TECHNOLOGY TRANSFER AND INNOVATION IN THE CANADIAN RESIDENTIAL CONSTRUCTION INDUSTRY

Prepared for

Canada Mortgage and Housing Corporation

by

James F. Hickling Management Consultants

Principal Consultant: Jacques Rostenne

CMHC Project Manager: Tony Wellman

January 16, 1989

ACKNOWLEDGEMENT

James F. Hickling Management Consultants acknowledges with thanks the contributions of the National Housing Research Committee Steering Group established to provide guidance for this project.

Organizations represented on the steering group were:

Canada Mortgage and Housing Corporation
Canadian Homebuilders' Association
Canadian Manufactured Housing Institute
Société d'habitation du Québec
Ministry of Housing, Ontario
Alberta Municipal Affairs- Housing
Canadian Standards Association
Energy, Mines and Resources, Canada
National Research Council
Indian and Northern Affairs Canada

The views expressed in this report are those of the authors and no responsibility for them should be attributed to CMHC or other members of the steering group.

This project was funded by Canada Mortgage and Housing Corporation under Part V of the National Housing Act.

TABLE OF CONTENTS

Page

1.0 INTRODUCTION

1.1 BACKGROUND

The Canada Mortgage and Housing Corporation (CMHC) commissioned James F. Hickling Management Consultants to undertake a study of the Low–Rise Residential Construction Industry (LRRCI) in order to examine the process of technology transfer and diffusion in this industry. Empirical evidence had indicated that innovations in terms of building materials and techniques, and in marketing and associated services, are not adopted quickly and do not spread widely. CMHC sought, through the identification of factors which drive and/or constrain the process of technology transfer and diffusion, to identify measures which the government and industry can play in encouraging the diffusion and adoption of technology in the residential construction industry.

The nature of the low–rise residential construction industry, itself, was believed to be one of the major reasons why innovations are not adopted as quickly and widely as in other industries.

Seventy in–depth interviews were conducted with manufacturers, distributors, builders, architects, tradespeople, trade associations and government experts. The entire effort was preceded and supported by an extensive review of the literature.

ACKNOWLEDGEMENTS

The authors of the report wish to acknowledge the cooperation extended by all the individuals and organizations which contributed to this study. In particular, the authors wish to thank THORKELSSON ARCHITECTS LTD. whose work on "Technology Transfer in Alberta" prepared for the Financial Assistance and Research Branch of the Housing Division of Alberta Municipal Affairs which was undertaken during the same period led to very fruitful discussion and methodological cooperation. The authors also wish to thank the CHBA and the Management of the R2000 program at EMR for their contribution.

1.2 SCOPE OF THE STUDY

The low–rise residential construction industry is the sum of all of the activities performed by contractors and others engaged in the assembly of housing units, as well as engineers and design professionals, manufacturers of components, materials and equipment, those involved in the research and development of related products and processes, those who regulate the industry and the people that purchase, own or use the houses that it produces. This study of the process of technology transfer and diffusion has focused on the path taken by the innovation after it has left the realm of the materials, equipment and product suppliers, who tend to be large companies such as Domtar, Dow, and Alcan with strong internal R & D programs. It recognizes that what happens at that earlier stage has little relationship to the way in which technology transfer and diffusion occur in the low–rise residential construction industry. Suppliers, however, have been studied for their role as sources of product innovations and as diffusion accelerators.

1.3 STUDY OBJECTIVES

The objectives of this project were to:

- describe the **workings of the technology diffusion process** in residential construction to enable those engaged in research and development in the field to structure their outputs in the optimum fashion, target them where they will have the most effect and generally frame their dissemination policy in an effective way,

- identify how circumstances or configurations of events influence the **pace of adoption** of new residential construction technology and how the technology diffusion process may differ depending on what is the **driving force** in the process at any point in time,

- identify the **impediments** to technology diffusion in residential construction, paving the way for actions which will eliminate these impediments, both on the part of governments and the industry,

- identify the **factors conducive** to technology diffusion to enable government and industry strategies to be framed in such a way as to reinforce these factors, and

- identify **ways** in which both government and industry can work to encourage the effective dissemination and adoption of new technologies in the residential construction industry.

1.4 METHODOLOGY

The methodology used to accomplish the study objectives consisted of seventeen case studies of innovations, supplemented by a literature review. The literature review sought to obtain information on the process of technology transfer and diffusion in the low rise residential construction industry generally and by area of case study.

The case studies were chosen to be representative of a cross-section of various industry components, subject areas and sources of innovations. Industry components included house buyers, builders, subtrades, architects and engineers, municipalities and trade associations. Innovations were categorized according to whether they fell under the heading of building materials, building products, construction techniques, construction equipment, building equipment, associated and related services and business management. Source of innovation included Canadian manufacturers, the private construction sector, non-Canadian manufacturers, and non-profit research organizations. Figure 1 summarizes these selection criteria in relation to the case studies.

Each case study involved a series of semi-structured interviews with individuals integrally related to the process including manufacturers, distributors, representatives from trade associations, research organizations and the builders themselves. (The questionnaire included in the Appendix was used as an interview guide.) This study did not involve interviews with house buyers, although information was obtained on house buyers indirectly via the case study interviews.

Figure: 1

CASE STUDY SUMMARY MATRIX

	U.V.Polyethylene	Drywall	Plastic Plumbing	Manufactured Windows	Insulated Sheathing	R 2000 Construction	Modular Construction	TYVEK	Tools & Equip. Rentals	Truck Mounted Cranes	Manuf. Chimneys	HRV'S	Air Source Heat Pump	Nat. Bldg. Code	Mat. Approval	Use Of Computers	CORIAN
Industry components																	
I - House Buyers;		●		●	●	●	●					●	●				●
II - Builders/General Contractors/Developers;	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
III - Subtrades(10);		●	●	●	●	●	●	●	●	●	●	●					●
IV - Architects and Engineers						●	●							●			
V - Building Material suppliers;		●	●		●			●		●					●		
VI - Building Materials and Product Manufacturers	●	●	●	●	●		●	●		●	●	●	●		●		●
VII - Municipalities / Public Interest Organizations	●		●			●											
VIII - Financial/Real Estate/Insurance /Fuel suppliers.						●	●							●	●		
IX - Trade Associations						●								●	●		
Subject area																	
A - Building Materials	●	●	●					●						●	●		●
B - Building Products				●	●									●	●		
C - Construction Techniques						●	●							●			
D - Construction Equipment										●					●		
E - Building Equipment									●		●	●	●				
F - Associated and Related Services														●	●		
G - Business Management																●	
Sources of Innovation:																	
1 - The Canadian Government /Public Sector Research/ Univ.						●						●		●	●		
2 - Canadian Manufacturers;				●	●						●	●	●				
3 - The Canadian Construction Private Sector;				●			●									●	
4 - The United States;		●	●						●				●			●	●
5 - Offshore;	●							●									
										●							

Interviews generally lasted between 45 minutes to over one hour; several interviews exceeded two hours. Altogether, approximately 70 interviews were conducted; a number of interviewees were queried on more than one innovation. This statistic does not include the approximately 70 additional short interviews conducted with building contractor firms to ascertain their level of computerization.

Interviewees were pre–qualified to ensure that their involvement in the innovation was direct, that they were a senior player in the area and that they were recognized as a credible source of information. As a result, the level of cooperation was excellent, with very few contacts refusing to cooperate.

Interviews in Ottawa were conducted in person, with the remaining cross–Canada interviews conducted by telephone. Lines of inquiry pursued during the interview itself included the interviewees' role in the innovation, level of involvement, perceptions of risk, perceived barriers and accelerators to diffusion. More detail may be obtained from the attached questionnaire.

2.0 THE STRUCTURAL ENVIRONMENT

Technology development and diffusion does not occur in a vacuum; it is dictated by the structure and diffusion permeability of the industry and market environment and by the political environment and its effects on such important institutions as CMHC, NRC, EMR and others.

2.1 CHARACTERISTICS OF THE INDUSTRY

The Low Rise Residential Construction Industry is characterized by:

- A large number of small builders and a small number of large builders. In certain areas, large builders are moving out of the Low–Rise Residential Construction Industry and into the High Rise/Commercial Construction segment of the industry, increasing even more the already high proportion of small builders.

- The discontinuity factor. The industry is adversely affected by time, vertical and lateral discontinuities. More than one third of firms have been in business for less than five years. It is also one of the least vertically–integrated industries. Finally, it is also characterized by "lateral" discontinuity as most of the work is subcontracted to independent sub–trades.

- The low formal level of education prevalent in many sub–sectors.

- A products and materials supply system which is geared to high volume, low mark–ups, a situation which works against high margin, low volume, and high value service innovations.

- A primary incentive to reduce costs to the builder.

- A descriptive rather than performance–oriented Building Code.

- o A locally focused inspection process and warranty requirements which inhibit adoption of innovations.

- o Strong local influences which favour local firms and act as effective non–tariff barriers. By discouraging competition, these influences also discourage innovation.

2.2 CHARACTERISTICS OF THE MARKET

With respect to the diffusion process, the characteristics of the Low–Rise Residential Housing market are:

- o The relative unimportance of the buyer as a "prescriptor". Besides a few very visible items, such as "Jacuzzis", "oak railings", "skylights" and other such "hot buttons", buyers play a minor role in determining the products and processes used in the construction of houses. The key individuals are the contractor and the sub–tradespeople.

- o The relative unimportance of long term or life cycle costs considerations to the buyer (initial price and carrying costs are more important than maintenance and operating costs). This mitigates against higher priced innovations even if they are of higher quality and help, for example, to reduce energy costs.

Isolation, lack of communications, risk avoidance, discontinuity and low levels of formal education are generally reliable indicators of an industry structure with low permeability to innovations. This is confirmed by John Landis among others who, in his study "Why Homebuilders Don't Innovate", came to the conclusion that in order to increase the technological level of the industry, more attention should be focused on the "problem of diffusion of innovations rather than on the promotion of inventions".

2.3 THE POLITICAL/INSTITUTIONAL ENVIRONMENT

The present environment can best be understood when put back into an historical perspective. Since World War II the two main actors at the federal level have been CMHC and NRC. In recent years EMR, Industry Associations and Provincial governments have played an increasing role.

CMHC's traditional mandate has been one to promote the construction of residential units. In the process it has played a major role in establishing good building practices and in improving the quality of building materials and components, but the political criterion for measuring success was primarily the one related to number of units built in any given year, rather than to achieving better performance in terms of energy use, air quality or any other similar criterion.

The energy crisis and the UFFI problem profoundly affected the political and institutional environment. EMR, as a result of its mandate in the energy conservation field became a significant player in 1980 through its R2000 program. The R2000 program was the first to focus on performance, it was also innovative in its system approach to buildings and in the type of relationships that it developed with the industry associations (especially the CHBA) and building trades.

The NRC has had a strong presence in the area since 1941 when it developed the National Building Code, but its participation, through the IRC (originally the Division of Building Research) was mainly focussed on developing minimum design requirements in the area of fore safety, structural safety and health.

More recently, the NRC has reversed its traditional reluctance to assume the role of a "certifying" agency and is awaiting Cabinet approval for the setting up of a Canadian Construction Materials Centre (CCMC) which will have a strong industry and provincial input. The purpose of the CCMC will be to evaluate new products and processes and encourage innovation through enhanced industry communication. The CCMC may eventually play an important role in the export promotion of Canadian building materials.

2.4 THE PROCESS OF TECHNOLOGY DEVELOPMENT, TRANSFER AND DIFFUSION

This section uses the James F. Hickling model of the process to illustrate the typical path of an innovation from the R & D stage through to market acceptance, and the unique characteristics which can be associated with the low–rise residential construction industry.

2.4.1 Scope of the Model

In assessing an innovation from inception to diffusion in the marketplace, a distinction is normally made among the three following processes:

1. technology development;
2. technology transfer; and
3. diffusion of innovation.

All three stages are considered in the cases, in conjunction with the three main categories of innovations, i.e., Fundamental, Functional and Adaptive although their relative importance does vary in each instance.

The process of technology development starts with the basic research and progresses through a series of stages. These are outlined in the attached "Proposed Technology Development, Innovation and Diffusion Process for the Low Rise Residential Construction Industry (See Figure 2).

The process of "Technology Development" continues until the "Product Launching" stage. Normally, the process of Technology Development is followed by "Diffusion of Innovation". In diffusing, the "product" goes through a series of steps (outlined in Part Two of the same schematic model) which include "Technical Risk Assessment" and the two concurrent steps of "Review and Approval by Influencers" and "The Regulatory Approval Process" (further detailed in Part Three and Four of the model) to the final stage of "Full Market Acceptance".

FIGURE 2
PROPOSED TECHNOLOGY DEVELOPMENT , INNOVATION AND DIFFUSION PROCESS FOR THE LOW RISE RESIDENTIAL CONSTUCTION INDUSTRY

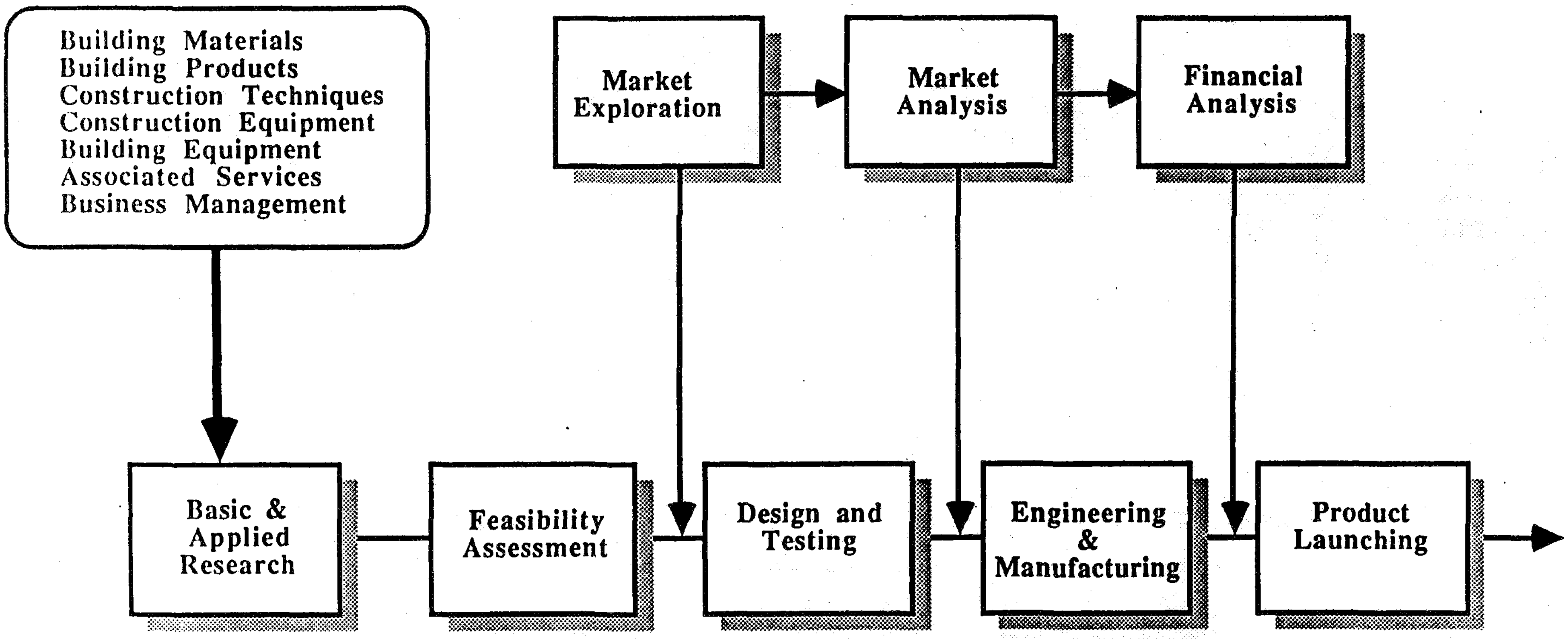
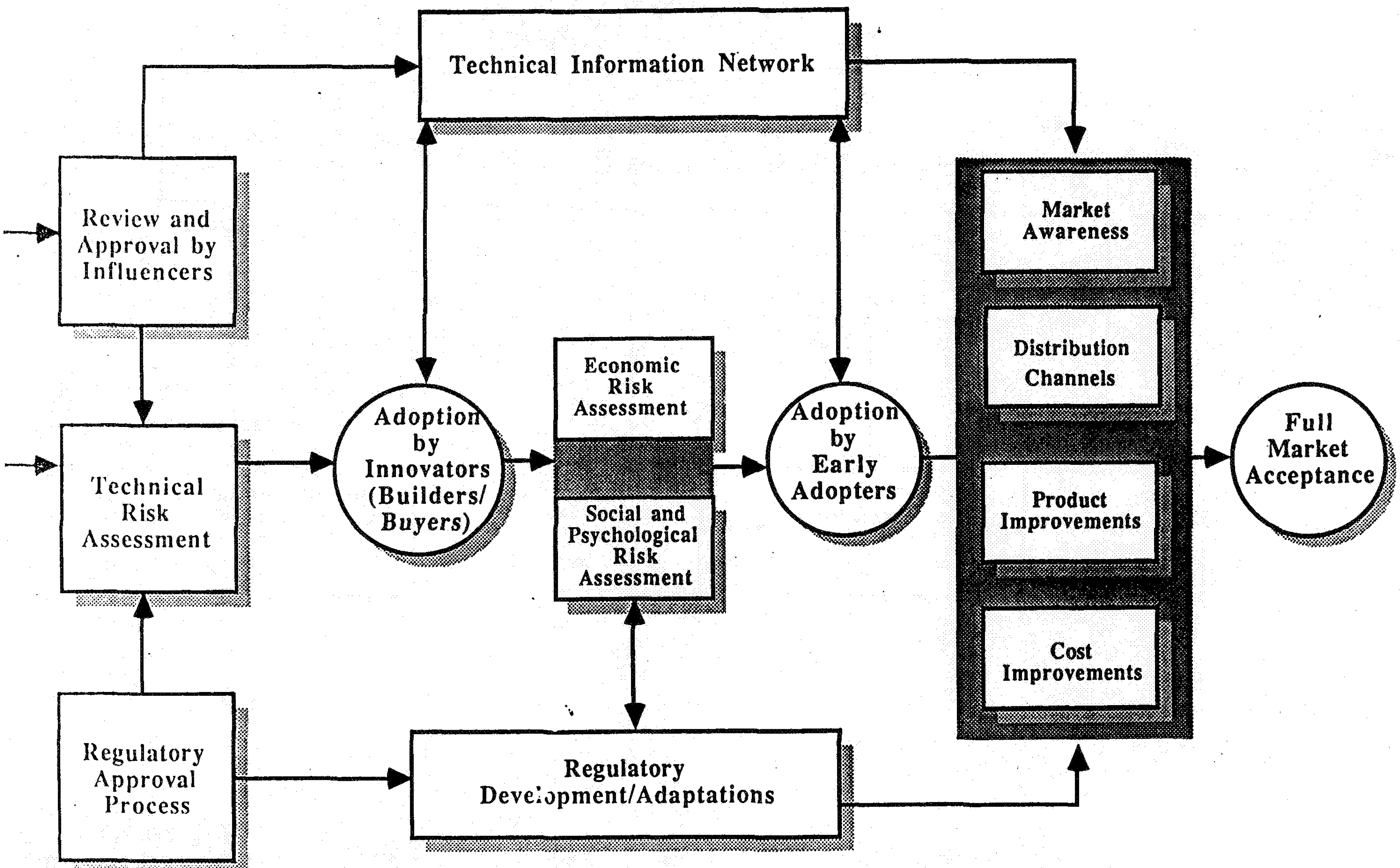


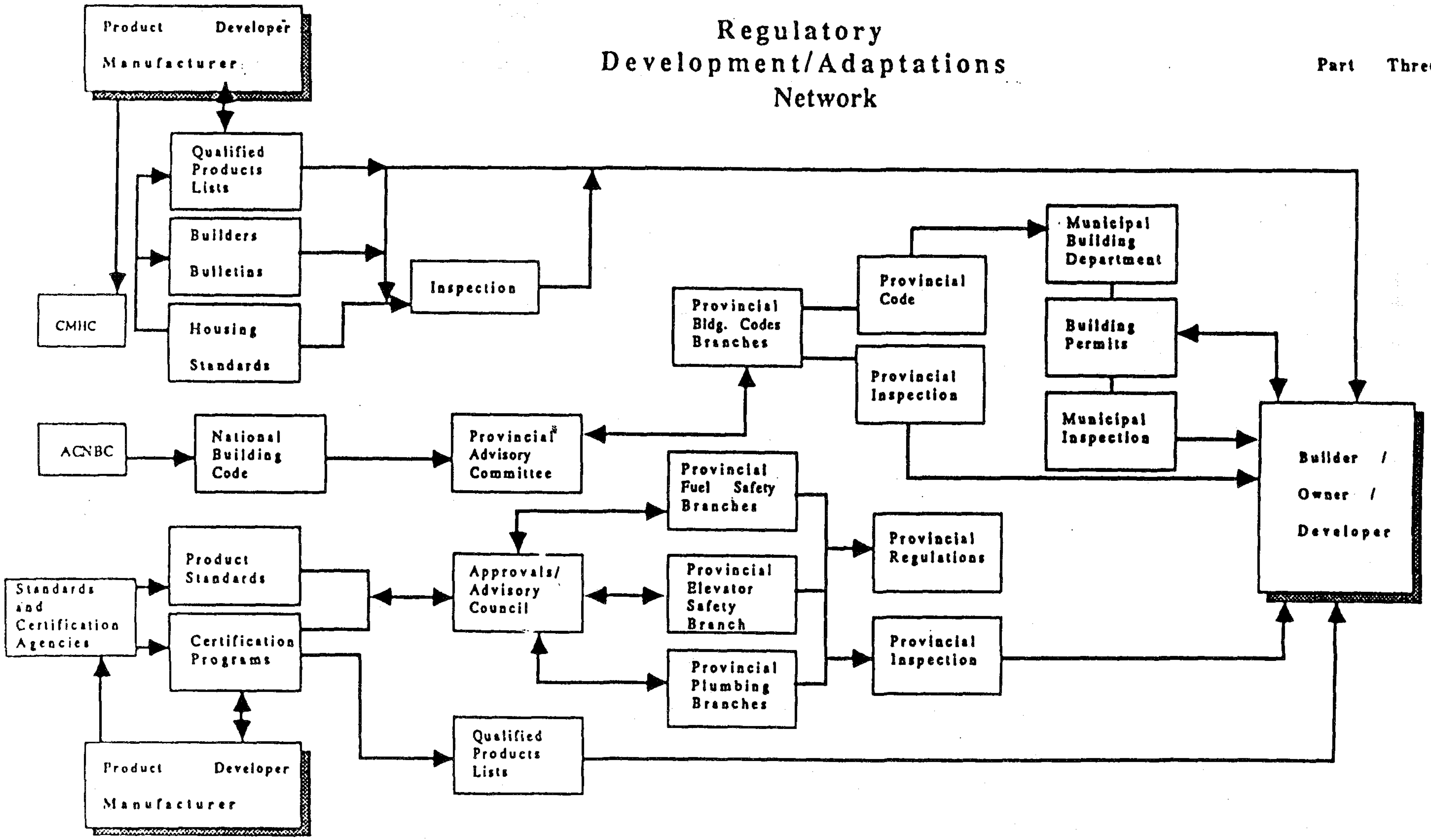
FIGURE 2
PROPOSED TECHNOLOGY DEVELOPMENT , INNOVATION AND DIFFUSION PROCESS FOR THE LOW RISE RESIDENTIAL CONSTUCTION INDUSTRY

Part Two

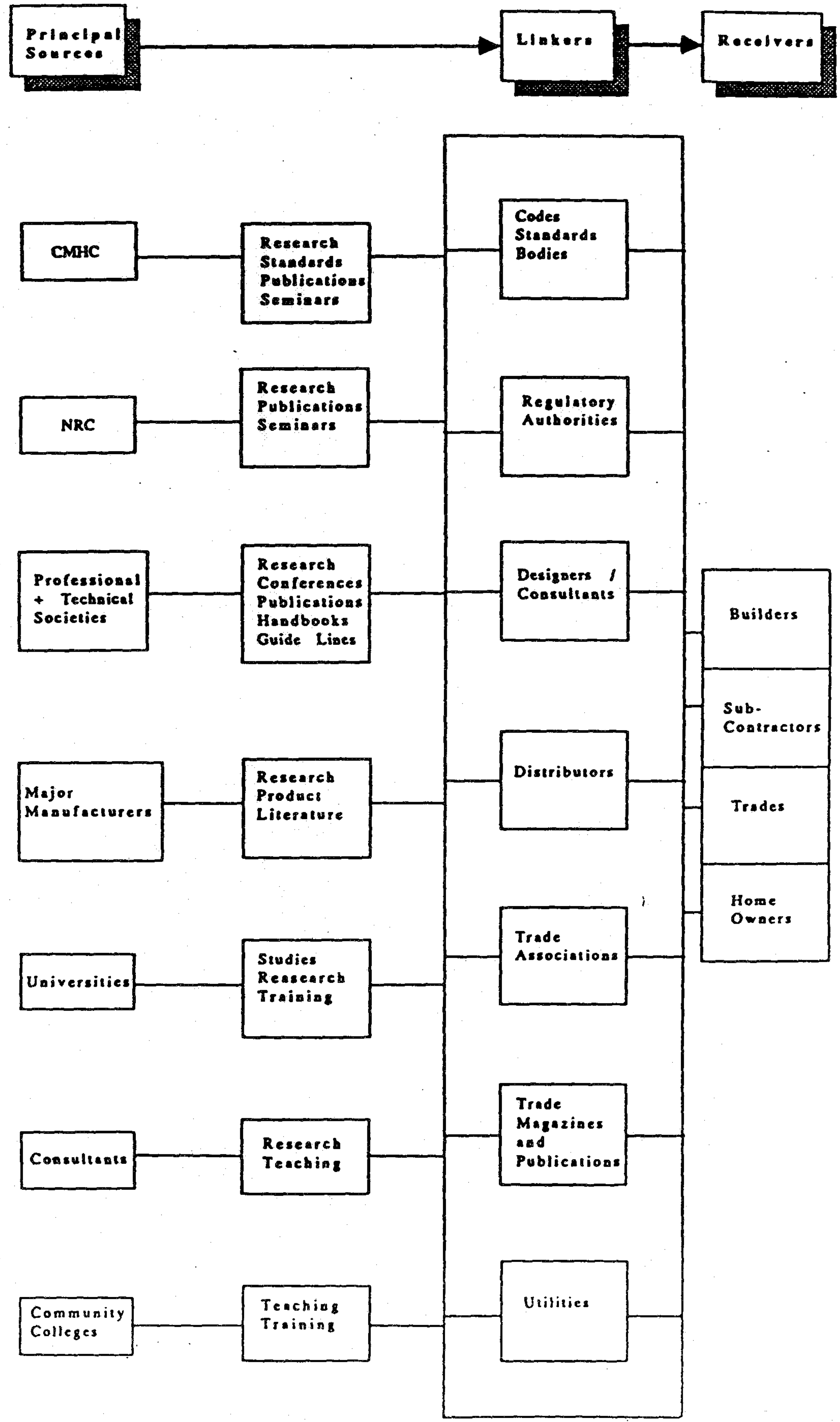


Regulatory Development/Adaptations Network

Part Three



Technical Information Network



2.4.2 The Diffusion Process

The diffusion process is the process by which an innovation is introduced into the market place until such innovation, be it a product or a process, becomes used "on a significant scale". As a product may never achieve total market domination (i.e., 100 per cent of all sales for that type or category of products) diffusion, for the purposes of this study will be said to have been achieved when current sales are in the twenty per cent plus range for the relevant target market. The notion of relevant target market is therefore the key in defining success. For instance, in the Corian Case study,success in terms of diffusion depends on one's definition of the relevant target market. If the broad definition for countertop material is used, then Corian at two per cent penetration might be considered a failure. If the target market is defined as high–priced custom houses and renovations then the extent of market penetration would probably be within the 20 per cent range making it a product used "on a significant scale".

