located in large population centres (which also tended to be larger projects) tended to have lower replacement expenditures per unit during the period 1973-1975, but by 1978, results had reversed.
- There is some evidence that low-rise housing (detached, row) characterized by absence of an elevator (also a surrogate for no balcony and wood frame construction), tended to have higher per unit replacement expenditures during this time.[95] In two of the six years considered, the estimated effect is captured in "absence of an elevator", and varies from $91 per unit in 1977 to $177 in 1976. In two of six years, other indicants of low

[94] In this and subsequent tables, only variables where at least one co-efficient was significant at the 99% confidence level are listed.

[95] When the percentage detached and/or row housing and non-elevatored building were removed from the MANOVA model and construction type "wood frame" or "presence of a balcony" was substituted, these variable produced MANOVA co-efficients which were also significant. These models, though, "explained" slightly less of the variance of replacement expenditures.

rise projects, percentage row housing had a statistically significant impact on replacement expenditures, and in one year, percentage single detached were significant. In 1974 and 1976, the estimated effect of having an all row house project versus none row housing ranged from $232 to $296 per unit. In 1977, the estimated effect of having all detached housing was estimated at $183 per unit.

In addition, two other variables were significant in explaining variations in replacement expenditures for more limited time spans:

- The relatively small stock of remote housing experienced higher levels of replacement expenditures during the period 1974-1975.
- During one year, 1974, the presence of high maintenance expenditures in the previous year was correlated with lower replacement costs in a subsequent year--an effect which is not in line with expectations. The effect was -$.033 per dollar of maintenance or approximately $2 per unit for a building with an average maintenance bill in 1973 ($583).

Utilizing a repeated measures MANOVA model for the 390 projects which operated through this time period and for which replacement expenditures data were available, produced a much more parsimonious model.[96]

Table VII.9
Estimated Overall and Within Era Effects of Building and Household Characteristics on Replacement Expenditures, 1973-1978

Overall Effect:				
Constant	Age	Remote	Log Population	% Detached
3582	41	420	-29	233
Within Era Effects[97]				
Component	Age	Remote x Age		
Linear	NS	NS		
Squared	-578	340		
Cubed	NS	-350		

The estimated average effect of age on replacement expenditures was $41 per year, somewhat

[96] These results are also in line with the univariate results reported in the CMHC Evaluation of Public Housing (1990).

[97] Here and below, the first three terms of the series of orthogonal polynomials fit are shown. The number of terms calculated is equal to the number of years considered minus 1, in this case, equalling 5. There is no reason to believe that higher order polynomial terms should characterize the distribution of these expenditures, and so, for the sake of parsimony, these results are not reported.

higher than was produced using the individual year models. This reflects the exclusion of the considerable number of project which began during this period and for which replacement expenditures were especially low during these first years of operation.

Areas with larger populations tended to report lower levels of replacement expenditures. Cities of 100,000 had replacement expenditures which averaged $42 lower than areas with a population of 10,000.

Projects with row housing tended to be substantially more expensive ($233 more per unit where all dwellings were row housing in contrast to where there was none).

Changes in replacement reserves can best be characterized by the squared term of a second degree polynomial, reflecting, first, substantial reported increases in constant dollar expenditures during the period 1973 to 1976 from an average of $261 to $570 per unit and substantial decreases during 1977 to $376 and in 1978 to $278. These changes occur irrespective of the general characteristics of the projects.[98] [99]

b. Maintenance Expenditures

Table VII.10 shows the results of fitting the maintenance expenditure model to the annual data. Here, expenditures patterns are more consistent, and, as would be expected, a much higher proportion of variations in expenditures are explained. The models, though, also tend to be more parsimonious--that is fewer independent variables significantly contribute uniquely to "explaining" variations in annual maintenance expenditures.

The same two variables as were significant in the replacement expenditure regressions are consistently important:

- Building age had a consistently positive effect upon maintenance expenditures, ranging from $19 per unit per year to $46. These estimated effects are, in four of six years, larger than those in the replacement expenditure regressions. The significantly higher increase in maintenance versus replacement expenditures during this period likely reflect the relatively young age of much of this portfolio (most of which had been built in the

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[98] There is also an interaction between remote location and time over this time period, reflecting large expenditures during a short interval during this period.

[99] For the reader unfamiliar with the fitting of orthogonal polynomials to repeated values in this type of analysis of variance, it should be noted that this analysis involves a fit of n-1 co-efficients to n within group differences--this the results always fit the data. Only the first 3 orders of the orthogonal polynomial are shown in this and following tables of results. Where there are large, random variations in expenditures over time, a large number of co-efficients will be "significantly" different from 0, these co-efficients will be large and will tend to point in opposite directions. This is invariably spurious result. Results are reported upon where there are a limited number of "significant terms" and at least one of these is characterized by a low order polynomial. The presence of large and offsetting co-efficients also likely indicates a high level of error in the "overall effect". This is evident, for example, in the Territories results for the 1979-1985 replacement expenditures analysis (Table VII.12).

decade or so preceding) and the relatively few projects reporting significant replacement expenditures. As noted above, it is expected that replacement expenditures will increase very slowly during the first years of operation.

- More money was dedicated to maintaining projects containing family housing. This effect was substantially greater than that reported for replacement expenditures. On a per unit basis, projects containing family housing had estimated expenditures of between $93 and $219 per unit per year more than for projects with no family housing.

Table VII.10
Estimated Impacts of Building and Household Characteristics on Maintenance Expenditures, 1973-1978

		EFFECT OF:						
Year	R^2	Constant	Age	Family	Log Population	% Row	No Elevator	Past Yr. Expend
73	55%	196	19	188	33	NS	98	NS
74	46%	944	33	219	49	NS	163	NS
75	38%	1315	46	168	38	NS	164	NS
76	37%	1536	33	187	NS	NS	NS	-.014
77	23%	1209	24	104	NS	231	NS	-.010
78	31%	482	36	93	56	245	208	NS

In addition, there were two strong, but less consistent results for data during this period:

- In four of six years, projects in large population centres had higher levels of expenditures on a per unit basis than units in small centres. This is the reverse of most significant co-efficients reported in the replacement equations.
- As in the replacement equations, units in non-elevatored buildings had maintenance expenditure levels that were higher than those in elevatored buildings in four of six years during this period. On a per unit basis, the co-efficients were these buildings indicated a difference of between $98 and $208. These effects were more consistent in their range and also of the same general magnitude as those in the replacement equations.

Finally, two variables were significant in differentiating maintenance expenditure patterns during more limited time spans during this era:

- Projects containing row housing tended to have higher maintenance expenditures, holding all else constant for the years 1977-1978. Maintenance expenditures were between $231 and $245 per unit higher in projects which were fully row house in comparison to those with no row houses. Similar magnitudes of results were reported for two other years in the replacement expenditure regressions.
- During a short time span (1976-1977), maintenance costs tended to fall relative to past year replacement expenditures. This affect was relatively minor. On a per unit basis, for

each dollar of replacement expenditure in the prior year, maintenance expenses dropped by roughly $.01. The impact on a per unit basis, given average maintenance expenditures for buildings during this period was $5.

Providing an overall perspective on maintenance costs during this period, through the use of the repeated measures ANOVA yields similar results:

- Maintenance costs over this era were higher by an average of $32 per year of building age, holding other factors constant. These results were consistent with those using single years, and larger samples.
- Costs were substantially higher in family housing, which tended to have maintenance costs which averaged $485 higher
- Costs were higher in larger urban areas. Cites of 100,000 were estimated to have maintenance costs that were $34 higher than in areas with a population of 10,000.
- Costs were higher in non-elevatored buildings by an estimated $289 per unit.

Table VII.11
Estimated Overall and Within Era Effects of Building and Household Characteristics on Maintenance Expenditures, 1973-1978

Overall Effect:				
Constant	Age	Family	No Elevator	Ln Population
2541	32	486	289	27
Within Era Effects				
Component	Age	Age x Family	Age x No Elevator	
Linear	185	-198	114	
Squared	NS	NS	297	
Cubed	NS	99	168	

Further, as time passed during this period, there was a strong linear effect of time on maintenance costs. During this time period, expenditures increase from an average of $576 per unit to $943. Table VII.11 indicates a negative linear trend in the gap between family and seniors housing. This is largely offset by a cubic term pointing in the opposite direction. Finally, over time, Table VII.11 also indicates that maintenance costs in non-elevatored buildings increased substantially. This large effect likely reflects the combined effects of reported increases maintenance costs in all non-elevatored buildings, generally, and in particular, row housing (See Table VII.9).

2. Public Housing, Canada Wide, 1979-1985

Beginning in 1979, data were made available from the CMHC evaluation division for the entire Canadian Public Housing portfolio. This data source allows for model estimation using a larger, more diverse data source and for the consideration of regional differences. At the same time, though, results obtained from this source are prone to considerable additional error since they were gathered from a number of different sources--the provinces and territorial housing ministry/corporations responsible for Public Housing administration. In addition, as noted above, the Public Housing Evaluation (CMHC (1990)) reported certain maintenance related expenditures, that were separately reported as "operations" such as janitorial services, miscellaneous maintenance and grounds maintenance and replacement expenditures. This introduced further error since the capacity to isolate these expenditures was not consistently available. It is known, for example, the accounting system provided by the province of Ontario allowed this separation of related replacement expenditures to be made in 1980 and 1981 only and for maintenance expenditures during the entire 1979-1985 period.

Table VII.12 shows the overall power of the individual year regressions, and the estimated effect of independent variables on expenditures using the MANOVA covariance model. Remarkably, there is a considerable improvement in the explanatory power of both the replacement and expenditure models with the addition of these data, in comparison to the 1973-1978 period. Much of this improvement can be attributed to the larger pool of variation in the data with the inclusion of projects from various provinces. Thus, the scope considered may have been more in line with the effects of the phenomena under consideration. In particular, the extremes of the Territories and the high costs of both labour and materials there seem well reflected in considerably higher maintenance costs. Again, though, these results may partly reflect differences in maintenance/replacement practices or, more troubling, differences in accounting practices. Overall, the simple average of variance explained in the replacement expenditure regressions increased slightly to 17% while the variance explained in the maintenance regressions increased to 57%.

a. Replacement Expenditures

In the replacement equation, the effect of age is consistent, and in the correct direction. The 1980-81 co-efficients are smaller than those of other years, likely due to excluded data, and are a relatively consistent effect of between $22 and $35 per year of age between 1981 and 1985.

Table VII.12
Estimated Impacts of Building and Household Characteristics on Replacement Expenditures, 1979-1985

		EFFECT OF:								
Yr.	R^2	Constant	Age	Remote	Family	Log Population	% Detached	Electric Heat	No Elevator	Past Yr. Expend.
79	9%	511	17	NS	90	NS	NS	NS	NS	0.004
80	7%	394	8	NS	NS	NS	NS	-10	NS	0.004
81	34%	1,407	31	73	78	-26	NS	-41	45	0.009
82	19%	931	22	NS	67	-6	NS	NS	NS	0.005
83	20%	1,478	32	NS	45	-24	124	-42	99	0.004
84	14%	1,200	32	32	67	-15	108	NS	109	NS
85	16%	1,558	35	35	88	-12	NS	-3	NS	NS

	Table VII.12 (continued) Estimated Impacts of Province/Territory on Replacement Expenditures, 1979-1985										
	PROVINCE										
Yr.	Nfld	PEI	NS	NB	Queb	Ont	Man	Sask	Alta	BC	Terr
79	-18	-139	45	45	-130	-45	-51	12	12	110	388
80	-120	-48	59	60	25	-31	236	15	55	-30	-158
81	-108	-211	-7	-7	-81	621	71	-65	63	-69	-176
82	-155	-47	107	367	-31	177	-154	-7	89	-108	-220
83	-165	328	-85	479	41	181	-230	-61	-127	-90	-251
84	97	-5	47	115	1	161	-288	74	-128	80	-156
85	64	123	-3	-35	0	236	-237	150	-178	303	-418

Two variables, building age and the presence of family housing were, as in the prior period, consistently significant in their impact on differences in replacement expenditures:

- Older buildings continued to tend to have higher levels of replacement expenditures, holding other factors constant. These effects ranged from \$8 to \$35 per unit per year of age. Excluding 1979 and 1980 data where it is known that some replacement/expenditure data are omitted, results are more consistent--varying from \$22 per year per unit to \$35, in line with estimates developed solely for the Ontario portfolio for the previous time period.
- In six of seven years, expenditures were higher in projects that have family housing. The effect is between \$45 and \$90 per unit, again in the range of the Ontario results for the prior time period.

Results were strong, but not as consistent for two other variables:

- Community size was negatively related to replacement expenditures. Thus smaller places were more likely than larger ones to see larger replacement expenditures on a per unit basis. Five of seven estimated co-efficients were significantly different from null and ranged from -\$6 to -\$26 for the natural logarithm of population. Thus a project in a town of 10,000, all else being equal, would have had estimated replacement expenditures which were lower by between \$14 and \$60 per unit for these years, in comparison to a building in a city of 100,000. This differences would roughly double for a city of 1,000,000 in comparison to a city of 10,000.
- High maintenance costs in the prior year influenced current replacement expenditures. Five of seven estimated co-efficients were significantly different from null and ranged from \$.004 per dollar maintenance expense to \$.009. In effect, all else being equal, projects experiencing high maintenance expenditures were likely to spend more money in the ensuing year on replacements. For a building with average maintenance costs in the prior year, this effect was an increase of between \$3 and \$6 per unit during that time period.

Lastly, co-efficients were significantly different from zero for four other variables, for at least 2 years of 7 during this period:

- Units in buildings with electric heat had significantly lower replacement expenditures than those with gas/oil heating systems in four years during this time span. It was estimated that units with electric had replacement expenditures that were between $3 and $42 per unit lower.
- Units in non-elevatored buildings tended to have higher replacement expenditure levels on a per unit basis, during three of seven years, a result similar to that reported earlier for the Ontario portfolio. Significant co-efficients ranged between $45 and $109 per unit.
- In three of seven years, units in remote areas had replacement costs which were higher than in the remainder of the country. Estimated impacts were $32 and $73.[100]
- In two of seven years, projects with detached units had estimated replacement expenditures which were higher than others. Estimates of the impacts on replacement expenditure of having only detached units ranged from $108 to $124 per unit during 1983-1984.

Estimated differences in replacement expenditures among provinces, holding other, significant factors constant are also reported in Table VII.12. The table indicates that there is some consistency in the ranking of the estimated effects of provincial/territorial location in these data over this period. Expenditures in the provinces of Ontario and New Brunswick were, in most years, among the highest. Nova Scotia, Saskatchewan and British Columbia tended to have expenditure levels which were very close to one another, and tended to be ranked at or above the median while Québec, Manitoba and Alberta were also similar and had expenditure levels usually at or below the median. Finally, Newfoundland and Labrador, Prince Edward Island and the Territories reported expenditures which usually were considerably below the median.

Substantial, interpretation of these results is hampered by differences in reporting and accounting practices noted above. For example, differences in co-efficients between 1979-80 and 1981-85 in Ontario are known to be related to reporting, as noted above. Ontario, thus moves from among those with relatively low to very high replacement expenditures, with the inclusion of additional cost categories. In addition, few projects in Newfoundland and Labrador (especially between 1979 to 1983), the Territories (especially between 1980 to 1985) and Prince Edward Island reported replacement expenditures for during this time. Still, these results provide some weak evidence that, as hypothesized, replacement expenditures tended to be lower in the prairies, possibly reflecting lower labour costs and a relatively benign climate, in contrast to Ontario, where labour costs are high.

Repeated measures analysis of covariance could be applied to the 2,471 projects that had operated over this entire period (See Table VII-12). This analysis again shows strong parallels with individual year results:

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[100] These effects were substantially below those reported for the small number of remote projects in Ontario, during the 1973-1978 period. Part of the difference may be due to the low number of projects reporting replacement expenditures during this period in the Northwest Territories/Yukon, where the majority of these projects were located.

- Average effects on replacement expenditures are similar to those reported in Table VII.12. Age had an average annual effect on replacement expenditures of $23 per year.
- Projects in larger areas tended to have lower replacement expenditures. Projects in cities or 100,000 were estimated to have expenditures $16 per unit low than those in communities of 10,000.

The effects of some characteristics were in the same direction but the estimated magnitudes were considerably larger:

- Projects in remote areas had expenditure levels that averaged $236 higher
- Projects comprised of non-elevatored buildings averaged expenditures that were $259 higher[101]
- Projects which were solely family housing averaged $341 above that of housing that was solely comprised of seniors and
- Projects with electric heating averaged replacement expenditures $126 below those with gas/oil heating.

Reflecting the older average age of buildings operating over this entire period, Table VII.13 indicates that replacement expenditures tended to increase linearly at a higher rate during this period than in the past, possibly indicating a tendency for the effects of wear and tear to accelerate with time. Further, during this period, the gap between family and non-family housing and between non-elevatored and elevatored buildings increased.

Table VII.13
Estimated Overall and Within Era Effects of Building and Household Characteristics on Replacement Expenditures, 1979-1985

Overall Effect:						
Constant	Age	Remote	No Elevator	Family	Electric Heat	Ln Population
3025	23	236	259	341	-126	-13
Within Era Effects						
Component	Age	Age x Remote	Age x No Elevator	Age x Family	Age x Elec. Heat	
Linear	508	NS	NS	134	NS	
Squared	NS	-168	297	NS	NS	
Cubed	NS	136	NS	NS	NS	

[101] As noted above, this higher co-efficient likely reflects the pooled effects of dwelling type (row and detached versus apartment) and larger unit sizes.

Table VII.13 (continued) Estimated Overall and Within Era Effects of Province/Territory on Replacement Expenditures, 1979-1985											
Overall Effect:											
	Nfld	PEI	NS	NB	Queb	Ont	Man	Sask	Alta	BC	Terr.
	-257	-18	-236	375	-286	305	-430	-222	-107	-148	1027
Age by Province Interaction											
Linear	300	310	-243	NS	NS	NS	-477	NS	-335	NS	808
Squared	NS	NS	NS	-305	NS	-181	NS	165	NS	367	-286
Cubic	-229	NS	135	-168	NS	267	309	214	258	158	-1086

As with the results based upon annual data, expenditure levels on replacements were especially high in Ontario and New Brunswick. In this exercise where projects that had operated solely over the seven year period were included, these "older" projects had very high estimated replacement expenditure levels in the Northwest Territories (averaging an estimated $1027 above the average). At the other end of the spectrum, well below the mean, are the majority of provinces (most notably Manitoba).

Table VII.13 also indicates that during this time period, a linear trend best characterized changes in replacement expenditures with time. The estimated increase over this time period was $507, or $72 per unit per year. This co-efficient is significantly larger than the effects of building age at the onset of this period. This provides some evidence that the rate of increase of replacement expenditures over time is increasing.

The influence of provincial/territorial location on replacement expenditures at the provincial level tend to the erratic, reflecting, among other things, changes in cost categories, and relatively few reported replacement expenditures. Table VII.13 reflects this in an inconsistent and widely varying set of co-efficients.[102] As a result, the fitting of a polynomial to the seven years of expenditure data reveals very little pattern. This can be seen in co-efficients which "reverse sign" and seem to offset with changes in polynomial order. For example, for the Northwest Territories, the linear component of the polynomial indicates an estimated increase of $808 over this study period, which is offset by a estimated decrease of $1086 using the cubed term. Still, during this period, Table VII.13 provides some evidence that expenditures per unit were tending to converge, with expenditures in New Brunswick, which were estimated to be high relative to other locations, decreasing over time and, conversely, expenditures in Saskatchewan and British Columbia, which were estimated to be low, moving towards the overall average.

b. Maintenance Expenditures

Table VII.14 shows that there are a number of very strong relationships between age and operating characteristics, and maintenance costs for the Public Housing portfolio. Between 41%

[102] Not shown is the high level of standard error associated with many of these co-efficients indicating, in some cases, small sample, and universally high levels of within province variation.

and 70% of the total variation of expenditures can be related to a limited set of characteristics. Four variables are consistently and strong in explained variation in maintenance costs during this time:

- Building age positively influences estimated expenditure patterns. The effect of each additional year of building life on maintenance expenditures per unit ranges considerably, from $9 to $45. As with earlier data, during the years 1979 and 1980, the effect of age remains larger than the corresponding effect on replacement expenditures. In 1981, the relative size of the estimated effects are reversed. For the period 1982-1985, the age co-efficient seems to stabilize at between $16 and $19 per year of age, in comparison to replacement costs in the $22 to $35 per year of age for replacement expenditures.

Table VII.14
Estimated Impacts of Building and Household Characteristics on Maintenance Expenditures, 1979-1985

		EFFECT OF:										
Yr.	R^2	Const.	Age	Remote	Family	Log Pop.	% Detached	% Row	% Hostel	Electric Heat	No Elevator	Past Yr. Expend
79	41%	1,692	45	239	156	NS	218	105	NS	NS	NS	NS
80	41%	1,376	39	225	41	NS	171	138	NS	NS	NS	-.006
81	65%	944	9	164	112	12	112	NS	NS	NS	NS	NS
82	59%	1,394	19	200	99	16	134	NS	255	NS	NS	NS
83	63%	1,264	16	230	106	NS	134	NS	NS	NS	103	-.003
84	63%	1,506	18	241	111	7	137	57	NS	-20	108	NS
85	70%	1,670	16	239	137	11	146	NS	NS	-70	NS	NS

Table VII.14 (continued)
Estimated Impacts of Province/Territory, Program and Type of Provider on Maintenance Expenditures, 1979-1985

	PROVINCE											PROGRAM				
Yr.	Nfld	PEI	NS	NB	Queb	Ont	Man	Sask	Alta	BC	Terr	Pub.	L.D.	Com. Based	Sect. 95	Post 86
79	516	129	-171	-172	-353	-256	-204	-223	-223	78	644					
80	371	152	-206	74	-389	-204	-275	-133	-192	-9	764					
81	63	214	-168	108	-296	-707	-110	-256	-86	25	1233					
82	133	377	-183	108	-416	-434	-11	-273	-267	-19	936					
83	238	266	-189	212	-449	-471	41	-234	-268	-171	977					
84	559	214	-195	447	-490	-520	-94	-337	-292	-23	672					
85	574	-16	-176	8	-514	-557	-218	-296	-243	-147	1519	-167	NS	191	24	NS

- Projects with family housing are consistently more expensive on a per unit basis. Inclusion of family housing increased costs per unit by between $41 and $137 per unit during this period. These results are consistent, but slightly less dramatic than those reported for Ontario during the earlier period and may reflect the increased presence of "mixed projects" during this time period.

- Remote projects tended to have higher per unit maintenance costs. The estimated effect of a remote location varies from $164 to $241 during this time period.
- Detached housing consistently is more expensive to maintain than other housing forms. Projects that are fully made up of detached housing have higher average per unit maintenance costs that range from $112 to $218 per unit, than projects with no detached housing.

The effect of one other variable was strong, but not as consistent:

- During four of seven years during this period, expenditures on maintenance in larger centres tended to be higher than those in smaller centres. The co-efficients, ranging from $7 to $16, indicating, for example, that locations in cities with a population of 100,000 had maintenance expenditures that were estimated to be between $17 to $37 higher than in communities of 10,000. These results are consistent with, but of a smaller magnitude, than those estimated for the earlier years of the Ontario portfolio.

Five other variables had co-efficients that were significantly different from zero in at two years:[103]

- During three of seven years, estimated expenditures in projects with row housing were higher than, on average, in other projects. Significant co-efficients ranged from $57 to $138 for projects which were completely made up of row housing in comparison to those with no row housing. Similar results occurred in earlier years in the Ontario portfolio.
- During two of seven years, the estimated effect of non-elevatored buildings on per unit maintenance costs was significant and positive, ranging from $103 to $108 per unit, in the range of earlier estimates using the Ontario portfolio.
- Past year expenditures on replacements had a very small but significant effect on present year maintenance during two years, of approximately $2 per unit, given average replacement expenditures.
- In line with results for replacement expenditures, buildings with electric heat tended to have lower maintenance expenditures than other buildings in two of seven years. In comparison with oil/gas heated buildings, this effect ranged from an estimated $20 to $70 per unit.[104]

Estimated effects of province on maintenance costs, holding other, significant factors constant, is much more consistent over time than for replacement expenditures and are also considerable. Further, rank ordering provinces/territories by estimated size of this effect leads to fairly

[103] Maintenance costs were also significantly higher during one year, 1982, for projects containing hostel units by $255. The small number of projects containing a significant number of hostel units limits the usefulness of this result.

[104] By and large, these results are in line with the analysis undertaken by CMHC in its Public Housing evaluation (CMHC (1990)). One exception is the identification of low-rise, non-elevatored buildings as generally more expensive than high rise buildings. This is primarily a result of isolating the effect of this factor from other correlates, such as the presence of seniors and building age.

consistent results. Yet as noted above, these results are likely highly influenced by reporting. Particularly suspicious is the very low reporting levels of Newfoundland and Labrador, the Territories and Prince Edward Island in replacement expenditures, in contrast to the very high maintenance expenditures reported. Thus first, and most dramatically, the estimated effect of a location in the Territories is considerable, ranging from $644 to $1519 per unit, and is well above those in the remainder of the country.[105] Well below these, yet, still well above those of the remainder of the country, are expenditures in Newfoundland and Labrador and Prince Edward Island. Some of this may be due to corresponding low levels of replacement expenditures, possibly indicating that the two have been merged for a number of projects.

As was expected, expenditures in New Brunswick were higher than average, British Columbia's expenditure pattern lies very close to the average and a gap then emerges between this province and a cluster containing the three prairie provinces. Québec's costs are also well below the norm, and below the expected ranking. Ontario is well below those of the remaining provinces. Expenditures in Ontario are likely lower than expected because of the exclusion of certain maintenance costs noted above. Finally, despite high taxation levels and the common use of wood exterior requiring frequent painting and repair, Nova Scotia maintenance costs were unexpectedly low.

Fitting the repeated measures MANOVA model produces results in line with the yearly analyses. Overall, maintenance expenditures were influenced by dwelling age, by an average of $19 per year. Further, projects fully made up of row housing were an estimated $52 per unit higher to maintain and those fully comprised of detached units were $105 per unit about the average.

As with the replacement expenditure model for this period, the estimated effects of family projects, which were $508 per unit, and of being located in a remote area ($705) were substantially higher than those estimated for individual years.[106]

Expenditures in Newfoundland and Labrador and the Northwest Territories were much higher than the norm ($1,530 and $1,628 per unit), while those in Québec, Ontario, and Saskatchewan were well below the mean (-1101, -1038 and -669 respectively). Examining the provincial single year results in Table VII.14 and the polynomial fits in Table VII.15 indicates considerable variation over time in maintenance expenditures within provinces which are difficult to characterize without more detail considering provincial operations.[107] Specifically, table VII.15

[105] Part of this difference is due to the inability to segregated other, operating costs from maintenance expenditures in the Northwest Territories (CMHC (1990)).

[106] There is little effect of time either directly in interaction with others factors (presence of seniors or location in a remote area). Table VII.15 also shows the presence of a significant co-efficient for the second degree polynomial of the interaction between age and family housing reflecting an unexplained dip in the effect of family housing during the middle of this period.

[107] As noted above, changes in accounting practice in Ontario allowing the removal of some accounts from maintenance expenditures reported in CMHC evaluation division data based may have produced this result, and the

indicates over this time that, in Saskatchewan and Québec, which tended to have low maintenance expenditures during this time, expenditures declined vis-a-vis other provinces/territories. In Newfoundland and Labrador, at the other end of the spectrum, the gap increased in the opposite direction. Only in Prince Edward Island, as with replacement expenditures was there a significant move towards the middle of the pack.

Table VII.15
Estimated Overall and Within Era Effects of Building and Household Characteristics on Maintenance Expenditures, 1979-1985

Overall Effect:					
Constant	Age	Remote	Family	% Detached	% Row
3587	19	705	608	105	52
Within Era Effects					
Component	Age	Age x Remote	Age x Family		
Linear	NS	NS	NS		
Squared	NS	NS	80		
Cubed	NS	NS	NS		

Table VII.15 (continued)
Estimated Overall and Within Era Effects of Province/Territory on Maintenance Expenditures, 1979-1985

Overall Effect:											
	Nfld	PEI	NS	NB	Queb	Ont	Man	Sask	Alta	BC	Terr.
	1530	348	-461	453	-1101	-1038	-261	-669	-274	-154	1628
Age by Province Interaction											
Linear	493	NS	NS	221	-154	-338	303	-90	NS	-194	-384
Squared	441	NS	NS	101	NS	220	-280	NS	NS	NS	-354
Cubic	-196	-262	NS	-254	NS	-109	-144	NS	NS	NS	887

3. The Post 85 Experience

Data for this period included examples of projects from all of the programs administered by CMHC, and are obtained primarily from CMHC's Administrative data base. For Public Housing, these data are supplemented by material collected by the CMHC evaluation division in 1986 and for Ontario Public Housing, by Blue book information.

estimate of lower than average expenditures in that province. Re-enforcing this hypothesis, the fitting of a polynomial indicates an increase during the first part of this period, followed by a decrease, likely corresponding to accounting changes introduced in the early 80's.

These data allow the testing of hypotheses relating to differences in program and provider[108]. In addition, significantly larger samples were obtained which included data of building related characteristics, and their impacts. Within these programs, a considerable amount of rehabilitated stock is included, some of which was identified. Unfortunately, though, for the majority of these additional projects, no differentiation is made in the characteristics of persons served. As a result, less confidence can be applied to estimated co-efficients for this variable.

The data series contains significant gaps. For example, no data were available for the pubic housing stock, outside of Ontario for the years 1987 through 1990. In addition, for the year 1987, Blue Books were unavailable for Ontario Public Housing with the exception of the eastern region of that province. As a result, the repeated measures analysis of variance model could be applied to only a relatively small number of projects (1,682) for this period. Within this group, there were an inadequate number of observations to differentiate the effects of 2 regions--Prince Edward Island and the Territories, and, by definition, no analysis was possible for the Post 1986 portfolio.

a. Replacement Expenditures

With the inclusion of this stock, and with the aging of the social housing portfolio, the number of projects reporting replacement expenditures increases substantially. As would be expected, the estimating power of these models substantially improved, although only between 20% to 30% of total variation in expenditures was captured.[109]

Table 7.16
Estimated Impacts of Building and Household Characteristics on Replacement Expenditures, 1986-1992

		EFFECT OF:											
Yr.	R^2	Const.	Age	Remote	Family	Log Pop	% Row	% Hostel	Elect. Heat	Unit Size	Shingle Roof	Rehab	Past Yr. Expend.
86	23%	1,055	27	84	68	-10	39	NS	NS	NS	105	NS	NS
87	24%	392	7	NS	216	NS	NS	-65	-77	NS	NS	NS	NS
88	28%	929	21	102	104	NS	80	NS	-34	NS	NS	NS	NS
89	29%	1,248	25	133	95	-9	NS	NS	-114	NS	NS	NS	0.002
90	30%	608	13	NS	201	NS	NS	-61	NS	NS	100	NS	NS
91	20%	968	24	93	NS	-8	NS	NS	-61	NS	NS	217	NS
92	29%	1,341	33	92	166	-13	109	NS	-45	35	NS	NS	NS

108 Type of provider cannot be isolated for projects in the Community Based Program. These are roughly split between community non-profit organizations and municipal housing corporation.

109 Some of this improvement may be an artifact of differing reporting conventions and requirements among programs. For example, replacement expenditures in the Limited Dividend Program are consistently lower than those in the Public Housing Portfolio, although projects in these programs are of comparable age. This may be related to the requirement for Limited Dividend providers to obtain financing for large capital projects using means outside the Program.

Table 7.16 (continued) Estimated Impacts of Province/Territory on Replacement Expenditures, 1986-1992											
	PROVINCE										
Yr	Nfld	PEI	NS	NB	Queb	Ont	Man	Sask	Alta	BC	Terr.
86	82	20	-99	-8	-12	164	-141	37	-134	162	130
87	103	-127	-7	-35	-78	-17	-33	160	-22	2	49
88	50	-167	16	18	-4	32	6	221	-22	36	-190
89	58	-142	-126	0	-25	55	8	222	-37	27	-47
90	28	-98	-51	-6	-75	14	38	185	-9	32	-62
91	-49	-210	-33	-73	-132	6	-53	-73	-99	-8	721
92	63	-151	-87	81	-28	310	68	216	-195	160	-438

Table 7.16 (continued) Estimated Impacts of Program and Type of Provider on Replacement Expenditures, 1986-1992									
	PROGRAM					PROVIDER			
Yr	Public	Limited Dividend	Comm Based	Sect. 95	Post 86	Co-op	Private Non-Profit	LHA/ Mun	Aboriginal
86	330	-294	-104	68	NS	NS	NS	NS	NS
87	623	-265	-179	-178	NS	NS	NS	NS	NS
88	751	-393	-240	-117	NS	NS	NS	NS	NS
89	531	-335	-144	-31	-22	39	-42	-48	50
90	586	-252	-117	-98	-119	8	-24	-38	55
91	608	-394	-173	-22	-27	NS	NS	NS	NS
92	413	-447	-145	72	107	50	-74	-17	40

As with previous results, two variables were important in explaining variance in replacement expenditures:

- Project age consistently positively influenced replacement expenditures. Estimates ranged from $7 to $33 per year per unit--consistent with those solely obtained using Public Housing data.
- In six of seven years, the presence of family housing continues to have a positive influence on replacement expenditures, ranging from $68 to $201 per unit. Year to year results vary to a greater extent than those obtained using solely Public Housing data for the prior period.

An additional three variables had effects which were strong but not as consistent:

- As in previous periods, population size had a negative effect on replacement expenditures, in four of seven years. Co-efficients ranged from -$8 to -$13, smaller in magnitude than those estimated in prior periods. The estimated effect of having a building in a city of 100,000 was a reduction of replacement expenditures of between -$12 and -$16 in comparison to a town of 10,000.

- In five of seven years, location in a remote community had a positive effect on average per unit replacement expenditures, ranging from $84 to $133. This was substantially above the effects estimated for Public Housing during the previous period.
- Also in five of seven years, projects which were heated electrically tended to have lower replacement expenditures than those with other types of heating systems. In comparison to projects with gas/oil systems, expenditures per unit were lower by $34 and $114.

Finally, three variables had estimated significant effects on replacement expenditures at two or three times:[110]

- Estimated expenditures for row housing were higher than those of other housing in three of seven years. For projects which were completely composed of row housing, estimated replacement expenditures were $39-$109 per unit higher than projects with no row housing. This variable was only found to be significant in previous regressions for Ontario Public Housing during the 1970's.
- Estimated replacement expenditures in projects with hostels were lower than those of other projects in two years. Hostel project replacement expenditures were lower by between $61 and $65 during these two years.[111]
- Projects with shingled roofs had estimated per unit expenditure levels which were higher than those with flat roofs in two of seven years during this period. The estimated impact of this variable was between $100 and $105 per unit during this period. The significance of this variable in the post 1985 portfolio may be a reflection of the higher proportion of the sample included here that reported roof type.

Estimated provincial variations in replacement reserves were considerably less volatile in the post 1986 data. No consistent pattern emerged, though, which was congruent with the hypothesized relationships. While there were statistically significant differences among the provinces overall, a number of provincial expenditure patterns were extremely similar. Saskatchewan had co-efficients which were consistently and significantly above the mean, reversing the 1979-85 results, and only Alberta and Prince Edward Island were consistently below, more in line with earlier results. Meanwhile, the Territories co-efficient fluctuated erratically, from $721 above the norm to $438 below. This may reflect the dual effect of a significant amount of new construction during this period and the considerable replacement expenditures stemming from accelerated deterioration (see INAC (1990) and IUS (1986)).

Program type had a considerable influence on replacement expenditures. This influence was more consistent and larger than the effect of regional variation. While programs were in effect during

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[110] There were also significant co-efficients in a single year for two other variables:

- Past year maintenance expenditures had a positive effect on replacement expenditures in 1989, in line with results during the 1979-1985 period. The effect was extremely small (approximately $1 per unit).
- Rehabilitated buildings had estimated replacement expenditures which were $217 higher than other building in the 1991 results. Only for the period 1988-1992 were there a sufficiently large number of observations to allow for the adequate estimation of this co-efficient for the period 1988-1992.