2.4.3 Communications and Diffusion

Effective communication for the purpose of diffusion requires that information be first given to the prospective adopter by a credible source. The quality of the information and its format are important, but the credibility of the source is the most critical element at this stage. The vertical communications step (so called because it generally goes from the manufacturer to the consumer) is not sufficient to achieve a change of attitude vis–a–vis the product. For this to happen, a second step must take place. The recipient and his peers must have an opportunity to discuss, exchange views, develop opinions and receive peer feedback. The importance of this step being related to the fact that peers are perceived as the highest credibility source available in the LRRCI. Case studies have confirmed that all effective communications were a combination of vertical communication (advertising, sales presentations, brochures, etc.) and opportunities for discussions at professional association meetings or training sessions. The R–2000 program is the most prominent example of the continued use of these communication strategies.

2.4.4 Source and Diffusion

In "International Business and Technology Innovation", Roman & Pruett indicated that the diffusion agency tends to vary depending on the reason for the innovation; a demand pull, a technological push or a regulatory requirement. The information gathered from the cases confirms this proposition. Furthermore, the cases also confirmed that the speed, if not the success, of the diffusion process depends on whether the institution responsible for the pushing is big or small and whether it has an insider or outsider status in the industry.

2.4.5 Effect on Inputs

The success and speed of diffusion of an innovation is related to its impact. On important industry inputs such as:

- construction time;
- labour time;
- required labour skills level;
- material costs; and
- first costs/life cycle costs

as well as the market conditions for each of the above. For instance, during periods of low construction activity, tradespeople tend to put a lower value on their time and are less likely to adopt time–saving innovations. On the other hand, gypsum board extended its market penetration due to the fact that lath plasterers were in short supply and its use required a lower skill level.

2.4.6 Measuring Diffusion

Diffusion of innovation is difficult to measure. First, the nature of the innovation changes as the process of diffusion evolves. Second, the presence of adaptive innovations make it impossible to establish the maximum potential diffusion of a given fundamental innovation. Therefore, it is not always possible to determine the level of diffusion which has been achieved. Third, there is a considerable difference between measuring the evolution in terms of number of adopters and in terms of the total production capacity affected by the innovation. Finally, the most commonly used criterion to measure success is financial, which is not necessarily directly correlated to diffusion.

For the purpose of this study, the proposed classification criteria are:

- **Unsuccessful.** First, the innovation did not achieve diffusion either in terms of numbers of adopters, percentage of production affected, or financial impact. Second, in the opinion of experts, the proposed innovation has been bypassed by subsequent technological developments.

- **Successful.** The innovation has achieved penetration in terms of number of adopters, percentage of applicable production affected and/or financial success.

- **Still to be determined.** The innovation cannot be termed successful yet, but in the opinion of experts, it has not been overtaken by technological evolution and its lack of penetration may be due to current market conditions.

2.5 THE PROCESS OF ADOPTION OF INNOVATIONS

2.5.1 The Basic Process

Diffusion is dependent on adoption. Adoption is nothing more than the same process viewed from the receiving end. Adoption has been initially broken down into several steps known as the A.I.E.T.A. model:

- awareness,
- interest,
- evaluation,
- trial, and
- adoption.

Everett Rogers refined the process by identifying several groups sequentially involved in the adoption process (innovators, early adopters, early majority, later majority and laggards) and by defining the characteristics which make a product more or less likely to be adopted (and therefore to diffuse):

- **Relative Advantage.** The extent to which the advantages of the innovation are Visible, Large and Immediate. For instance, wood foundations were accepted readily in the west because of their imperviousness to alkali which is an obvious advantage over concrete.

- **Compatibility.** The extent to which the innovation is consistent with current practices and past experiences of intended users – how much change is required in the organization in order to use the innovation?

- **Complexity.** Does the innovation require a significant higher skill or knowledge level from its intended users?

- **Trialability.** Can the innovation be tried out at a low risk?

- **Communicability.** Can the intended use of, function, and advantages of the innovation be easily described to its intended users?

There are obvious relationships between these diffusability characteristics and the previous A.I.E.T.A. model of adoption. The greater the relative advantage and the higher the communicability, the easier it is to obtain awareness and to sustain interest. The higher the compatibility, the more favourable the evaluation. The lower the complexity and the lower the risk associated with trialability, the more probable is trial occurrence and the more favourable all of the above are, the higher the likelihood of adoption.

2.5.2 The Unit of Adoption

When the unit of adoption is small, i.e., when individuals can adopt one at a time at their own pace or can try out the innovation by consuming only a small quantity at one time, the diffusion process is facilitated because innovators and opinion leaders can play their usual role. When the adoption unit transcends the individual, as for example, in the case of water fluoridation, the normal diffusion process does not occur and there can be considerable resistance to the regulatory process which engendered it. This concept is particularly relevant to the construction industry where a number of innovations have been introduced through regulation with or without strong market support.

3.0 FINDINGS AND RECOMMENDATIONS

3.1 HOW THE DIFFUSION PROCESS WORKS IN THE LOW RISE RESIDENTIAL CONSTRUCTION INDUSTRY

3.1.1 The Industry as a Source

The Low Rise Residential Construction Industry is not a generator of innovations. Almost all of the innovations adopted by the industry over the last several decades originated externally. In terms of Development, Innovation and Diffusion Process (figure 2) it means that the LRRCI does not conform to the proposed model. New building products and materials were brought in by manufacturers and suppliers (which we have defined as part of the larger Construction Industry but outside the parameters of the Low–Rise Residential Construction Industry). Manufacturers and suppliers, not builders and contractors, were involved in Basic R&D, Design & Testing, marketing evaluation and engineering of manufacturing. When a new product is introduced the LRRCI assumes the role traditionally held by consumers rather than the one traditionally played by producers in other industries. The cases included in this study exemplifies this, e.g., Drywall, Polyethylene, Plastic Plumbing, HRVs and Manufactured Chimneys, etc. These examples show innovations being introduced by the manufacturing sector with the majority having been developed either in the U.S. or in some cases, in Europe (Plastic plumbing, Polyethylene, Articulated Cranes and HRVs).

Moreover, the Low–Rise Residential Construction Industry is not a major source of construction techniques. For example, the R–2000 Program was originally devised by EMR, winter construction by CMHC. Only the manufactured housing technology can be said to have originated inside the L.R.R.C.I. However, in light of its market penetration of four per cent, after several decades its success is questionable.

3.1.2 The Industry as an Adopter

The industry is perceived as slow and reluctant to adopt innovations. The major reason is that the L.R.R.C.I. does not possess many of the characteristics which normally favour diffusion and is beset with most of those which hinder it.

The L.R.R.C.I. is not homogeneous. Despite its local, regional and national industry organizations, it remains fragmented and locally focused. The industry lacks opinion leaders with national impact. The Technical Risk Assessment (see Figure 2, part 2) is largely performed outside of LRRCI itself yb Regulatory Agencies and by the Technical Information Network (see Figure 2, Part 4).

Innovators normally play an important role, they perform the Economic, Social and Psychological risk assessment for the entire "Community" (see Figure 2, Part 2). Because the LRRCI "Community" is generally localized, every innovation has to diffuse again and again in each microcosm. This is a great burden that only very large, typically international, product material and equipment materials suppliers or governments can afford to overcome.

While in other industries a demonstration project can be used on a nationwide basis, the L.R.R.C.I. requires that demonstration projects be replicated many times over (at great expense) in the regions and locally.

The case studies also confirm that the L.R.R.C.I. is compartmentalized by function which further hinders diffusion. This tends to work against the introduction of innovations which require multi–sub–trade cooperation. The R–2000 program is an obvious example of the massive undertaking required to introduce multi–focused innovations in the L.R.R.C.I.

As stated earlier, the industry not only suffers from lack of diffusion accelerators (homogeneity, shared "culture", strong communications, strong opinion leaders), it also suffers from the presence of many diffusion barriers.

The first is the high risk aversion prevalent in the industry. Figure 2, part 2 clearly shows that "Risk" is an important consideration in the diffusion process. The higher the risk bearing capabilities (high capitalization, high education, high stability), the higher the capacity (and generally willingness) to adopt innovations. Case after case shows that most builders and sub–trades will not take risks. Reasons for this type of behaviour include lack of a capital which heightens financial risks, the lack of formal education which increases the apparent complexity of innovations and the lack of pressure for change.

In addition, there exists a fear of liabilities which is perhaps one of the greatest deterrents to innovations in the industry. Figure 2, parts 3 and 4 clearly show the complexity of the Regulatory and of the Technical Network. Small LRRCI builders and contractors have almost no direct involvement (and probably little knowledge) in this process. As a result, the LRRCI sees regulation and technical evaluation as potential sources of liabilities. Small builders, contractors and sub-trades do not include long term contingencies in their costs and for them the trend of enforcing greater liability for work and materials is a disincentive to innovate. Two cases provide examples in this area. In plastic plumbing there is a reluctance to use plastic supply pipes, especially the CPVC type for fear of later liability. In the HRV case, the need for the installer to guarantee against negative pressures and back-drafts is a strong disincentive to its diffusion.

Another dimension of the risk/liability issue is related to the local enforcement of building codes (see Figure 2, Part 3 for details). Municipal inspectors routinely reject innovations forcing delays and added costs upon builders. Cases such as manufactured chimneys are a good example of this type of barrier.

Despite all of the above considerations, the reality is that the L.R.R.C.I. is not significantly slower than other industries to adopt innovations in which it finds real advantages.

3.2 TYPES AND CATEGORIES OF INNOVATIONS

The proposed recommendations are the result of the combination of three inputs: the HICKLING diffusion of innovation model, the dual classification of innovations, and the case studies.

As indicated in the body of the report, the first Innovations can be put on two continuums: the first from Fundamental to Adaptive and Functional, the second from Direct to Cosmetics to Invisible. The basic characteristics of Fundamental innovations is that they either fulfill a need which was not being satisfied before or fulfill a given need in a completely novel way.

Adaptive innovations are innovations which already exist in one industry sector and which are being adapted for use in another sector. The fact that they already operate successfully in one sector tends to reduce considerably the barriers to adoption.

Functional innovations are the least disruptive. They occur naturally in the evolution of a product and they involve the use of a known product in a related field in the same industry.

The dual classification of innovations allows the recognition of which innovations will succeed, which probably will not and what is the probable pace of the innovation process.

Innovations can also be categorized according to Direct Substitutes, Visible Cosmetics and Invisible Innovations. Direct substitutes maintain all the essential characteristics of the previous products while adding one or more comparative advantages. Visible cosmetics are fashion or fad items such as fireplaces, skylights or Jacuzzis. Invisible innovations differ from the two previous categories in the they have no immediate or obvious comparative advantage over the products they are supposed to replace and they also lack strong prestige based consumer support.

For purposes of diffusion, innovations can be divided into three major categories:

- o Direct substitutions;
- o Visible Cosmetics; and
- o Invisible innovations.

Perfect direct substitution occurs when the new product maintains all the essential characteristics of the previous product while adding one or more comparative advantages. Adaptive innovations tend to be better "direct substitutes" than fundamental innovations, for example ABS DWV piping is a better direct substitute for iron piping than Drywall is to plaster and lath.

The reason is directly rooted in the difference between the two types of innovations. As a rule, fundamental innovations are "very different" and it takes a while until their characteristics are known and understood and until the perception of risk associated with all that is new and unknown subsides.

The more perfect a direct substitute, the more it reduces or eliminates the problems of complexity, viability and communications (these are important diffusion related characteristics which are dealt with in detail later). It is also more likely to be compatible with current regulations and to achieve faster market acceptance.

"Visible Cosmetics" are items such as Jacuzzis and oak railings which are used by builders to attract buyers. These products are as much fashion items as they are innovations. The most representative example in this study is the CORIAN Case. Diffusion of innovation of visible cosmetics follows the traditional diffusion patterns determined by consumer awareness, interest, evaluation, trial and adoption.

"Invisible Innovations" are not supported by consumer demand and have no immediate or obvious significant comparative advantage in terms of cost, time saving or availability to the builder or tradesperson. Regardless whether they are fundamental or adaptive, builders consider these as strictly cost items without "value added". They are usually unwilling to include them in their basic package because they feel that it would put them at a competitive disadvantage.

At best, builders will agree to include them in the "add-on" list. The most representative examples in this study are HRVs, Active Solar Systems and Air Source Heat Pumps. The important point to note here is that a change in market conditions can improve significantly the prospects for these innovations, but as a rule, the Low-Rise Residential Construction Industry does not easily adopt them.

3.2.1 "Direct Substitutions"

Direct substitutes diffuse most easily, e.g., DWV plastic plumbing and aluminum wiring. Direct substitute innovations maintain the essential characteristics of the previous product and add one or more comparative advantages either in terms of immediacy or magnitude of the benefits. Because of this, the Technical Risk

Assessment (Figure 2, ppart 2), the review and approval by influencers and the regulatory approval process are facilitated.

"Direct Substitutes" start out with a higher level of awareness (see section 2.5.1); interest is easier to obtain and sustain because comparative advantages can be better focussed. Since by definition, Direct substitutes have one or more comparative advantages the "evaluation" function is speeded up and its results are certain to be positive. Since prospective adopters already use a "similar" product (the one being superseded) "trial" opportunity should not be a problem. All of the above translate into a higher probability and a faster adoption pace.

"Direct Substitutes" may come in a variety of levels of "unit of adoption". As indicated in Section 2.5.2, the higher the unit of adoption the more the process of innovation is "collapsed". The fact that all adopters, not only the innovators (see Figure 2, Part 2) must adopt at the sam time does not necessarily reduce the resistance to the introduction of an innovation, rather it is the amount and immediacy of benefits derived which determine the level of resistance.

Compared to other types of innovation, Direct Substitutions have a higher level of acceptance for any given level of unit of adoption. The U.V. stabilized 6 mile file shows however that "Direct Substation" and "unit of adoption" must be defined in terms of the prospective adopters, not as perceived (or desired) by producers.

ABS DWV piping was an exact replica of the previously used product. It required no changes in the all important design or sizing of the plumbing system and it was 50 per cent less expensive and much lighter and easier to work with. The switch from the old caulking method to the new gluing method represented a substantial reduction in complexity. Furthermore, the product was easier to carry, store and use. Given all these positive characteristics, its diffusion was one of the most rapid ever experienced by the industry. Even then it took the better part of 3 years to go from its Canadian debut to full adoption (or eight years if one considers the first worldwide introduction of the product).

The situation for aluminum wiring was similar to ABS DWV piping. It resembled copper wire and was certainly used interchangeably. Small problems with brittleness and conductivity were largely ignored. Acceptance was again facilitated by price and availability considerations and the support of a strong manufacturer. First market use in Canada occurred in 1948 (1946 in the U.S. and 1934 in Europe) with real market push occurring in the late 1950s and 1960s. The product had achieved very significant distribution in the mid 1970s when it was withdrawn due to the fact that it became more and more obvious that aluminum and copper wires were not interchangeable and were not even compatible.

3.2.2 "Visible Cosmetics"

Visible cosmetics are a different category of innovations altogether. They are the so called "hot buttons" which developers and builders use to attract buyers. The only case study which might be seen in this category is "CORIAN".

Visible cosmetics such as Jacuzzis, oak railings and skylights are as much fashion fads as innovations.

Visible cosmetics are market driven with the L.R.R.C.I. capitalizing on the promotional work done by the manufacturers.

Because visible cosmetics are the only type of innovation in which the consumer is involved, (see Figure 2, Part 2) its diffusion process is very different from the other two types of innovations. Visible cosmetics are the only kind of innovation in which buyers played a role as Innovators, Early Adopters, and so on, and in which buyer related socio–economic factors are deemed relevant. As indicated in the proposed LRRCI diffusion model (Figure 2), Innovator (buyers) do the economic, social and psychological risk assessment on behalf of the potential buying "public". The role of the innovators and Early adopters is complicated by the fact that house buying is (at best) an infrequent behaviour. As such, the number of innovators directly involved in a purchase evaluation process at any one time is lower for housing related item then for most other goods. On the other hand, the purchasing of "visible cosmetics" tends to generate a high amount of communication. The high "social value" of visible cosmetics tends to facilitate awareness creation (see section 2.5.1) and interest. Evaluation is not based on performance or cost criteria but on image. The benefits are social, not economic and the "immediacy" factor is very important in accelerating the adoption process (to have any kind of prestige value a visible cosmetic must be adopted early enough in the diffusion process to project an image of trend setter on the adopter).

Another great advantage of visible cosmetics is that they rank very high in terms of compatibility and "communicability" (see Section 2.5.2).

The high communicability of Visible Cosmetics is a key to their diffusion because producers must take over the communication "networking" role normally fulfilled by innovators and early adopters. If visible cosmetics were not so easy to "communicate", the high fragmentation of the industry would make diffusion very difficult. The CORIAN case typifies this situation by showing that the product first penetrated the high end of the market and the trendy "yuppies" renovation movement.

Oddly enough, CORIAN is also doing well among "empty nesters", a group which, based on age, one would not expect to be in the Innovator category. This may indeed signal an important twist in diffusing patterns, i.e., that the greying of society is changing the socio-economics of diffusion patterns.

3.2.3 "Invisible Innovations"

Active solar systems, Air Source Heat Pumps and HRVs are examples of "Invisible Innovations".

In terms of diffusion process (see Figure 2), "Invisible Innovations" share one common characteristic: they are the result of a product push where the basic R&D; feasibility; design; engineering and production stream greatly overshadows the market exploration and analysis stream. This is generally due to the fact that "invisible innovations" cannot be compared to anything already on the market (e.g., 4RV's) or because market demand was predicated on certain factors which never materialized (e.g., sustained energy scarcity).

A number of "invisible innovations" make it to the Adoption by Innovators stage (Figure 2, Part 2), but innovators typically represent 2.5 per cent of the total population of potential adopters, which is insufficient to insure successful diffusion (see Section 2.4.6). "Invisible Innovations" by definition, rank unfavourably in terms of one or more comparative advantage factor such as economic, social and psychological risk and are therefore predivided to diffuse further.

Figure 3 (Barriers and Diffusion Accelerators) confirm the fact that invisible innovation have a negative rating on a significant number of relevant diffusion factors, when compared to direct substitutes or visible cosmetics.

Builders tend to consider invisible innovations as strictly cost items without "value added". They are unwilling to include them in their basic designs because of the added costs which they feel they cannot recoup from buyers who tend to be most concerned with the initial purchase cost to the exclusion of life cycle maintenance and operating cost considerations.

At best, builders will agree to place these innovations on the add–on list which is used to bolster the profit margin beyond the basic unit.

When the market for housing increases and becomes a seller's market, builders become very selective about the invisible items they are willing to include. They will even discard items such as higher quality windows and air barriers and may even refuse to bother with add–ons.

The very nature of invisible innovations suggest that they will not diffuse easily. In order to diffuse, a product must leave the "invisible" category and become a:

- "visible cosmetic" product; or
- direct substitution product; or
- a legislated product (see below for details).

A product can shift categories by virtue of being presented differently, by emphasizing a more sought–after quality. For example, HRV is now enjoying greater success because it is being sold for its ability to control humidity rather than heat.

Interestingly, solar systems and HRVs were not designed originally as "invisible products". It was expected that the evolution of the energy situation would create such a high level of consumer awareness that they would become "visible" (if not "cosmetic") products. Manufacturers of these products are well aware of this situation and are seeking assistance to gain further economic advantages and eventually reposition themselves as direct substitution products. HRV manufacturers also hope that the rise of the indoor air quality issue will bring added consumer awareness and stronger regulatory backing.

The importance of the above observation is clearly outlined in the Polyethylene Vapour Barrier case study. Manufacturers of polyethylene film know that they cannot diffuse the new six mil film (a typical "invisible") until they get the support of a standard which mandates its use. They have therefore refrained from producing the new product until the regulation is in place.

Legislated Products

Some products owe their use to a regulatory requirement rather than to market conditions. The study sample contained only one product which could be classified as such, the UV stabilized polyurethane vapour barrier film. However, as of this writing, the product had not achieved the desired status as a "mandated" product.

The lack of specific data on "legislated products" precludes any conclusion, but it appears that any type of product (with the probable exception of visible cosmetics) may achieve the related status of legislated product with the obvious result that both success and diffusion pace would be greatly enhanced.

BARRIERS AND DIFFUSION ACCELERATORS

As indicated in Summary Figure 1, there are a number of characteristics which affect innovation. The following is a brief discussion of each of those characteristics. It must be noted that these have been stated as separate items for explanation purposes, although, in reality, they are all intertwined. Summary Figure 2 highlights the cumulative effect of barriers and accelerators on the diffusion process itself in terms of probability of success and resulting innovation pace.

Relative Advantage

If an innovation does not yield a cost saving,labour saving or allow for the use of less skilled labour or that of a more abundant type, i.e., time or energy saving, it will not be of interest to the potential user. Adoption of an innovation is not only related to the existence, size and type of advantages, it is also related to how concrete and how immediate the advantages are. In terms of Diffusion Process, the degree of perceived Relative Advantage impacts directly on te economic, social and psychological risk assessment (Figure 2, Part 2). As such it is the major barrier to diffusion between Innovators and Early Adopters.

Compatibility

A tradesperson is not interested in adopting an innovation which either forces him to change working habits or which threatens his livelihood. A good example is manufactured housing which generates little enthusiasm from those it would displace. Low compatibility is typical of the information picked up by the technical information network (and by the informal peer group information network).

Low compatibility directly affects the risk assessment component of the Diffusion process (Figure 2, Part 2).

Communicability

In a way, communicability is directly related to relative advantage. If the advantages are easy to explain, they are easier to understand. Tyvek, with its slogan "windbreaker over a sweater" is a brilliant example of how to overcome a potential drawback of the product, i.e., what does it do, and int his particular case, what is the difference with the vapour barrier and why should ti go on the outside.

High Complexity

It is a corollary of the previous factor. If an innovation is too complex it is seen as too risky and incompatible. HRVs are seen as complex and this is a barrier to their support by heat and ventilation tradespeople.

Trialability

Trialability is directly related to risk perception. The consumer (or builder) is reluctant to commit to a choice which may involve considerable financial or market, or for that matter plain operating risks. If the prospective adopter is allowed to "try" the product, he is in a position to make a better evaluation of the real risks. As a rule, if the product performs according to expectations this greatly facilitates the process of adoption.

The Sears Roebuck company has built its entire marketing strategy on this element of the diffusion process. Its slogan "satisfaction or your money back" was directly aimed at having consumers try out products at no risk.

Risk

Members of the L.R.R.C.I. have a low tolerance for risk. They will stay away from any innovation which carries a market risk, a competitive risk and especially a financial risk. This is due to their low level of capitalization which does not allow them to use a product before it is well accepted by the market, even if the product has proven itself in another area (e.g., wood preserved foundations) nor if it may increase costs without "adding value" (competitive risk).

The low risk tolerance of the LRRCI is an important element in the explanation of why "direct substitute" and "visible cosmetics" products are adopted while "invisible innovations" are not.

Distributor Strength

If the distributor launching a new product does not have the prestige and the resources, he may not be able to undertake the promotional, advertising and training activities needed and therefore fail to give the push necessary to establish the product on the market. A strong distributor has the staying power necessary to shepherd his product through the various steps of the process.

Trade Resistance

The L.R.R.C.I. is very fragmented and characterized by very low vertical integration and very high sub–contracting. In such an environment, each participant tends to have a very specialized role such as excavation, foundation form, cement, framing, electricians, plumbers, drywallers, roofers, etc. Each operates in a time tested way which minimizes interfacing problems with the other sub–trades and, incidentally, with the municipal inspectors. Any product or process innovation has the potential to upset this carefully balanced situation.

Regulatory Resistance

It used to be linked to product structure, increasingly it is being linked to product performance and to possible secondary, delayed or combined effects.

Plastic pipes are being held back in part because there were delays in approving their use for hot water, and even for cold water when connections are of the "crimped" type (because of flow restriction).

Manufactured chimneys had to prove themselves province by province, town by town before they finally overcame regulatory resistance.

The stagnation of HRV sales is to an extent linked to the fact that installers are, by regulation, responsible for the ventilation balance of the dwelling where an HRV is being installed.

All of the above indicate that regulatory resistance can be a major barrier to diffusion and an important element in determining the pace of diffusion.

Liability

Small builders and sub–trade people do not, as a rule, have a high level of formal education. The cases confirm that word of mouth is their major channel of communication. Information is passed on by the manufacturer's representative or by a distributor, but because of their low credibility this information is first cross–checked in discussion with peers before it is acted upon. Over the years, builders have become more and more concerned about liabilities. The various provincial home warranty plans have done nothing to calm these fears.

The high fear of liabilities is not being checked by the communication network and this is resulting in builders and sub–trades people rejecting innovations for fear that they may lead to unforeseen liabilities down the road. As mentioned in the plastic plumbing case, it leads to the so called "IBM" syndrome. A builder will use the traditional product because, if it fails, he cannot be blamed while he may be if he used a new "untried" product.

Supporting Innovations

Many times, an innovation fails to diffuse because it is held back by a technical problem as was the case with CORIAN, or by drywall before the invention of the tape, drywall screw and ready mixed compound. A supporting innovation, such as cladding or double glazed, sealed panes, can increase the relative advantage of a product and facilitate or speed up its diffusion.

Government Support

Government assistance for R & D, demonstration, training, or sales support is an obvious aid to diffusion since it lowers costs, favours communications, reduces risk and increases relative advantages.

Consumer Resistance

Consumers have only a limited knowledge of the construction process and of what materials are utilized. Nonetheless, over the years, consumers have formed strong opinions about certain products and these opinions have affected the purchasing behaviours of builders and developers who are unwilling ot take market risks or eve to spend time and money in the process of educating the consumer. For example, in the early days Drywall was considered inferior. This perception slowed down Drywall diffusion for many years.

CPVC pipes are being hampered because builders believe that consumers are concerned about the fact that they are a "chlorine" product. To an extent, all "foam" insulating material are suspect because consumers are still concerned about "UFFI".

The best example is perhaps the treated wood foundations which are widely used in other areas but almost non–existent in others because of "consumer resistance".

THE PACE OF INNOVATION

Any classification along a continuum is open to discussion, any a posteriori classification is even more so. The diffusion of innovations literature which spans more than 20 years and hundreds of products is sufficiently robust to support the classifications which have been made below nonetheless these conclusions are being offered as indicative only until they are validated by a sufficient number of cases involving a– priori classifications followed by the necessary monitoring of market penetration.

The three figures that follow highlight the influence of innovation type on the pace of diffusion. The first figure, Figure 4, shows the time it took for each innovation studied to diffuse in Canada (and in the world). The second figure, Figure 5, is an attempt to classify innovations along the Fundamental Adaptive/Functional Continuum and across the "Direct Substitute"/"Visible Cosmetic"/"Invisible Innovation" range. It also indicates if diffusion was successful and how long it took to succeed (in Canada).

The third figure, Figure 6, is a summary of the preceding one and it shows that:

- o The Direct Substitutes included in the sample had a 100 per cent diffusion success rate. This rate held for all three categories: Fundamental (three case studies), Adaptive (two case studies), and Functional (one case study). While the low number of case studies int eh sample precludes sweeping conclusions, the results are nonetheless indicative of the probably existence of an explanatory relationship.

- o As expected, there is a continuum int eh Canadian pace of innovation, even within a given category. For example, in the case of Direct Substitutes:

  - It took an average of 28.8 years for Fundamental Innovations to diffuse in Canada
  - It took only 14.8 years for Adaptive Innovations and
  - Only seven years for functional ones.

  This acceleration of the diffusion process is in step with the diffusion theory which holds that:

  - the success of an innovation is related to its classification on the Direct Substitute/Visible Cosmetics/Invisible Innovation nominal scale; and
  - the pace of diffusion is related to the classification on the Fundamental/Adaptive/Functional classification.

- o As expected, there are no Fundamental/Visible Cosmetics products. To be successfully, "visible cosmetics" products must offer little or no risk. This tends to preclude innovations which by definition have some element of risk. As a rule one would expect Visible Cosmetics to originate from the adaptive or functional areas.

- o The Visible Cosmetics/Adaptive products included in the sample (two case studies; CORIAN and Tyvek) have a high diffusion success rate. In fact, if one considers Tyvek as a success (although results are still pending) the rate would be 100 per cent.

- It took CORIAN 13 years to diffuse in the LRRCI from its first introduction (in the institutional market) in Canada. It took only six years from its introduction in the LRRCI to achieve success in its target market.

- The case study sample includes six Invisible Innovations, they have a 0 per cent rate of diffusion success. Some of the products in this category have been on the market for as long as 40 years, most have been available in Canada for 13 years and longer.

As can be seen in Figure 2.2, risk assessment is a key part of the diffusion process. Tolerance to risk is directly associated with willingness to adopt (the higher the tolerance the faster the adoption).

A strong distributor is likely to be a member of several institutions involved in the technical information and regulatory networks (see Figure 2, Parts 3 and 4). This participation may be in the form of presence on committing or opportunity to express positions at association meetings. A strong distributor is also able to support the information effort required to bridge the communications gap between innovators and early adopters due to the market fragmentation. A strong distributor will also be able to support the repeated demonstrations required to achieve level of awareness in Canada.

A strong distributor is also better able to support the distribution channel development as well as the product and cost improvement (see Figure 2, Part 2) process which is necessary to fine tune the product in relation to the market.

The Dupont company is an example of what a strong distributor can do (see CORIAN Case Study).

FIGURE : 3
BARRIERS AND ACCELERATORS TO DIFFUSION

Product *	Relative Advantage *	Compatibility*	Communi-cability *	Complexity*	Trialability*	Risk *	Innovator* Strength	Trade * Resistance	Regulatory * Resistance	Perceived Liability Risk *	Supporting * Innovation	Government * Support	Consumer * Resistance
Drywall (after 1945)	O	O	O	O	O	O	O	⊗	⊗		O		⊗
Aluminum Wiring	O	O	O	O	O	O	O		⊗				
ABS DWV	O	O	O	O	O	O	O						
CPVC Pipes	⊗	⊗		O	⊗	⊗	⊗	⊗	⊗	⊗			⊗
Pb Pipes	⊗	⊗		O	⊗	⊗	⊗	⊗	⊗	⊗			⊗
HRV's	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗		O	
Manufactured Windows	O	O	O	O	O	O	⊗				O		
Insulated Sheathing	O	O	O	O	O	O	O						
Modular Homes	⊗	⊗	O	O	⊗	⊗	⊗	⊗					⊗
Telescopic Cranes	O	O	O	O	O	⊗	⊗						
Articulated Cranes	O	O	O	O	O	⊗	⊗						
Manufactured Chimneys	O	O	O	O	⊗	O	O	⊗	⊗		O		⊗
Air Source Heat Pump	⊗	O	⊗	⊗	⊗	⊗	⊗					O	
Tool & Equipment Rental	O	O	O	O	O	O	⊗						
CORIAN	O	O	O	O	O	O	O	⊗			O		
Active Solar Systems	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗				O	
UV Poly Film	⊗	O	O	O	O	⊗	O	⊗					
Micro-Computer use by Building Contractors	O	O	⊗	⊗	⊗	O							
The National Building Code	O	O		⊗			O	⊗				O	
Materials Approval	O	O		⊗			O	⊗				O	
TYVEK	O	O	O	⊗	O	O	O						⊗

* Information On This Table Is Only Indicative
Please Refer To Case Studies For Specific Details ,
Especially When Evaluation Was Involved.

⊗ REPRESENTS A BARRIER TO DIFFUSION

O REPRESENTS A DIFFUSION ACCELERATOR

FIGURE : 4
THE PACE OF INNOVATION

Product (2)	Earliest (1) Marketing Worldwide	Earliest (1) Marketing in Canada	Significant (1) Diffusion in Canada	World Related Pace (1)	Canadian Pace (1)
Drywall	1910	1930's	1960	50y	30y
Aluminum Wiring	1934	1948	1965	31y	17y
ABS DWV	1960	1965	1968	8y	3y
CPVC Pipes	1975	1975	not reached	--	--
Pb Pipes	1972	1975	not reached	--	--
HRV's	--	1976	not reached	--	--
Manufactured Windows	--	1945	1955	--	10y
Insulated Sheathing	--	1980	1987	--	7y
Modular Homes	--	1945	not reached	--	--
Telescopic Cranes	--	1950	1980	--	30y
Articulated Cranes	1945	1955	1985	40y	30y
Manufactured Chimneys	1933	1933	1965	32y	32y
Air Source Heat Pump	--	1970	not reached	--	--
Tool & Equipment Rental	--	1945	1965	--	20y
CORIAN	1972	1974	1987	15y	13y
Active Solar Systems	1960	1975	not reached	--	--
TYVEK	1982	1983	not reached	--	--
Micro-Computer use by Building Contractors	1973	1974	1988	15y	14 y
The National Building Code		1941	1965		24y

(1) All Dates Are Approximated

(2)The CMHC Materials Evaluation and the UV Stabilized Polyethylene vapour barrier cases are Not Included In This Table.

FIGURE :5
INNOVATION TYPOLOGY AND DIFFUSION

PRODUCT	INNOVATION CATEGORY	INNOVATION TYPE	BARRIERS	ACCELERATORS	SUCCESS	WORLD PACE	CANADIAN PACE
MANUFACTURED CHIMNEYS	Direct Sub.	Fundamental	low	medium	Yes	32 y	32 y
DRYWALL	Direct Sub.	Fundamental	low	high	Yes	50 y	30 y
NATIONAL BLDG. CODE	Direct Sub.	Fundamental	low	high	Yes		24 y
							Avg = 28.7 y
TOOL & EQUIPMENT RENTAL	Direct Sub.	Adaptative	low	high	Yes		20 y
ALUMINUM WIRING	Direct Sub.	Adaptative	none	high	Yes	31 y	17 y
MICRO COMPUTERS	Direct Sub.	Adaptative	low	medium	Yes		14 y
MANUFACTURED WINDOWS	Direct Sub.	Adaptative	low	high	Yes	15 y	10 y
ABS DWV PIPES	Direct Sub.	Adaptative	none	high	Yes	8 y	3 y
							Av = 12.8 y
INSULATED SHEATHING	Direct Sub.	Functional	none	high	Yes		7 y
							Av = 7 y
TELESCOPIC CRANES	Direct Sub.	Fund/ Adapt	low	low	Yes		30 y
ARTICULATED CRANES	Direct Sub.	Fund/Adapt	low	low	Yes	40 y	30 y
							Avg=Not aplic.
CORIAN	Visible Cosm.	Adaptative	none	high	Yes	15 y	13 y
TYVEK	Visible Cosm.	Adaptative	low	high	?		
							Avg= 13 y
CPVC PIPES	Invisible Innov	Fundamental	high	low	No		
PB PIPES	Invisible Innov	Fundamental	high	low	No		
HRV'S	Invisible Innov	Fundamental	high	low	No		
AIR SOURCE HEAT PUMPS	Invisible Innov	Fundamental	medium	low	No		
ACTIVE SOLAR SYSTEM	Invisible Innov	Fundamental	high	low	No		
MODULAR HOMES	Invisible Innov	Adaptative	high	low	No		

(1) The Data contained in this figure was obtained from Summary Figures 1 and 2, as well as from the case studies.

(2) The " Materials Evaluation " and the " UV Stabilized Poly Film " cases were not included because no Track Record is yet available

FIGURE : 6

INNOVATION TYPOLOGY AND DIFFUSION

SUMMARY TABLE

% RATE OF SUCCESS / AVERAGE PACE of DIFFUSION	Direct Substitutes	Visible Cosmetics	Invisible Innovations
Fundamental Innovations (1)	100 % / (2) 28.7 Years	N.A / N.A	0% / - 0 -
Adaptive Innovations (1)	100 % / (2) 12.8 Years	50 % / 13 Years	0% / - 0 -
Functional Innovations (3)	100 % / (3) 7 Years	N.A / N.A	N.A / N.A

(1) Excludes Telescopic and Articulated Cranes which could not be adequately classified
(2) This figure represents the average number of years it took this category of products to achieve successfull diffusion in Canada , as per figure 3
(3) Based on 1 product only
(4) Does not include TYVEK. If TYVEK is considered successfull, figures would be 100 % and 9 Years.

3.4.3.1 The Manufacturers

Manufacturers perform two accelerator functions. They reduce risk by providing information and generate demand through advertising and consumer–oriented communications.

Manufacturers provide information about the product and, in many cases, they also provide the training required to use or install the product efficiently. These two factors, information and training, are a constant in all successful innovations. It can, in fact, be said that those are a necessary condition for the success of an innovation. Unfortunately, they are not necessarily a sufficient condition of success.

The training component is a very important part of the mix. The Corian Case is an example of what may happen without appropriate training.

Manufacturers and the distributors also play a role in educating the public, an important consideration for "visible cosmetics" products and in educating local building inspectors.

3.4.3.2 Associations

Because of the requirement for "standardized interfaces", every product must fit into a particular class. Isolated manufacturers are not generally in a position to establish standards for a whole class of competing products and brands. This is the role of the associations.

Standard setting associations reduce risks at the interface level. Trade associations also reduce risk by providing a forum for the evaluation of new products and processes. They may also reduce liability risks by acting on behalf of the trade in negotiations and by diffusing credible information on risk–related matters.

Finally, associations reduce risks by supporting training and certification programs.

3.4.3.3 Government and Government Supported Institutions

The cases show that in Canada the Federal government, through such agencies as CMHC and NRC, and to an extent through EMR, has had a long standing policy of pro–active involvement. The case studies also show that this involvement was generally supported and sometimes led by Provincial departments and institutions operating in similar areas.

Case studies show clearly that the one area in which government agencies have been prominent is the area of process innovation and diffusion. The major examples are winter construction, the introduction of the of the materials approval, the spearheading of National Building Code, the R–2000 Program and the present sustained effort to introduce Unified Canada–wide Material Evaluation and Reporting Program.

All major process related innovations have, to a large extent, been conceived and diffused by government. Government agencies have also played a leading role in promoting development through their direct involved (NRC) or financial support (CMHC, EMR) in the areas of R & D and testing of new products. There is, however, a cautionary note. The UFFI case was not a part of this study, but references to it were made on numerous occasions by respondents. The gist of these comments is that the UFFI case has, of late, had a chilling effect on the activities of certain government departments involved with the Residential Construction Industry. It has a particularly strong effect on CMHC's Materials approval which tended to become overly cautious and, from a strong diffusion accelerator that it had been, may have shifted to a gate keeper role. To an extent, the same comment has been kicked at the NRC.

3.4.3.4 The Tool and Equipment Rental Sector

The Tool and Equipment Rental sector, as shown by the case on that sector, is playing a very central role in the diffusion of tools and equipment in the L.R.R.C.I. As stated in the case and confirmed in interviews with builders and sub–tradespeople, a considerable quantity of new tools and equipment enter the

L.R.R.C.I. through rental channels. Rental people claim that all tools and equipment innovations are now being introduced through this channel.

Tool and equipment renters are in a unique position to reduce risk. First, they reduce risks associated with business fluctuations. A tradesperson will rent additional tools when the volume of business increases temporarily rather than buying. Second, they reduce the complexity risk. A small builder may well prefer to rent equipment and pass through the cost rather than own the equipment and have to estimate per job costs based on amortization and depreciation formulas. Third, they reduce the financial burden associated with owning outright some fairly expensive pieces of equipment regardless of frequency of use. For a chronically undercapitalized group, this is a considerable comparative advantage.

Then there is the reduction in the product risk itself. A framing carpenter may be reluctant to spend $700 on a power nailer but will generally be willing to pay $20 to give it a try for a day. Apparently this process is now going even further. Tradespeople are now comparison shopping through successive rentals of different types and makes of equipment.

The strong trial and risk reduction function of the tool and equipment rental sector has become a leading diffusion accelerator. Unfortunately, no comparable institution exists in the area of products and processes.

3.6 COMMUNICATIONS IN THE LOW-RISE RESIDENTIAL CONSTRUCTION INDUSTRY (L.R.R.C.I.)

Understanding and mapping the communication process was a constant concern throughout this study. Each interviewee in each case was asked how he had become aware of the existence of this item, (see attached Questionnaire, Question 19), what was his main source of early information on product capabilities and characteristics, (Question 20), and which are his most reliable source of industry–related information, (Question 21).

The response was always basically the same; word of mouth. In some cases, this was qualified; word of mouth through the trade associations, manufacturers' representatives, or peers. Only government respondents and members of Standard Setting Committees and Association members rely regularly on written sources of information. In the field, the information flows verbally.

The study confirms the low credibility attached to supplier originated information which is considered biased, the overall low level of importance of written information and of information in general. Inter-group communication such as between architects and builders or between them and electricians or plumbers do not play a significant factor in information gathering. In fact, the study did not identify any such sustained communication. In no case was another trade a significant source of information or was it named as a credible source.

This study's conclusion is that communication in the L.R.R.C.I. is not an unknown phenomenon; it is an underdeveloped one. In terms of diffusion, this presents a major challenge because, as stated several times in this study, innovation diffuses through risk reduction and risk reduction can best be affected through communication.

OBSERVATIONS AND CONCLUSIONS ON DIFFUSION OF INNOVATIONS IN THE LRRCI

Given the characteristics of the L.R.R.C.I., and the findings from the case studies, the conclusion is that the L.R.R.C.I. may be slow, but is not significantly slower than other industries. What is important is that Direct Substitutions Innovations do diffuse and that the cases allow the identification of two distinct phases in their diffusion. The first stage is the latent stage or incubation period which could be accelerated. The other is the take-off phase which is already fairly fast.

Based on the analysis of Summary Figures 1, 2, 3, 4 and on observations from the case studies. A number of tentative conclusions can be drawn. Because of the small sample size of case studies these conclusions are presented as working hypothesis which should be submitted to further validation.

It is important to note that the conclusions of this study concur with those made by THORKELSSON ARCHITECTS in their study prepared for the Financial Assistance and Research Branch of the Housing Division of Alberta Municipal Affairs. Namely that:

1. The process by which innovation and technology transfer takes place is not well understood, particularly by the innovators who are involved in it.

2. Innovators are not as skilled as they need to be in assessing and refining their innovation and explaining its full advantages to others whose support would help the innovation's acceptance.

3. There is a general lack of money to develop innovations.

4. The general ignorance of a house buyer about most aspects of residential construction precludes him from being an effective contributor to the trends in housing innovation as it applies to building technology, materials and products.

5. Builders by and large are risk averse and resist incorporating innovations into their building processes unless there are well proven and demonstrated advantages.

In addition to the above, this study yielded the following:

1. The probability of success of an innovation is directly related to its classification as a Direct Substitute, a Visible Cosmetic or an Invisible Innovation.

2. Direct Substitutes and Visible Cosmetics appear to have a very high rate of success.

3. Where the innovation is not supported by consumer demand and has no immediate or obvious significant comparative advantage to the builder or tradesperson (i.e., it is an "invisible" innovation), it has very little prospect of diffusion success.

4. The pace of diffusion of an innovation is directly related to its classification as a Fundamental innovation, an Adaptive innovation or a Functional one.

5. Functional innovations diffuse fastest, followed by Adaptive innovations and Fundamental ones.

6. The strength of the company launching a product can influence the pace of adoption.

7. The strength of the company launching a product has less influence on the eventual success than the type of innovation involved.

8. Trade resistance can slow down the pace of innovation, but does not appear to determine the eventual probability of success.

9. Trade resistance is mainly based on incompatibility between the proposed innovation and current habits and practices.

10. Sub–trade specialization and reluctance to update other trades is a major factor in trade resistance.
11. Being able to try–out a product is an important diffusion accelerator.

12. Product complexity, or at least perceived product complexity is a barrier to diffusion.

RECOMMENDATIONS

1. Credibility of source, importance of peers, large number of small builders, risk aversion, etc., points to the necessity for government and industry to concentrate on developing communications within the industry and encouraging exchange of information on new products.

2. One excellent opportunity occurs when builders gather in large numbers at their annual convention. The industry should make "technological innovation,

new products and techniques" the theme of one of its forthcoming annual conferences.

3. CMHC/Industry Associations should further strengthen the regional/local networks of local builders. The strengthening of these networks could be achieved by encouraging regular meetings/workgroups between CMHC regional/local staff, appropriate staff from NRC/EMR and local builders for the purpose of discussing issues related to recent innovations and other issues of importance.

4. The risk aversion of builders and other LRRCI participants suggests the usefulness of including up to date diffusion related information (who is using what, where, and their experience). This information tabulated by type and size of users, as well as by geographical distribution should be incorporated into NRC's Canadian Construction Information System (CCIS) and in CMHC workshops.

5. Construction Centres should provide excellent vehicles for the transfer of new ideas. Federal government agencies should be in a position to provide advice, assistance and work with provinces, local building associates, etc. in establishing such centres and ensuring linkage between them.

6. The high level of risk aversion, i.e., the desire not to be first to adopt an innovation, suggests that "demonstration" is an extremely important diffusion accelerator. CMHC should consider initiating a demonstration program in coordination with industry to demonstrate worthwhile innovations in techniques and products.

7. This study demonstrated the relatively unimportant role played by buyers in the diffusion process because of lack of information. The government should take the lead in sensitizing the consumer to the long term implications of his purchase decisions. CMHC Brochures/Seminars for new purchasers and the availability of selected CCIC information to the consumer media and consumer groups would go a long way towards bringing consumers more fully into the diffusion process.

8. Both government and industry should take steps to identify and publicize innovations. CMHC's "job site innovation program" is a step in this direction. Government and industry should consider the production of brochures for each trade, describing new ideas and techniques to improve practice and increase productivity. These could be updated on a regular basis.

9. Given the complexity of the process of technology transfer, it is apparent that efforts to facilitate transfer, to be effective, must adopt a multi–pronged and fully integrated approach. This must take into account education and training, marketing, the interface with other components of the production process, and consideration of codes and standards.

4.0 THE R-2000 PROGRAM

4.1 INTRODUCTION

The R–2000 program is one of the most far reaching diffusion of innovation efforts ever undertaken on behalf of the Low Rise Residential Construction Industry.

Because of its complexity and pervasiveness, the R–2000 Program was not included as a case study in this report, mainly because it would have overshadowed all other cases in terms of resource requirement. The impact of the R–2000 Program is such however, that it was felt that no report on current conditions for technology transfer and innovations in Canada would be valid without the inclusion of a background chapter on the R–2000 Program as a means to introduce the reader to its structure, its objectives, its main activities, its main intended outputs and its probable impact on other relevant actors and sectors of the Low Rise Residential Construction Industry. Furthermore, the R–2000 program is being included as an example of an integrated technology development, transfer and diffusion program from which many diffusion related lessons can be learned.