[111] As with Limited Dividend housing, this may be a reflection of the requirements in many locales, depending upon financing from outside program resources for obtaining funds for capital projects.

distinct periods and did not overlap significantly the effect of program had considerably more to do with what was allowed as a replacement/modernization/improvement expenditure, than did the age of the program. Projects in the Public Housing portfolio had significantly higher replacement expenditures, holding all else constant, than those in other programs, averaging between $300 and $600 per unit above the mean. In contrast, in the early programs where provisions were relatively scant--Limited Dividend and Community Based expenditures were considerably smaller--consistently between $250 and $450 below the mean in Limited Dividend projects and $30 and $175 in the Community Based projects. Projects in the later, Section 95 program, where replacement reserve provisions were more generous, lay somewhere in between. In post 1986 projects, sufficient data were only available for projects in the period beginning in 1989. During that time, expenditures were very similar to those in the Section 95 program, averaging just below the mean. In the next section, it will be shown that the rank order of maintenance expenditures by program is reversed, likely indicating that the surrogate for replacement expenditures--non-recurring expenditures includes a significant amount of what would be considered or allotted to maintenance work in the non-profit sector.

Type of provider had a relatively small impact upon replacement expenditures. In four of seven years, differences among providers could not be differentiated. Throughout this period, there was though, a fairly consistent ranking of replacement expenditures among providers. In the three years, 1989, 1990 and 1992, where expenditure patterns could be differentiated Aboriginal and Co-op providers were at one end of the spectrum and non-profit/LHA/municipal providers at the other end. Co-op/Aboriginal providers had expenditures that averaged between $8 and $50 per unit above the mean while LHA/municipal and non-profit provider expenditures were below the average, ranging from -$17 to -$74 per unit.

Turning to the application of the repeated measures models, many of these results are re-iterated:

- The estimated average effect of aging on replacement expenditures was $12 per year.
- The estimated effects of family housing were considerably higher, averaging $905 per unit
- Having electric versus gas/electric heat was estimated to reduce average replacement expenditures by $332
- Row housing expenditures tended to be higher, on average, than those of other housing forms ($81 per unit where the project was totally row in contrast to no row housing).[112]

Using this block of data, the average effects of population and location in a remote locale were not significantly different from zero.

Results which isolate the average from the trend over this period indicate more consistently the hypothesized ordering of provincial effects. Generally, expenditures in the prairies tend to be lower than those in the Maritimes. Québec's expenditures also tend to be relatively low. Newfoundland and Labrador, with a considerable number of projects in more remote areas and high material costs registers relatively high replacement expenditures.

[112] The effects of detached housing and hostels point in the correct direction, but because these types of dwellings make up a relatively small part of the portfolio, and because expenditures on replacements are relatively small, these impacts cannot be differentiated.

Table VII.17
Estimated Overall and Within Era Effects of Building and Household Characteristics on Replacement Expenditures, 1986-1992

Overall Effect:				
Constant	Age	Family	Electric Heat	% Row
1667	12	905	-332	81
Within Era Effects				
Component	Age	Age x Family	Age x Heat	
Linear	242	449	NS	
Squared	NS	-141	84	
Cubed	NS	485	NS	

Table VII.17 (continued)
Estimated Overall and Within Era Effects of Province/Territory on Replacement Expenditures, 1986-1992

Overall Effect:									
	Nfld	PEI/NS	NB	Queb	Ont	Man	Sask	Alta	BC.
	304	86	-117	-150	-26	-168	435	-288	-74
Age by Province Interaction									
Linear	NS	NS	NS	NS	NS	NS	NS	NS	NS
Squared	NS	NS	NS	NS	99	NS	NS	NS	NS
Cubic	NS	NS	NS	15	NS	NS	NS	NS	NS

Table VII.17 (continued)
Estimated Overall and Within Era Effects of Program/Providers on Replacement Expenditures, 1986-1992

Overall Effect:								
	Program				Provider			
	Public	L.D.	Comm. Based	95	Co-op	Non-Profit	Municipal /LHA	Aboriginal
	1701	-883	-411	-406	-133	-148	-52	335
Age by Program and Provider Interactions								
Linear	165	-95	-31	-38	NS	NS	NS	NS
Squared	308	-118	-136	-53	93	81	1	-175
Cubic	389	-146	-136	-107	NS	NS	NS	NS

Results indicating the overall effects of Program during this period reflect the results of repeatedly using single year data, in that projects built under the Public Housing programs had significantly higher replacement expenditures that those built under any other program. The estimated effects of program differences are, though, considerably larger. Further, projects operating under the Limited Dividend program reported extremely low levels of replacements, significantly lower than those operating under the Community Based Program.[113] Further, projects operating under Community Based and Section 95 programs had, on average, almost identical levels of replacements, holding all other factors equal; these averaged an estimated $1290 per unit less than in Public Housing but $470 higher than in the Limited Dividend stock, holding other factors equal.

The overall effect of differences in provider type are considerably different than the year to year results. Aboriginal project expenditures remain above the mean--but by a substantially larger amount ($335), and Non-profit expenditures tend to be below the mean--by $148 per unit. Using this model, though, Co-op, Non-profit and Local Housing Authority/municipal effects cannot be distinguished. The average and the range of Co-op and Non-profit projects are almost identical--with Co-op projects having a marginally lower mean. Local Housing Authority/municipal replacement expenditures are, on average, higher--but not to the degree that they can be distinguished as different.

Over this period, replacement expenditures tended to increase linearly over time. Estimated expenditures for family versus non-family housing also were estimated to have increased substantially during this period but with a the path that was curvilinear, indicating a more complex path. Further, there was a weak but significant curvilinear increase in effect of electric versus gas/oil fuel systems, estimated as $84 over this 7 year span.

In examining the effects of provincial variations with time, there was only one significant trend--there were greater fluctuations in Ontario replacement costs during this period than those of other provinces. Table VII.17 indicates a U-shaped distribution of differences in expenditures which could be attributed to the Ontario Portfolio, with a slight divergence in expenditure levels vis-a-vis other provinces at the end of period.

Changes in expenditures among projects administered under different programs increased substantially. The gap between Public Housing and other delivery mechanisms in replacement expenditures increased substantially. Further, projects in Limited Dividend and Community Based programs behaved in a similar manner, while those in the Section 95 program tended to increase relative to those in the Limited Dividend and Community Based. programs. In contrast, the gap in expenditure due to difference in provider tended to narrow, with differences in the Aboriginal portfolio and other portfolios decreasing, especially relative to Co-op and Non-profit projects.

b. Maintenance Expenditures

With the inclusion of stock from the non-profit sector, the power of the model characterizing maintenance expenditures dropped substantially. The proportion of variance in maintenance costs explained by the 1979-1985 models varied from 41% to 70%. In the post 1985 regressions, the range was between 15% and 24%. Part of the difference in the two sets of regressions is likely a result of how expenditures are allotted. In the non-profit sector, minor replacement expenditures and work not included under replacement reserve provisions, becomes part of

[113] This is very little data evidence in the CMHC data available of Limited Dividend Projects expenditures for replacements during this time period.

maintenance expenditures. There are also substantial changes in the variables which explain a significant proportion of variance in maintenance expenditures.

Table VII.18
Estimated Impacts of Building and Household Characteristics on Maintenance Expenditures, 1986-1992

		EFFECT OF:												
Yr.	R^2	Const	Age	Remote	Family	Log Pop	% Apt	% Det	% Row	% Hostel	Elect. Heat	No Elev.	Rehab	Past Yr. Expend
86	23%	1,173	13	226	88	10	NS	50	NS	112	NS	81	153	NS
87	15%	546	7	NS	69	12	NS	NS	NS	144	NS	59	NS	NS
88	17%	603	5	NS	104	16	NS	NS	NS	197	NS	56	NS	NS
89	15%	699	4	NS	30	13	-109	NS	NS	159	NS	41	NS	-.003
90	19%	962	4	333	NS	21	-168	NS	NS	107	NS	81	148	-.002
91	24%	981	9	375	67	27	-52	NS	-92	210	NS	NS	192	-.002
92	22%	806	2	348	NS	22	-60	NS	NS	134	-52	85	89	NS

Table VII.18 (continued)
Estimated Impacts of Province/Territory on Maintenance Expenditures, 1986-1992

	PROVINCE										
Yr	Nfld	PEI	NS	NB	Queb	Ont	Man	Sask	Alta	BC	Terr
86	303	119	-102	-19	-414	-339	-175	-188	-125	-249	1136
87	223	431	-16	-191	-269	-43	-195	-339	-142	-242	759
88	97	487	-127	-194	-276	-15	-32	-409	-148	-232	842
89	116	819	65	-224	-168	-2	-50	-461	-173	-280	362
90	311	449	-79	-172	-155	-88	-9	-342	-97	-182	174
91	85	306	-115	-165	-224	25	-20	-314	-98	-163	677
92	-104	192	-5	-341	-320	-170	-158	-348	-114	-196	1565

Table VII.18 (continued)
Estimated Impacts of Program and Type of Provider on Maintenance Expenditures, 1986-1992

	PROGRAM					PROVIDER			
Yr.	Public	Limited Dividend	Comm Based	Sect. 95	Post 86	Co-op	Private Non-Profit	LHA/ Municipal	Aboriginal
86	NS	NS	NS	NS	NS	-40	84	-132	88
87	-264	37	167	60	NS	-162	12	14	138
88	-244	83	130	32	NS	-177	-1	-38	217
89	-82	104	178	70	-268	-335	-124	-3	462
90	-200	106	102	37	-44	-324	-86	-43	454
91	-258	23	89	94	52	-351	-131	-20	503
92	-60	85	74	-13	85	-338	-98	-56	493

In total, four variables provided significant power to the maintenance model during this time:

- Building age, again, consistently is important, and effects are in the hypothesized direction. The estimated effect of building age, though, is considerably reduced, in comparison with results using Public Housing data only. Co-efficients for regressions using data from this period varied from $2 - $13 per unit per year, with an average of $6 per unit per year in contrast to a range of between $9 and $45 for the period 1979-1985, an average of $23. Given the considerable difference in these co-efficients, further analysis was undertaken of the interactions between program, provider and effect of aging and these are described below.
- The effects of population size were consistently important in explaining differences in maintenance costs. The co-efficients measuring the effect of the natural logarithm of population size varied from $10 per unit to $27, indicating that maintenance costs for a unit in a city of 100,000 were estimated to be between $12 and $40 higher than those for a unit in a city of 10,000. These results lie below those estimated for Ontario Public Housing during the 1973-1978 period, but well above those of the entire Public Housing portfolio for the period 1979-1985.
- With the inclusion of a considerable amount of stock containing hostel units, projects with these units were estimated to have maintenance costs on a per unit basis that were considerably higher than was the case in non-hostel projects. Projects that were completely comprised of hostels had estimated maintenance expenditures per unit that were between $107 and $210 higher than projects with no hostel units, holding all else constant.
- Distinguishing buildings with and without elevators had a consistent effect. In six of sever years, significant amounts of the variance in maintenance costs could be explained using this variable. Buildings <u>without</u> elevators had consistently higher operating costs per unit than others. Estimated differences ranged from $41 to $85 per unit, considerably less than for earlier periods where data was solely from Public Housing sources.

An additional five variables had effects which were strong but not as consistent:

- Projects with family housing, in five of seven years had estimated maintenance costs that were higher than other projects. The effect of including family housing was substantial, varying from $30 to $104 per unit, but was considerably below that of results reported for earlier periods. The diminished effect of differentiating family housing from other types of housing may be a result of two major factors:
    - There was a small number of projects which specifically identified non-elderly singles and persons with disabilities as residents. In many of these circumstances, there are special maintenance requirements (for example, greater wear and tear to flooring and baseboards due to wheelchair use). An insufficient number of these projects was identified, though, to allow testing of related hypotheses.
    - In post data, a much larger proportion of projects were mixed, including both seniors and family housing and other household/special needs groups, including, for example, non-elderly seniors and disabled persons.
- Housing in remote locations was estimated to have significantly higher maintenance costs

than was other housing, in four of seven years.[114] The effect of remote location was estimated to be between $226 and $375 during this time. Estimates for the 1990 to 1992 period were substantially higher than those in the period 1979 to 1986.

- For the first time, beginning in 1989, the presence of apartments in projects has a distinct, negative effect on maintenance costs per unit. Prior to this period, the high level of correlation between apartments and other factors, such as presence of an elevator, electric heat, and presence of seniors housing, reduced the unique explanatory power of this variable. With greater diversity in housing construction and social mix within projects, the ability to differentiate this housing emerged. During four years, between 1989-1992, projects that were totally made up of apartments had estimated maintenance costs that were between $52 and $168 less per unit than projects with no apartments, holding all else constant.
- For four of seven years, estimated maintenance expenditures in rehabilitation projects were higher than those in other projects by between $89 and $148 per unit.

In addition:

- During three of seven years, projects which had replacement expenditures in the past year tended to have lower maintenance costs in the following year. The effects on a per unit basis as in prior periods were even smaller than in earlier years, averaging approximately $1 per unit.[115]

While the effect of provincial/territorial location was considerable, it was, in many circumstances likely linked to factors such as differences in reporting. Expenditures on maintenance in the Northwest Territories were well above those of other provinces, though, averaging $787 per unit above the norm during this period. At the other extreme were expenditures in the prairies and in Québec which consistently were below the mean. In Ontario, while replacement expenditures tended to be low, maintenance costs, vis-a-vis other provinces, were relatively high.

Program effects were slightly more open to interpretation, except in 1986, when no significant difference could be found among the programs. Maintenance expenditures in Public Housing were significantly lower than those in other portfolios on a per unit basis (averaging $223 per unit per year lower than those in the Section 95 program, which the second least expensive, during the period 1987-1992). These lower expenditures to some degree counterbalance much higher expenditure levels on replacements. Estimated expenditure levels in the Community Based Program were, on average, the highest, averaging $53 per unit above those in the Limited Dividend portfolio, which in turn were on average higher than those in the Section 95 program

[114] Data for a large proportion of the Public Housing stock were not available for the period 1987-1989, considerably reducing the number of projects in remote locations. During these years, the effect of remote location was not significant.

[115] In addition, for a single year, co-efficients were significant for three other variables. Projects fully composed of detached housing were estimated to be more expensive than projects with no detached housing, by $50 per unit in 1986, in line with earlier results based solely upon Public Housing data. Projects with electric heat tended to have lower maintenance costs than others, in 1992, in line with earlier regression results. The estimated effect was -$52, in comparison with those having gas/oil heat. Lastly, in 1991, projects with row housing was seen to be relatively inexpensive, in comparison with other housing forms, by a maximum of $92. This single co-efficient was not in line with past estimates.

(by $28 per unit). A large enough data set to make reasonable inferences was only available for the period between 1989 and 1992 for post-86 projects. During that period, there was considerable movement in maintenance costs from being among the lowest towards being indistinguishable from other projects.

Clear differences occurred in maintenance costs in comparisons among providers, and in line with hypothesized relationships. Maintenance costs among aboriginal providers were considerably higher than those of other providers, holding all else constant. The estimated difference between aboriginal providers, and the next most costly provider, Local Housing Authorities/Municipalities averaged $386 per unit. LHA/Municipal providers were an unambiguous second, although private profits were only an average of $10 per unit less. Finally, Co-ops were considerably below all other providers. There, expenditures were an estimated average of $198 per unit below that of Private Non-profits. The low estimated cost of maintenance in co-op housing may be a reflection of the use of volunteer, member labour. (see also CMHC (1992)). Part of this difference though, may be attributable to the smaller size of Co-ops and the greater likelihood of having staff who handle multiple functions and who thus are not able to attribute labour to maintenance related accounts.

Because there was a substantial reduction in the magnitude of the estimated effect of age on maintenance with the introduction of data from the various non-profit programs, it was decided to experiment with models which included interaction effects between aging and type of program and provider. While results were similar, the interaction between program and age explained a significantly higher proportion of variation in maintenance expenditures. Table VII.19 shows the result of this experiment for the years 1987 to 1992, where this interaction effect provided significant results. It shows the combined effect of aging and the interaction between aging and program.

Within the Public Housing portfolio, the relatively substantial effects of aging had, during this time, disappeared. In fact, for the very limited data available for the 1987 to 1990 period, the effect of age could not be differentiated from zero with 99% confidence.

Table VII.19
Estimated Effect of a Year of Aging on Maintenance Expenditures for Projects Administered Under Various Federal Programs

	1987	1988	1989	1990	1991	1992
Public Housing	-1	5	-4	4	13	7
Limited Dividend	-6	-10	-8	-13	-6	6
Community Based	19	18	36	33	11	7
Section 95	25	27	23	15	10	22
Post 86			31	167	106	83

More perplexing are the effect of the interaction between age and Limited Dividend projects on maintenance expenditures. During much of this period, maintenance expenditures per unit were estimated to actually have decreased with age. It may be that for the older projects in this and the Public Housing portfolio, increases in maintenance costs are substantially damped, and that instead, considerable replacement expenditures have been substituted.[116] These results are consistent with expenditures patterns reported in private, owner occupied housing, both in the United States and in Canada (Stewart (1984), Shear (1984) and results derived from Statistics Canada (1991a)). In the projects administered under the newer, Community Based and Section 95 Program, the effects of aging on maintenance costs were similar. In the relatively new Post 86 projects, though, there is evidence of a substantial increase in maintenance costs with age over the first few years of these projects.

The results of the analyses of the repeated measurement of maintenance expenditures produces similar, but more parsimonious results than the individual year analyses (Table VII.20):

- Units in older buildings had maintenance costs which increased an average of $6 per year of age.
- Units in larger centres were more expensive. Projects in cities with a population of 100,000 had maintenance costs which averaged $18 more than those in cities of 10,000.
- Apartment units were considerably less expensive to maintain than others, by an average of $114 per unit.
- Family housing ($376) and units in rehabilitated projects ($506) were considerably more expensive. The effects of family units and rehabilitation are, as in the other repeated measures models noted above, substantially higher than the estimates produced using individual years of data.