An evaluation of the diffusion of R–2000 technology in the Canadian home building industry has recently been completed by the Bureau of Management Consultants.

Based on very conservation calculations, at least 12,000 homes in Canada have to date been constructed to the R–2000 standard. Based on additional factors including heat recovery ventilator installations and the frequency of air tightness testing of homes, the number of R–2000 type homes constructed in Canada to date could easily exceed 20,000.

To date approximately 3,000 homes have actually been enrolled in the R–2000 program.

4.2 PROGRAM DESCRIPTION

The Super Energy Efficient Home (SEEH) program also known as the R–2000 program was originally announced as part of the National Energy Program in 1980 and was approved in principle in January, 1981. The program is delivered by the Canadian Home Builders' Association in co–operation with Energy Mines and Resources Canada.

The initial program was to terminate on March 31, 1984, but in December, 1983, the Government approved a seven–year, $50 million dollar extension.

The purpose of the program, and the reason for its initial inclusion in the NEP was to encourage conservation, oil substitution and the development of adequate and secure non–petroleum energy and alternate fuels to meet Canada's energy requirements and export opportunities.

Initial studies had identified the Low Rise Residential Housing Sector as a substantial user of heating oil. It also determined that amongst the three broad options; Active Solar Heating, Passive Solar Heating and the Super Energy Efficient house, the third option was the more desirable because of its fuel economy and because of its cost advantages.

The principal objective of the R–2000 Program is to ensure that the construction of Super Energy Efficient (SEE) R–2000 housing becomes self–sustaining by 1991.

The proposed approach is to stimulate the demand for R–2000 housing and to build up the supply so that the housing industry is in a position to produce R–2000 houses on a commercial basis without the need for further government support by 1990/91. In order to meet this objective, demonstration homes were built, training programs were provided for the industry, technical and monitoring activities were complemented, and a public information program was initiated.

In the next several paragraphs we have outlined the structure and activities, the intended outputs and expected effects of the program with regard to its target groups, the builders and the consumer, as well as details about the education and technology development aspects of the program.

4.3 INCENTIVE TO BUILDERS

One of the key characteristics of the program is that it provides contributions to builders for the construction of R–2000 homes. This financial assistance is strengthened by two other elements of the program: support for the construction of R–2000 demonstration homes in all regions of Canada; and, the provision of technical assistance and advice to facilitate the introduction of new house design, construction methods and more energy efficient house components and building products. The idea is to train builders to think of a house as an integrated energy efficient system rather than an assemblage of unrelated parts.

Originally, the plan was to involve at least 2000 builders in the construction of 20,000 R–2000 homes by 1990/91. Recent studies indicate that the number of houses built to R–2000 or to near $ 2000 standards, but for which R–2000 certification is not being sought, is several times larger than the number of R–2000 certified homes built in the same period.

4.4 INDUSTRY INVOLVEMENT

Diffusion theory has long supported the proposition that vertical communication is insufficient to change attitudes. It has been demonstrated that the most effective communication model is one in which communication starts as a vertical process (from the manufacturer to the consumer, or in this case, from the program to the builders), but where the process is supplemented by a horizontal communication process in which individuals can discuss the newly received information, test peer reactions, develop new group opinions, evolve new perceptions and forge new individual positions supported by the group. The R–2000 Program made massive use of this approach. The R–2000 Program has enlisted the assistance of every significant building trade related association in its communication effort.

Several manufacturers groups are also active in support of the R–2000 Program. They promote the development of R–2000 related products and equipment. They support the marketing effort, train builders and support a servicing network.

Builder groups exist in every region of the country. Besides building and marketing R–2000 houses, they serve as a focus group for discussing R–2000 related issues. They also provide the field support for introducing new techniques into demonstrative units.

In addition to the above, the program also coordinates activities with a number of provincial ministries in the area of labour, education, consumer protection, health, safety, building industry regulations, etc..

Finally, the program has, through the Public Television Network, developed a number of public information and training films.

4.5 TECHNOLOGY IMPACT OF THE R-2000 PROGRAM

An in–depth survey of all the aspects of the R–2000 program is beyond the scope of this study. For purposes of background information, we have included a brief review of the major impact areas in terms of technology development and diffusion.

As a rule, the R–2000 program has not generated "new" products. HRVs, six mil polyethylene, high insulation materials, vapour barriers and air barriers pre–existed the program. What the program has been doing is to integrate their use in a systematic fashion to obtain a Super Energy Efficient house. This is why we have included a chart tracking the construction of certified, non–certified and near R–2000 houses. On the other hand, the R–2000 program has certainly been an important catalyst in accelerating the diffusion of a number of innovative products listed below.

Whenever appropriate, we have included cross references to specific case studies. As a result, the reader should gain some of the pervasiveness of the influence of the R–2000 Program on the Low Rise Residential Construction Industry and, to an extent, on the entire construction industry, in its broader definition, i.e., including the products and material suppliers.

The major areas of impact of the R–2000 program have been:

- **Insulation.** (See case on Insulated Sheathing)
  The program has been instrumental in promoting higher R–values and also in shifting the performance evaluation from an evaluation based on the intrinsic R–value of the insulation material to the R–value of the finished component such as a wall or a ceiling. This approach has resulted in a better use of insulation materials and has led to more importance being put on air tightness.

- **Air Tightness.** (See case on Tyvek and Polyethylene Vapour Barrier)
  Although the concept itself pre–dates the program, the R–2000 Program can be credited for having been a major contributor to the sped up diffusion of air barriers and vapour barriers and the techniques for installing these materials to achieve an airtight building envelope.

- **Ventilation.** (See case on HRV)
  Because air tight Supper Energy Efficient homes require mechanical ventilation and heat recovery, the R–2000 program has been a major factor in the diffusion of HRVs. As a matter of fact, R–2000 and near R–2000 houses probably account for the bulk of all HRVs being sold currently.

- **Windows and Doors.** (See case on Manufactured Windows)
  Through its promotion of tighter, better insulated and weather stripped windows, the program has helped the diffusion of more efficient windows. Low E windows should also benefit from the same evolution.

- **Heating Systems**

  The R–2000 Program has supported more energy efficient home heating units of various types. For purposes of case studies, we have selected Active Solar Systems and Air Service Heat Pumps.

- **Overall Housing Design.** (See case on Modular Construction)

  By sponsoring the concept of the Super Energy Efficient home as an integrated system, the program has influenced the design and even more so, the construction processes. R–2000 houses are not just built merely carefully, they are indeed built differently.

Consumer Awareness

It is the intention of the program to promote the widespread consumers demand for R–2000 homes. In order to achieve this objective, the program has put in place a number of education and information activities ranging from pamphlets to magazine articles to present at home shows, publication of technical brochures and development of the R–2000 logo. The program has assisted builders in promoting the R–2000 product through the organization of co–marketing events with public utilities and component manufacturers.

It is believed that if consumers are better able to assess the energy efficiency of a home and if they have a greater awareness and appreciation of the financial and other benefits of R–2000 housing, this will results in increased demand for R–2000 homes in particular, and for energy efficient homes in general.

CASE: DRYWALL

A. DESCRIPTION

Gypsum board, commonly known as drywall, is the generic name for a family of non–combustible sheet products consisting of a core, primarily of gypsum, with paper surfacing. Gypsum board has evolved from the original wallboard to encompass a variety of different products. Water resistent gypsum board is used in bathroom and other areas where humidity may be a problem. Vinyl faced gypsum board, which consists of gypsum board sheets with a surface finishing, is being widely used in commercial construction but still very little in residential construction although some manufactured houses already have it. Other types include gypsum backing board for those interior walls or ceiling which will receive some sort of cladding (acoustic or other); gypsum sheeting board for residential use; and, the 1" thick gypsum core board used for face walls and other special applications. Additional types of gypsum board are available but are not applicable to the low–rise residential construction industry.

In the low–rise residential construction industry, drywall, and to an extent wood panelling, have taken over the market.

B. DIFFUSION

Drywall was first developed in the United States at the turn of the century. Production by the pioneering U.S. Gypsum Company started around 1910. Technical improvements allowing the production of a consistently standardized wallboard occurred in the 1920s and early thirties. The use of gypsum wallboards was greatly facilitated by the development in the late 1930s of the drywall joining tape.

Drywall became available in Canada in the 1930s but its market penetration remained very limited until World War II. At that time, drywall was considered to be greatly inferior to the dominant technology of plaster and lath. To gain wider acceptance, several approaches were used. The most common approach consisted of applying a "skim coat" of plaster on the gypsum wallboard.

The market penetration of gypsum wallboard was greatly sped up by the low cost residential construction boom which followed WW II. Gypsum board, which had been used in the construction of a number of temporary military facilities, became an attractive alternative to lath and plaster because it required less manpower to install and, more importantly, there was a considerable downgrading of the skills required to complete the job. Both of the above were crucial considerations for builders at the time. Their need to produce low cost commodity–like housing made time saving in completing the job a primary consideration and the availability of trained plasterers was completely outstripped by the demand.

One of the most interesting results of this lack of trained plasterers was that the quality of lath and plaster walls deteriorated to the extent that gypsum wallboards actually gained an advantage over plastered walls in terms of quality.

Trade resistance to gypsum wallboards became irrelevant because it gave rise to its own trade specialized in drywall. Plasterers working in the residential construction sectors were not unionized and could not effectively oppose the introduction of drywall. Plasterers in the commercial and institutional sector of the construction industry were unionized and held on longer. The Toronto Dominion Center built in 1965, was the first major commercial project to use drywall. The reason was that the engineers calculated that disposing of all the humidity in the plaster in such a sealed, air–conditioned structure would put considerable added stress on the mechanical equipment. In fact, it was calculated that it would add almost 10 years of wear and tear on the air–conditioning. Once the Toronto Dominion Center made the move, drywall became the de facto accepted standard for high–rise construction. Contrary to the plastering trade which required years of apprenticeship and a sizeable investment in tools and heavy equipment, the drywall trade had great case of entry with low technical requirements and a few inexpensive tools.

By the early 60s, gypsum drywall, with the occasional assistance of wood panelling, had almost totally replaced lath and plaster walls in residential construction. A few pockets of resistance remained. They were concentrated in smaller towns where lath and plaster were strongly ingrained in the ethnic heritage and where qualified tradespeople were more readily available. Kitchener, Ontario was one of the hold out areas largely because of its German ethnic heritage. Windsor and the Niagara

Peninsula were also affected to a smaller extent. Large urban centers such as Toronto and Montreal had a faster adoption rate. By the end of the sixties, hold outs in the residential sector represented less than 5% of the Ontario market and probably even less in national terms.

In the U.S., resistance to the introduction of gypsum board took a slightly different approach through the use of "veneer plaster" over gypsum backing boards. Again, this does not represent a significant factor.

In the 1950s and 1960s, the major technical problem faced by gypsum board was related to joints. The control of edges improved gradually, first through the tapering of the sheet edges, then through improvements in the reinforcing tape and through the introduction of ready mixed joint compound.

Each of the above innovations took a considerable amount of time to be fully accepted. For instance ready mix joint compound, which replaced powdered mixes, took about 10 years to be accepted by drywall users. Contractors who, because they were not putting any value on their own time, preferred to go through the long and laborious process of mixing the powder (on site, the day before!) rather than "pay extra for water". The wider use of gypsum wallboard in commercial construction generated a loop feedback with such innovations as self–tapping screws, fire and humidity resistant wallboards, as well as pre–wallpapered wallboard sheets.

Self taping screws were introduced in 1960; until then drywall had been nailed. The intent was to resolve the problem of "nail popping" due to the twisting of green framing members. Initial reception was negative because screwing takes longer than nailing. In 1961, salesmen went out to contractors with Black & Decker screw guns offering to install for free, screws for one house.

Eventually, two factors combined to facilitate the diffusion of screws (which nonetheless took 5 to 7 years). First, call backs for pop nails were becoming a costly nuisance, but under CMHC rules, contractors were responsible for repairs at the one year inspection. Since screws almost eliminated pops (which were costly to fix because the builder had to send someone back 6 to 12 months later), they became better accepted.

Secondly, in the mid 60s, the construction market was in a downturn and drywall contractors began offering better quality at the same price to get contracts. In effect, they were offering screwed on rather than nailed drywall. Drywall contractors eventually developed a mixed method by which they would nail the edges of the sheets and then screw the surface.

C. FACTORS AFFECTING DIFFUSION

Drywall had been in existence for forty years and available on the Canadian market for almost twenty before it started to take off. Drywall eventually dominated the market not because it was intrinsically better than plaster, (in fact it can be argued that it is not), but because it benefitted from a concatenated succession of diffusion related events which made it the product of choice.

Interestingly enough, even though it benefited from all these favourable "breaks", gypsum drywall still took an entire decade to fully replace plaster walls (and indeed somewhat more if high rise commercial buildings are included). Furthermore, every complementary innovation took 5 to 10 years to diffuse.

Gypsum wallboard matched the construction philosophy of post war low cost tract builders. In the prevailing market, the only relevant variable was affordability as the objective was to achieve mass production quickly and inexpensively. Gypsum wallboard, by eliminating the slow and costly lath and plaster approach, was seen as a great advance. It also incorporated two other important diffusion accelerators:

- It was easily integrated in the builders' construction process and was not the least disruptive; and

- The invention of the joining tape, compound and assorted tools, as well as the development of the self–taping wallboard screw were important complementary innovations which facilitated diffusion.

As mentioned earlier, market considerations played an important role. Gypsum wallboard, which was at first considered inferior, became not only significantly less expensive, but was eventually considered to be superior to the low quality plaster work produced under strained supply and demand conditions for proficient plaster tradesmen. The same phenomenon may be at work in the area of studs; 2 x 6' and even 2 x 4' quality has increasingly caused cracks in the drywall, thus metal studs are now being looked at as a more attractive alternative.

Gypsum wallboard is a good example of a successful substitute being simpler than the product it replaced.

CASE: ALUMINUM WIRING

A. INTRODUCTION

Copper has been known and used for many purposes for many centuries. Since the beginning, it demonstrated superior electric conductivity properties compared to any base metal and, as a result, has been used in electrical wires from the start.

Aluminum on the other hand, is not a natural element. Although aluminum had been discovered in the late 1700s, it was not produced in commercial quantities until late 1800s. Its use in connection with electrical transmission took another century and it is only in the beginning of the twentieth century that aluminum began to be used for transmission cables.

As the price of aluminum dropped, its use for high–voltage cables increased. By the 1940s, aluminum had totally replaced copper in high–voltage transmission lines; but copper is still the only material used in low voltage applications.

Immediately after WW II, copper became scarce and aluminum began to be considered more often as a substitute for copper because of several comparable advantages which are normally present in the transition from any material:

- o Aluminum was suitable for the proposed uses;
- o Aluminum was readily available and enjoyed a much greater stability of supply than copper; and
- o The cost of aluminum was lower, with the added benefit, as far as Canada was concerned, that aluminum was being processed here in large quantities.

On the negative side, aluminum wire has less conductivity than copper and aluminum wires must have a diameter roughly 30% larger to accommodate the same conductivity.

Aluminum wires can be problematic as they are harder to work with and if they become loose, they begin to oxidize, deteriorate, heat up and fail with the possibility of causing a fire. It must be noted, however, that these drawbacks of aluminum wiring were totally unknown when aluminum wiring arrived on the Canadian scene in 1948.

B. DIFFUSION

It took two hundred years for aluminum to be used for high voltage transmission lines and forty more for it to dominate that segment of the industry. If one considers the use of aluminum residential wiring in Europe where it started in Germany in 1934 and expanded to Austria, Italy and France in the last 1930s, it took low voltage aluminum wiring some 40 years to become the standard material for residential wiring – at least in Canada – a position it maintained for only a short few years after which it was withdrawn. It can be argued that since aluminum wiring was only introduced in 1948, aluminum took "only" twenty years to reach almost full maturity.

The expansion of aluminum wiring in Canada can be traced back to an experiment conducted by the Alcan company which involved the wiring of 75 houses in Arvida, Quebec in 1948. This experiment came one year after the Canadian Standard Association had authorized the use of aluminum wiring as an alternative to copper in residential housing in Canada. Initially, this authorization covered "hard" wires. Price fluctuations and shortages of copper in the early 1950s during the Korean war, boosted the demand for aluminum wiring. Use of aluminum wiring spread. In 1953 the town of Kitmat, site of another Alcan Plant, was totally aluminum wired.

Although electricians found hard aluminum wires difficult to work with, there was no real trade resistance because demand was driven by price availability considerations. During another crisis affecting copper availability and cost in the mid sixties, the price differential between copper and aluminum was such that the cost of "conductivity" in copper was, by then, four times greater than for aluminum.

Statistical figures available for the U.S.A. where aluminum wire was introduced in 1946, show clearly the progression of aluminum. In 1960, aluminum represented 11 per cent and copper represented 89 per cent of total conductor usage. By 1969, aluminum had garnered a full 23 per cent of the market and by 1974 it had reached at least 33 per cent.

As the use of aluminum wiring grew, one point was never addressed. That was that most electric equipment then in use had been designed for connection to copper wire.

By 1974, roughly 450,000 to half a million Canadian homes had been aluminum wired.

Aluminum wiring was well on the way to becoming the dominant wiring product when serious problems began to surface and the product became embroiled in a process which eventually led to its demise.

C. FACTORS AFFECTING DIFFUSION

The aluminum wiring case is important as it is an example of diffusion through direct substitution. The diffusion literature stresses the fact that a product is more likely to be adopted if it is advantageous, compatible, simple, etc. Obviously, if a new product is apparently indistinguishable from its predecessor, backed by a prestigious name (an "insider") and cheaper as well, it will enjoy a fast adoption curve. This is what happened with aluminum. As it became cheaper, it made further and further inroads in the copper market. After a "fast" 25 years, it was becoming dominant.

The crucial point of this case is that aluminum was, for all intents and purposes, being "used as copper". The substitution was one for one (allowing for the required differences in gages). Cabling techniques and terminal serving techniques remained the same. So did all receptacles and switches.

It is only in 1975 when diffusion was reaching saturation, that the difference between aluminum and copper began to be perceived and that the CSA began issuing new standards. At this point it became increasingly obvious that aluminum wiring required retraining of tradespeople because aluminum is more difficult to join and bad joints are dangerous. This led to a requirement to redesign all terminals and low voltage distribution devices.

It also became apparent that what had once appeared to be a simple substitute was in fact a very complex one requiring such materials as tin, cadmium or zinc coating to protect against corrosion.

Although aluminum wiring retained some of its price advantage to the end (copper prices fell back to their 1965 levels) it lost most of its comparative advantage because all the above changes were introducing more and more elements of "incompatibility".

The aluminum wire case is an example of a situation where several elements combined to favour a rapid rate diffusion. First, the usual regulatory barriers which have, over the years, held back or slowed down many other innovations, did not, in this case, play a significant role as a diffusion barrier. Second, economic conditions created such a lopsided situation that aluminum wiring was clearly or directly substituted for copper. Third, tradespeople reluctance was not a significant factor, although the product was not as easy to deal with as copper.

Aluminum wiring is also a good example of the influence, both in size and prestige, of the innovation source on the acceptability of the product.

In the final analysis, the lesson to be learned from this case is that diffusion and acceptability are not irreversible. As soon as aluminum wiring proved to be incompatible, complex and subject to liabilities, the process of diffusion reversed itself dramatically.

CASE: PLASTIC PLUMBING

A. INTRODUCTION

The basic plumbing system of a house is comprised of the main sub–systems: the Drain, Waste and Vent pipes (the "DWV") and the cold and hot water supply lines (the "pressure system").

Ninety five per cent of the one and two storey houses built in Canada in the last 20 years contain ABS DWV piping. In the last few years, the underground portion of the DWV system has increasingly been turned over to PVC piping. Because of fire code considerations, ABS is still limited in its use to one and two storey houses.

The water supply lines market is being supplied by three main products. Copper piping which is still, by far, the most commonly used product since it replaced iron pipes more than 30 years ago; Chlorinated Polyvinyl Chloride ("CPVC") which has been available in Canada since the early 1970s and Polybutylene (PB) which was introduced in Canada in the mid 1970s.

In terms of market share, best estimates are that PB (Polybuthylene) has achieved a 10 per cent market share in the residential sector, with considerable regional variation while CPVC is hovering at the one per cent mark.

B. DIFFUSION

The acceptance of ABS piping was, by all accounts, rapid. When it became available in Canada in 1965, ABS proved to be fully compatible with trade operating habits. ABS pipes were exact replicas of the old cast iron ones but they were much lighter, much easier to carry around and work with, much cleaner and considerably less expensive. Furthermore, the use of a solvent for installation purposes was less complex than the "gucking" method required by the old cast iron pipes. Altogether, ABS had all the desirable diffusion characteristics required for fast diffusion. Despite some inertia in local code approval, ABS became the dominant DWV material in less than three years making it one of the diffusion successes of the industry.

The above situation did not repeat itself as far as CPVC and PB are concerned for pressure systems applications.

Copper still dominates the market. Its known drawbacks are that:

- It is susceptible to freezing, an increasingly minor inconvenience in heavily insulated houses;

- There have been documented problems in the United States, not with the copper pipe itself, but with the lead based solder, to the extent that certain U.S. states, for instance Delaware, now require an antimony based solder instead of a lead based one; and

- Copper is a world traded commodity which recently has been the subject of important upward price fluctuations.

The CPVC resin is manufactured in Canada by B. F. Goodrich. It has been on the market for some 15 years. CPVC pipes are rigid, joints are glued not soldered, but the curing period is twenty four hours, requiring a time consuming extra visit by the plumber for testing purposes. The major drawback of CPVC is that its use has, for many years, been restricted to cold water pipes thus making it unattractive as it would entail a dual copper CPVC system anyway.

Because of its low market share, CPVC has been losing distributors over the last few years. Several wholesale distributors have discontinued it because it is such a low volume item among their trade clients.

The PB (Polybutylene) resin is manufactured in Canada by Shell Canada. It was introduced on the Canadian market in the mid 1970s. There are now two manufacturers of PB piping and two importers of U.S. manufactured product. PB is a totally inert material. In thin film form, PB has been approved, on a limited basis, for food packaging by the U.S. FDA. PB is not a rigid material and PB pipes can be bent without elbows up to 12 times the diameter of the pipe. For a 1/2" pipe, this means that a 6" radius twin is possible without the use of fittings thus reducing flow restrictions. Furthermore, PB can go through a freeze thaw cycle up to 12 times before structural damages in the form of loss of contracting back capability begins to appear. PB pipes are not subject to corrosion and are not prone to lime build up. Large size PB pipes (1" and above) must use compression fittings. Smaller sizes, typically used in the hot and cold water supply system of low rise constructions must be either crimped or use a compression fitting. Contrary to what happens to CPVC they cannot be glued.

The crimping process involves introducing a fitting inside the pipe, then a ring outside and crimping the set with a fairly large specialized hand tool. Crimping a 1/2" pipe results in a flow and pressure reduction. Because of this fact, PB piping is not acceptable in many areas. To overcome the flow restriction, it is necessary to use 3/4" pipes (or at least a combination of 3/4" and 1/2" inch pipes) a fact that makes PB piping less attractive. Cause of failure of fittings is the same as for copper, i.e., improper installation.

Life expectancy of PB piping is 50 years.

Although the cost of 1/2" PB piping is lower than the cost of copper piping, crimping is time consuming; fittings are expensive and crimping tools are awkward making the system cost less competitive. Using compression nuts is too time consuming and too expensive for commercial use, although it may be attractive to do–it–yourselfers.

At present, the national market penetrations of PB is about 10% but there are considerable regional variations, for instance, penetration in the BC market is close to 20% and PB is also widely used for radiant heating in garages and homes in the west. No such market has developed in eastern Canada.

Market penetration of PB has grown, from 5 per cent of the market five years ago, to the present 10 per cent. According to industry sources, diffusion could be considerably accelerated by the following factors:

- Work is continuing on alternative fittings which would eliminate flow restrictions and remove existing legal barriers to the use of PB;

- Market penetration in the mid 80s was slowed considerably by depressed copper prices. If copper prices continue to rise as has been the case recently, and if the price of the commodity increases by a further 40 to 50 per cent, it is expected that the system cost for copper piping would go up by at least 20 per cent, creating a significant price advantage for PB.

- PB has not been extensively used by large contractors. Access to these new accounts would rapidly bring PB to a national market share of 30 per cent.

C. FACTORS AFFECTING DIFFUSION

Both CPVC and PB are single source resins originally developed in the U.S. All the original R & D and testing were performed in the U.S. Under these circumstances, the focus of this case has been on the diffusion process rather than on the manufacturing technology development and transfer.

Builders consider two types of risks. One is a liability risk in case of product failure. Builders unfamiliar with plastic plumbing tend to have what is known as the "IBM" reaction. Under the current evolving legislation, they are increasingly liable for construction defects. As a result, they take the position that if they use copper piping and it fails, they cannot be blamed, but that if they use a plastic piping and it fails, they might be accused of having used an "inferior" product.

The other type of risk is the competitive risk. Again, many builders believe that purchasers prefer copper piping and that using plastic piping could put them at a competitive disadvantage. In any case, they are reluctant to commit to products which still carry code restrictions (at least until economic advantages become pressing).

There may be another liability related risk perception in relation to the CPVC. Builders, mindful of the UFFI debacle, are reluctant to adopt a product which may, later on, prove harmful (e.g., present concerns about "chlore" in the CPVC) and involve them in future litigations or loss of reputation.

None of the above concerns would be insurmountable if plastic plumbing had a definite cost advantage to the builder. Under present circumstances there are no cost advantages to the builder. As a result, the real push for use versus non-use rests with the plumbing contractor.

Plastic plumbing is fully compatible with the builder's construction practices. However, this is not the case with the plumbers. While ABS DWV piping can be glued in a matter of minutes, CPVC requires a 24 hours curing period which forces the plumber to make two extra trips to the site for testing purposes. This is a definite drawback as is the restriction of its use for hot water piping.

PB on the other hand, is more time consuming and complex to install, even considering flow restrictions.

Whenever plumbers are paid on a per job basis, they are less interested in a product which reduces the number of houses they can rough in or finish in a day's work.

In order to establish a track record for its product, at least one manufacturer (Bow Plastics) was until recently supplying free PB piping for inclusion in developers model homes as well as including free crimping tools to installers of PB systems.

D. CONCLUSIONS

This is one case in which diffusion for the product could be boosted through the development of an alternative joining technique or at the very least, through the development of a more practical and less cumbersome crimping tool. In diffusion terms, this would mean focusing on the "complementary innovations" to enhance the "integrability" of the prime innovation.

One manufacturer indicated that diffusion would be sped up if trade schools emphasized the training of tradespeople on new materials and if there were more opportunities to train and certify plumbers in the very busy Toronto market. According to him, plumbers are just too busy to be willing to spend time on acquiring a new skill and to take risks with change.

Industry could also take steps to reduce the risk perceptions by builders either through training, additional information or more likely, some form of guaranteed assumption of risk related to possible product failure.

CASE: HRV

A. INTRODUCTION

Heat Recovery Ventilation systems (HRVs) are mechanical devices which are integrated into forced air heating and air conditioning systems.

HRVs have two main functions: first they capture part of the heat contained in the exhaust stale air and transfer it to the incoming fresh air; and second, they can be used to trap part of the humidity contained in the incoming air to reduce high humidity problems.

Traditionally built houses do not require HRVs because they are so "leaky" that they go through several air changes per hour without any assistance from mechanical ventilation systems. In addition, most houses have some form of mechanical ventilation; in the kitchen, a range hood and in bathrooms, a ceiling or wall exhaust fans.

Leaky houses are not energy efficient. The need for increased energy efficiency has led to the development of "tight" houses which are vapour insulated and sealed. Tight houses do not automatically undergo the minimum required number of air changes and must have some form of mechanical ventilation to insure that indoor air quality does not deteriorate and that moisture does not accumulate in the house.

Exhaust fans and simple air intakes and can provide the number of air changes required but they defeat the purpose of the energy efficient tight house. If heated, air is continuously exhausted without heat recovery. Heating costs might even be higher than before.

Canadian HRVs are central heating oriented and can only be used in connection with forced air systems. Other countries such as Japan, have produced room oriented HRVs usable with non–forced air systems.

As indicated earlier, HRVs are "integrated" into the heating and air conditioning system. "Balancing" an HRV system to avoid negative pressures and especially back–

drafts when the fireplace, the range hood or bathroom fan are operating is a complex task which requires skills beyond those required from traditional heat and ventilation tradespeople.

As tighter houses become more numerous, HRV manufacturers and installers expect demand to expand beyond the estimated 5,000 to 12,000 units, including retrofits installed in Canada by 1987.

HRV manufacturers further expect that as tighter houses become more prevalent, the issue of "indoor air quality" including perhaps the issue of radon gas will become more acute and result in increased consumer awareness and greater demand.

Developers and contractors in general do not consider heating and ventilation appliances as "hot button" items which help make a sale, therefore they limit themselves to the minimum requirements. As a rule, they will install mid efficiency, not high efficiency, furnaces with piped make-up air intakes and inexpensive exhaust fans. They consider HRVs as strictly a cost item with no "value added". Although developers recognize the possible advantages of HRVs, they take the position that they are in a very competitive marketplace and that they cannot afford to include items such as HRVs which would put them at a competitive disadvantage vis-a-vis their fellow developers.

B. DIFFUSION

HRVs originated in either Sweden or Japan. They were first introduced in Canada by the Mitsubishi Company which attempted unsuccessfully to market them in Canada during the mid seventies. This attempt failed because the product was not designed for the Canadian environment. It was room oriented rather than central heating oriented. Furthermore, it could not cope with the harsh climate. The concept itself however, did take hold and a number of homegrown units were developed in Canada in 1976/77.

Research and Development proceeded along two tracks; one in the small entrepreneurial private sector; the other at Government research facilities (especially NRC's Prairie Research Centre, and later the Ontario Research Foundation Sheridan Park facility).

All of the initial manufacturers were small and were relative outsiders to the heating and air–conditioning establishment.

The initial objective was heat recovery not ventilation. At the time the issue of energy conservation was gaining in popularity, there was general interest in energy saving devices but no expressed demand for air to air heat exchangers.

Developers largely ignored HRVs which they considered strictly as a cost item with little or no "sales appeal". Architects did not specify their use in subdivision developments and heating contractors were reluctant to get involved.

In the early 1980s, the ventilation function of HRVs began to overtake the emphasis on energy recovery. A substantial number of the HRVs sold in the period 1981 to 1985 were installed to solve UFFI related problems. Houses affected by UFFI require a considerable amount of mechanical ventilation. Fan based ventilation systems can provide the number of air changes per hour but the energy costs are very high.

During the same period, HRVs also achieved a small measure of market penetration as retrofit in houses with high humidity problems, but the real long term breakthrough appears to be linked to the advent of the concept of the "tight house" spearheaded by the R–2000 Program.

Early HRVs were developed in a complete regulatory vacuum; there were no standards to assess efficiency or to guide installers and the National Building Code was silent on HRVs. Standards for HRVs were developed fairly rapidly, not because of consumer demand, but as a result of the intervention of government agencies such as EMR and NRC. Standards evolved from a combination of the work of various ASHRAE, HRAI and CHBA committees on ventilation, heat recovery and indoor air quality and of the R–2000 HRV testing program at the Ontario Research Foundation.

As a result of the work of the above committees, and of the recognition that tightly built houses need mechanical ventilation, a number of ASHRAE and CSA standards were developed and the National Building Code now requires some form of mechanical ventilation in all new residential constructions. This provision is to be implemented shortly by Nova Scotia as well as by Manitoba and B.C. while other provinces have yet to follow suit.

It is noteworthy that the regulation only mentions mechanical ventilation and does not specify the use of HRVs to satisfy the requirement.

C. FACTORS AFFECTING DIFFUSION

The question pertaining to diffusion accelerators and barriers is normally focused on the main beneficiary of the innovation, or alternatively, on the purchase decision maker. In this case, there were two groups with the required prerequisites; developers and house buyers.

The house buyer has played a dual, but conflicting role in the introduction of this innovation. He has been a driving force in the area of custom designed houses, many of which tend to incorporate HRVs (but true custom designed homes represent less than one percent of new low rise residential constructions), while being one of the most stubborn barriers to the large scale introduction of HRVs in development projects. House buyers are perceived by everybody in the industry as being single mindedly focused on the purchase price of houses even to the detriment of life cycle cost considerations and sometimes simple quality. Moreover, house buyers are generally uninformed about HRVs and, where they are, uninterested.

While the demand pull is depressed by the low level of perceived comparative advantages, its apparent complexity and problems in the area of communicability, the "push" side is affected by a series of diffusion–related weaknesses.

First, there is the low involvement of potential prescriptors. Architects, engineers and developers have had little involvement or impact on the diffusion of HRVs. Municipal building inspectors have also, on occasion, hindered diffusion by refusing to sign off on HRVs through lack of knowledge and fear of liability. This situation is expected to resolve itself through greater familiarity with CSA Standard C444.

Then there is the lack of overall size and strength of the manufacturers although the original entrepreneurs have been, in general, enthusiastic. Few large established heating and ventilation equipment suppliers have, so far, joined the ranks of HRV producers. Given that HRVs must be fully integrated with the rest of the system to obtain optimum performance, the absence of a full line producer capable of offering a "package" has hindered diffusion.

Trade associations have cooperated in the area of standards, guidelines development and training (their involvement was greatly facilitated by EMR financial assistance). On the other hand, there is a marked reluctance by tradespeople to deal with a complex system which involves on–going liabilities since the HRV installer is responsible for the balancing of the system and the absence of back–draft.

As a result of the weak market demand and of the absence of a strong push on the part of the manufacturing sector, the government has ended up playing a major role in bringing HRVs to their present state of technology development and diffusion.

Not only has NRC played an important role in the basic R & D but CMHC has supported the development of prototypes and EMR has picked up the tab for the performance testing. EMR has also been a key financier in support of the training and certification effort aimed at the heating and ventilation trade.

It is important to note EMR's involvement in supporting the testing programs for HRVs which had a considerable effect on further HRV technological development because most early HRVs failed the ORF test due to icing and other problems. Later models of participating manufacturers passed those same tests, thus highlighting the importance of the initial and on–going government support and the effect of the development of evaluation standards.

As a result of the sustained government involvement in the HRV R & D and diffusion process, there is a strong flow of communication between researchers, manufacturers, concerned government departments and relevant committee members of industry associations. This situation is always desirable and generally present in the early stages of successful diffusion processes when most of the individuals involved are "innovators". The problem is how to expand this process beyond the innovator group. HRVs do not appear to have broken out of the innovator group and have not yet advanced beyond the early stages.

D. CONCLUSIONS

This case is a good example of the successful cooperation between government, industry and trade associations. As a result of this cooperation there is now a technically viable product, a trained core of tradespeople and a balanced regulatory environment. In the absence of an energy crisis or an indoor air quality crisis, the subsequent steps in the diffusion process should properly be market driven. On the other hand, if indoor air quality is considered as an upcoming concern, then there is hope for policies aimed at insuring the survival of a core of HRV manufacturers while further R & D is directed to the indoor air quality questions.

CASE: MANUFACTURED WINDOWS

A. DESCRIPTION

All windows presently being installed in Canada, be it in new construction or in renovations, are manufactured windows, although a certain per cent are custom made.

The Canadian manufactured windows industry is very fragmented; it operates at four distinct levels. The lowest level is the local level with many, very small scale manufacturers with low overhead offering customized products. The second level is regional, with larger companies with a broader product offering. Generally, these companies are the outgrowth of former small, local manufacturers. Depending on regional market conditions these can be substantial producers. The third level, the national, consists of a few large single or multi–plant operations. Finally, there are international companies with imports from the U. S. occurring at the high price end of the spectrum.

The industry is characterized by a considerable ease of entry at the low end due to the relative low technology required in the manufacturing process and the small runs typical of the customized business. Another characteristic favouring ease of entry, is the lack of vertical integration.

Canadian manufactured windows are made of either wood, aluminum or plastic or a combination of the above (e.g., clad windows). Models vary greatly from vertical and horizontal sliders to casement and awning types.

Although all types of windows are available everywhere in Canada, there are still distinct regional preferences for certain types. For example, the Montreal area has traditionally tended to favour aluminum sliders on four sides of the house, while the Ottawa market favours wood casement on the street scape and thermal sliders on the remaining three sides.

In the present construction boom, Toronto has continued to favour vertical sliders on the street scape and double glazed sliders on the remaining three sides.

The above observations tend to reflect the situation in tract developments and do not necessarily apply to custom houses.

The Canadian manufactured windows industry does not engage in formal R & D. Innovations are the result of observation of what is being done in the United States and of the availability of new components such as new casement hardware, thermal panes and low E glass which are supplied by third parties.

B. DIFFUSION

Until World War II the practice was to build the window frames on site then add the glazed sashes and have a finish carpenter plane off the frame and install it to fit. The entire structure of the window was wood on wood which always tended to create problems. There were no standard sizes for windows as houses tended to be built one at a time rather than as tract housing.

The transition to manufactured windows did not occur in the same way at the same time all over Canada but the general characteristics and the time frame were consistent.

The introduction of manufactured windows is always linked to the switch from single unit construction to multiple unit construction, a phenomenon which started during the war with temporary military facilities, grew considerably after the war with the veterans housing program and gained momentum with larger and larger tract housing projects over the ensuing few years.

Initially, windows for veterans housing, which consisted of very simple double hung vertical sliders, were made in the shop, a few at a time, in custom sizes. At that time, as the number of units under construction increased, the size of the runs grew to the point where manufactured window production became continuous, moved out of the general woodworking shop and became a product line unto itself. The popularity of Pearson type windows had a considerable influence on the evolution process because Pearson–type windows were the first to come in standardized sizes and builders became used to frame up for those sizes.

In Ontario, the E. S. Nicholson and Son Company out of Burlington, is said to be the first to have produced, in the mid to late forties, a complete manufactured window for the wholesale market.

A number of other lumber yards started to produce manufactured windows in the early and mid fifties.

Initially, there was resistance from finish carpenters who considered prefab-windows inferior. One of the reasons for their objections, was that shop manufactured windows tended to be built more loosely, with larger tolerances in order to avoid "sticking". In order to resolve this problem, window manufacturers added weather stripping to stop air leakage. Resistance by finish carpenters was never militant owing to the fact that demand for their services was considerably above supply of trained craftsmen and that the introduction of manufactured windows tended to free them for other finishing jobs.

By the mid 1950s, manufactured windows had not yet achieved one hundred per cent market penetration, but were fully accepted.

The number of Canadian manufacturers and the size of Canadian production grew steadily from then on. Canadian companies did not engage in R & D or in exhaustive product testing. Evolution was mainly due to observation of what was being done in the U.S. by such industry leaders as Andersen, Pella and Marvin. Some Canadian manufacturers, such as Dashwood, went as far as to establish a formal technology sharing agreement with a U.S. leading manufacturer, in this case Andersen, and eventually manufactured U.S. designed windows for the Canadian market.

Innovations were also spurred on by the efforts of components and hardware vendors. All of the advances in the glazing area were the result of R & D by large, U.S. and European glass manufacturers. Aluminum windows and aluminum cladding were the result of development efforts by such aluminum manufacturers as Alcan and the development of casement windows was again the result of U.S. developments in the window hardware area. Window related innovations tend to reach Canada two to five years after they appear in the U.S. market. Market acceptance and eventual market saturation tends to lag behind the U.S. market by even more.

No significant innovations have filtered directly from Europe or Japan to Canada. Export of Canadian manufactured windows outside of the U.S. market are virtually nil.

Early windows tended to be sashless, followed by wooden sash ones. Casement windows with crankcases appeared by the mid 60s. They had single glass panes on the sash and screwed on storm panels. At the time, this type of window was comparatively expensive. Swing up awning windows also appeared in this period. Double glazed wood sliders with screens appeared by the late 60s. They faded from the market in the 70s.

The major innovation of the early seventies was the move to sealed panes and the increased popularity of hermetically sealed glazed casement and awning models. Aluminum clad casement windows appeared in the late 70s. They included weather stripping and offered a maintenance–free outside surface as well as colours. Maintenance–free vinyl horizontal and vertical sliders also appeared on the market at that point.

The manufactured windows industry grew up in a regulatory vacuum. There were no standards and no controls and as a result product quality was uneven. The situation began to change in the 60s through the effort of the Canadian Manufacturers Association and of the C.S.A. and C.G.S.B., committees on window manufacturing standards. CMHC participated in the efforts of these committees. With the advent of the CMHC approval number required for windows used in CMHC–financed construction, the quality standards of the industry improved. Still, only a fraction of current manufacturers (some 160 out of an estimated 1000 manufacturers) have obtained a declaration that their products meet the minimum standards set by the Building Materials Evaluation Branch.

Although NRC pioneered sealed galzed testing, until recently, when the ORF established a window performance test facility, permanent government assistance in the research, development and evaluation of new technologies relating to the window industry was non–existent. The industry did receive government support for the establishment and expansion of production facilities in the form of grants and tax incentives but these were the result of broad, rather than focused, industry support policies.

C. FACTORS AFFECTING DIFFUSION

The initial move away from site built windows to shop built windows is by now forty years old. Even though manufactured windows are of better quality and lower cost than site built ones, it took almost 10 years for the transition to be complete, which is an indication of the fragmentation of the industry, its conservative nature and of the importance of local market conditions.

Most window manufacturers started out by doing in the shop what they had been doing on the site. Finish carpenters were doing manufactured windows, as well as doors, and other shop work. The manufacturing of windows did not require specialized machinery, nor did it require expensive inventories since glazing was supplied by a third party. As a result, ease of entry (and exit) has been considerable over the years with entries and exits tied to the cyclical nature of the residential construction industry itself.

Even though manufactured windows are now fully standardized in terms of sizes, the industry still operates mainly on the basis of order taking, not on the basis of speculative inventories. This factor, which is related to the "maximum postponement of adjustment" principle, allows the industry to avoid over production of certain sizes and scarcity of others. This results in a better utilization of resources and in a reduction of market and financial risk.

If the risk factor is low on the manufacturing side, it is even lower on the contractor's side. Tract builders have been keen supporters of manufactured windows since the very beginning. It lowered their costs, sped up their operation and gave them a standardized product. Today their only risk is a commercial risk tied to their particular choice of windows for a particular development. this risk is minimized by the fact that windows are not "fad" fashion items. Evolution in local tastes is generally slow and continuous.

One interesting development illustrates how compatibility is not a permanent state of affairs. From the beginning, contractors had favoured manufactured windows. They would frame up, leave an appropriate opening, then go back to block, level and install the windows. Some window manufacturers noted, however, that in the last few years, larger developers have tended to subcontract window installations and that these subcontractors, due to time pressure or otherwise, were not blocking and leveling carefully enough leading to poorly installed windows and numerous complaints. Manufacturers have had to modify their procedures to correct for this change in the construction contracting process, i.e., doing the blocking at the plant.

The manufactured windows industry is a good example of innovation complementarity. The industry has repeatedly evolved by incorporating innovations developed by third parties, especially in the glazing and hardware areas. This indicates that by focusing R & D assistance on external inputs, it is possible to spur the development of an industry as much as would be the case by focusing on internal inputs.

CASE: INSULATED SHEATHING

A. INTRODUCTION

Insulated sheathing is a category of products which has been developed to satisfy the requirements for additional external insulation for new construction and for upgrade and renovations. In Canada, the market is divided into construction and upgrades and renovations. The market is further divided among the semi-rigid fiberglass type such as Glasclad[1] which is the leading product and the rigid types such as Esclad[2] as well as polyisocyanurates such as cellotex which is a U.S. import and expanded polystyrene sheets from various sources.

Because space is limited in exterior walls built out of 2" x 4" lumber, exterior insulated sheathing is used to increase the insulation value by an R equivalent of four to five units. Insulated sheathing is also very useful in renovations and upgrades as it allows wall insulations to be augmented without having to remove the old insulation. The siding is removed, insulated sheathing is nailed to the studs and new siding can be nailed back over the insulated sheathing. Joints can be taped to form an air barrier. Fiberglass insulated sheathing is designed to be vapour permeable in order to avoid condensation in the wall cavity. Insulated sheathing rigid board come in 4' x 9" units in order to cover headers as well. Some products, such as Glasclad and Esclad, have an ultraviolet stabilized backing which allows them to be used as temporary outside finishing for three to six months until final brick or siding is applied.

B. DIFFUSION

Insulated sheathing was developed as a response to market forecasts which anticipated higher insulation demand. Several alternatives were developed. Building Products Ltd. developed Esclad in 1981 to compete with Glasclad produced by the Fiberglass Company. Esclad was developed in house, in Canada, with R & D taking

---

1 Glasclad is a registered Trademark of the Fiberglass Company of Canada Ltd.

2 Esclad is a registered Trademark of Building Products of Canada Ltd.

place from 1981 to 1983. Market testing was first in Quebec with distribution through regular marketing channels immediately after. The product received a CMHC "number" and was accepted by the three U.S. model building codes.

In the beginning, manufacturers' expectations were that standards for wall insulation requirements would increase beyond what could be accommodated in a 2" x 4" wall and that this product would be a cost effective alternative to a full 2" x 6" framing. Although this has not occurred, higher insulation became such a strong selling point in Quebec that sales took off during the 1983/85 period.

During that period, several improvements were introduced in the Esclad product, the most important being an improvement in the membrane backing in order to reduce breakage and to ensure its suitability as a temporary outside finishing.

Although no statistics are available, it appears that insulated sheathing has become a method of choice for increasing the insulation of outside walls in renovations and upgrades.

No sub–trade resistance was identified. This type of product has been adopted by contractors to increase external walls R–value to the extent that growth rate for this type of product is said to be above 20% with the two leading products enjoying yearly sales increases above 30%.

C. FACTORS AFFECTING DIFFUSION

As stated earlier, the basic comparative advantage is that it is a cheaper, faster alternative than the use of batts in 2" x 6" framing to achieve high R–values.

Although energy costs are low, manufacturers, distributors and many contractors are receiving feedback from prospective purchasers which indicates that they want high insulation values in their walls and ceilings. As such, insulated sheathing is more compatible with present contractors building habits than would be a change to the 2" x 6" alternative.

This type of product is very simple to use. It does not require new skills from the tradespeople involved nor does it add much labour time to the construction cycle. Insulated sheathing, especially Glasclad, has a high visibility on site because it forms the external envelope of the house until the final siding is applied. As such it gains a measure of recognition on the part of consumers which facilitates diffusion. Provided acceptance continues at present rates, insulated sheathing may achieve full diffusion in less than 15 years of market availability in Canada which would put it among the innovations with the highest diffusion rates.

CASE: MODULAR HOMES

A. DESCRIPTION

Modular homes differ from others types of construction as they are built completely indoors, in two or more sections which are then transported to the site where they are lifted and placed on regular foundations. As a rule, joining of sections and finishing is completed in one day.

Modular homes should not be confused with other types of housing built off–site such as Panelized homes which consist of unassembled wall sections with no finishing, wiring or plumbing, house kits which consist of bundles of pre–cut lumber, assorted hardware and assembly instructions. Finally, modular homes are not house trailers.

Canadian modular homes were built under CSA approved standards which allow for enclosed wiring and plumbing. As a rule, structural standards for modular homes are more stringent than current practices for site built homes. For instance two major Ontario modular homes manufacturers indicated that their houses were built with 2" x 10" floor joists at 16" center rather than the more common 2" x 8". Insulation is R.30 in walls and R.42 in ceilings rather than the minimum requirement of R.12 and R.20. Exterior walls are built with 2" x 6" lumber with 5 1/2" bats, 1/2" Glasclad, Tyvek and aluminum siding or brick (added on site).

Modular homes can be built to R–2000 standard, but because the standard applies to the whole house including basements which are built by outside third parties, manufactured home suppliers do not sell their units as R–2000 homes. Work is going on to find a solution to this problem.

According to industry sources prices of modular homes are 5% to 10% lower than comparable site built houses, where the site is within a reasonable distance of the plant.

Canadian manufacturers of modular homes stress that their current products compare or surpass site built homes in terms of quality of materials and workmanship. They state that there is no detectable difference between manufactured houses and site built houses, when fully-assembled and sided.

B. DIFFUSION

Modular housing around the world has evolved from various sources. In Scandinavian countries, it evolved as a means to achieve year round construction despite inclement weather. The Japanese modular housing industry is said to have evolved from a need to make maximum use of raw materials. The U.S. modular housing industry is, to an extent, an outgrowth of the house-trailer industry and enjoys its highest market share in the sunbelt.

Early Canadian modular homes were reputed to be plain and poorly-built, an image which it has not been able to eradicate.
Another significant factor which may explain the difference in market penetration between Japan, the Southern U.S. and Canada is the population/market density factor.

Shipping costs are a significant portion of the final cost of a manufactured house. In Japan, very high population densities reduce delivery costs considerably and allow manufacturers to take full advantage of their more efficient production set up. On the other hand, Canadian population densities tend to be much lower. Moreover, large tract construction projects tend to have construction costs more comparable to manufactured housing than to single on site built units.

Although the concept of modular housing has been widely known since at least WWII, the growth of the industry has been dramatically different in different parts of the world. Modular houses represent 85% of all new low rise residential housing built in Japan. The U.S. market share for modular houses is estimated to be 40 per cent to 60 per cent. Industry sources in Canada estimate that the market share for Canadian modular homes is less than five per cent.

Construction of modular homes started in Ontario in the early 1970s. The construction process was moved from the site to the shop while most aspects of the process itself remained intact. The only major difference was that each section or "box" was built as a self-supporting structural unit.