Two major differences occur when the single year and repeated measurement models are compared. Firstly, the estimated effect of hostel units and non-elevatored buildings on maintenance expenditures is not significantly different from aero, with 99% confidence, despite strong results in the annual models. The reduction of the effect of hostel units is largely an artifact of having very few hostel projects where a full seven years of data were available. Part of this is a reflection of the large proportion of hostel projects which are relatively new. Secondly, there is a loss of the non-elevatored co-efficient largely. This likely reflects the high level of correlation between elevators and apartments.

Provincial results using repeated measures were similar to those using year by year data. Ontario reported the highest estimated maintenance expenditures ($463 above the mean), while expenditures in Manitoba, Saskatchewan and Québec were substantially below the mean. There was one major change--in the relative position of Alberta, which along with Nova Scotia, were substantially above the mean.

Estimated between group differences, isolating program and provider differences using repeated measures, were somewhat higher but in the same direction using repeated measures as those using single year data. Maintenance costs in the projects administered under the Community Based and Section 95 programs were extremely close and were again, considerably higher than those in the Public Housing portfolio (an average of $470 per unit), offsetting some of the large

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[116] This hypothesis was tested and it was found that in the Public Housing portfolio, the combined effect of age and type of program was substantially greater when replacement expenditures were examined. For Limited Dividend housing, replacement also significantly increased with age, but at a rate substantially below that of Public Housing, and in line with the Community Based and Section 95 projects.

differences in the opposite direction in replacement expenditures. Again, though, reported maintenance expenditures were higher (by an estimated $125) than in the Limited Dividend projects.

Table VII.20
Estimated Overall and Within Era Effects of Building and Household Characteristics on Maintenance Expenditures, 1986-1992

Overall Effect:					
Constant	Age	Family	Rehabilitation	Ln Population	% Apartment
2367	6	376	516	14	-152
Within Era Effects					
Component	Age	Age x Family	Age x Rehab		
Linear	466	NS	NS		
Squared	NS	NS	NS		
Cubed	NS	NS	NS		

Table VII.20 (continued)
Estimated Overall and Within Era Effects of Province/Territory on Maintenance Expenditures, 1986-1992

Overall Effect:									
	Nfld	PEI/NS	NB	Queb	Ont	Man	Sask	Alta	BC.
	-157	294	-140	-228	463	-169	-256	266	-72
Age by Province Interaction									
Linear	-178	NS	NS	NS	63	NS	NS	NS	NS
Squared	NS	NS	NS	NS	-47	NS	NS	NS	NS
Cubic	NS	124	NS	NS	NS	NS	NS	NS	NS

Table VII.20 (continued)
Estimated Overall and Within Era Effects of Program/Provider on Maintenance Expenditures, 1986-1992

Overall Effect:								
	Program				Provider			
	Public	L.D.	Comm. Based	Sect. .95	Co-op	Non-Profit	Municipal /LHA	Aboriginal
	-326	26	157	143	-576	-279	-680	1535
Age by Program/Provider								
Linear	NS	NS	NS	NS	-312	-331	-386	1029
Squared	-136	76	NS	NS	61	NS	NS	-142
Cubic	NS	NS	NS	NS	NS	NS	NS	NS

Housing administered by groups providing housing to Aboriginal peoples was considerably more expensive to maintain than any other type of housing, averaging $1814 per unit more than the next most expensive--private non-profit housing. Co-op housing and Local Housing Authority/municipal housing reported the lowest per unit maintenance costs, with private non-profit expenditures averaging $300 more per unit than co-ops and $400 more per unit than LHA/municipal housing. Again, lower expenditures in LHA/municipal housing on maintenance partly counterbalanced higher replacement expenditures.

During this period, reported expenditures on maintenance per unit increased substantially over time, by an average of $66 per unit. There were no significant changes in the effects of rehabilitation or type of household over time. In contrast, during 1979-1986, there were slight increases in the differences between family and seniors housing maintenance expenditures over time.

During this period, relative expenditure levels decreased vis-a-vis other provinces in Newfoundland and Labrador while PEI/Nova Scotia projects moved to a point of being relative high cost providers. Further, despite a dip vis-a-vis other provinces in maintenance expenditures during the middle part of this period (represented by the negative squared term in Table VII.20), the gap between Ontario and the remainder of the country in maintenance expenditures increased slightly (as indicated by the slightly higher linear co-efficient).

Maintenance expenditures during this period declined by a total estimated $136 in Public Housing vis-a-vis other housing, while limited dividend expenditures increased slightly, as would be expected for this older portfolio. With the aging of Aboriginal projects, maintenance costs increased substantially. In contrast, maintenance costs declined by very similar amounts in other portfolios, led slightly by LHA/Municipal projects.

C. Time Series Analyses

Two analyses were undertaken using time series of expenditures for projects where at least 16 years of expenditure data were available. The requirement of a sufficiently long series led to the restriction of the scope of this analysis to Ontario Public Housing projects built before the mid-70's. First, individual project series of replacement and maintenance expenditures were regressed against time using a series of non-linear functions. The objective of this exercise was to determine if there were functional forms which best reflected a large proportion of cases, long term trends and whether co-efficients for these functions were, generally, interpretable. Secondly, maintenance and replacement expenditure series were grouped in terms of vintage and years of data available. The goal of this exercise was to determine if vintage effects[117] could be deciphered and whether, holding vintage constant, general long term trends could be identified in expenditure patterns.

1. Individual Project Regressions

A total of 408 maintenance and replacement project expenditure series each regressed against date of expenditure. Each series was initially deflated using the Ontario Consumer price index.

[117] Vintage effects may include differences in a wide range of factors including architectural characteristics of the period to major re-focusing of programs. For example, the move away towards seniors housing in the Public Housing program during the 1970's and corresponding changes in built form may have had considerable effects on the relative size of present day maintenance and replacement requirements.

Best fits were then estimated using each of the eight functional forms described in the previous chapter, Table VII.21 summarizes the percentage distribution by type of "best fitting" curve.

For 20% of project replacement and 37% of maintenance expenditure patterns, none of hypothesized relationships with time fit well enough to reject the null hypothesis that the pattern was produced randomly (using a 99% confidence band). Second and third degree polynomial fits produced the "best fits", most often. Over a third of replacement expenditure patterns and close to a half of maintenance expenditure patterns over time could be relatively well represented using these polynomials. A compounding function, the surrogate for the Gompertz distribution produced "best fits" for another 23% of replacement expenditure regressions and a compounding function for 19% of maintenance expenditure regressions. This may indicating that in a significant number of cases, a model akin to that which is often best in modelling the effects of human aging among seniors on health care costs as well as mortality may apt in many circumstances in modelling replacement and maintenance expenditures. Lastly, an S "best fit" 6% of replacement and 13% of maintenance expenditure distributions.

Table VII.21
Distribution of Best Fitting Curves--Project Regressions
Sample of Ontario Public Housing Stock

	Replacement Expenditures	Maintenance Expenditures
No Fit rejected null hypothesis with 99% confidence	20%	37%
Linear/Weibull[118]	12%	5%
2nd. Degree Polynomial	17%	31%
3rd. Degree Polynomial	13%	13%
S Curve	6%	13%
Power Function	10%	0%
Compounding	23%	1%

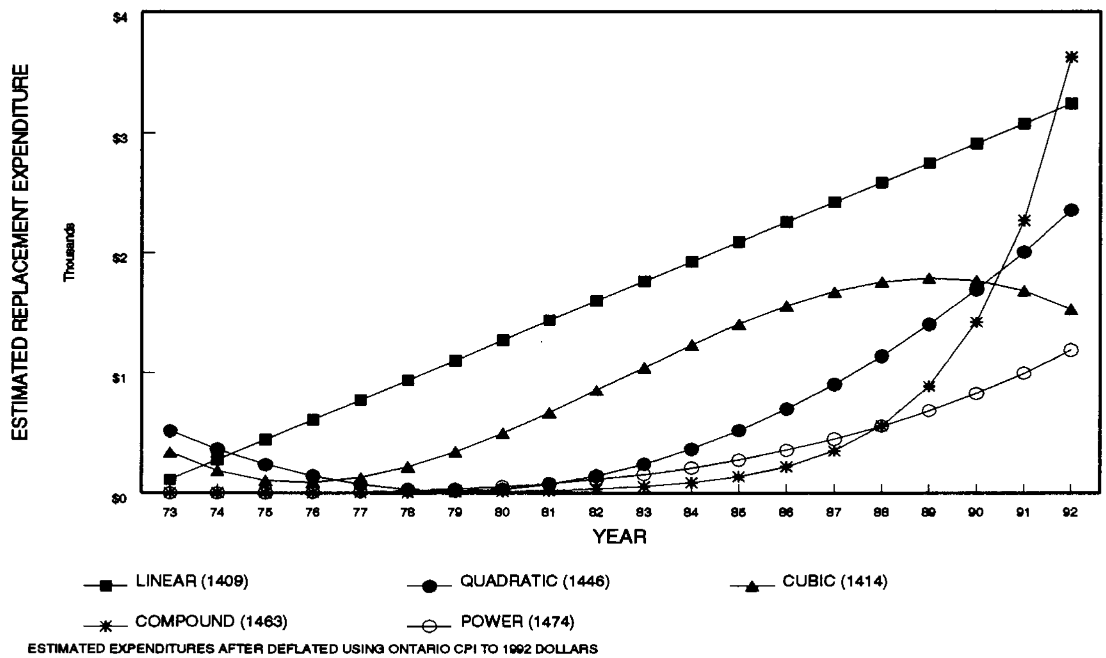
There is a tendency in the individual regression results for "significant" relationships to occur only where there are relatively large expenditures on replacement and/or maintenance expenditures. Overall, in cases where there is no "good fit", expenditures are on average, significantly lower than in other projects. In other words, fit is more likely to be achieved where there is sufficient variability to decipher trends from "error". As a result, in the following, estimated expenditure levels, particularly in latter years tend to be higher than those which would be developed using the MANOVA models discussed above, and should thus be viewed with caution.

[118] It was possible to fit Weibull distributions to only a very limited number of distributions because the non-linear regression algorithm used often did not converge on an adequate best fitting curve. Almost invariably, where a Weibull distribution could be fit, so too could a linear distribution and the resultant line/curve were very similar. Further, the differences in the goodness of fit in most cases were marginal. As a result, the combined results of fitting linear/Weibull distributions are reported in this table.

a. Replacement Expenditures

Figure VII.1 provides examples of fitted curves for a sample of 5 Public Housing projects for which at least 19 years of operating data were available. These projects were largely began operating between 1966 and 1973. Each reflects a class of best fitting distributions, representing at least 10% of the projects examined. Projects represented here and in the following figure are "well behaved". In these cases there have likely been no extreme events resulting in large expenditures or, conversely, extreme long term neglect.[119] The curves shown in Figure VII.1 characterize between 60% and 70% of the total variance in replacement costs.[120] These represented characteristics of replacement expenditure patterns common in the other fit distributions:

Figure VII.1
Estimated Replacement Expenditures Over Time Using best Fitting Curvilinear Functions, Sample of Ontario Public Housing Projects



- Almost universally, a clear progressive trend of increases in real dollar replacement expenditures occurs over time.
- With relatively few exceptions, low expenditures (less than $500 per unit per year) during the first decade of operation.
- In many cases (characterized by best fitting quadratic and cubic functions (shown for cases 1466 and 1414), an initial period of moderate levels of replacement expenditures, followed by a dip during middle age occur, indicating the hypothesized bath tub effect.
- For a significant minority of buildings, a long hiatus of low replacement expenditures

[119] Among roughly a quarter of projects where there was no good fit, extremely large expenditures had been undertaken over a short time span.

[120] An average of 38% of the variance in replacement expenditures was characterized by the curves fit.

occurs, followed by a surge in replacement expenditures (characterized by fitting of the power services for project 1474), or a surge in middle age followed by a relative lull (as characterized by the cubic fit for 1414).

- An increasingly wide variance in the range of expenditures occurs with aging.[121]
- Best fitting curves for a small majority series indicate that an increasing rate of change in replacement expenditures with time (as illustrated by the quadratic, compounding and power function "best fits" shown in Figure VII.1).

This last point is also significant in explaining the generally increasing proportion of variance "explained" in the single year replacement expenditure regressions reviewed above. Replacement expenditures shown in Figure VII.1 are, for most projects, relatively small and infrequent during the first years, particularly following the initial years (often characterized as a shake-out period). Factors which may be significant in accounting for differences in replacement expenditures during this time may have a relatively minor part to play. In the regressions reviewed in Section D.1 for the period 1973-1978, the great majority of buildings examined were new. As a result, the regression models were particularly weak. Over time, the significance of these and other factors (many of which can be considered as random) in extending or curtailing individual building component lives come to the fore, and as shown above, variability in replacement expenditures increases. For example, the effect of the wear and tear of families versus seniors on housing would seem to be an increasing concern from the evidence provided above.

ii. Maintenance Expenditures

Figure VII.2 provides a sample of 4 curves which characterize maintenance expenditures over time. In each case greater than 50% of the total variance of expenditures was characterized by these curves. As with the replacement expenditure regressions, these projects were completed in the decade prior to 1966-73 and included at least 19 years of operating data.

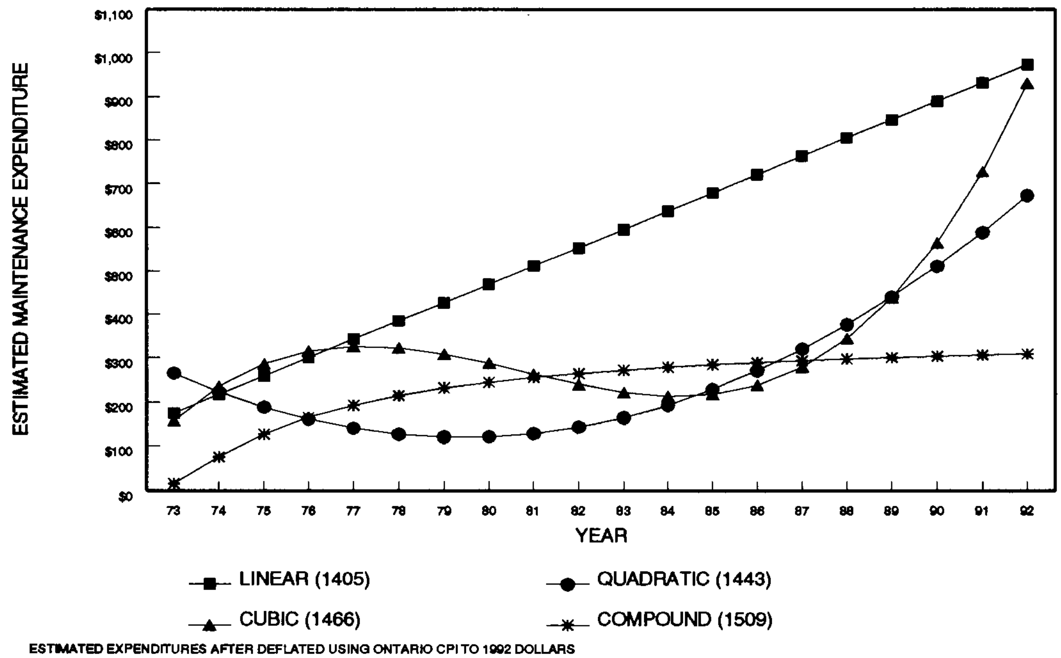
As noted above, in 37% of projects examined, the range of functions utilized could not be used to characterize a sufficiently large amount of the variation in these patterns to reject a null hypothesis with 99% confidence. Despite maintenance expenditures being more frequent and consistent, these results are not quite as "clean" as the replacement regressions. An average of 39% of variation was explained, similar to that of the replacement expenditure regressions. There were relatively few regressions where over half the total variation in expenditures was characterized. There are two reasons why the maintenance regressions likely did not provide quite as clean results, on a project by project basis:

- As is clear through comparing the Y axes of Figures VII.1 and VII.2, maintenance expenditures did not vary, on a per unit basis, as widely as replacement expenditures over time. Figure VII.2 indicates that for these projects, per unit estimates of maintenance costs varied from $10 to $300, while by the middle of the second decade, costs had increased from $300 to $800. In contrast, best fitting replacement expenditures tended to settle at a lower range in the first few years of operation, but then increased substantially,

[121] As has been noted above, the utilization of data which excludes some replacement expenditures for the period 1979-1981 likely has some effect upon these estimates. In particular, the relatively strong performance of the quadratic forms, in a number of cases, showing a dip during this period may be partly a result of the use of these data.

to over $1000 per unit per year in all cases by the end of the second decade;. and

Figure VII.2
Estimated Maintenance Expenditures Over Time Using best Fitting Curvilinear Functions, Sample of Ontario Public Housing Projects



- Accounting data for the period 1979-1986 did not include approximately 15% of expenditures captured during earlier and later periods for this portfolio.[122] This is also likely the reason for the predominance of the second degree polynomial in providing "best fitting" distributions.

There are, as with the replacement regressions, strong trends characterized by these sample plots of regression results:

- Over time, maintenance expenditures tend to increase. In line with the results reported in Section D.2, above, they increase at a substantially slower rate than do replacement expenditures.
- By and large, maintenance expenditures, during the early years of a project, begin at a higher level than replacement reserves.
- In a number of situations, as with replacement expenditures, there may be a settling out period, where after a few years of operation, expenditures decline, as indicated in the quadratic and cubic fits (series 1443 and 1446).
- In a few cases (approximately 1 in 7 projects), expenditures seem to rise and fall in a wavelike fashion, possibly reflecting surges in turnover or in minor maintenance requirements (as indicated in the quadratic fit for 1446).

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[122] This estimate is based upon the comparison of a sample of Ontario Blue Book project data for this period with the CMHC Evaluation data base.

- In another relatively common situation (again 1 in 7 projects), changes in expenditures are characterized by the utilization of an S curve, (for series 1509). Here, after an initial rise, expenditures increase very slowly through the second decade of operation.

Generally, maintenance costs remain relatively steady over time. There is strong evidence here and above, somewhat mitigated by problems in accounting, that over time these expenditures increase, particularly during middle age, at a level outstripping inflation. The rates of increase of replacement and maintenance costs are, though substantially different. During the early years of these Public Housing projects, maintenance costs dominate. Beginning in middle age, somewhere in the second decade, there is some indication that replacement expenditures begin to dominate. As a result, in the Ontario Public Housing stock that in 1992 where the average age of the portfolio was 18 years, every dollar of recurring cost (maintenance) expenditure was matched by two dollars of non-recurring (replacement) expenditure.

The post 1986 results which include other, non-profit projects indicate that replacement expenditures, holding all else constant are considerably higher in the Public Housing portfolio than in other portfolios, while maintenance expenditures are lower. Further, the estimated total of maintenance and replacement expenditures is higher, holding other factors constant, in Public Housing than in other forms of social housing. Differences in management and accounting practices likely lead to a significant amount of these differences, as do differences in the nature of costs facing Public Housing providers versus other non-profit providers.[123] Yet these results also reflect broad trends in expenditure patterns in private owned and rental accommodations described in Chapter III.

2. Vintage Effects

To examine the effects of vintage, average replacement and maintenance expenditures were calculated for projects built at different points in time or "vintage", where at least 19 years of data were available or, where complete histories were available for projects that were 16, 17 or 18 years of age.

i. Replacement Expenditures

Very clear patterns emerge when replacement expenditure series are grouped and averaged by project vintage. For over three quarters of the 17 models run, where each was an average of all projects with a similar IAD date, average expenditures can be well characterized by a linear function.[124] In 3 of the remaining best fitting functions, departures from linearity were marginal. In only one regression no clear pattern could be discerned. Further, the fitting exercises produced results which replicated an average of over 60% of the variance of these series, ranging from a low of 40% to a high of 87%.

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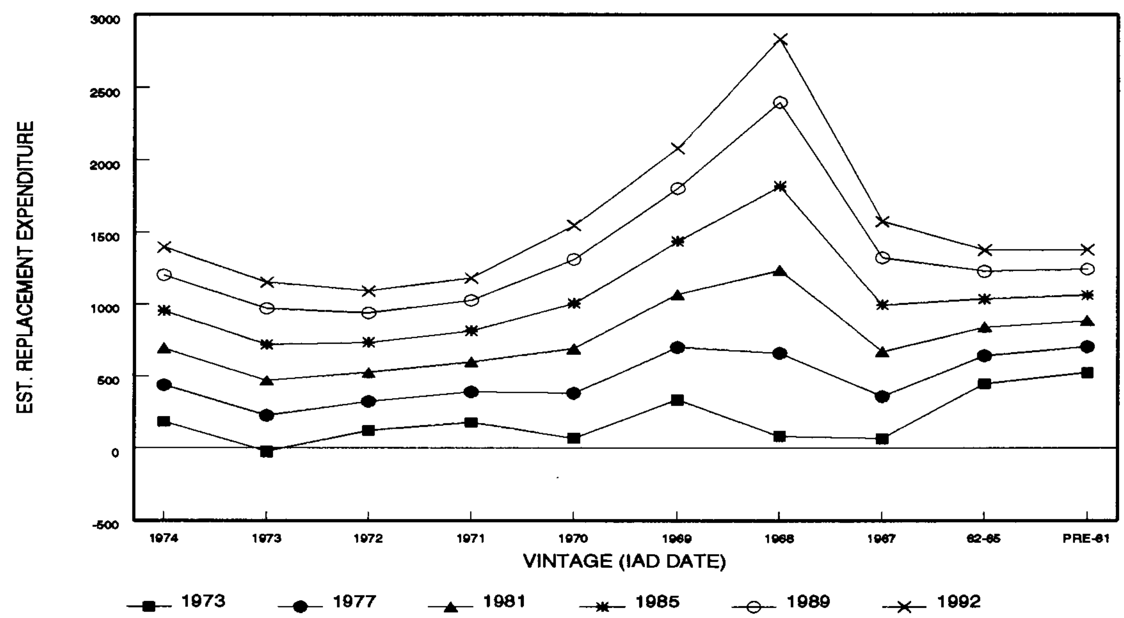
[123] For example, Sewell (1994) indicates that in many, larger Public Housing projects, waste disposal and the maintenance of access ways is the responsibility of the Local Housing Authority. These expenditures are less common for the numerous, smaller non-profits and co-operatives.

[124] Projects with sufficient data, built prior to 1978, were grouped by IAD date. Where at least 10 observations were available, classes were comprised of a single year. This was the case for projects built between 1962 and 1977. All pre-1961 building were grouped into a single category.

Figure VII.3 shows selected results of applying best fitting regression models developed for buildings of the same vintage. It indicates that, irrespective of vintage, there are clear increases over time in replacement expenditures. Yet the rate of increase over time in replacement expenditures seems to vary considerably by vintage, especially as time progresses. Buildings constructed in the late 1960's have considerably higher increases in replacement expenditures, especially during the late 1980's and early 90's. As a result, while comparisons by year yield very similar results over the period 1973-1992, the "cleanness" of the relationship between start date and replacement expenditure declines when comparisons are made of projects built at .different points. In comparing estimated replacement expenditures in 1973, a progression is evident--regressing 1973 estimates of replacement expenditures by age provide results which "explain" approximately 43% of the differences in costs. By 1992, repeating the same exercise produces no significant relationship. At this point, older projects are entering their fourth decade of operation, while younger projects are midway through their second. In line with the MANOVA results above, this suggests that over the decades, factors such as differences in client mix and building form, all of which may be vintage related play an increasingly significant role

Figure VII.3
Estimated Replacement Expenditures for Selected Years by IAD Date
Projects Built Prior to 1975 and 20 Years of History



in influencing replacement expenditures and that there is a strong requirement to take these into account in isolating age related cost differences.[125]

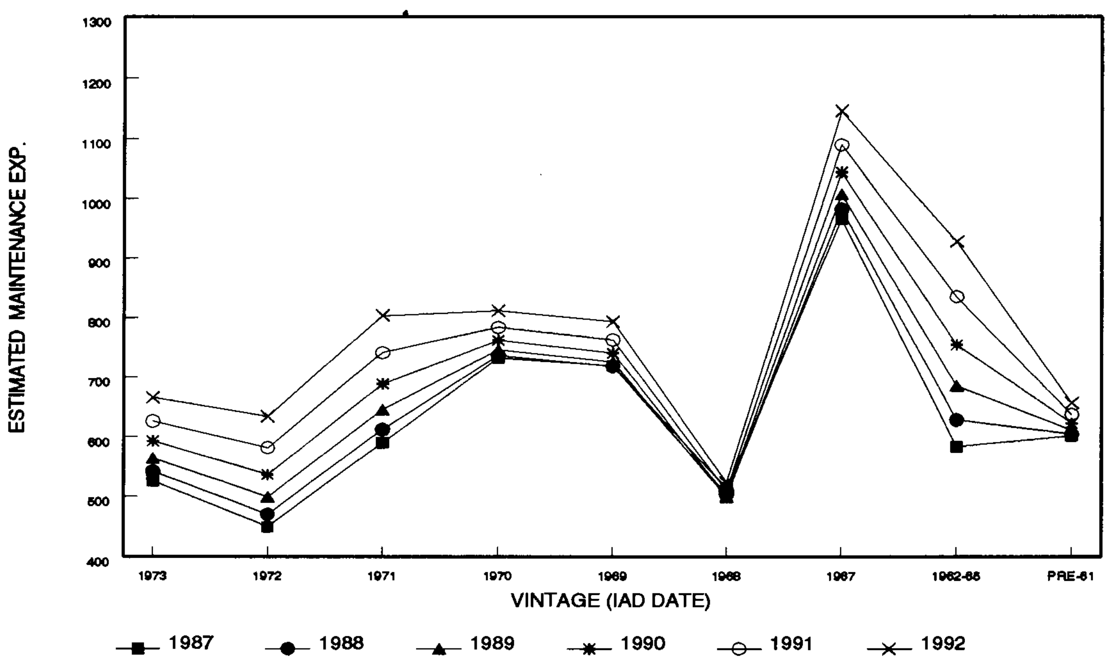
[125] Estimated replacement and maintenance expenditures tend to stand out for projects completed between 1967 and 1969 (especially those with an completion date in 1968). For projects completed in 1968, estimates of replacement costs were particularly high and maintenance costs, very low. The author was unable to decipher any clear reason for these anomalous results.

ii. Maintenance Expenditures

The results of aggregating data for maintenance expenditures by vintage were not as strong as for replacement expenditures. Where fits were achieved, an average of just over 34% of the total variance of these aggregations was characterized. Where a fit was achieved, a quadratic produced the "best" fitting line in all but one circumstance.[126] Because it relates to all projects, a dominant factor in the form and pattern of expenditures is inconsistent accounting during the middle 1980's. Best fitting quadratic regression lines consistently indicated a reduction in maintenance costs during this period, likely reflecting the exclusion of certain cost categories in the CMHC Evaluation data base. Also important, though, is the strong evidence that maintenance costs per unit do tend to increase over time, but at a rate substantially less than that of replacement costs.

Figure VII.4 shows estimated maintenance expenditures for the same projects as discussed in the last section for the period 1987-1992 only.[127] It shows, again that irrespective of vintage, maintenance costs increase over time. Contrasting Figure VII.4 and VII.3 indicates, that the maintenance costs per unit are estimated to be considerably less than for replacement expenditures. In other ways, these two figures are remarkably similar. First, as with replacement expenditures, maintenance costs in 1987 are higher in older buildings. As time progresses

Figure VII.4
Estimated Maintenance Expenditures for Selected Recent Years by IAD Date
Projects Built Prior to 1975 with 20 Years of History



[126] For the complete 16, 17 and 18 year series, best fitting lines were also achieved using a quadratic function. In these cases though, an insufficient amount of variance was explained to reject the null hypothesis that expenditures were not related to time.

[127] Earlier results are not provided because the effects of various amounts of missing data for the 1981-1986 period predominant estimates for any earlier period.

through to 1992, these gaps have decreased in magnitude. As with replacement expenditures, other vintage related factors seem to become more important with time. There is some strong evidence of vintage effects, possibly related to type of resident in comparing projects built between 1969 and 1971 and those built in 1972-73. The older buildings have higher estimates maintenance costs than would be expected given marginally older dwelling age. These results are likely related to the higher proportion of family projects included in the earlier period.

H. Summary and Conclusions

1. Univariate ANOVA Results

Univariate results showed a number of strong, consistent patterns:

- Positive relationships exist between project age, average unit size, proportion of housing which was detached and both replacement and maintenance expenditures. Masonry, and to a lesser degree, wood frame construction, was positively related to higher replacement and maintenance costs;
- Negative relationships were found between both maintenance and replacement expenditures and the presence of seniors, and the proportion of apartment units, location in Québec and co-operative housing;
- Replacement expenditures tended to be high in projects in the older Public Housing program;
- Positive relationships existed consistently between high maintenance costs and location in the Territories, Newfoundland and Labrador, remote areas in general and in Aboriginal housing; and
- A strong negative relationship existed between presence of electric/baseboard heating and maintenance and replacement expenditures.

These univariate results provided a starting point for the single year multivariate covariance models. Only variables which were consistently strong in differentiating maintenance or replacement expenditures were utilized in subsequent models.

2. Multivariate Analysis of Variance/Covariance Results

Overall, there are a number of clear and unambiguous results concerning per units costs which are, for the most part, in line with hypothesized relationships:

- Building age was consistently positively related to both maintenance and replacement expenditures. As buildings age, the effect on aging was an increasingly more important influence on replacement expenditures than on maintenance expenditures;
- Family housing was more expensive to maintain and incurred greater replacement expenditures than seniors housing. Because of high levels of multicollinearity, it is not clear whether it is the senior/family housing distinction itself, or the combination of characteristics of building type, unit type and related equipment and facilities available to seniors as compared to families that is significant as a causative factor in very large differences. There is also some evidence that over time, replacement costs increase at a higher rate, possibly reflecting the cumulative effects of wear and tear, while conversely there is some narrowing of the gap in maintenance costs, as replacement expenditures more quickly replace continuing maintenance;
- Housing in remote areas was more expensive in terms of both maintenance and

replacement;

- Replacement expenditures tend to be lower in more populated areas while maintenance costs tend to be higher;
- Maintenance costs in aboriginal housing were considerably above the norm, while in Co-op housing these were considerably below the norm; and.
- Maintenance costs were extremely high in units located in the Territories. Replacement and maintenance costs were relatively low in the prairies and in Québec.

There is also significant evidence that:

- Detached, and to a lesser degree row housing units, were more expensive to maintain and had higher replacement requirements than apartment units;
- Maintenance expenses were higher on a per unit basis in projects containing hostels.
- Projects that were electrically heated tended to have lower replacement expenditures than those heated using oil or gas;
- Projects with buildings that had at least one elevator tended to have higher replacement and maintenance expenditures than projects without elevators;
- Projects which had been rehabilitated tended to incur higher maintenance costs than other units;
- Buildings that had high replacement costs in the past year were slightly more likely to lower maintenance costs, likely reflecting the effects of replacement expenditures. Buildings which, in the past year had high maintenance costs were slightly more likely to have had higher replacement expenditures in the ensuing year, possibly reflecting a response to a maintenance problem. Both effects were small.

There is also weak evidence that replacement expenditures are higher in projects sponsored through the Section 95 program and various post 1986 programs, holding age constant, which feature more generous replacement reserve provisions than in the older Community Based and Limited Dividend programs. Further, non-recurring (replacement) expenditures in the Public Housing Program are quite high in comparison to other programs, although partial off-sets occur in lower maintenance costs. These results likely indicate that obvious--that replacement expenditures is at least partly tied to availability of funding.

Using the weighted averages of the single year MANOVA results, Table VII.22 provides a rough indication of the percentage impacts of factors which were most consistent in influencing replacement and maintenance expenditures, given "typical costs".[128] It very clearly shows the very large effect that location in the Territories has upon maintenance costs and that recurring costs reported in the Public housing stock stand well above replacement expenditures levels in other social housing. Maintenance costs stand out, but to a lesser extent, in remote locations, in Newfoundland/Labrador, and in housing build under Aboriginal Programs. Maintenance expenditures have been significantly lower in Québec and in Co-op housing and Replacement expenditures in housing primarily occupied by seniors.

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[128] Approximate order is calculated by dividing the weighted average of linear regression co-efficients in the single year regression models (from Tables VII.8,10,12,14,16 and 18) by the weighted average of annual maintenance and replacement expenditures (derived from Table V.4). Co-efficients which were not significantly different from zero with 99% confidence were set to zero. Weights are defined as the number of projects included in each annual regression model.

Table VII.22 Approximate Orders of Magnitude of Consistently Significant Relationships between Factors and Replacement Expenditures		
	Replacement Expenditures	Maintenance Expenditures
Average Expenditures/Unit	$286	$659
Building Age		
1 Year of Aging	8%	2%
Rehabilitated Building	---	10%
Location		
Town of 10,000 versus City of 100,000	-3%	2%
Remote Locale	20%	30%
The Territories	---	135%
Newfoundland/Labrador	---	30%
Québec	-15%	-45%
Manitoba	-15%	-15%
Unit Type		
Detached Housing	---	8%
Apartment	---	-6%
Hostel	---	15%
Program/Management		
Public Housing	125%	-15%
Aboriginal Housing		35%
Co-op Housing		-25%
Client Type		
Seniors	-35%	-10%
Building Characteristics		
Elevators/Balconies		-10%
Electric Heating	-10%	---

Overall, an average of just under 40% of maintenance expenditures and just under 20% of replacement expenditure variations could be explained using these models. In either case, the results presented are strong enough in indicate trends in maintenance and replacement expenditures, but the majority of variation in expenditure levels in social housing projects remains "unexplained" using these models.

With the overall aging of the portfolio, models characterizing maintenance expenditures tend to explain lower proportions of differences between projects, while models of replacement costs tend to improve. In characterizing maintenance costs, it would seem that broad factors such as location and project size are significant over the life of the project but are obscured somewhat by the increasing attractive alternative with the passing of time of replacing rather than repairing. In contrast, as the portfolio ages with time, and the significance of replacement expenditures increases, so too does the capacity to see the ramifications of variations due to building type, client type and other factors as well, and in concert with aging.

3. Time Series Analysis

The fitting of individual time series indicate that replacement expenditures tend to be relatively minor and relatively rare during the early years, especially after an initial "shake out" period. Beginning in middle age, beginning, approximately during the second decade of operation, these requirements become more common and cost increases relatively quickly. While there are strong project by project variations in the replacement expenditure histories, in the majority of projects modelled, the range of change of replacement expenditures over time increased.

Because of inconsistencies in data collection methodology, and lower levels of variation in maintenance costs over time than in replacement expenditures, patterns in maintenance expenditure series are more difficult to decipher. In 37% of maintenance expenditure series, no distinguishable trend emerges. While a second degree polynomial tends to characterize just under half the remaining maintenance series, this largely reflects the absence of a number of maintenance expenditure accounts during the middle parts of a number of time series. Still it is clear that in the majority of cases, maintenance costs begin at a higher level than replacement costs and either remain steady or increase at a rate well below that of replacement expenditures. There is weak evidence, further, that maintenance costs rise at a slightly increasing rate over time. In characterizing both social housing replacement and maintenance requirements, the individual project results provide some very weak evidence of the nature of an overall trend. In some circumstances, it would seem a process akin to human aging, such the Gompertz distribution (as characterized by a surrogate, compounding function) as discussed in Chapter III and suggested by Gleason (1981) may have applicability.

Examining replacement and maintenance costs for buildings of the same vintage indicate that, irrespective of the period built, there are clear and progressive impacts of time on both maintenance and replacement costs. During the third and forth decades of operation, the effects of other characteristics, which may be possibly related to vintage seem to "drown out" simple aging effects. Vintage may mean a number of things when discussed from the context of social housing. For example, at various junctures of the history of social housing, major policy changes having impacts upon factors influencing maintenance and replacement costs have been made. For example, during the mid 1970's, a considerable portion of new Public Housing was dedicated to seniors. Much of this portfolio consisted of large high rise buildings with elevators in larger urban centres and relatively small row and apartment buildings without elevators in small towns and rural areas. In contrast, prior to this period, a great majority of the stock was family housing, much of which was built in large urban areas and consisted of lower density row and apartments without elevators with considerable common amenity space (CMHC 1991)). For example, the move from family housing to seniors housing and changes in built form in the post 1972 period may be reflected in significantly lower estimated maintenance costs in buildings built just after this period vis-a-vis those built just before this period.