C. FACTORS AFFECTING DIFFUSION

Over the years, building technology has advanced faster in the manufactured housing sector than in the comparable site built housing sector. For instance:

- All components of manufactured houses are built on jigs to ensure standardization and fit;
- Manufactured houses use more pre-fabricated components and larger panel sizes;
- Manufactured housing plants make much greater use of cranes than low rise site built buildings;
- Almost all framing and finishing is being done with such automatic tools as air guns;
- Airless spray equipment is used for painting;
- All wood cutting is done with the more precise large master saws rather than with hand held saws.

All of the above tools and techniques are available to the on site builder but penetration is significantly different in each industry segment. On the other hand, manufactured housing still uses the same materials as site built units. There has been no significant developments of specialized materials.

As stated earlier, large tract developers can achieve costs comparable to manufactured housing and do not see manufactured housing as having a comparative advantage.

Small builders, most of which started out as tradesmen in framing or finishing still suffer from "marketing Myopia". They see themselves as builders, not as "suppliers of housing".

This situation is reinforced by the lack of consumer pressure, derived from the negative perception of manufactured housing among Canadians.

Contrary to the rest of the residential construction industry which, for small builders, is characterized by a high "ease of entry" (and exit), low risk (little or no inventory of finished product) and low investment, manufactured housing is an industrial process requiring considerable investments in infrastructure, equipment and raw materials. Manufactured housing also tends to have much larger fixed costs because it does not rely on subcontracting.

All of the above factors point to manufactured housing as a high risk endeavour for the producer. Given the cyclical nature of the residential construction industry and the geographical limitations on market access imposed by shipping costs, the long term risks are even higher. Thus, successful Canadian manufactured housing producers have tended to avoid overexpansion in boom periods to avoid overexposure on the downturn of the cycle. As a result, they have not benefitted as much as they could in the current southern Ontario construction boom, which may explain, in part their low penetration rate. Still, manufactured housing sales have expanded steadily over the last two decades.

CASE: TRUCK MOUNTED CRANES

A. DESCRIPTION

Truck mounted cranes come in various sizes and types. Large mobile cranes have a considerable lifting capacity (over 36000 lb) and can reach over 50 feet. Although mobile cranes are "truck mounted", they occupy the whole space and are used exclusively to lift and place heavy equipment or objects which are carried by other trucks. Their use in connection with low rise residential construction is very limited. Another type of truck mounted crane is the telescopic crane, the most widely used in Canada being the Pittman–National. Telescopic cranes have a reach and lift capacity which makes them ideal for such tasks as positioning trusses on houses up to two storeys. They have been around for a long time and were first used in pipeline laying work in the 1950s.

Articulated truck mounted cranes form the third group. One of their main uses is in conjunction with a "bucket". They are then known as "cherry pickers" and are mostly used by utilities. Their use, in the low rise construction industry, is to unload and position building materials such as brick and gyprock.

B. DIFFUSION

Telescopic cranes came to the residential construction industry via the heavy construction sector. As noted above, telescopic cranes were used for pipeline laying in the early 1950s. From the 1950s to the mid to late 1950s they were used to lay down sewer pipes in towns and were eventually used to unload and place steel beams on construction sites, as well as air conditioning units on top of flat roofs. The popularity of telescopic cranes grew slowly as cranes took less and less space, became easier to operate and, to an extent, less expensive. By the early to mid 1980s, telescopic cranes had been accepted in the industry, mainly by building material suppliers.

Articulated cranes were originally developed in Europe in the mid 1940s. They were relatively rare in North America for the following 15 years and grew in popularity slowly over the years, mostly because they were not capable of heavy lifting or long reach. Early articulated models had a top lift of 3000/4000 lb. and a reach of 16 feet. In fact, such lift and reach made them ideal for work on low power transmission lines. Equipped with buckets, they became the famous "cherry pickers". For a long time, utilities were their main market.

Over the years, articulated cranes have grown to a point where they now rival telescopics, having a range of 40' to 60' and a lift in the 20,000 lb range.

Contrary to telescopic cranes, which are based on drum and cable, articulated cranes are mainly hydraulic systems.

Articulated cranes have several advantages over telescopic ones. First, they fold over themselves and use less platform space when not in use. Second, they can place loads through windows or other such openings far easier than telescopic cranes which need more "head room" to achieve their range. On the other hand, they tend to be costlier with the simplest unit priced at $20,000 plus and larger, more sophisticated units ranging between $80,000 to $100,000. As with telescopic cranes, the majority of users in the construction industry are building material suppliers.

The increased availability of truck mounted cranes, especially articulated ones, has introduced a change in the type of service offered by building material suppliers, which probably began with manufactured trusses dealers who began to place the trusses on the roof rather than just unload on site. Today, more and more contractors are requesting that their drywall or brick or heavy patio doors be positioned rather than unloaded "at the edge" as was once the custom.

Truck mounted cranes of both types are still used for no more than loading and unloading and placing. Truck mounted cranes are still too expensive to be used as a permanent working tool which is what utility companies are doing with their cherry pickers.

C. FACTORS AFFECTING DIFFUSION

Historically, the use of truck mounted cranes in Canada has followed the availability of the product, with price, lift and range as determinant factors. Diffusion has been determined by the twin factors of comparative advantage (price) and compatibility with intended use (reach and lift). Market shift to telescopic cranes and more recently, away from telescopic cranes toward articulated ones, has also been determined by the same diffusion factors. However, diffusion is still very limited since use is still limited to a very narrow segment of the full range.

One interesting aside is that, by law, truck mounted crane operators must be certified "hoist engineers". Such a certification requires a three year apprenticeship. It appears that this quaint piece of legislation has had no barrier effect on the diffusion of truck mounted cranes.

CASE: MANUFACTURED CHIMNEYS

A. DESCRIPTION

A manufactured chimney is defined as a fully self contained product used in a regular housing environment without the necessity of masonry or brickwork enclosure.

Modern factory–built chimneys are manufactured to meet standards for different applications, the principal ones being: Type A, now used only for gas and oil–burning appliances; HIgh–temp Type A, used for wood stoves; and, Type M, intended for wood stoves and factory–built fireplaces.

The modern class A or M manufactured chimney is composed of three major elements; an outer casing made of galvanized steel or more likely of aluminum, an insulating material, probably a ceramic fiber or an even more recent high grade mineral wool and an inside flue liner made of stainless steel. The Type M chimney must conform to ULC standard S 629 which requires it to withstand a flue fire of up to 2100°F for three test periods of 30 minutes. The zero clearance fireplace chimney has also had its ULC standard raised to a 2300° but the required resistance period is only 10 minutes.

Factory–built chimneys intended only for venting gas–fired appliances are referred to as gas vents. These are also of double–walled construction with an air space between. Type B vents are usually used where a draft hood or diverter is employed with flue gas temperatures up to 470°F, and have an aluminum inner liner and a galvanized outer casing. Type L vents have a stainless steel inner liner and are designed for flue gas temperatures up to 570°F. Type B H venting systems are designed and tested for use with appliances having special requirements.

There are today, five manufacturers of chimneys and five manufacturers of gas vents in Canada. Because some companies produce both products, the actual total number of manufacturers is only seven.

Total industry sales are estimated at roughly 200,000 units per year split 50/50 between chimneys and gas vents. Manufactured units represent 85% of total market, the balance being made up by masonry built chimneys, mainly for use in conjunction with fireplaces.

B. DIFFUSION

The invention of manufactured chimneys can be traced back to August 1933 when a Selkirk, Manitoba tinsmith named Sveinson developed the first factory built chimney. The company named Selkirk Metal Products was subsequently sold to a Winnipeg group of industrialists and moved to Winnipeg in 1944.

The early manufactured chimneys were awkward and bulky. Although factory made, they were custom made for a specific house and were shipped to the site in one piece, flashing and all. It was then dropped in place from the roof. Later models moved to a sectional approach. Manufactured chimney flues became available in standard length sections from two to seven feet.

With the advent of standard sizes, distribution through building suppliers became more feasible. The distribution network started in the west, then spread to Ontario and later on through agents and dealers to the whole of Canada.

When the Brockville, Ontario plant opened in 1962, Selkirk moved its national sales head office there. At that time there was still no competitors to Selkirk. Advertising started early, first in western farm papers, then through participation in trade shows and advertising in building supply magazines. The thrust of the advertising message was to explain the product and its advantages, and to stress its rigorous testing and approval by the UL laboratories in Chicago (at that time ULC did not yet exist). The point was also made that these chimneys were approved in contrast to masonry chimneys which wre not (because they were custom built on each site). Consumer resistance crumbled slowly. Initially, nobody wanted a "tin pipe" for a chimney. Sales maintained a steady, but slow, growth rate. Trade resistance took two forms; one was by building inspectors who resisted the innovation. Selkirk had to threaten to go to court several times to force acceptance, although no court action was actually undertaken. The process was lengthy and cumbersome because, at that time (1950s) each jurisdiction had to be approached individually and recognition had to be obtained in each township. The ULC labelling obtained in the early 60s helped speed up acceptance, but the problem was only really solved when the National Building Code began to fulfill its role as a model code.

It is important to note that penetration was further complicated by the fact that the heating appliance also had to gain independent recognition in each township.

The second group to offer resistance was comprised of the masons themselves, but eventually (around 1964/65) many masons adopted factory built chimneys for fireplaces as they allowed them to be more productive and hence more profitable. Today, masonry chimneys are only available in some areas of the country. They are very rare in the west and the Maritimes but still available in larger centers such as Toronto and Montreal where older tradesmen still prefer to build custom fireplaces. Building supply dealers adopted manufactured chimneys because it was a more profitable strategy than supplying bricks for masonry chimneys.

Diffusion of manufactured chimneys was sometimes helped by temporary localized conditions. For example, slab houses, fairly common at one time in the Prairies could not accommodate a full fledged masonry chimney because they lacked the proper foundations. Factory built chimneys could be easily mounted on the furnace (which was generally located in the center of the house). That market segment, small was, played an important role in to further growth.

From 1963 to 1965, Saskatchewan was promoting home garbage gas incinerators in urban areas, a policy which greatly helped the sales of class A manufactured chimneys because gas vents could not be used.

In rural areas, the custom was to put the cooking stove at one end of the room and to run a pipe to the other end where the chimney was located. Two innovations changed that practice; the advent of tight combustion controlled stoves (the best known being the Ashley), and the introduction of factory built chimneys. Ashley stoves were much more efficient than the old Franklins and would burn all night, but they would not work with a long flue pipe. Furthermore, tighter stoves have cooler flue gases. In non–insulated chimneys, the danger of creosote build up and fire increases considerably. Even early manufactured chimneys could withstand 1700° Fahrenheit fires for ten minutes which was (then) considered a safe standard against chimney fires.

Thus, the advent of advanced stoves spurred the diffusion of manufactured chimneys. And that phenomenon was not limited to the Prairies. The Department of Northern Affairs was another client which helped sales growth and diffusion in the crucial early 60s period. Northern Affairs was building houses with oil burners. Unfortunately, residents were in the habit of adding wood into the combustion chamber of oil forced furnaces. There were many cases of creosote build up and fires. Northern Affairs switched to class A chimneys and the woodburning Ashley type stoves.

By the mid 60s, several more Canadian manufacturers of pre–fab chimneys appeared on the market. Manufacturing also started in the United States. One of the early U.S. manufacturers was metal bestos. It eventually bought out Selkirk, the Canadian pioneer of the manufactured chimney industry.

Technological evolution in manufactured chimneys has been mostly in the area of improved material and all of it came about because materials became available on the market and were adapted to use in chimneys. For instance, the initial insulating material on manufactured chimneys was fiberglass. In the late 1940s, it was replaced by a mixture of silica powder and mineral wool which had been developed in California. In 1980, ceramic fibers were introduced as insulating material. Again, it came from the U.S. The latest material to be used is high grade mineral wool which was originally developed in Europe.

In addition to the Canadian contribution of inventing the product in the first place, one of the most significant technological advances was a set of venting tables developed by metal bestos (Dick Stone, 1953) which quantified the performance of gas vents . For the first time it became possible to match the appropriate chimney to a given situation. The tables which are easily usable by installers, later became a cornerstone of the installation standards and are still in use today.

Since the early 1950s, manufacturers of chimneys have been educating consumers and the trade. Recognizing, for instance, that a lot of the early chimneys used in rural areas were installed by the prospective user, they included instructions based on pictures and intended for use by persons with a low level of literacy. At the same time, company sales people set up chimney and gas venting courses for users, installers and municipal inspectors. In the mid 60s, when it still had a virtual monopoly on manufactured chimneys in Canada, Selkirk had twenty five full time representatives on the road throughout Canada; each with a dual sales and education role.

C. FACTORS AFFECTING DIFFUSION

It took nearly two decades for manufactured chimneys to become the dominant product. Initially, they were seen as incompatible with consumer preferences and trade traditions but, as was seen in the historical descriptions, various conditions provided manfuacturers with the opportunity to nuture their product in the early stages. Furthermore, most sales and growth in the first twenty years, were directly to the consumer, not through the trade because manufactured chimneys had one great advantage – anyone could install them, a great advantage over masonry chimneys. In many cases, it was not a matter of cost, but of availability of the manufactured chimney versus the absence of a trained mason.

CASE: AIR SOURCE HEAT PUMPS

A. INTRODUCTION

In Canada, the market for Air Source Heat Pumps is primarily driven by the air conditioning market. Current prices for Air Source Heat Pumps (ASHP) are too high to be amortized by the savings obtained during the winter heating season. Only when it is considered in conjunction with air conditioning for summer use do the economics become attractive.

The average ASHP has a price of roughly $3500. For this price, the consumer receives a substitute for an air conditioning system whose costs would be about $2500. For the additional $1000, the homeowner gets summer air conditioning, plus a saving in heating costs during the winter. Winter savings in Ontario for an average house would represent up to $400 if the house was electrically heated (about a 40 per cent saving), $200 to $250 if oil heated because of currently depressed heating oil prices, $100 if using a normal gas heating unit and no savings at all if using a high efficiency gas furnace. Costs of running the unit for air conditioning purposes are comparable to the costs of running an equivalent air conditioning unit.

B. DIFFUSION

By the mid 1970s, the number of ASHP being installed in Canada began to climb rapidly. In 1975, information available for Ontario shows that there were 4000 installed units. All the units installed until 1975 were U.S. imports. Early studies undertaken by Ontario Hydro through a special unit created to undertake research in this area, showed that ASHP suffered from maintenance problems, that their performance record was uneven and that units tended to have compressor problems and require numerous service calls.

Units being sold in canada were second generation ASHP technology sold primarily in the southern U.S.A. where there was a strong market for ASHP as add–ons.

The market continued to grow through the late 1970s and picked up speed during the 1981–1985 period. Again, for the Province of Ontario for which statistics are available, sales during that period were in the 5000 to 8000 units per year range.

One major incentive for this market expansion was undoubtedly the Canadian Oil Substitution Program (COSP). The COSP program run by the federal Department of Energy Mines and Resources, involved a grant of up to $800 if oil consumption was reduced by 50 per cent or more. Given an additional cost of $1000 over a combination heating and air conditioning unit, an ASHP ended up costing no more than $200 to the purchaser which was an attractive proposition even if winter heating savings were not substantial.

With the end of the COSP program, coupled with a diminishing concern over energy costs, Ontario sales of ASHP dropped to 2500 units program which is representative of the trend (if not the numbers) in the national market.

Sales have, however rebounded and new installations in 1987 topped the 6000 mark in Ontario and 10,000 units for Canada as a whole.

Since the beginning, there has been a concern that the ASHP available in Canada, was not designed for the Canadian climate, posing a major barrier to more widespread diffusion. In 1979, the Canadian Electrical Association, in partnership with Ontario Hydro, began to push for a more efficient ASHP designed specifically for Canada. The idea was introduced to a major international audience in 1980 and, subsequently, because of insufficient interest on the part of Canadian manufacturers, the CEA decided to fund a prototype to be built by the Keaprite Co.. At that time, the Keaprite Corporation, owned by Intercity Gas, was the major Canadian manufacturer of ASHP. It took five years to build the prototype, at which point, corporate commitment had already begun to shift. Keaprite was less interested in the Canadian market and more interested in the U.S. market. Their attention appears to have been focused on developing a more price competitive unit for the Southern U.S. market. In 1986 the company moved to Tennessee where it appears to be successful.

At 10,000 units plus per year, sales have not yet reached the 10 per cent threshold for new housing. The Canadian market may appear large to a small manufacturer, but it is almost insignificant when compared with the U.S. market where annual sales are in the one million unit range owing mostly to the more moderate climates where ASHP have a better overall performance and do not always require a back up heating system.

U.S. manufacturers tend to be large, with the two biggest, Carrier and Heil–Quebec, controlling 60 per cent of the market. Until recently, they had been approaching their own market in a monolithic way, with no adaptation to regional considerations. However, as U.S. manufacturers begin to address the requirements of their own northern markets, new equipment, better adapted to Canadian requirements, may be developed.

One other consideration which may explain the lack of aggressiveness of major ASHP manufacturers stems from the fact that they are integrated producers of a whole line of heating and air conditioning equipment. Since ASHP are a substitute for air conditioning units, they may not be keen to cannibalize their own sales.

At the other end of the spectrum there are small Canadian manufacturers who have attempted to design systems aimed at Canadian conditions, but they tend to lack the size to make a large impact on the market. For instance, Cool Fire Ltd. which has received U.S. and Canadian Patents for its uniquely designed ASHP started in 1980. It has since grown from a 50 unit a year operation to 500 plus units per year. Its product line is limited to heat pumps and it has had to rely on some 50 small independent dealers for distribution.

C. FACTORS AFFECTING DIFFUSION

ASHP are "compatible" with present heating/air conditioning combinations, although in Canada they have no comparative advantage over each element taken separately. In fact, given the technological advances in high efficiency gas furnaces, ASHP may have no comparative operating advantage at all over high efficiency forced air/gas and air conditioning. The fact that the Canadian market is so much smaller than the U.S. market also has a bearing on compatibility as products tend to be designed for the much larger markets.

ASHPs are complex. Operating principles are totally different from heating equipment and are more related to air conditioning principles. That complexity means that, in terms of diffusion, ASHP faces a more important barrier than, for instance, high efficiency heating.

Bigger manufacturers set up training courses for their authorized dealers, a positive move which also means that markets tend to expand slowly by following on the expansion of certified dealership networks.

While products manufactured by major producers tend to focus on the needs of southern U.S. customers, small Canadian producers lack the volume and experience curve to compete on a price basis. Furthermore, because product trialability is low, customers tend to feel more comfortable with well known brand names.

As is the case with Heat Recovery Ventilators, contractors consider this item to be a cost item with, at least under current energy prices, no "leverage sales appeal". ASHP are, therefore, an add–on or more suited to the renovation market. Although no sub–trade resistance was documented, the fact that installation and maintenance is carried out by authorized dealers may pose an additional barrier to the diffusion process.

D. CONCLUSIONS

The CEA recognized the need for the technology to be adapted to the Canadian environment, and actually funded the development of a prototype. This action not appear to have been successful in breaking the market impasse caused by low Canadian demand versus massive U.S. economies of scale.

Interestingly, the largest Canadian manufacturer opted for a transfer to Tennessee rather than continue to struggle in the Canadian market.

As in other cases, where Canada is a peripheral market for U.S. technology, one fundamental question must be answered:

- Do we wish to promote the diffusion of the product regardless of its origins or do we wish to promote the diffusion of a Canadian based product?

The COSP program could be interpreted as a positive response to part one. In fact, it was more focused on reducing oil dependency and in fostering the emergençe of alternative technologies home grown or otherwise. The CEA effort was clearly a positive response to the second option, but it was not successful.

Taking the best of both approaches, it may be possible to promote selectively Canadian technology assistance program aimed at promoting systems tailored to the Canadian climate. In the long term, such a policy would only have permanent positive results if the end technology showed sufficient environmental performance under "northern weather" conditions that it could capture a share of the U.S. market as well.

CASE: TOOL & EQUIPMENT RENTAL

A. DESCRIPTION

The rental industry evolved after WW II spurred by people in the construction industry who found that they could gain revenues from renting their equipment when not in use. This phenomenon occurred at both the heavy equipment end with Simmons in Winnipeg renting heavy construction equipment to road builders. Tom Douglas started renting wheelbarrows, then welders and heaters at the low end. The same phenomenon occurred in the east ten to fifteen years later.

Originally, renters would buy used equipment. They did not have the capital investment required to maintain an inventory of new equipment and clients did not demand it. Tool and equipment renting has evolved considerably from its earlier days. Today, tool and equipment rental companies operate mainly in three fields with many of them operating in all three. The three fields are:

- New construction tools and equipment;
- Tools and equipment used for yard work and repairs by homeowners; and
- Party equipment.

B. DIFFUSION

The importance of the tool and equipment rental industry to diffusion of innovation in the construction industry, especially the low rise residential sector, can perhaps best be summarized by the statement made by Mr. Norm Cinch, President of the Rental Association of Canada. According to Mr. Cinch, "For at least a decade now, anything which made its way into the construction industry made it through the rental business".

Tool and equipment rental businesses aggressively attend trade shows and hardware shows for the purpose of seeking out new pieces of equipment. As a rule, renters will buy a piece of equipment which contractors would not. However effective, a new piece of equipment may not be attractive to the contractor because its use would not be sufficient to justify the initial capital cost. The renter can use such a tool economically because its cost is shared among many individual users.

Over the years, two factors have favoured tool renting in the low rise construction industry sector.

First, because of the cyclical nature of the industry and the low level of capitalization of most of the trades involved, contractors and tradespeople have tended to own the basic tools required for their work but increasingly rent on a short term basis, (by the week or even by the day), to meet peak demand.

Second, many contractors have concluded that it is easier to estimate the cost of a job when the equipment is rented than when it is owned because depreciation and amortization rules are too complicated to cost out.

Among the new equipment which has been introduced to the industry through the rental business over the years, the following examples have been identified:

- Mini Excavators. These are small tracked devices with a cab capable of rotating 360°. It has a back–hoe arm which can operate in zero clearance parallel to a foundation wall. Its major advantage is that it can operate where a full back–hoe cannot and can do in two hours what would take several days to do by hand. It has been available in the United States for the last five years, in Canada for the last two years, mostly through the rental basis.

- Air caulking guns, coupled with small compressors for on site work, have been on the market for five to six years, again mainly through rental channels.

- Air nailers for on site framing have diffused faster in Western Canada and are now penetrating the eastern market. Most, if not all, users have been introduced to this innovation through rental companies.

- Finishing power nailers for cabinets and trims replace hand tools, leave no mark, and speed work up considerably. The three and a half pound Brad nailer costs $669.00 to purchase but can be rented for $30 per day. Tradespeople who have been trying them out, are now starting to buy them and rental businesses are beginning to sell the products they rent.

- Skid Star loaders are very small rubber tire loaders. Each unit costs some $30,000 and can be used to backfill basements at $150 a day. They can do four to five basements in one day. This tool is also very useful for excavating driveways. This Skid Star loaders are apparently a strong, upcoming rental item.

- Laser levels can cost up to $5000. They allow one person to do precisely leveled work without an assistant. Rental rates are $200 to $300 a month. Apparently, this is strictly a rental item.

- Airless paint sprayers paint under pressure with no air involved. Painters started by renting them but most of them now own their equipment. Paint stores are, however, aggressively renting this equipment to homeowners.

Because rental companies have a high usage rate on their equipment, they usually have a good maintenance shop. This has given them another advantage as they can sell and service equipment as well as rent and service. Tool manufacturers are turning increasingly to renters as dealers.

Renters influence diffusion in yet another way. Tradespeople do their equipment selection through "comparative rental". Tradespeople rent different brands and models, and test each for a few days. This allows them to make a more educated, less risky, purchase decision.

Finally, tradespeople tend to favour the tools most popular at centers because they believe that any tool that can withstand the heavy use engineered by rental must be of good quality.

C. FACTORS AFFECTING DIFFUSION

Clearly, the tool and equipment rental business is a strong diffusion accelerator. Its main function is to reduce risk by facilitating trialability. Its other functions are to supply equipment for peak period demand, a function for which it is uniquely suited. The tool and equipment rental business appears to be perfectly matched (which is as much compatibility as one would desire) with the operating practices of the industry it serves.

Tool rental has two other advantages. One is the comparative advantage of cost of short term rental over ownership. The other is that it reduces the complexity inherent in the ownership of construction equipment of all types. Such complexity is defined as technical with respect to maintenance and storage, and fiscal with respect to depreciation and amortization (as opposed to straight flow through).

D. CONCLUSIONS

The tool and equipment rental case was selected because of its strong impact on diffusions of innovations. It is a good example of how products can have their diffusion accelerated through a process of risk reduction, easy trials and strong compatibility. It is also an indication that diffusion oriented policies must meet these same criteria in order to be successful.

CASE: CORIAN*

* Corian is a registered trade mark of E.I. Dupont de Nemours U.S.A.

A. DESCRIPTION

Corian is an acrylic based solid surface molded or fabricated counter top material. Corian is unique as it does not simulate any other material; it is not a laminate, although it has the same applications. Corian is a thick non porous material, resistant to heat and staining. It can be repaired (buffed) and is machinable with regular wood working tools. Because of its price of close to $100 per running foot, Corian does not compete with laminates; its competition is from polyester based products such as cultured marbles.

Production of Corian is concentrated in two plants, one in Buffalo, N.Y. servicing the entire North American market, and one in Japan covering the Pacific Rim market.

Since 1987, Corian has been available in colours and patterns.

B. DIFFUSION

Corian was developed by the Dupont company in the early 1970s. Corian was not the result of a focused R & D program aimed at developing a high priced counter top material, rather it was one of the many new products generated by Dupont's research laboratories and given an opportunity to find its market niche.

The Dupont company recognizes that these types of products go through a "venture stage" and the company is generally willing to give them support for a five year period during which "product managers" attempt to identify market niches and achieve market penetration.

Corian was launched in the United States in 1972 and in Canada in 1974. During the 1974/75 period, the target market was the hospitality industry. Such hotels as the Queen Elizabeth, the Meridien, the Montreal Airport Hilton, the Chateau Laurier and the Ottawa Westin Hotel were outfitted with integral top and bowl vanities made of molded Corian. After the 1976 Montreal Olympic games, construction of new hotels slowed down considerably and the commercial market lost momentum.

Sales to the residential market started slowly in 1980. The new marketing focus was made possible by the development of the "seam kit". Before the development of the "seam kit", Corian had to be either molded or fabricated and joined with silicone beads. Molding was not a satisfactory solution for the largely custom residential market nor was the appearance of the fabricated product with silicone caulking satisfactory.

The "seam kit" allows for a completely seamless joint in such a way that the final product has all the characteristics of a molded unit while actually being a fabricated one. Under these circumstances, the residential market for upscale customized houses could be serviced.

In 1983 a television advertising campaign in four test cities raised consumer awareness from five per cent to 50 per cent. Demand grew rapidly but defective installation created a lot of unhappy customers. An analysis of the situation revealed that local fabricators had been misusing the new adhesive compound. They had attempted to use the "seam kit" as if it were a wood glue. The subsequent decision was to embark on a process of educating the fabricators.

The distribution network was revamped in 1984 with five distributors and eight stocking points established across Canada. Each distributor was given the responsibility to develop and educate a network of fabricators in his region. Fabricators specialize in counter tops; they are either suppliers to independent kitchen cabinet dealers or operate as in–house fabricators for larger kitchen cabinet dealers. Under the new education program, fabricators are either sent to a three day training program at a special training facility operated by Dupont in Pennsylvania or they are trained on the job by specialized field trainers employed by the distributors.

Each distributor must also supply a full time Corian specialist who delivers presentations to architects on how to specify the material, and organizes seminars to kitchen dealers, and attends trade and consumer fairs. The efforts of the Corian specialist are supported by printed and video material supplied by the manufacturer.

By early 1988, there were 67 fully trained fabricators from coast to coast in Canada. This new approach has all but resolved earlier installation problems. Although no major advertising campaigns have been undertaken, market penetration has progressed satisfactorily with sales increasing by 12 per cent in 1984/85, 14 per cent in 1985/86 and 40 per cent in 1986/87. Still, in spite of healthy growth, the 1987 market penetration is estimated at only two per cent.

The residential market for Corian is concentrated in the following segments:

- o The high end custom built houses (mostly in Toronto). These new units, priced at $450,000 and above, tend to have all the key "prestige" items of which Corian is an important one. Penetration in this market is considerably higher than in other market segments.

- o The high end condominiums for empty nesters. This market, which is made up of people which have benefitted from the increased value of their previous single family home, is also within the core market for Corian.

- o The renovation market. As far as Corian is concerned, sales are concentrated in the kitchen and bathroom remodelling market for "two income "yuppies". In 1987/88, this market segment, by itself, generated more sales than all sales to new construction.

Sales to the above target groups are strongly supported by three coordinated communication/education/image building efforts:

- o Information and education of high end kitchen dealers and architects who have a strong prescriptive role in the choice of materials for custom built houses and high end renovations.

- Creation of the appropriate image through advertising and articles in targeted "high living" publications.

Besides sales to the residential market, Corian is also being installed in toilet facilities, new "exclusive" office buildings, as well as in new health care facilities such as hospitals, retirement homes and laboratories.

C. FACTORS AFFECTING DIFFUSION

This is an interesting case as Corian is a product which started out with a comparative disadvantage compared to available alternatives and which ended up creating a new high end market which it leads. This case illustrates how other relative advantages can be used to overcome an apparent price disadvantage. Dupont has been successful in differentiating its product to the extent that, although cost remains a strong barrier to the expansion of sales outside of the high end market segment, it is no longer a basis for comparison.

Although market penetration of only two per cent (of new houses and estimated renovation volumes) may appear to be an indicator of failure, success in this case must be measured in terms of the much smaller "high end" segment for which no specific information was available. The Dupont company considers the annual growth rate as a more important indicator of success.

Another interesting aspect of this case in diffusion terms, is related to the compatibility/complexity dimension.

The initial Corian product was not compatible with the residential market because it had to be integrally molded to project the image of quality associated with its price. This was possible for large multiple unit institutional projects but not for one of a kind custom kitchens. Dupont overcame this barrier by developing the "seam kit" (an excellent example of innovation "complementarity dependence"), but in the process, created a new, unexpected barrier to diffusion since (unknowingly) it was introducing a new measure of "complexity" in the use of the product. Fabricators did not realize that, although Corian can be worked on with normal woodworking tools, the seam kit is not just another wood glue. Again, Dupont reacted by first recognizing then removing this barrier in a systematic deliberate fashion. The training program of fabricators has fully overcome the initial problem.

A complete Corian kitchen counter can cost several thousand dollars; nevertheless insistence on product trials is very low. This is because through its information/education/image campaign aimed at prescriptors and prospective consumers, Dupont has been successful at eliminating all perceptions of risk associated with the product. Concern about non–performance of Corian is a non–issue.

For those who cannot afford a full Corian counter, trialability is being achieved through the Corian "insert". Such inserts as Corian chopping blocks, baking areas and hot plates are helping to familiarize new potential customers with the product and its advantages.

Dupont appears to have correctly identified the key individuals involved in the decision making process in its various target segments. It is successfully supplying "narrow beamed" information to each group.

Risk reduction for the Corian fabricator is closely linked to the concept of "maximum postponement of adjustments".

The fact that Corian can be custom fabricated and retain its "integral" molded image is very important in reducing the market and financial risk associated with working with such a high priced item. Few countertop fabricators would be in a position to take the risk associated with holding a broad enough inventory necessary to satisfy the demand of a custom oriented market insistent on the integral seamless molded look.

CASE: ULTRA-VIOLET STABILIZED POLYETHYLENE VAPOUR BARRIE

A. DESCRIPTION

Some type of vapour barrier, tar paper or some substitute has been in use in the Canadian Low Rise Residential Construction Industry since at least the twenties. Polyethylene film has been available since the early fifties. Early polyethylene film was rather thin, rating around two mils. It came in four feet wide rolls and was often manufactured with a certain percentage of recycled resin.

Recent research results indicate that the older polyethylene film was subject to ultra violet degradation while exposed to sunlight, on site and during the construction process, and that there was a certain amount of degradation over time inside the walls. No catastrophic failures were, however, noted.

The same research suggests that the degradation of the polyethylene film itself was of little relevance, given the fact that installation methods, size of roll and work procedures followed by construction tradespeople led to puncture points or gaps in the film. Electricians, in particular, made the degradation of the polyethylene film a moot point. The vapour barrier usefulness of the old polyethylene film may indeed have been a myth.

Because vapour barriers were required by the National Building Code, adopted by all Provincial codes and enforced by Municipal Building Inspectors, polyethylene film acquired the status of product of choice for vapour barrier requirement purposes.

Information on the demand side suggests that only Ontario Hydro's "Golden Medallion Homes" and builders of "Tight Houses" such as the R–2000 homes, have any interest in heavier polyethylene film but they only represent a small percentage of annual residential constructions. One could speak of a market driven product, but there is little market support for the introduction of a new "standard".

The reason behind the push for a new standard may have other purposes, i.e., to ensure fast diffusion and eliminate the competition from the present two and three mil gage products produced from recycled resin.

Certain polyethylene film manufacturers, whose main line of business is outside of the vapour barrier market, have on occasion, offered low cost off–grade thin film made with a substantial amount of recycled resins.

The new polyethylene film is less vulnerable to that competition because, besides the larger width and the six mil gage, it requires one hundred per cent new resins, the U.V. stabilization treatment, and the water mark three characteristics which make it unattractive as an "off peak" product.

Although this product has not yet been actually introduced to the market, this innovation appears to have most of the characteristics required for rapid diffusion.

Once the regulations are in place and the product is available (it is expected that all eight Canadian producers will start shipments by mid 1988) contractors will have no other option than to require it (a clear case of relative advantage).

C. FACTORS AFFECTING DIFFUSION

The approach taken by the industry to introduce the new product seems to indicate strong communication among the manufacturers themselves (at least the Majors) and between them,(via the industry association) and the relevant government departments.

This is a situation where adoption of the new technology at the producer level is expected to be almost instantaneous, with diffusion occurring shortly thereafter. If the product is "legislated" the "unit of absorption" approaches "one". As a matter of fact, even if it is not included in the National Building code, "voluntary" CGSB standards make it mandatory once it becomes a CMHC requirement.

According to available information, the new polyethylene film will increase the cost of a standard detached house by about $40. It is not expected that house buyers will notice the difference.

Individual contractors do not feel affected by any small price increase which affects all competitors, as it can be passed on and does not affect their competitive position.

Few builders support the new standard but will not risk seeing their project disqualified by CMHC for purposes of mortgage insurance. Many building inspectors will reject the old type polyethylene vapour barrier once they become accustomed to the new polyethylene film carrying the new CMHC approved "water mark".

House buyers seem to have played little or no direct role in the introduction of this product. It is not expected that they would have a more important role in the actual market acceptance of the product.

D. CONCLUSIONS

This case is an example of an attempt to achieve "diffusion through legislation". One of the interesting aspects of this approach is that it involves what is known as an "unitary" approach to diffusion.

Instead of allowing innovators and early adopters to play their role off "risk reducers" there is an attempt to collapse the whole process to achieve instant legally enforced adoption.

The literature shows that in these cases, barriers and resistances do surface, but they make their presence felt before regulations are past in the form of opposition to such a move.

Although unitary adoption may be justified when safety or security considerations are at stake, it is doubtful that responsible institutions, especially governmental entities, should routinely support such an approach to diffusion of innovations.

CASE: ACTIVE SOLAR SYSTEMS

A. DESCRIPTION

Active Solar Systems are comprised of three basic elements: a set of solar collectors which convert solar energy into thermal energy, a storage component and some means to transfer the heat for purposes of use or storage. The transfer mechanism can be a pump or some other device or it can use the thermo siphon process where no pump is required (not currently used in Canada because it lacks freeze protection). Although thermo siphon systems are technically passive systems they are included with other active solar systems because they share all their other characteristics.

The Canadian climate does not favour the use of active solar systems for space heating because seasonal demand and peak demand correspond to the periods of the year with least sunshine availability (Nov–March). The few existing systems are hybrid systems which depend on non–solar back ups.

Water heating requirements can be better matched with sunshine availability as in the case of summer hot water demand for residential pools, camp grounds and marinas. With the use of antifreeze or an appropriate freeze protection mechanism, active solar systems can be used year round for hot water supply purposes, but they also require back ups.

B. DIFFUSION

Early research on active solar systems can be traced back to an 1936 M.I.T. bequest sponsoring of R & D in the field of solar energy systems. That effort spearheaded by Dr. Hoyt Hottel was followed independently by research directed by Prof. Ferrings Daniels from the University of Wisconsin who worked in this field before 1945. Interest spread in the late 50s and early 60s. France undertook a project of solar furnaces and created the "Mediterranean Cooperation Program for Solar Energy". In the same time period, the Solar Energy Society was created in Arizona and an international conference on solar energy was held in Rome in 1957. In 1958, the Association for Applied Energy organized a contest entitled "Living with the

Sun" for the development of a solar house. Meanwhile, the Journal of Solar Energy of the American Society for Mechanical Engineering and ASHRE's publications supported an increasing interest in the field.

The decade of the 70s was crucial for the development of solar energy. The UNESCO Paris Conference on solar energy (1973) was one of the last before the beginning of the 1974 energy crisis. In 1974, the Federal Department on Urban Affairs (Minister Barney Danson) made a commitment of $100 million for the purpose of demonstrating Canadian technology in this field. In 1974, CMHC was present at a Vancouver exhibit on solar energy. With the help of Urban Affairs four solar buildings were commissioned across the country in time for reports to be available at "Habitat 1975" in Vancouver.

In 1976, NRC undertook a Solar Energy Demonstration program involving 18 houses. The need to monitor the performance of these demonstration units gave rise to a performance evaluation program starting in 1976/77.

In 1978, two new Federal programs were added; the PASEM program (program of Assistance to Solar Equipment Manufacturers) and the PUSH program (Purchase and Use of Solar Heating for Federal Buildings).

In July 1978, Public Works started implementation of the PASEM program by offering $10,000 in assistance to 24 companies selected amongst 150 applicants. They were to use these funds to prepare their PASEM proposal. In 1979, the 24 companies which had received assistance in addition to 19 others submitted formal proposals. Ten companies were selected, each receiving between $300,000 and $400,000 in assistance under the PASEM program, to develop a manufacturing capability. Under the PUSH program, the federal government purchased active solar systems and installed them in a variety of federal buildings ranging from post offices to military installations. For a time, this program was the mainstay of the industry.

Nine of the ten companies which received assistance under the PASEM program have, by now, gone out of business, the last one is no longer in the solar field.

The PUSH program was overtaken by the Solar Energy Demonstration Program administered by EMR and begun in 1983. That program had a five year time horizon. The intent was to provide companies with an opportunity to enter the residential market. The program was open to all qualified producers. A sliding subsidy scale was implemented starting at $2100 per installed unit in 1983, bottoming out at $600 per installed unit by the end of the program (March 1988). Pool heating systems were not eligible. Over the program period, the net price per unit to customers was kept fairly constant. The objective was to allow companies to continue to develop their products and acquire more experience. As a result of these programs, the industry has (compared to foreign producers) produced excellent systems, at a comparatively low cost. Its current lack of success can be attributed to low energy prices.

Because of energy prices, the industry is not competitive nationally, although it is doing better in P.E.I. and N.S. where energy prices are higher.

Since 1983, a number of standards have been developed through CSA's Coordinating Committee for solar collectors and its three subcommittees on Collectors, Systems and Installation. Some of the standards already in place are:

- Installation: CSA F383–87
- Domestic hot water systems CSA F379.1–88
- Domestic hot water systems CSA F379.2–88 (seasonal)
- Solar Collectors CSA F378

The above standards have been developed with the assistance of the ORF National Solar Testing Facility originally sponsored by NRC. Because the above standards are for structure and installation procedures rather than for performance, contacted manufacturers said they were potentially inhibiting factors to diffusion.

As of this writing, there are less than five remaining commercial solar system manufacturers in Canada. More than 12,000 houses are equipped with residential hot water systems, and there are also several thousand pool heating systems. The number of residential operating space heating systems is close to zero.

C. FACTORS AFFECTING DIFFUSION

The PASEM, PUSH and Solar Energy Demonstration program were fundamental elements of technology development in the active solar systems field. Building up upon existing basic and applied research, the PASEM program spearheaded the technology through the initial stages of development up to the production stage. The PUSH program gave manufacturers an opportunity to initiate production, test and evaluate performance and introduce necessary refinements. The five year Solar Energy Demonstration program aimed to place the industry on a competitive footing with alternative heating options. While the above programs were successful in advancing the technology and creating a core industry, they could not support it in the face of crumbling energy prices.

In terms of effect on impacts, the situation is clear. Installation costs are high and this is enough to discourage builders to include it as standard equipment. Active solar systems are restricted to customized homes or retrofit.

Even for household water heating, comparative advantages are neither large nor visible nor immediate. On the contrary, initial cost is high and the system requires a back–up system which is either a gas, oil or electric water heater. Between 1979–82, it was possible to imagine of a situation in which an active solar system operating 30 to 40 per cent of the year would have an attractive pay back period, but this is not the case under present energy prices. If, in Ottawa for instance, electricity prices were 7 cents a Kilowatt instead of 4.5 cents, demand for solar systems would increase dramatically. (The national average in the U.S. is 7 cents.)

Because of the seasonal demand, government subsidies, and low interest loans, (e.g., Ontario Hydro's Normack 8.9% Program), a number of pool heating and residential heating systems were sold at low prices, but no firm market has yet been established.

From the house owner's perspective, the first compatibility issue is generally an aesthetic one. Not all homeowners favour active solar system on the public side of their house.

Another issue relates to the right to sunshine. Under present bylaws in most Canadian municipalities, the right to sunshine is not recognized which suggests that some innovations have legal barriers which must be overcome to ensure unrestricted diffusion.

Homeowners desire maintenance and supervision–free appliances; solar technology is regarded as less than fully satisfactory on that score. Consumers are concerned about the need to drain the system in the winter and the consequences of not doing so. The perception of active solar systems as complex and problem prone may no longer reflect reality. Recent improvements have led to the development of systems for which maintenance is very low and there is good freeze protection. The fact that a number of demonstration systems installed in the last five years were subjected to performance analysis and showed serious installation defects, leaks and failure to operate may be an indication that consumer perceptions are not unfounded.

At present, active solar systems do not lend themselves to trials as they are only available in large units and must be purchased.

In terms of communicability, solar systems suffer from low visibility. When a consumer makes use of a facility serviced by an active hot water solar system there is no way for him to know it or to judge if the system is performing adequately, therefore there is no demonstration effect.

CASE: USE OF COMPUTERS BY BUILDING CONTRACTORS

A. INTRODUCTION

The use of computers by members of the construction industry is a recent phenomenon. The objective of this case study was to assess the level of diffusion of computers among building contractors as an indication of the use of computers in the industry.

A number of building contractors were contacted nationwide and asked the following questions:

- o Did they have a computer?
- o If yes, since when?
- o If yes, for what purpose is it being used, and if possible, when was each function added?
- o What type of computer is it?
- o Has it been upgraded? if yes, when?
- o Is any software or hardware upgrade being contemplated? if yes, what?

Information was obtained by region and for different sizes of building contractors but the sampling was random rather than stratified. Because of the limited size of the sample and because of the sampling procedure, (use of yellow pages without recalls), this data is offered as indicative only. (Building contractors contacted did not build only or primarily low–rise housing, they also worked in renovation and commercial construction.) It does, nonetheless, offer an interesting insight into the matter.

B. DIFFUSION

The attached Table clearly indicates that computers are a very recent phenomenon in the L.R.R.C.I.; that regional differences are considerable; and that the use being made of the available equipment is mostly routine. Computers are being used as a support tool in the small business function (accounting, wordprocessing, payroll, inventory) to a much larger degree than they are being used for operational purposes such as scheduling, estimating or design.

USE AND DIFFUSION OF COMPUTERS AMONG CANADIAN BUILDING CONTRACTORS

COMP.	SIZE **	PROV.	TYPE	YEAR PURCHASED	APPLICATIONS *	UPGRADE PAST	FUTURE
NO	10 E	NFLD.	--	--	--	--	--
NO	15-20 H	NFLD.	--	--	--	--	--
YES	--	NFLD.	IBM	1986	1,2,4	NO	--
YES	250 H	NFLD.	CAT 3	1983	1	--	--
NO	SMALL	N.S.	--	--	--	--	--
YES	--	N.S.	IBM	1986	1,5	--	--
YES	--	N.S.	Buroughs	1987	--	--	--
NO	2 H	N.S.	--	--	--	--	--
YES	SMALL	N.S.	IBM	1986	1	--	--
NO	SMALL	N.S.	--	--	--	--	--
YES	AVG.	N.S.	IBM	1986	1,5	--	new printer
NO	SMALL	P.E.I.	--	--	--	--	--
NO	SMALL	P.E.I.	--	--	--	--	--
NO	SMALL	P.E.I.	--	--	--	--	--
NO	300 H	N.B.	--	--	--	--	--
NO	3 H	N.B.	--	--	--	--	--
NO	--	N.B.	--	--	--	--	--
NO	--	N.B.	--	--	--	--	buy one
NO	--	N.B.	--	--	--	--	--
NO	SMALL	N.B.	--	--	--	--	--
YES	250 H	N.B.	IBM	1987	1	YES	2
YES	75 H	N.B.	VENUS	1984	1,6	--	--
NO	--	N.B.	--	--	--	--	--

* 1.ACCOUNTING 2.INVENTORY 3.SCHEDULING 4.WORD PROCESSING 5.ESTIMATING 6.DESIGN

** H - HOUSES PER YEAR E - EMPLOYEES

COMP.	SIZE **	PROV.	TYPE	YEAR PURCHASED	APPLICATIONS *	UPGRADE PAST	UPGRADE FUTURE
NO	--	B.C.	--	--	--	--	--
YES	200 H	B.C.	IBM	1985	1,4,2,5	5	--
NO	6 H	B.C.	--	--	--	--	--
YES	SMALL	MAN.	Ultimate	1985	1,4	--	replace system
NO	3 H	MAN.	--	--	--	--	buy one
YES	500 H	MAN.	IBM clone	1986	1,4	--	--
YES	580 H	MAN.	Digital	1978	1	soft+hard-wares	--
YES	--	ALB.	MAC,IBM	1985	1,4	--	--
NO	50 H	ALB.	--	--	--	--	--
YES	9 E	ALB.	IBM clone	1987	1,4	--	--
YES	--	QUE.	Amiga	1987	1	--	--
NO	--	QUE.	--	--	--	--	--
NO	--	QUE.	--	--	--	--	buy one
YES	30 H	QUE.	IBM PC	1985	1,4,5	hard+soft-ware	--
YES	--	QUE.	IBM	--	1,4	--	--
YES	20 E	QUE.	IBM,PS2	1986	1,4	--	--
YES	250 E	QUE.	PC,PS	1983	1,5	--	no
NO	30 E	QUE.	--	--	--	--	--
YES	--	QUE.	--	--	--	--	--
YES	5 E	QUE.	--	--	1	--	--
YES	4 E	QUE.	ATARI	1987	1	--	--
NO	3 E	QUE.	--	--	--	--	--
YES	75 E	QUE.	MAI,PC	1982	1,4	--	--
YES	70 E	QUE.	IBM PC	1988	1	--	no

* 1.ACCOUNTING 4.WORD PROCESSING
2.INVENTORY 5.ESTIMATING
3.SCHEDULING 6.DESIGN

** H - HOUSES PER YEAR
E - EMPLOYEES

COMP.	SIZE **	PROV.	TYPE	YEAR PURCHASED	APPLICATIONS *	UPGRADE PAST	UPGRADE FUTURE
YES	95 H	ONT.	IBM	1986	1	no	software
YES	1000 H	ONT.	IBM	1984	1,2,3,4	software	network
YES	1500 H	ONT.	Personal	1986	1,2,3,4,5	as needed	as needed
YES	50 H	ONT.	IBM clone	1987	1,3	no	no
NO	--	ONT.	--	--	--	--	buy sytem
YES	300 H	ONT.	Personal	1982	1,2,3,4	software	software
YES	60 E	ONT.	IBM	--	1	--	--
YES	SMALL	ONT.	IBM	1984	1	--	--
YES	50 H	ONT.	Commodore	1986	1,2	--	--
NO	SMALL	ONT.	--	--	--	--	--
NO	7 E	ONT.	--	--	--	--	--
NO	12 H	ONT.	--	--	--	--	--
NO	5 H	ONT.	--	--	--	--	--
YES	450 H	ONT.	IBM	1987	1	--	--
YES	30 H	ONT.	PC,AT&T	1986	1,5	--	--
YES	2000 H	ONT.	Compac	1986	1,2,3,6	yes	--
NO	12 H	ONT.	--	--	--	--	--
YES	25 H	ONT.	MAI	1987	1,2	upgrading	--
YES	25 E	ONT.	IBM PCAT	1987	5	--	--
NO	--	ONT.	--	--	--	--	--
YES	4 E	ONT.	MAC	1986	4	--	soft+hard-ware
NO	12 H	ONT.	--	--	--	--	buy system
NO	20 E	ONT.	--	--	--	--	buy sytem

* 1.ACCOUNTING 2.INVENTORY 3.SCHEDULING 4.WORD PROCESSING 5.ESTIMATING 6.DESIGN

** H - HOUSES PER YEAR E - EMPLOYEES

Micro–computers have made one of the fastest take–offs of all products ever introduced. From a near stand–still in 1985, they have achieved a significant number of users in less than three years.

The information obtained from the interviewees does not allow speculation as to why computers did not diffuse earlier. One of the reasons is that, in most cases, the contact person was in charge of the office and could tell us about the computer; when it had arrived; what it did, but not why it had been purchased or why it had been purchased at that time and not earlier.