4. Estimates of the Effects of Aging on Replacement and Maintenance Expenditures

Estimates of the effect of aging on replacement requirements indicate an effect which averages just over $25 per year over the first four decades of operation (in 1992 dollars) using the single year and repeated value MANOVA models. There is evidence that during this period, the effects of aging are magnified and are thus somewhat higher in projects which are targeted towards families. But this estimate covers a time period where changes in replacement expenditures are far from linear. There is some evidence of a general bath tub effect--a period of high initial requirements followed by downturn and thus an initially slow, but increasing level of expenditures. The repeated measure analysis of variance produce the passing of aging in older buildings has a greater effect on replacement expenditures than in younger buildings. For example, between 1979-85, for buildings operating throughout this time period, the effect of time on replacement expenditures was estimated to average $49 per year, in contrast to an average of $30 for each year prior to 1979. In the post 1985 period the estimated effect of time was $26 per year, in contrast to $12 per year of age prior to 1985. Lower co-efficients in the post 1985 period, further, likely reflect the inclusion of a large number of relatively new non-profit projects.

Estimates of the effects of aging on maintenance expenditures vary more widely. Universally the effect of aging was estimated to be lower than for maintenance costs, averaging over $15 per year using the single year MANOVA models. Further, there is a limited, but inconclusive evidence that over time the rate at which maintenance costs increase in turn increases.

Overall, while gaps in the data base and inconsistencies in reported expenditures contribute considerable sources of error, the data base does allow the identification of broad trends in expenditure patterns and a number of correlates. The data, though, do not allow for the identification of a specific, dominant underlying form for the relationship between time, other factors and changing maintenance and replacement costs. Thus, while there is clear evidence using a number of difference methods that there is a general, non-linear increase in replacement expenditures with time, it is not possible to unambiguously identify a specific best fitting function.

VIII. Applying The Results--Implications for Reserve Funding

In this chapter, a series of scenarios are put forth which utilize the multivariate results obtained in Chapter VII. Six archetypical projects are described, and a stochastic model is used in a series of simulations. The result is a series of plots of maintenance and replacement expenditures over the first three and a half decades of project operation. The stochastic model uses both the best estimates of the effects of various building characteristics and the estimated "error" of these estimates.

The development of simulation models using the parameter estimates developed in the last chapter should be considered with some caution. While strong trends are indicated, there are also considerable variations in the estimated magnitudes of co-efficients. Further, a relatively small fraction of the total variance of expenditures is characterized by these models. Further, it is clear that data problems severely limit the capacity to characterize the form of key relationships, such as the effects of aging upon maintenance requirements. Still, results are sufficiently in all of the simulation exercises to provide insight into expected ranges and overall magnitudes of expenditures and of variations based upon these same key relationships.

A. Methodology

Hypothetical projects were developed with the aid of a clustering algorithm, used to define groups of similar projects. Fifteen clusters were defined based upon a algorithm which maximized differences based upon a combination of unit sizes and types, type of occupant, location, population size, and type of occupant (Norusis/SPSS Inc. (1988) and Everitt (1974))[129]. Each pair clusters could be differentiated based upon differences in the overall distribution of these characteristics with 99% confidence. The characteristics of a random selection of 6 of these clusters were chosen for the simulation exercise. These characteristics are rounded values of group centroids of the variables used. Each of these clusters represents a minimum of .5% of the projects included in the analysis.

The six hypothetical projects constructed included:

1. A 200 unit Public Housing family project, with a mix of apartments and row housing in predominantly 2 bedroom units located in an Ontario city of a 1,000,000. Buildings are heated using gas or oil and are primarily frame construction. An elevator is present on site;
2. A 20 unit family Co-op located in Québec in a city of 100,000. Units are row housing, have an average of 3 bedrooms and are constructed using wood frame techniques and are electrically heated;
3. A 12 unit project, housing Aboriginal peoples in detached units located in a remote area in the Northwest Territories. Units have 3 bedrooms, are wood frame and are heated by gas/oil;

[129] The heuristic used does not guarantee groups which were maximally "different". Further the selection of 15 groups was arbitrary. It was based upon the common practice of using an error term such as average normalized deviation from the group mean of group members and examining the change in this error term with changing numbers of groups. A "plateau" using the mean square error criteria seemed to occur in the 14-18 group range.

4. A 40 unit Private Non-profit for seniors located in a small town in Manitoba. Units primarily contain one bedroom and are located in a walk-up apartment and use electric heat. The project is funded under Section 95;
5. An 80 unit apartment building with an elevator operated by a Municipal Non-profit in an urban area of over 500,000 in Alberta housing seniors. Units are bachelor/one bedroom and are heated with gas/oil. The project is funded under the Community Based Program; and.
6. A 60 unit hostel in a low rise operated by a private non-profit in under a Post-86 program in a mid-sized city in New Brunswick.

Simulation costs were based upon:

- Average co-efficients and standard errors for the 20 single year MANOVA analyses.
- Where evident, average interactions between time and other factors were included.

For replacement and maintenance expenditures, a linear form of the effect of time on expenditures was utilized. This is congruent with the form which best fits the aggregate results of the replacement time series regressions reported in the last chapter. The linear form was utilized for the maintenance simulations because data collection problems make the identification of an appropriate functional form difficult.

For each hypothetical project, the estimated effects of varying building characteristics were applied for each of the first 35 years of simulated history. A normally distributed error was added to each term, based upon the average standard errors of the significant MANOVA co-efficients.[130] In each case, 100 replications of the simulation were run. Average results were regressed over time, and upper and lower bounds, representing estimated limits of 99% of project expenditures were estimated.

Finally, replacement simulations are used to assess the range of available under various operating agreement replacement reserve provisions.

B. Life Cycle Cost Histories

1. Replacement Expenditures

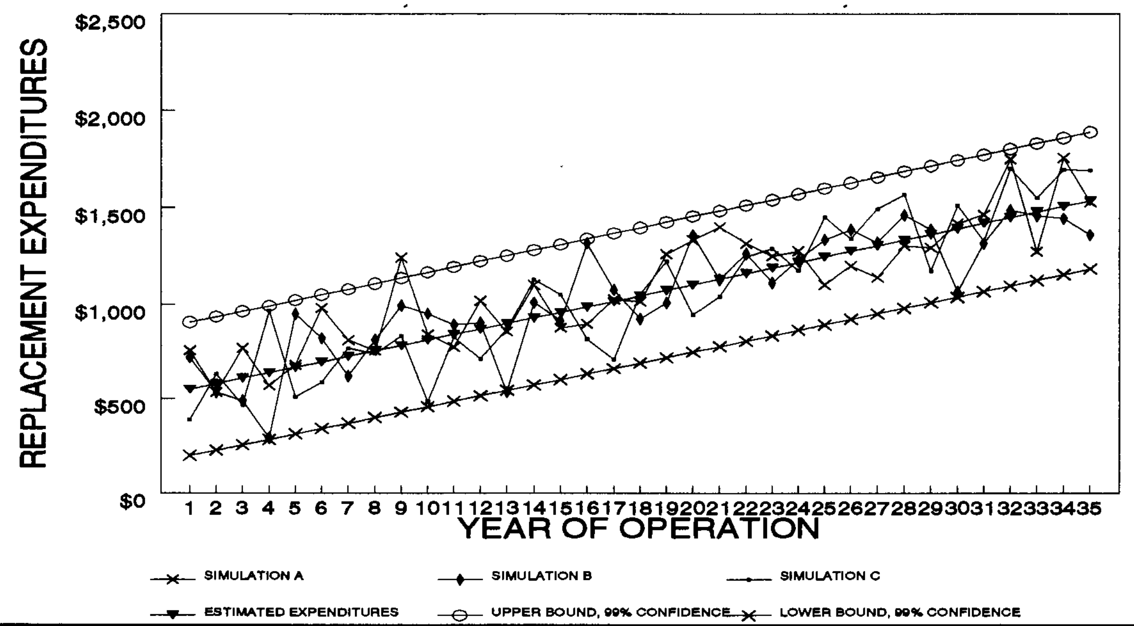
Figure VIII.1 provides the results of estimating the initial 35 years of replacement expenditures for project 1--the large family, Public Housing project in the large Ontario city. Estimated expenditures are the average results from 100 simulations. In addition, 3 individual simulations are shown as are the range of 99% of the simulation results.

Over this time frame, estimated replacement expenditures vary from a low of just under $500 to a high of $1500 per unit--a change of, in total of an average $31 per year. During any given year, estimates vary about the mean by just over $700 per unit. Expenditure levels are high due to presence in the Public Housing portfolio, by being family housing and by presence of gas/oil

[130] There is evidence provided in the last chapter that the variance of expenditures increases over building life. The time series results, though, that would have allow the estimations of the degree of change in variance over time did not produce sufficiently stable or consistent results to allow this analysis to be done.

heating. Counterbalancing these influences is the location in a large urban areas and a built form

Figure VIII.1
Results of Simulations of Large Public Housing Project Expenditures Over First 35 Years of Operation



which includes a building with an elevator.

As noted above, this and the other replacement requirements simulations, are based upon the assumption of a linear increase in replacement requirements, in line with the dominant form of the time series analyses reviewed in the last chapter. Further, as shown in the repeated measures analysis, a linear term is introduced to represent acceleration in replacement requirements due to the presence of family housing. The parameter chosen for the pure effect of time is based upon the average 20 of years of regression results and is very close to the repeated analysis estimated effect. It is, though, only roughly half that estimated in the time series analysis. With the introduction of accelerated requirements due to families, much of this difference is eliminated.[131]

Individual simulations indicate high levels of variation from year to year and over the lifespan viewed.[132] As a result, as in individual project series, there are wide fluctuations in expenditures, reflecting the "lumpiness" of replacement requirements.

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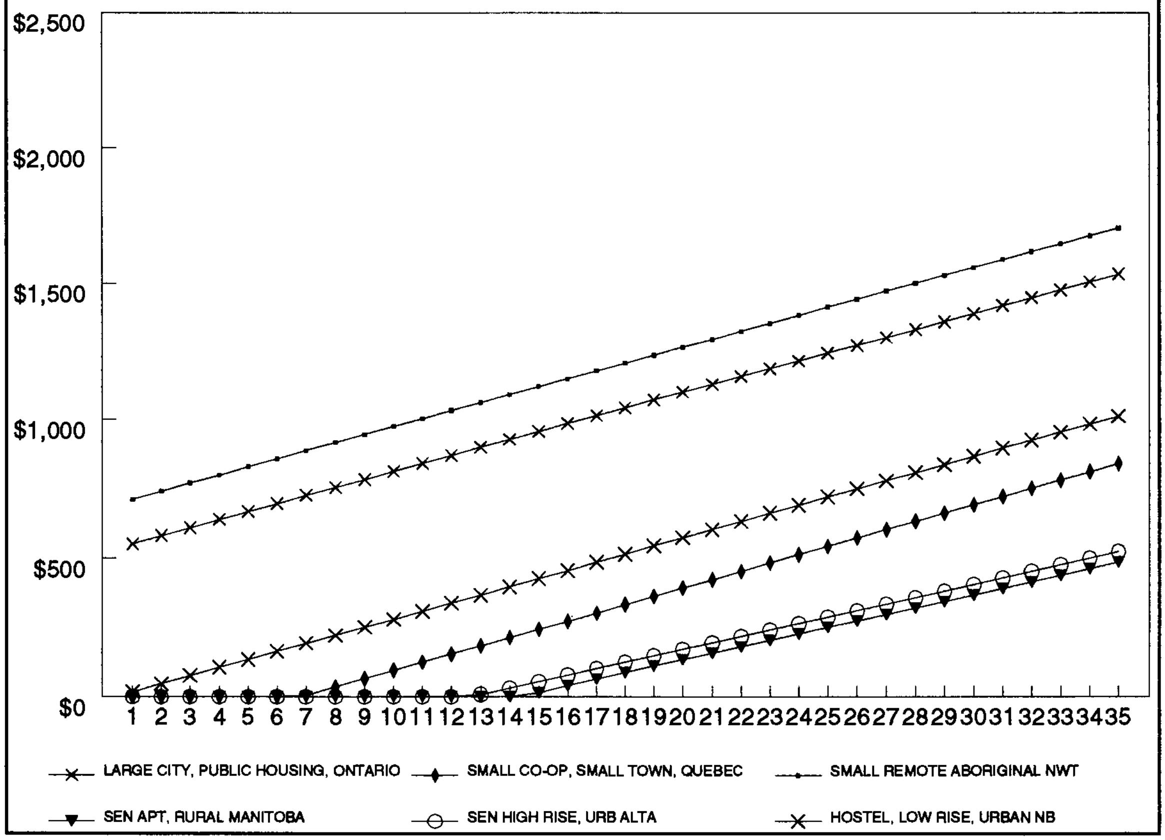
[131] The Public Housing projects used in the time series analysis were completed prior to 1974, when family housing was a primary goal of this program. Differences in the estimated effects of time may therefore be related to compositional differences--that is the absence of seniors.

[132] Incorporated in this model is a low level of autocorrelation, using the average of parameters estimated in the individual year regressions.

Figure VIII.2 provides the averaged results of replacement simulations for all six projects. Predominating in these simulations are the effects of time, remote location, the family/seniors dichotomy and location in remote locales. There are considerable variation in average

Figure VIII.2
Averaged Results of Replacement Expenditure Simulations, 6 Hypothetical Projects

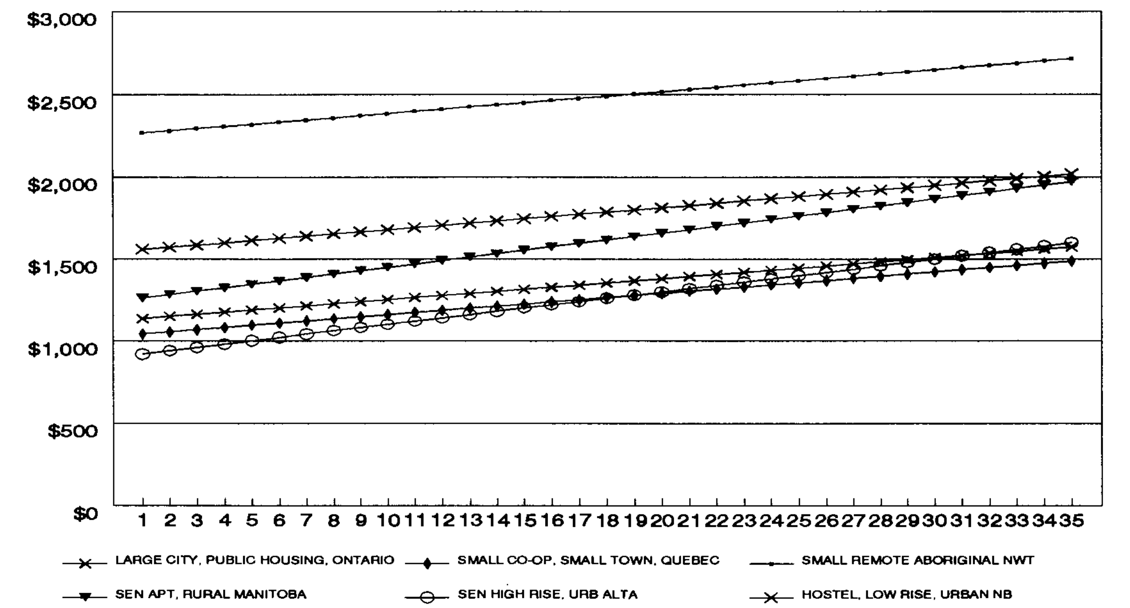


replacement expenditures over time. The seniors buildings in Western Canada tend to have relatively low average replacement expenditures over the full term of the simulation, peaking at just under $500 per unit. At the other end of the spectrum is Public Housing in the large Ontario city and Aboriginal housing in the remote community in the Northwest Territories. Both have considerable replacement requirements throughout the term of the simulation, peaking at $1,500 per unit. The small Co-op project in Québec provides a scenario more typical of the portfolio of family housing as a whole, with very small requirements over the first decade of operation, gradually rising to $750 per unit at year 35. The hostel in New Brunswick, tends to have replacement requirements in the mid range.

2. Maintenance Requirements

Figure VIII.3 shows the averaged results of the Maintenance simulations. Maintenance expenditures occur from the onset of projects, but increase more slowly. As noted in the last chapter, while there are substantial increases in the incidence of replacement expenditures in family versus seniors housing with time, expenditures on maintenance tend to converge.

Figure VIII.3
Averaged Results of Maintenance Expenditure Simulations, 6 Hypothetical Projects



Maintenance expenditures in the Aboriginal project in the Northwest Territories begins and remains roughly twice that of the other hypothetical projects, reflecting the high costs of maintaining detached family housing in remote areas. The hostel project in New Brunswick have less extreme, but still relatively high maintenance expenses. At the other end of the spectrum is the seniors high rise building. Low costs here reflect are a result of the resident population and the apartment setting. Reflecting lower maintenance costs in Co-operatives and in Québec, the small co-op produces modest average maintenance expenditure estimates.

Comparing Figures VIII.2 and VIII.3 indicates that over time, replacement and maintenance costs tend to converge. Only in the Public Housing simulations are replacement costs greater than maintenance costs at any point during the simulated period--a crossover occurring at the beginning of the third decade.

The standard errors of the simulation results are considerably higher in the maintenance simulations than in the replacement simulations (averaging 227 versus 104), reflecting in part, a somewhat poorer fit of the maintenance equations and larger degrees of variations in provincial and program estimates of maintenance expenditures. As a result, there are considerably larger fluctuations in maintenance simulations than in those concerning replacements. This would seem counter-intuitive given the greater "lumpiness" in replacement expenditures.[133]

C. Adequacy of Replacement Provisions

[133] This may be a reflection of the long initial hiatus in many replacement expenditure series and the considerable number of years where expenditures are null or are very small, on a unit by unit basis.

In this section, expenditure levels are compared to replacement reserve contribution levels for these projects as specified under various operating agreements. Table VIII.1 provides replacement reserve contribution levels and various assumptions used in this exercise.

Table VIII.1 Replacement Contributions and Other Assumptions, Evaluation of Provision Adequacy	
Provision Level 1: (as in the Community Based Program)	Annual Contribution .5% of Initial Capital Costs
Provision Level 2: (as in the Section 95 Program)	Annual Contribution .625% of Initial Capital Costs
Provision Level 3: (as in the ILM co-operative Program)	Annual Contribution .625% of Initial Capital Costs, Inflated using CPI
Provision Level 4: (as in the present Ontario Program)[134]	Annual Contribution .125% of Initial Capital Costs, Inflated using CPI, remainder borrowed
Other Assumptions:	
Capital Costs:	Maximum Unit Costs for Region and Unit Type, 1992 - Random amount (average 5% below MUP)
Inflation:	4%
Replacement Reserves Earnings:	Real Rate of 3.5%
Failure:	Reserve Deficit Exceeds 50% of MUP (Assumed Economic Value of Building)

Since contributions are related to initial capital costs, 1992 Maximum Unit Prices (MUPs) for the 6 hypothetical projects were gathered (CMHC (undated)). Since most project final capital costs average slightly below MUP, a random amount (Normally distributed with a mean of 5% and a standard deviation of 2%) was subtracted.

It was also assumed that replacement reserves were invested in a security which provided a fixed real return of 3.5%. Because early replacement provisions provided no compensation for inflation, over time, annual contribution levels declined in real dollars. It was assumed that these levels declined by an inflation factor of 4%. It was assumed that when reserves were exhausted, additional moneys could be borrowed at a real interest rate of 5%. The project failed when the total amount borrowed reached 50% of the original capital cost.[135]

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[134] The Ontario program also takes into account variations in building type, age, client type and city size in providing for replacement reserve contributions. This leads to some variation around the 20% contribution level.

[135] The trip point of 50% was selected because it was further assumed that at the end of 35 years, mortgage indemnity would be eliminated and it would then be possible to substitute the amortization of this debt. Half of original MUP was chosen (in real dollars) because in most current circumstances construction costs are greater than economic value and further, at 35 years, renovation and rehabilitation would in many cases be required, putting a further strain on the equity built up in the project.

Figure VIII.4
Net Replacement Reserves Over 35 Years of Operation, 6 Simulated Projects, Replacement Reserve Level: .625% of Capital Cost Indexed by CPI

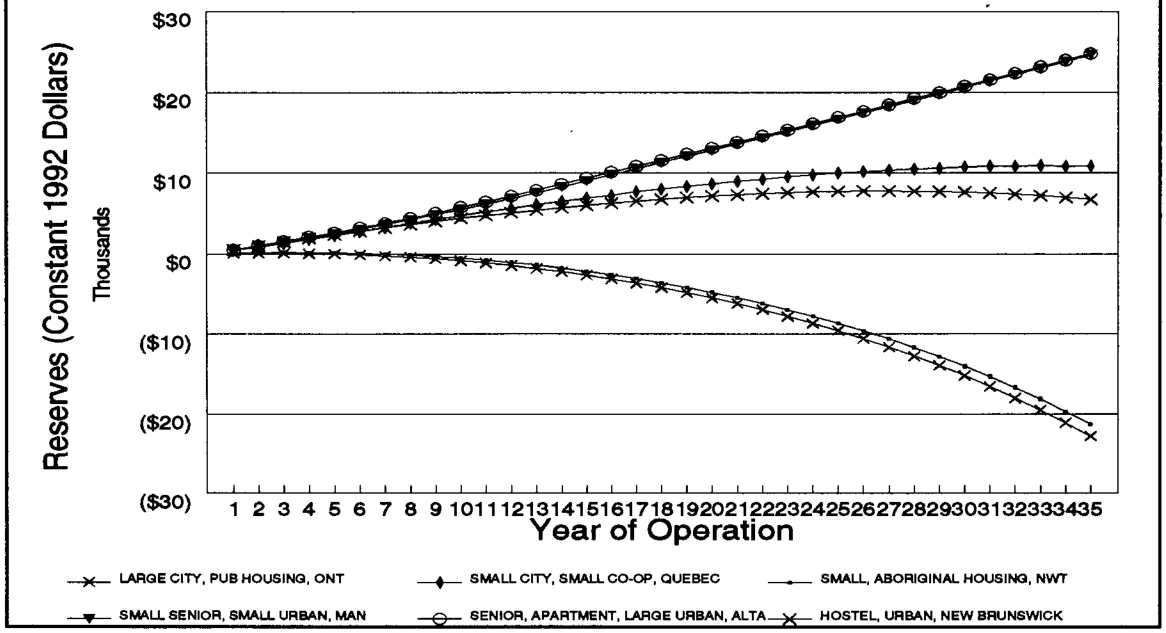

Figure VIII.4 shows the effect of utilizing the most generous provisions (Level 3) and the average expected replacement expenditure levels for the 6 projects. It indicates that the simulated replacement expenditures for the average large city family Public Housing project and the small, aboriginal housing project in the Northwest Territories exhaust replacement reserve contributions and accrued interest within the first decade of operation. On the other hand, both seniors projects, retain considerable surpluses over the entire 35 year period. The Québec Co-op and New Brunswick Hostel behave in a similar manner, remaining in a modest surplus position through this period.

Table VIII.2 indicates that under the provisions of the Community Based Program (Provision 1), none of the large city Ontario Public Housing projects or the remote aboriginal housing projects "survive". Further, a small group (1%) of the Québec co-op and New Brunswick hostel simulations fail. Still, at the end of 35 years, 82% of co-ops and 36% of the hostel simulations lead to the exhaustion of replacement reserves at the end of a 35 year period. At the other extreme less than .5% of the two prairies seniors projects exhaust their reserves, and none fail.

Moving to the more generous provisions of the ILM co-op program (provision 3), 88% of the Ontario Public Housing projects and 97% of the remote aboriginal projects still fail. At the same time, all of the remaining projects survive. Additional analysis shows that no seniors projects, only 4% of the co-ops and 24% of the hostels exhaust replacement provisions at the end of 35 years.[136]

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[136] The slight vulnerability of the co-op simulation is related to the tie between replacement costs and initial capital costs. Capital costs are relatively low vis-a-vis other locations in small cities in Quebec (due to factors such as low land and municipal servicing costs) but the cost of replacements (due to high materials costs) are relatively high).

Table VIII.2 Percentage Likelihood of Failure Due to Substantial Debt Accumulated for Replacement Reserve Requirements			
Project	Provision 1	Provision 3	Provision 4
1 Public Housing	100%	88%	100%
2. Co-op	1%	0	20%
3 Remote, Aboriginal	100%	97%	0
4 Small, Rural, Seniors	0	0	0
5 Urban Seniors	0	0	0
6 Hostel	1%	0	35%

The general form of the present Ontario provisions universally lead to the exhaustion of replacement reserves and a need to tap into the lending market. In the case of the seniors buildings, though, this occurs, on average, in the early part of the third decade of operation. Under this scenario, there is less than a .1% likelihood that these projects would fail. In contrast, one in five of the small co-op projects and one in three of the hostel projects reach a point where replacement requirements lead to a debt of over 50% of construction price, and failure.[137]

These simulations provide some evidence that given existing expenditure levels, projects with much higher than average replacement requirements, related to factors such as their location, client mix or built form have, under a number of existing provisions considerable rise of having inadequate reserves to cover needed replacement requirements. Conversely, projects with the "right" location, client mix or built form may reach the end of their operating agreements without taxing replacement reserves and may, in fact, be left with considerable surpluses to enter "mid-life". Further, the new Ontario provisions produce a situation where a wide range of projects which will enter mid-life under considerable debt and risk.

D. Summary and Conclusions

1. Methodology

In this chapter, a series of simulations were reviewed which were designed to provide estimates of replacement and maintenance expenditures over the first 35 years of operating life in "typical" social housing projects. Six archetype projects were defined based upon the selection of elements characteristic of significantly large clusters of social housing projects. These included a far northern and remote aboriginal project, Public Housing in a large Ontario community, a co-op in a small city in Québec, a hostel in urban New Brunswick and two seniors projects in the prairies. These simulations are only as good as the models and data upon which they are based and there is considerable evidence of data problems and only moderate performance in estimating actual expenditures using these models. Yet, results are likely sufficient to allow for the development of broad insights through the use of these methods.

[137] It would be possible to considerably worsen this scenario by introducing the recent 3 year freeze on replacement reserves. The freeze leads to the two senior projects, on average, requiring borrowing in the midst of the second decade of operation, but only slightly increases the likelihood of failure. In contrast the likelihood of failure in the hostel and co-op projects increases by between 5% and 10%--to 1 in 3 co-ops and 2 in 5 hostels.

Simulation parameters were derived by taking averages of significant co-efficients in the individual year Multivariate Analysis of Variance/Covariance results discussed in Chapter VII. Interaction terms were also introduced in order to characterize relationships between factors such as building aging and household type relevant to how costs change over time. These came from estimates in the repeated measures multivariate analysis of variance/covariance described in Chapter VII. In both cases, the effect of time, and of interactions with time were assumed to be linear. Despite evidence of the appropriateness of alternative forms, results using these alternatives was not sufficiently conclusive for inclusion in this exercise. Especially in the case of changes in maintenance costs over time, better fitting alternative forms may be related to data problems.

2. Simulation Results
The simulations generated:

- high replacement expenditures in the family project, especially the large Ontario Public Housing project and the far northern aboriginal project resulting in simulated expenditure levels which stood out. At the other end of the spectrum were very low levels of replacement expenditure in the prairie seniors non-profits;
- high maintenance costs in the remote aboriginal project;
- hostel project replacement expenditures results which were "middle of the road" but where higher levels of wear and tear in this type of project translated into very high simulated maintenance costs;
- very low replacement requirements in a Manitoba seniors project but maintenance costs which converged with the average for other projects over time; and
- maintenance costs at the low end of the range in the co-op in rural Québec, the large seniors apartment in Alberta and the Ontario Public Housing project. The inclusion of this last project in the "low maintenance cost" group is likely a reflection of the substitution of capital or "non-recurring" expenditures for maintenance expenditures.

When, the results of these scenarios were juxtaposed against existing replacement reserve provisions in a sample of federal programs and the recently negotiated Ontario non-profit program, almost all cases, estimated expenditure patterns for the large Ontario city Public Housing project and remote, northern Aboriginal project could not be sustained under these provisions. In contrast, the two seniors projects would in all likelihood, have reserves remaining at the end of the 35 year simulation period under existing federal provisions. The hostel and small Co-op, in contrast, would likely exhaust reserves by the end of the simulation period under the most stringent original Community Based provisions, but would rarely "fail" even under these circumstances. On the other hand, the imposition of rudiments of the new Ontario provisions produce a significant likelihood of failure for these two types of projects. The significant failure rate, in particular of the mid-cost small co-op would point to a inordinate level of risk created in the new Ontario replacement reserve provisions.

IX. Summary, Conclusions and Recommendations for Further Research

A. Summary

This work assesses the possibility of estimating building life cycle maintenance, repair and replacement costs using well known stochastic (probabilistic) models. It provides an assessment of how well these models can be used in estimating these long term costs for existing social housing portfolios.

Specifically, it:

- provides a comprehensive review of the literature in the building science, economics and appraisal fields concerning general factors influencing maintenance and replacement costs over building life and the theory or application of stochastic models for estimating these costs;

- consolidates and assesses the usefulness of historical data on operating costs and replacement reserves collected by CMHC and various housing providers throughout the country for housing built through provincial and federal housing programs for low and moderate income households and organizes these in a manner amenable to analysis; and

- develops and tests a series of models which estimate long term maintenance, repair and replacement costs in this portfolio.

1. Synopsis of the Literature and Model Specification

The literature reviewed in the report comes from two general sources--the building sciences literature and the economics and appraisal fields.

The **building sciences literature** treats time related wear-and-tear and deterioration as important factors for the modelling of optimal building maintenance and component replacement practices. Yet in the building sciences, there is scant attention given to the subject of life cycle costs at an the aggregate level of overall building structures. Rather, emphasis is placed upon the performance of individual building components and systems.

In particular, reliability models commonly used in this literature may be extended to characterize expenditure of a certain, standard amount to maintain or replace a building component. In their simplest forms these models characterize the probability at any point in time of a component continuing to "survive", as opposed to fail. In this case, expenditure is seen as a type of failure. In reliability models, the passage of time, or aging is seen to be equivalent to exposure to hazard or risk leading to failure. The interaction between exposure and the system that eventually culminates with failure can, under a number of circumstances, be characterized by one of a number of well understood stochastic models. This is the case, for example when failure is a cumulative result of a large number of small and independent events or where there a period of defect related failure, relative smooth running, and then a period where components are highly likely to "burn out". A predominant emphasis lies in the development of models which characterize the failure patterns or materials or components under a range of controlled circumstances (factors affecting material/component performance, level of degradation forces etc.). The objective is to specify under well defined and controlled sets of circumstances, optimal maintenance and replacement regimes. In modelling project level maintenance and replacement expenditures, there is a requirement to include and to model the effects of factors which define corresponding relevant circumstances.

At an aggregate, project wide level, circumstances cannot be tightly defined, and in this literature, there is little research dedicated to what these aggregate circumstances might be. Still, the methods used in the reliability literature suggest the avenues of research conducted here. In this report, building maintenance and replacement expenditure patterns, rather than practices, of the large "system" of a social housing project are posited to be the outcome of a stochastic process.

In the **economics and appraisal literature**, there is a more direct concern with expenditures on building maintenance. In addition, studies have examined a broad range of building related and other factors which may have likely influenced levels of building related expenditures. Here, focus is primarily upon how "used" housing is treated by an investor as a commodity in the market place. Aging, as in the materials science literature, is seen to be the cumulative effect of deterioration and a factor in the determination of maintenance/replacement expenditure levels. In addition, these expenditures are related to two other factors--obsolescence and competing alternatives for scarce funds.

Research in the area is sparse and diverse in its methodological approach and generally has not had high degrees of success or predictive power in estimating maintenance/replacement expenditures or requirements. Still, consistently, the results reported indicate a tendency for housing to deteriorate and/or become obsolete at an increasing rate with age and for the sum total of maintenance, repair, alteration and renovation requirements to increase though the economic life of residential buildings. There is also evidence of a short initial expenditure peak during the early building life where remodelling and the repair of defects are quite common.

Taken together, these produce a distribution of expected total maintenance and replacement expenditures over the first half century of building life which seems to correspond to a "bath tub" curve, characteristic of a great many building component expected life distributions. Further, there is a very gradual shift indicated in this literature from a very slowly increasing level of ongoing maintenance requirements to a greater need to address replacement, renovation and modernization requirements.

In addition, a number of other general factors have been seen to significantly affect maintenance and replacement expenditure patterns in this literature. These include climatic and geographical considerations (such as community size and location), household size and composition, turnover, building form, building and unit size, and building materials which are considered here.[138]

2. The Model and Results

The considerations posed in these literatures give rise to a series of potential influences upon maintenance and expenditures levels in Canada's social housing stock (See Table IX.1).

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[138] In addition, this literature provides evidence that a number of other broad factors which are not considered here as relevant in the context of Canadian social housing (for example, tenure, neighbourhood "quality" and alternative economic opportunities) significantly affect maintenance and replacement expenditure patterns.

Table IX.1 Summary of Factors Hypothesized to Influence Maintenance and Replacement Expenditures in Canada's Social Housing Stock	
Characteristic	**Specifics**
Building Age	* Years since new construction * Years since rehabilitation (for rehab. buildings) * Original Age (for rehab. buildings)
Building Location	* Province * Population of urban area/community * Location in a northern/remote area
Project and Unit Characteristics	* Total number of units * Types of unit (apartments, row etc.) * Average number of bedrooms
Household Type	* Household Form (i.e. seniors, families, etc.)
Institutional Characteristics	* Program built under * Provider type (housing authority, co-op etc.)
Building Characteristics	* Construction type * Exterior cladding * Roof type * Heating type (forced air, hot water etc.) * Heating fuel * Presence of balconies * Presence of elevators * Predominant unit floor covering * Presence, extent of landscaping * Presence/type of parking

Another objective is the exploration of the form of these relationships. In particular, the literature points to a curvilinear function as best characterizing the effect of time upon maintenance/replacement expenditures. The fitting of non-linear functions may further provide some evidence as to the nature of a predominant stochastic process.

Data concerning some factors seen in the literature to influence expenditure levels were not captured directly in the data available. Principally, these include tenant behaviour and characteristics (turnover, levels of vandalism, and the presence of special need) and specific evidence of maintenance and/or replacement practices.

Histories of annual maintenance and replacement expenditures and project characteristics covering the three quarters of social housing stock in Canada were used in testing these hypotheses. In total, histories spanning an average of 8 years were brought together with project characteristics concerning 13,223 projects (approximately 505,000 housing units). This represents approximately 30% of all annual maintenance and replacement expenditures reported since the first major inception of social housing in Canada. Maintenance and replacement expenditures series averaged 8 years in length but in some cases, spanned periods of up to 20 years.

These data were obtained from 4 sources:

- a survey administered to a small sample of non-profit housing providers;
- the Ontario Public Housing annual budget books;

- the administrative data base of CMHC; and
- the CMHC Evaluation Division Public Housing data base collected for the 1990 Public Housing Evaluation.

The data are limited by a number of holes and error sources. In particular, there are inconsistencies in how maintenance and repair expenditure data were classified across projects and over time. These inconsistencies are due to changes and differences in accounting rules and difficulties in isolating and tracking expenditures in these areas. In addition, a number of building characteristics were available for only a small fraction of the total stock. The noise produced by these problems severely reduced the capacity to assess the validity of a number of research hypotheses.

Best fitting maintenance and replacement expenditures models were estimated using multivariate analysis of variance and covariance techniques. In addition curves characterizing a number of possible underlying stochastic processes were fit and results compared for long individual project expenditure series.

Overall, an average of just under 40% of maintenance expenditures and just under 20% of replacement expenditure variations could be explained using these models. While these results are strong enough to indicate general trends in maintenance and replacement expenditures, a good majority of variation in these expenditures is left "unexplained".

More specifically, these analysis result in a number of strong inferences concerning per unit expenditures on replacements and maintenance:

- **The influence of aging:**

    - Building age was a consistent and strong predictor of both replacement and maintenance expenditures. On average, variations in building age could be used to explain 8% of all differences in replacement expenditures and 6% of differences in maintenance expenditures.