C. DIFFUSION

If the L.R.R.C.I. behave like other industries, there will be a lengthy plateau during which more and more builders and other components of the industry will use computers, but for purely routine work. It would be interesting to track new software, to identify what new functions are being added to the system, and to use this example as a test case for promoting the diffusion of a visible substitute, or at least to attempt to identify a visible substitute "a priori".

CASE: THE NATIONAL BUILDING CODE OF CANADA

A. DESCRIPTION

The National Building Code (NBC) is a model setting minimum design requirements for buildings primarily with respect to fire safety, structural safety and health. It is written in the form of a set of regulations intended for adoption by provincial or municipal governments. The document is produced by the National Research Council through its Associate Committee on the National Building Code following the consensus approach. It is revised currently every five years. Detailed requirements for plumbing services are contained in a separate Canadian Plumbing Code issued by the Associate Committee and referenced in the NBC. The NBC achieves comprehensiveness by referencing documents such as the Canadian Electrical Code, produced on the basis of consensus by Canadian standards writing organizations. The National Building Code is now used in one way or another as the basis of building regulations in all of the Provinces and Territories.

B. DIFFUSION

In the Canadian Federal systems the Provinces have broad responsibility for public safety and health considerations including those associated with buildings. The Provinces originally gave local municipalities the responsibility for the regulation of buildings in the public interest. With some 4000 municipalities, this inevitably led to differences in the content and adequacy of building safety by–laws. Thus, arbitrary differences in design requirements and permissible materials, components and systems, as well as in levels of safety provided arose.

It was in this context that the concept of a model national code, written in the form of a building by–law, was developed when the federal government introduced the first National Housing Act. The objective was to promote rational and uniform building regulations throughout Canada. The first NBC was completed in 1941 by the National Research Council in association with the Department of Finance. The second edition was completed in 1953 by the newly formed Associate Committee on the National Building Code (ACNBC) with the assistance of the Division of Building

Research (now IRC) established in 1947. This arrangement has continued since that time with new editions issued at intervals, currently every five years.

Members of the ACNBC are appointed by the NRC to be broadly representative of the building industry, with geographic balance. The ACNBC is supported by a large secretariat provided by IRC. IRC also carries out research in support of the on-going technical development of the NBC, which was one of the reasons for associating the NBC activity with the NRC.

The rate of adoption of the NBC in regulations was inhibited for many years by the number of municipal jurisdictions. Nevertheless, by 1965 it could be said that of the 165 Canadian cities, 138 used the 1953 or 1960 edition in one way or another. By the end of the 1970s, legislation had been enacted in all Provinces which affected significantly the use of the NBC throughout Canada. In some Provinces the use of the NBC by municipalities was required; in others the responsibility for building regulations was taken back by the Province and the Provincial Code was based on the NBC, or it was named as the Provincial Code in the legislation. In 1975, liaison with Provincial Code authorities was formalized through the formation of an autonomous Provincial Advisory Committee on the National Building Code (PACNBC), with representation from all Provinces and Territories. The PACNBC met regularly and offered policy advice to the ACNBC related to adoption and the use of the NBC. More recently, there has been a move by the Provinces to discuss Code policy matters at meetings of Provincial Deputy Ministers and this appears to be leading to a higher profile Provincial/Territorial Committee on Building Legislation reporting to the Deputy Ministers' Committee. It can be said that one of the original principal objectives, that of uniformity of building regulations, has been achieved to a large degree. However, even if there were complete uniformity in the regulations across Canada, practical uniformity requires a consistent application of the NBC. The ACNBC Secretariat assists in problems of interpretation, by providing views on the intent of Code clauses on request, and there is liaison between Provinces on matters of interpretation. Another important aspect of application relates to the approval of new materials, systems and design concepts that are not covered explicitly by the provisions of the NBC, but by existing standards. In the view of many regulatory authorities and others, this aspect has not, up to now, been adequately developed. This topic is dealt with under the Case on Approval of Building Materials.

Finally, uniformity of application depends upon an adequate level of training of building officials in the use of the Code. No national training scheme has been devised, although training programs are operated by a number of Provinces; in others, the provincial building officials association is active in training.

The second principal objective of a national building code was rationalization of technical content. Some significant advances have been made, for example, in the development of structural load data, particularly that arising from climate and seismological factors, and in structural design technology. Significant improvements have also been made in data on structural fire protection, fire resistance and flame-spread ratings. The development of fire safety requirements for high-rise buildings has been a major advance. Much of this and other improvements has arisen out of the work or support of the NBC.

Despite the improvement in the NBC over the years, many of the requirements are prescriptive in nature, without a clear definition of performance objectives and specific performance criteria. As with similar documents in other countries, the requirements reflect traditional good practice and changes or revisions are made incrementally to reflect changes in practice. The document is, to a large extent, a reflection of the current state of the knowledge at the practitioner level. This has certain advantages in applications of the Code. There is, however, an increasing demand by the industry that provisions in the NBC and, particularly, proposed changes, be justified on the basis of cost versus social benefit. One of the fundamental problems is that the Code is intended to control the level of risk to life and health but the acceptable levels of risk have not been quantified; and practical methods for establishing the relationships between level of risk and all of the design factors that affect it significantly, have not been developed. Rigorous cost/benefit analysis is therefore inhibited. Currently value judgments are made by Code committees based on technical knowledge and experience, evidence of actual or perceived failures in practice and perceived impacts on the industry. The Ontario government is presently funding a study intended to provide an analytic framework and data base through which the consequences of Code requirements in terms of their economic and social impact can be evaluated. The results of the study should provide a clearer view of how such evaluations can be made and the principal gaps in knowledge and techniques required to make valid assessments.

C. FACTORS AFFECTING DIFFUSION

There were no concerted efforts to encourage use of the first version of the NBC published in 1941; and the rate of diffusion was relatively slow following the introduction of the first post-war version in 1953 when building regulations were the responsibility of local municipalities. An exception was the widespread use of Part 9 of the Code because of its association with the Residential Standards used by CMHC. Use of the NBC as a source document at the municipal level was facilitated because of its compatibility with building by-laws. On the other hand, there was resistance to introducing changes at the local level where increased complexity presented a problem to both building officials and builder. Achievement of the objective of practical uniformity would probably have continued as an elusive goal if the Provinces had not each decided to enact legislation calling for uniformity of building regulations. Such legislation would probably not have been effective, or even possible, in some Provinces if the NBC and the mechanisms for its development had not been in place and if it had not been perceived as an acceptable base document.

D. CONCLUSIONS

There are some current risks. Provincial officials have a natural desire and need to exercise some control over changes to their building regulations. They are exposed to political pressures when objections are raised by builders to more restrictive measures and are faced with risks of implementing new provisions when the system may not be capable of responding adequately to a change. A recent example is the reluctance of the Province of Ontario to implement new measures in the 1985 NBC for mechanical ventilation of residences. One of the results has been an increasing tendency for differences to arise between the NBC and Provincial regulations. While there may always be some inevitable incompatibilities between current regulations and a model code which should strive for improvements and therefore innovation, techniques for improved communication and coordination could result in both improvements in the NBC and in ease of adoption of changes. This appears to be evolving with arrangements between NBC and the Provincial Deputy Ministers, providing for increased Provincial participation in the development of the NBC, with increased assurance that the NBC will be adopted with minimum change. Complementary technologies such as improved techniques for making cost/benefit assessments of changes, and a national system of approval of new building materials should ease the introduction of innovations in the Code and in the building industry and thus contribute to the goals of uniformity and rationalization.

CASE: APPROVAL OF BUILDING MATERIALS

A. DESCRIPTION

In the context of building regulations, "approval of building materials" refers to decisions by the regulatory authority that a building material, component or system will meet the intent of the building code. Because of the complexity of making such judgments, building officials have long sought assistance in establishing whether materials (including equipment) are thus acceptable. In certain critical areas such as electrical products and fuel–burning appliances, this is achieved through certification by a nationally recognized agency that the equipment conforms to standards referenced in the code, and that the on–going production will continue to meet the requirements. This is referred to as third–party certification. Product certification is costly and there are many product standards referenced in building codes for which there are no certification programs; and new products, or new applications of existing products that are not adequately covered by existing standards, are continually being proposed. Building officials and other members of the building industry have long called for some uniform service to assist in establishing whether such use meets the intent of the regulations. In the past, with major differences in regulations between municipalities, a uniform service on a national scale would have been extremely difficult. With the evolution of the National Building Code as the base document for building regulations in all Provinces and Territories, the provision of a national service has become more practical.

B. TRANSFER

Since its formation, Canada Mortgage and Housing Corporation (CMHC) has administered a residential construction code for houses built under the National Housing Act (NHA) across Canada. This code, covering both safety and quality requirements, was originally published by CMHC and subsequently by the Associate Committee on the National Building Code (ACNBC) so that there was consistency between housing regulations in the National Building Code (NBC) and the Canadian Code for Residential Construction used by CMHC. CMHC field inspection staff responsible for ensuring that the requirements were met, had a problem similar to that of building officials. In the immediate post–war period, there were many new materials and systems being proposed, and there were few standards even for products in common use. To support its field staff in making decisions about the acceptability of products for use in houses built under the NHA, CMHC established a Materials Acceptance Program. This provided a central evaluation service and a list of acceptable materials for use by the inspection service. The detailed approach to establishing acceptance depended upon the circumstances, taking into account evidence provided by the field inspection, conforming with relevant standards, and expert assessments primarily by the Division of Building Research (DBR from IRC) and the Forest Products Laboratory (now Forintek). Often the evaluation pointed to the need for research into methods of evaluation and performance criteria, and for the development of standards and certification programs. Many current standards can trace their origins to this source.

The CMHC materials evaluation system was the only comprehensive national one in existence and was maintained, essentially unchanged, until 1981. CMHC published its Manual of Acceptable Building Materials and building officials found the CMHC acceptance list of great assistance in their decisions on the approval of building materials. Gaining CMHC acceptance greatly aided manufacturers or proponents in gaining acceptance of new products across Canada. CMHC did not provide certification of products, only evidence that the manufacturer was capable of producing an acceptable product. Products were dropped from the list if performance in use was determined to be unsatisfactory, if the product was discontinued, or if it was covered by a certification program. There was periodic re–evaluation of products to determine if they continued to comply with the basis of acceptance.

While the CMHC program filled a major need for material suppliers and regulatory authorities, it did not cover products and systems intended for non–residential construction. With the increasing use of the NBC as the basis of building regulations across Canada, a national system of building materials evaluation in relation to the requirements of the NBC became an attractive objective. In 1970, the ACNBC appointed a Special Task Group on Evaluation of Materials, Systems and Components. In 1973, the Task Group proposed the establishment of a Central Evaluation Board to recommend to building officials on the acceptance of new products in relation to the requirements of the NBC. The Board would report to the ACNBC and receive administrative and technical support from NRC. Both the Housing and Urban Development Association (now CHBA) and the Canadian Building Officials Association (CBOA) strongly endorsed the proposal. Management of DBR/NRC requested favourable consideration of the proposal by the NRC Executive. The request was turned down on the basis that the NRC Executive was reluctant to have the ACNBC (or any NRC component) turned into a "certifying" agency.

In 1978, the ACNBC appointed a new Task Force to reassess the earlier proposal for national materials evaluation service in relation to the NBC which confirmed the need. The NRC Executive held to its earlier objections to having an evaluation service operated under the aegis of NRC. The Task Force, therefore, proposed that the service be operated under the sponsorship of the Provincial Advisory Committee on the NBC (PACNBC), the CMDA or the Standards Council of Canada (SCC). The service proposed would produce evaluation reports and would apply to new products or applications for which there were no standards or those which were not covered by a certification program. The proposal received the unanimous support of the PACNBC which saw the SCC as the preferred sponsor. The SCC deferred on the basis that it did not want to appear to be in competition with accredited certifying agencies.

By 1979, CMHC had begun to review its materials acceptance operations, partly as a result of the questions arising from the earlier acceptance of urea formaldehyde foamed insulation (UFFI). The UFFI situation had raised the problem of evaluating the toxicity of emissions from building materials and the issue of public liability. As a result of this review, CMHC in 1981, converted its program to one modelled after a national evaluation service, issuing evaluation reports giving the basis and the results of assessments rather than an acceptance. Subsequently, CMHC endorsed the creation of an independent body to provide the service.

A CMHC Special Task Force was appointed in 1981 with membership involving a cross-section of the industry concerned with materials evaluation. It produced a report in 1984, detailing a proposal for a national organization to carry out independent technical evaluations of building materials. A national survey was conducted to obtain the views of a broader group to the recommendations; 86 per cent of the respondents were in favour and 8 per cent were opposed, based on concerns for cost, adverse effects on standards and certification programs, and lack of quality monitoring. Government policies (e.g., the "Nielsen" Task Force) supported transfer of the evaluation service from CMHC and it entered into discussions with NRC on the options. In early 1987, CMHC and NRC officials met with representatives of the provincial governments to determine the extent of provincial support for a central materials evaluation service and preferences regarding location and structure. As a result of changing policies and priorities at NRC, one of the options was an agency associated with the NRC. This ultimately became the preferred choice of all involved.

The new centre became operational in May 1988. It consists of a construction materials evaluation service operated by NRC. The evaluations will be carried out by an operational unit, the Canadian Construction Materials Centre (CCMC), and administered by IRC/NRC. The CCMC will receive policy direction from a new Associate Committee on Materials which will liaise with a Provincial/Territorial Committee on Building Regulations providing policy advice on levels of safety and cost. The CCMC will develop the basis of evaluation of products in relation to the requirements of the NBC, with advice from the ACNBC secretariat, and NRC technical staff will assess the evidence and issue evaluation reports. Testing services will be provided by private and public regionally–based research and testing facilities. The core staff for the CCMC will come from the current CMHC evaluation operations which will bring and maintain the CMHC data base of evaluation reports. CMHC will provide start–up funding at its current level of expenditure for two years with support dropping by 50 per cent over five years. By then the expectations are that the Provinces will make up for the reduced CMHC contributions. Proponents of products will pay on a cost–for–service basis.

Once fully operational, the CCMC service will be expanded to include all types of construction covered by the NBC. In addition to the evaluation reports, it will provide listing of products that have been shown by tests to conform to published standards. The service is seen to offer many advantages including:

- a central authoritative service for building officials;

- a one-stop evaluation service for manufacturers, avoiding the need for multiple approvals;

- ready access to evaluation reports through the proposed Canadian Construction Information System (CCSI) of NRC. This will also include a master list of standards and certified products and other qualification listings;

- encouragement to innovation through communication services and reduction of institutional barriers;

- identification of needs for new and improved test and performance standards and for certification programs;

- identification of recommended changes to the NBC; and

- cost savings through replacement of several evaluation services currently operated by Provincial Governments and Federal agencies.

It is also believed that the service can be expanded to facilitate export of products. The CCMC will maintain communication with evaluation services and requirements in other countries and will be able to advise Canadian exporters on what is needed to comply. For example, building materials evaluations in the European Economic Community are coordinated through the Union of European Agrément, which follows a process similar to that proposed for the CCMC. The CCMC will maintain close links with the European body, to mutual benefit.

C. FACTORS AFFECTING DIFFUSION

It will have been noted that a national evaluation service is only practical if there is a national regulation or standard in use. This was the case with the housing construction standards employed by CMHC and a successful system was developed. A national evaluation service in relation to building regulations became possible when national uniformity in building regulations came close to a reality through use of the NBC throughout Canada. A system might have been put into place as early as 1974. There was broad support and the expertise was available within the NRC however, the climate within the NRC and the federal government at the time (and subsequently in 1979) did not allow the creation of the proposed national service in association with NRC. A practical alternative was not available. By 1984, CMHC, whose evaluation program was a key element, had made a corporate decision to discontinue operations of its program and to support an alternative national system. The climate within the federal government had changed and with came changes in relevant policies and procedures at NRC. This included increased emphasis on technology transfer, industry support, and shared programs with the Provinces. Thus there was the will within the two key federal agencies to create the national building materials evaluations service and it appears that it will now become a reality.

The proposed output from the systems should find a ready market. The product has already been tried successfully by CMHC and it is committed to use the service. The proposed output is compatible with and complementary to, other services within the National Standards Systems. there is official support at the Provincial level and the necessary mechanisms for on–going communications on policy. Existing Provincial and municipal evaluation programs are likely to be replaced by the new service. Another important cornerstone is the apparently renewed commitment at the provincial level to use the NBC in largely unmodified form.

The principal short–term challenge appears to be to meet the expectations for an expanded service relevant to all buildings covered by the NBC. Some of the technical problems are likely to be complex and the process protracted. The longer–term risk relates to developing a sound basis for funding the service.

D. CONCLUSIONS

It is hoped that use of the new service will commend itself to other federal government agencies involved with construction (e.g., DPW, DND). DND operates a materials qualifications service for its own use and cooperation with the CCMC would work to mutual benefit. Similarly, DPW makes extensive use of the National Master Specifications (NMS). If the CCMC service provides extensive information on products that meet standards referenced in the NMS, it will be of value to all users of that system, including designers and specification writers. This could be a legitimate source of income to the CCMC. The market for services will be further enlarged if exporters of Canadian products find the service of value. By the same token, it may facilitate the evaluation of products to be imported from other countries.

Associating the outputs of the CCMS with CCIS will greatly facilitate communications of its services to all users across Canada and correspondingly increase the value of the services.

CASE: TYVEK[3]

A. DESCRIPTION

TYVEK is a plastic vapour permeable continuous air barrier which is installed on the cold side of the insulation. TYVEK comes in 4½ and 9 feet wide rolls of 60 and 195 feet length. The continuous envelope is achieved by securing the film to the sheathing with tacks or roofing nails and by caulking edges along joist headers and windows and door openings.

Besides being a superior replacement for the traditional secondary rain screen made up of tar paper, TYVEK has been shown to have a positive effect on air infiltration and energy efficiency. The added efficiency is due to the fact that the existing insulation is no longer subjected to air infiltration and exfiltration and also because its vapour permeability characteristics minimize condensation inside the walls.

TYVEK was developed by Dupont in the US in 1979 as one of a number of products aimed at increasing the energy efficiency of low and medium rise construction with a secondary market in renovation/re–siding.

Initial tests were conducted at the University of Purdue, Ill., followed by testing in Canada in 1982/83 by the Saskatchewan Research Council. The Canadian test consisted of renovating one existing residential unit by removing the old siding, wrapping the house in TYVEK and installing new siding. Before and after test results showed a reduction of 26.9 per cent in air infiltration and a reduction of 12.8 per cent in heating costs.

Following these tests, the product was introduced on the Canadian Market in 1983. (The product had been introduced in 1982 on the US market.)

---

[3] TYVEK* is a registered Trademark of E. I. Dupont de Nemours USA.

B. DIFFUSION

The new product was introduced through independent distributors. Starting with the Toronto/Montreal market which was covered by one distributor, distribution was quickly expanded to cover the Maritimes which were initially served by a distribution agent, since upgraded to a full distributor. Similarly, the West was originally covered by a sub–distributor which has since been upgraded to a full distributor. By 1984, the national distribution network was in place although distribution still lacked depth in the regions.

Initial reception for the product varied according to region, type of builder and real estate market conditions. Another factor affecting adoption was the amount of confusion which existed, and to an extent still persists, regarding the differences between TYVEK and the traditional polyethylene vapour barrier normally installed between the gyprock and the insulation.

To facilitate the diffusion process Dupont used two main avenues: (1) production of information/promotion pamphlets aimed at the trade and at consumers, (2) the display of the product at trade and renovators shows where there is an opportunity for face to face contact and detailed explanations. Dupont and its distributors have also used their membership in all major national, regional and local relevant trade associations to communicate the product and its advantages.

Although precise estimates of market penetration are not available, it is known that sales have grown very rapidly, albeit from a very low base, from 1983 to 1985. During that period, sales surpassed 100 per cent per year. Since 1985 sales have continued to grow rapidly but at a lower rate. Overall market penetration is continuing as sales continue to increase faster than the number of new residential units under construction.

Market penetration differs by region. According to Dupont sources, the Maritimes lead, followed by Quebec and the West, with Ontario, especially Toronto, lagging behind.

Market penetration can be segmented by size of builder, type of construction and market conditions. Large builders have a lower rate of adoption than small builders, and custom built houses have a much higher proportion of use than tract developments. Market conditions over the last few years has resulted in builders taking a lowest cost, lowest manpower approach. As a result TYVEK, which adds up to $200 on a single story house, plus additional hours for installation (above and beyond what would be required for tar paper) is being resisted by Toronto development builders. It is, however, being used for custom houses and in renovations involving re–siding.

C. FACTORS AFFECTING DIFFUSION

If TYVEK were to be used as replacement for tar paper to fulfill the building code requirement for a secondary rain barrier it would suffer from a cost disadvantage since it costs 11¢ per square foot compared to 5¢ per square foot for tar paper. It also takes more time and care to install TYVEK because it must be caulked or otherwise sealed at the edges, especially along joist headers and window openings.

For builders concerned with satisfying mandatory requirements, cost as well as additional labour time and skills are a strong disincentive for adoption. Fortunately for TYVEK, market pressures in Toronto tend to be an exceptional case.

For example, in the Maritimes awareness of the problems that can be caused by humidity, and, to a lesser extent by wind, is high, which forms the basis for the diffusion of vapour porous air barriers. Also, developers tend to be smaller and in closer contact with their customers. Another factor facilitating diffusion is that Maritime house buyers tend to be less transient and more willing to consider life cycle costs over first costs. Overall, Maritimers are more receptive to TYVEK's comparative advantages and have a higher level of use in new construction as well as in renovations.

Present acceptance of TYVEK appears to be based on vapour porosity considerations rather than on energy saving impacts.

To diffuse rapidly, an innovation must have relative advantages that are large, visible and immediate. In the case of TYVEK, Dupont has made the advantages "easy to visualize" by stressing the image of TYVEK as a "windbreaker over a sweater". The concept is that in windy conditions sweaters lose their insulation capacity because the air rushes through the open weave. With the addition of a windbreaker, insulating characteristics are restored. The image is a simple but effective one.

Trialability does not appear to be an issue. Small scale use for purposes of testing compatibility with current operational practices is well within the capabilities of any builder or do–it–yourself consumer. Since liabilities are not associated with the use of the product, the requirement for trialability is low.

Once the initial confusion between air barriers and vapour barriers is resolved, air barriers appear to be compatible with present residential construction habits.

Concern was expressed over the sometimes improper application of air barriers; if improperly applied, i.e., if the continuity of the envelope is repeatedly broken because the sheet is torn or because edges are not properly caulked, the air barrier tends to lose its effectiveness. The added time and care (a form of "complexity") needed for proper installation was mentioned often.

The extent of improper applications is not known, and since this is not a building code requirement, it does not tend to be corrected by building inspectors.

D. CONCLUSIONS

TYVEK could easily have been one more invisible innovation. It is a tribute to its manufacturer that the product has been given a "visible" identity. This was done by using diffusion–related knowledge and building it into the marketing strategy of the product. Whatever success TYVEK has achieved, has been by:

- o targeting geographical areas where Consumer Awareness of TYVEK's comparative advantage in moisture control is highest, i.e., Maritimes;

- targeting the do–it–yourself consumer renovation and upgrade market which is less price sensitive and where TYVEK again offers advantages;

- coining a very good slogan; and

- attempting to turn TYVEK into a consumer driven product; a "visible cosmetic" to force builder's hand.

To date, the diffusion strategy seems to have worked on a regional basis and in the renovation market. Results on the visibility campaign are still inconclusive.

edges are not properly caulked, the air barrier tends to lose its effectiveness. The added time and care (a form of "complexity") needed for proper installation was mentioned often.

The extent of improper applications is not known, and since this is not a building code requirement, it does not tend to be corrected by building inspectors.

D. CONCLUSIONS

TYVEK could easily have been one more invisible innovation. It is a tribute to its manufacturer that the product has been given a "visible" identity. This was done by using diffusion–related knowledge and building it into the marketing strategy of the product. Whatever success TYVEK has achieved, has been by:

- targeting geographical areas where Consumer Awareness of TYVEK's comparative advantage in moisture control is highest, i.e., Maritimes;

- targeting the do–it–yourself consumer renovation and upgrade market which is less price sensitive and where TYVEK again offers advantages;

- coining a very good slogan; and

- attempting to turn TYVEK into a consumer driven product; a "visible cosmetic" to force builder's hand.

To date, the diffusion strategy seems to have worked on a regional basis and in the renovation market. Results on the visibility campaign are still inconclusive.

dge and building it into the marketing strategy of the product. Whatever success TYVEK has achieved, has been by:

- targeting geographical areas where Consumer Awareness of TYVEK's comparative advantage in moisture control is highest, i.e., Maritimes;

- targeting the do–it–yourself consumer renovation and upgrade market which is less price sensitive and where TYVEK again offers advantages;

- coining a very good slogan; and

- attempting to turn TYVEK into a consumer driven product; a "visible cosmetic" to force builder's hand.

To date, the diffusion strategy seems to have worked on a regional basis and in the renovation market. Results on the visibility campaign are still inconclusive.