    - Overall, during the first four decades of operations, maintenance expenditures increase on a yearly basis by an average of about $15 per year (1992 $'s) while replacement expenditures increase by roughly $25. During the period between 1973 and 1992 maintenance costs the "average" 8 year old social housing unit had annual maintenance costs of $670 and replacement expenditures $303.

    - Maintenance expenditures are higher than replacement expenditures during the early years of social housing projects. In the beginning of the third decade of operation, replacement expenditures cross over in some projects to become larger than maintenance expenditures. By the fourth decade, replacement expenditures are larger than maintenance expenditures in most projects. Increases in maintenance expenditures tend to slowly creep up to and above $15 per year while replacement costs tend to stay low and tend to decline in some cases in the first decades of operation. In the middle of the second decade, replacement costs begin to slowly and consistently inch up.

- Maintenance costs are consistently higher by roughly 10% per unit in rehabilitated buildings, holding all else equal.[139] These older buildings often include technology and form which is hard to currently sustain at low cost.

- The evidence seems to point at a process akin to that evident in health care requirement with human aging. The likelihood that health care is required is high during early life, then declines and stays low through childhood and early adulthood. In mid-adulthood,, these requirements tend to slow rise and accelerate reaching high levels in the senior years. These trends also correspond well to the from of a "bath tub" curve. There is, though, insufficient evidence to indicate that a particular stochastic process predominates in the progression of replacement expenditures over time.

- A clear pattern in maintenance expenditure series pointing at a dominant process cannot be deciphered because of inconsistencies in data collection methodology, and smaller degrees of change in maintenance costs over time.

- In comparing results from the CMHC's Federal Co-operative and Public Housing Program Evaluations, it is clear that a larger proportion of required replacement work needs to be addressed in the older, Public Housing program. The economics literature indicates that home owners and private rental building managers very often do not make maintenance and replacement expenditures which fully off-set slow, steady and accelerating deterioration in their buildings and the generality is likely also apt in the Canadian social housing context. As a result, focusing solely upon expenditures may not tell the complete story of maintenance and replacement needs over time.

■ **The Effects of Building Location:**

- Replacement expenditures tend to be lower in larger centres. Expenditure levels in towns of 10,000 are estimated to be approximately 5% higher than in cities of 100,000. This likely reflects economies of scale in undertaking capital work in the larger projects in larger areas and lower materials costs, which make up a high proportion of replacement expenditures.

- Conversely, maintenance expenditures tend to be lower in smaller towns. For example, in towns of 10,000, expenditures averaged approximately 3% less than in cities of 100,000. This likely reflects a higher labour component in this type of work and higher wage rates in urban areas.

- Maintenance expenditures are especially high in remote areas, irrespective of the

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[139] The estimated effects of various factor on replacement and maintenance expenditures are subject to considerable error and provide a very rough indication of magnitude.

part of the country. Replacement expenditures also tend to be higher, but trends were less consistent. Maintenance expenditures were consistently estimated to be well over 30% higher in remote locales all else being equal. Given high levels of deterioration due to climate and other factors and relatively short building lives in these areas, it is likely that considerable ongoing maintenance expenditures are in many cases, substitutes for replacement expenditures. Further, deterioration in many of these locations often occurs to the point where the unit becomes uninhabitable at a time where in most other locales, major replacement requirements come to the fore.

- Maintenance expenditures in the Territories and Newfoundland and Labrador stand out, reflecting the effects of high material and labour costs and climatic extremes. Even after removing the effects of small population size and remote location, in the Territories, maintenance expenditures were consistently estimated to be more than double the average of comparable projects in the remainder of the country, in Newfoundland and Labrador, approximately 30% higher.

- At the other end of the continuum, in Québec and to a lesser consistent degree in the Prairie provinces (especially Manitoba), maintenance and replacement expenditures are consistently lower than the national average. Manitoba has particularly low labour costs, a dry climate and low/average levels of sales tax. In both cases, average replacement expenditures were estimated to be approximately 15% lower that in comparable projects elsewhere. Maintenance expenditures in Québec averaged approximately 45%less and in Manitoba, 15% less than in comparable projects elsewhere.

■ **Project and Unit Characteristics:**

- Single detached housing is much more expensive to maintain than other building types, reflecting a range of factors including higher costs of travelling to these dispersed units, high amounts of exposed, exterior wall and significantly more landscaping space per unit of housing. Apartment units tended to be least expensive to maintain. Single detached units had estimated maintenance expenditures that were just under 10% higher than the norm, while apartment units were just over 5% below the norm.

- Reflecting the high levels of wear and tear associated with hostels, maintenance expenditures tend to be particularly high. Hostel units had maintenance costs that averaged in the range of 15% higher than other types of units.

■ **Variations by Household Type:**

- Projects specifically targeted to seniors consistently have considerably lower maintenance and replacement costs than those targeted to families. Maintenance costs were estimated to be between approximately 10% lower while replacement expenditures averaged roughly one third less. Some of this difference is attributable to the smaller size of senior housing units and location in relatively low cost built forms. There is also evidence that over time, replacement costs increase more quickly in family housing, possibly resulting from the cumulative effects of the heavy wear and tear of young children.

- **Institutional Effects: Program and Management Type:**

  - Replacement expenditures (non-recurring costs) in Public Housing are estimated to be considerably higher than in other portfolios, averaging over twice the norm for comparable units, although these were partly off-set by lower than average maintenance (recurring) costs, which averaged 15% below the norm.

  - Maintenance expenditures are estimated to be higher in projects managed under Aboriginal housing programs by approximately 35%, holding other factors constant. These higher costs likely reflecting both the effects of high levels of crowding in this housing and the location of a considerable amount of this stock in hard to reach rural, remote and far northern locales.

  - Expenditures on maintenance are particularly low in co-op housing, averaging an estimated one quarter less than in comparable units, likely due to the role of volunteer, unpaid labour and possibly due to lower levels of vandalism resulting from high level of resident attachment to their community.

- **Variations due to Differing Building Characteristics:**

It is difficult to disentangle the effects of specific building components and maintenance/replacement expenditures because a number of these components were highly correlated. Still, some strong trends emerge:

- Units in larger buildings with elevators and balconies tend to have relatively low maintenance expenditures, averaging approximately 10% below those of comparable housing elsewhere. This appears to reflect a range of factors including relatively small unit sizes and various economies of scale in larger buildings.

- Units with electric baseboard heating tend to have lower replacement and maintenance expenditures, likely reflecting the simplicity of this type of heating systems vis-a-vis alternatives. Replacement costs were roughly 10% below those of comparable units, maintenance costs 2%. At the same time, utility costs in these buildings most likely far outweigh savings in this area.

3. Simulations of Maintenance and Replacement Expenditure Levels

These empirical results were used to develop parameter inputs to simulations of maintenance and replacement expenditures over the first 35 years of the life of 6 archetypal social housing projects. The simulations indicate that taken together, factors leading to high cost can produce a risk of onerous burdens on operating budgets and reserves when they occur together. That is likely the case in significant numbers of social housing projects. Specifically:

- Building, tenant, locational and other risk factors (for example, detached, family housing in Newfoundland and Labrador) have considerable effects upon replacement expenditures over time. Highest simulated annual expenditure levels were triple that of the lowest expenditures in replacements expenditure simulations and just under double those of the lowest in the maintenance simulations.

- Some risk factors predominate. Simulated replacements expenditure levels in the Public Housing project and the remote aboriginal project were high throughout the simulated life of this project, as was maintenance in the hostel simulation. At the other end of the spectrum, factors such as seniors targeted housing, location in a low cost area or member contribution to maintenance work (as is the case in many co-ops) may translate into very low expenditure requirements.

A way of assessing risk is to assess expenditure levels given existing program provisions. Replacement reserve contributions provide such a base. An assessment of a range of simulated expenditure levels given replacement reserve provisions under various programs indicates that:

- Under existing federal provisions for non-profit housing there can be a considerable strain on replacement reserves during the second and third decade of operation. The level of strain is, though, only too high in extreme circumstances. These circumstances include the simultaneous presence of a number of risk factors (for example, Aboriginal family, detached housing in a far north, remote location). Conversely other combinations of circumstances may exist where it is very likely that a project will have more than adequate reserves (urban, high rise, senior projects are cases in point).

- The replacement reserve contribution levels which form the base of the new Ontario program, particularly when matched with the recent freeze in contribution levels significantly broaden the base of projects at risk to the point where a sizable minority of projects will likely either defer needed replacements or will be burdened with a considerable debt level during the middle life of these projects.

C. Recommendations for Further Work

There is no published work which systematically examines the magnitude of maintenance and replacement expenditures in Canadian housing and the factors which contribute to variations in these costs. Even internationally, this type of work is relatively rare. Much of the material contained in this report will not surprise property management professionals, especially those involved with Canada's social housing stock. Yet the details of this work, and more broadly, the news that there is capacity to use existing information to estimate these costs, provide a considerable extension on existing knowledge in the area.

The study points out a number of inexpensive research efforts that would considerably enhance these findings:

➔ If work like this is to proceed, there is a need for a census of building and project characteristics. Such a census should include broad elements of building infrastructure (type of construction, building type, presence and type of parking facility). It is clear from the results above that these attributes may have a considerable impact on maintenance and replacement expenditure patterns over time and that better estimates of these impacts would likely allow for a much enhanced capacity to undertake long term expenditure forecasting and planning.

➔ There is a need to develop a broad but uniform classification of financial accounts and instructions which define how various operating and capital costs can consistently "fit" in a framework useful for expenditure forecasting and planning. For the purposes of this type of work, activity based account complexes are particularly useful and should be encouraged.

➔ There exists a considerable amount of data in the field on existing maintenance and replacement expenditures, especially within the Public Housing portfolio. Much of this is already in computer readable form. Minimal effort could consolidate this material into a formidable research data base.

➔ There is almost no research which examines buildings as holistic systems. Yet it is clear that there are definite and marked trends in broad classes of buildings in maintenance and replacement expenditure requirements over the life cycle. With minimal additional work to enhance the data base established in this work, there is promise of considerable additional progress in strengthening the groundwork of results established here and in developing reasonable estimates of maintenance and replacement expenditures over time. This would allow for a better capacity to plan expenditure levels, especially for large providers able to make decisions at a portfolio level, and to better manage scarce funds in the intermediate and long term.

D. Conclusions

The number of very clear results which emerge are very encouraging and point at the potential usefulness of this methodology. Aging has a considerable effect on both maintenance and replacement expenditures, and it is clear that the great majority of social housing projects that are now moving through the second and third decades of operation will be facing rapidly increasing replacement requirements and significant but more slowly increasing maintenance needs. Further, factors such as location, built form and household composition make considerable differences in the level of maintenance need and the expected service life of building components.

The large degree of error in maintenance/replacement expenditure data and the limited available data on building characteristics severely constrained the scope and strength of the conclusions drawn. Work designed to gather consistent, uniform data on replacement expenditures, and to capture and create a data base to inventory detailed project characteristics would almost certainly enhance the predictive capacity of the model developed above and provide useful insights into long term maintenance and replacement requirements in the social housing stock.

There is some evidence that the most recent replacement reserve provisions in federally funded non-profit programs generally provide adequate levels of reserves for this sector. Results from the recent co-operative housing evaluation indicates, further, that given present expenditure patterns and the condition of this stock, these contribution levels will, in most circumstances, lead to housing that satisfies current adequacy standards. These provisions, though, do not take into account significant variations in maintenance and replacement requirements that are tied to risk factors such as client type, location and built form, especially when combinations of high risk factors simultaneously exist. Further, while leaner levels of replacement funding such as that provided in the new Ontario provisions may prove adequate for a majority of social housing providers, they cut much closer to the bone. Where risk factors such as remote location, or housing geared towards families occur, there is a very high likelihood that long term replacement requirements cannot be met.

Finally, an implicit but very strong theme in this work has been the need to refocus a small amount of the considerable expertise, effort and resources that are dedicated to the technical audit of specific buildings and projects. This study points to the potential of developing a strong set of general principles concerning the behaviour of existing building systems over time at a macro level. Technical audits may be telling the same story over and over on a project by project basis--that certain types of forms, uses and locations, especially in combination, are expensive. Systematically doing this fundamental research, and portraying and communicating these to the building sciences, design, policy and delivery community can only serve to enhance our capacity to manage and conserve the very scarce and very valuable social housing resources available today.

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Appendix A
Non-Profit Providers Survey Related Materials

A. Cover Letter and Request for Information to Non-Profit Providers

May 31, 1993.

FIELD(address)

Attention: **FIELD**(ATTENTION)

Re: **Request for Data concerning Non-profit and Public Housing Maintenance and Replacement Costs**

Dear **FIELD**(name)

With reference to our recent telephone conversation, we would like to thank you for agreeing to assist us with our research project.

Ark Research Associates has been awarded a C.M.H.C. external research grant to collect and analyze data about long term maintenance, major repair, and capital replacement costs for provincial and federal non-profit and public housing. The primary goal of this project is to develop models which can be used to estimate long term costs. It is hoped that these models can be used to assess how well current replacement and maintenance reserve provisions reflect operating realities and to allow better planning for long term costs.

As discussed, we are developing a data base containing cost and descriptive information about private and municipal non-profit and public housing buildings across Canada, and we appreciate your support. We are particulary interested in buildings over two years of age. The specific information we would like to receive is provided in the accompanying guideline sheets.

We understand that it will take some time to compile this data and confirm approval for its release. In order to meet our deadline for this project, we would like to receive this information sometime between July and late September.

Once again, we would like to thank you for participating in our research project and if you wish, we would be pleased to have a copy of the final report sent to your office from C.M.H.C. In the meantime, if you require any further information, please contact me at (613)-722-3484 or write to Ark Research Associates at the address below.

Yours sincerely,

Aron Spector
Chief Consultant
Encl.

B. Guideline Sheet
Data concerning Non-profit and Public Housing Maintenance and Replacement Costs

- Expenditures on types of major maintenance and repair items and capital replacements on a yearly basis since building completion (or as far back as possible);

- City and province;

- Number of Units

- Building occupancy eligibility using the following terms:
  - family
  - seniors
  - mixed family/seniors
  - single non-elderly
  - special care (for example, exclusively second stage housing or housing designed for those with health and/or activity limitations)
    mixed other
  - Other (specify)

- The government program under which the building was constructed/rehabilitated

Building Characteristics

- Building type
  - apartment
  - row units or garden homes
  - duplex or triplex
  - semi-detached
  - single
  - stacked row
  - rooming house
  - hostel
  - Other (specify)

- Construction Method
  - Wood Frame/Stick Built
  - Solid Masonry/Hollow Concrete Block
  - Concrete
  - Steel Frame
  - Other (Specify)

- Predominant Exterior Cladding
  - Brick/Brick Veneer
  - Aluminum Siding
  - Wood Siding/Other Wood Cladding
  - Stucco
  - Concrete
  - Other (Specify)

- Heating System
  - Forced Air
    - Electric
    - Gas
    - Oil
    - Other
  - Hot Water
    - Gas
    - Oil
    - Other
  - Baseboard Heaters (Electric)
  - Other (Specify)

- Predominant Floor Finishing (Interior)
  - Carpet
  - Linoleum
  - Tile
  - Hardwood
  - Other (Specify)

- Roof Type
  - Sloped, Shingled
  - Flat -Tar and Gravel
    -Steel
  - Other (Specify)

- Elevatored (Yes/No)

- Balconied (Yes/No)

- Age of buildings
  If building was rehabilitated, also provide years since "rehabed"

Site Characteristics

- Type of Parking Area
  - exterior lots
  - garage
    - underground interior
    - at grade, interior
    - separate structure

Presence of Commonly Maintained Landscaped areas (Yes/No)

C. List of Participant--Survey of Non-Profit Providers

Capital Region Housing Corporation
Victoria, British Columbia

Calgary Home Properties (City of Calgary)
Calgary, Alberta

Centretown Citizens Ottawa Corporation
Ottawa, Ontario

City Living,
Ottawa, Ontario

City of Halifax Housing Authority
Halifax, Nova Scotia

City of Halifax Non-Profit Housing,
Halifax, Nova Scotia

City of Kitchener
Kitchener, Ontario

City of Orillia
Orillia, Ontario

Cityhome
Toronto, Ontario

Dartmouth Non-Profit Housing Society
Dartmouth, Nova Scotia

Edmonton Non-Profit Housing Corporation
Edmonton, Alberta

Halton Development and Non-Profit Housing
Regional Municipality of Halton, Ontario

Kingston Regional Housing Authority,
Kingston, Ontario.

Lindsay Non-Profit Housing Corporation
Lindsay, Ontario

Native People of Thunder Bay Development Corporation
Thunder Bay, Ontario

Nepean Housing Corporation
Nepean, Ontario

Niagara Peninsula Homes Inc.
Welland, Ontario

Ottawa Carleton Regional Housing Authority,
Ottawa, Ontario

Region of York Housing Corporation
Newmarket, Ontario

West Nipissing Non-Profit Housing Corporation
West Nipissing, Ontario

Appendix B
Summary of Variances from CMHC AGRSHRX Data Base Project Records

	East	Québec	Ontario	Man./Sask.	Alberta	B.C./Terr.	Canada
Original Records:	4,518	10,665	10,820	12,858 (all western records)			38,861
Unique CMHC Account #'s	2,224	3,820	3,636	2,106	1312	2086	15,184
Removed:							
No Financial Data	185	170	483	200	112	436	1,587
Multiple Locations, not in same urban area:	6	1	0	2	1	1	11
IAD Jan. 1, 1992 or later	39	111	11	1	23	6	191
Less than 10 months of operating data:	64	7	14	5		17	104
IAD dates more than 2.5 years apart:	8		26	15		10	59
Duplicate Data:	1				1		2
Removed and Replaced by Sample Data	7				16		7
Moved to Other Files (wrong province)			4	1	-1	-4	0
No IAD or Commitment Date				2		1	3
Combined to be consistent with OHC records			47				
Subtotal:	1,914	3,530	3,051	1,880	1,176	1,619	13,170
Added:							
Created by Combining CMHC/Sample Data	35	0	0	0	18	0	53
Sample:	1,949	3,530	3,051	1,880	1,194	1,619	13,223
% of Original Data	88%	92%	84%	89%	91%	78%	87%