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**LA THÈSE A ÉTÉ
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THE LAW OF THE RETARDING LEAD:
THE ADOPTION OF CABLE TELEVISION
AND TELEPHONE SWITCHING EQUIPMENT

by

Marc André Levesque
B.A. (Hons.), Carleton University

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfilment of
the requirements for the degree of
Master of Arts
Department of Geography

Carleton University
Ottawa, Ontario
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May, 1986

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"THE LAW OF THE RETARDING LEAD: THE ADOPTION OF
CABLE TELEVISION AND TELEPHONE SWITCHING EQUIPMENT"

submitted by Marc André Levesque, B.A. (Hons.)
in partial fulfilment of the requirements for
the degree of Master of Arts.

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ABSTRACT

The Law of the Retarding Lead relates economic growth to the timing of adoption of innovation. The Law thus developed is an extension of diffusion research. Two current innovations in Canada, cable television and telephone switching equipment, provide good examples of how later adopters achieve faster adoption rates. The process of growth, innovation and diffusion is characteristic of a product life cycle. Each stage of the process is associated with various forms of ideas, technology, supply and demand, products and standardization. The analysis thus provides empirical support for a Law which has been suggested but never vigorously tested in the past.

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CHAPTER 1

PATTERNS OF GROWTH

1.1 The Universality of Patterns

Growth is a universal phenomenon -- and everything which grows -- whether physical, biological or social -- seems to follow common patterns which suggest universal processes and regulation of growth. These patterns emerge whether growth is measured as an absolute characteristic through time, with age, or allometrically, as a relative characteristic of the part of some system in relation to the whole.

Theories of growth describe processes of change. A unified theory of growth assumes a relationship between structure and rate of growth. The evolution of ideas stem from concepts related to a variety of disciplines. The most comprehensive attempt to describe and illustrate the processes of diffusion of growth is D'Arcy Wentworth Thompson's On Growth and Form (first published in 1917 and later edited by J.T. Bonner in 1961). Thompson uses "...the term growth in two senses, ... on the one hand as a process, and on the other as force". (Thompson, 1961, p.13). Thompson's experimentation with co-ordinate transformations

lead him to conclude that form is a "diagram of the forces" acting during growth (Thompson, 1961, p.11), Figure 1.1 demonstrates how Thompson applied a transformation of a carapace of a single crab to arrive at a genus of five others. This was achieved by elongating and compressing the carapace with a series of orthogonal and logarithmic lines. The relevance of this concept of space to geography has been noted by Harvey (1969) and helps us to identify the properties and forms of various projections, among others.

Among these universal regularities we can list a fundamental distinction between two measurements of growth. The first is growth through time and age. This is the absolute growth of the system. Kenneth Boulding (1956) introduced a simple fundamental assumption that "growth creates form but form limits growth." Two kinds of absolute growth have been identified by Boulding: populational and simple. Whereas "simple growth" refers to the addition or deletion of members of elements or systems; "populational growth" implies that what grows is itself capable of creating growth. Populational growth is therefore, related to its age structure (births and deaths). Absolute growth, whether simple or populational may be either logistic or exponential in form. The second kind of growth, allometric growth, can be characterized as system growth or the relative growth of parts of the system through time/across

FIGURE 1.1
TRANSFORMATION OF CARAPACES
OF VARIOUS CRABS

(a) Geryon, (b) Corystes; (c) Scyramathia;
(d) Paralomis, (e) Lupa; (f) Chorinus.

Source Thompson, 1961, p.294

space, as individual elements in a system act and change interdependently.

Consistent regulation creates repetition -- and in turn repetition creates pattern (as in the symmetry of a flower, a cathedral or a central place system). Pattern thus implies regulation and control, which guides growth toward some balance of organs or parts (Bertalanffy, 1960) or balance of power, or balance of dependencies. One important form of regulation in social and economic systems is the setting of standards. Standards are set in social systems through economic and political regulation. For example, industrial economies are regulated by adhering to a wide range of technical standardization. Laws and regulatory bodies enforce standards for health and safety reasons, among others. When standards are set, they are known to lock in existing technology. The danger is however that standards lock out future technological advances. In short, regularity implies regulation, particularly in the application of diffusion of innovation. Whatever the system, the pattern of growth reveals underlying regulation and control and system laws of growth. These controls and the patterns they produce can be described in a set of system laws of growth.

The objectives of this thesis are to explore the spatial implications of these laws of growth and link these

laws with spatial diffusion within the framework of the Law of the Retarding Lead (Romein, 1979). The Law of the Retarding Lead states that there is a relationship between the rates of growth of a technology or other innovation in any location and the timing of the spread of that technology (or other innovation) to that location. More specifically, the Law of the Retarding Lead asserts that later adopters achieve faster growth. This account of technological growth will be investigated for two important current innovations: cable television and telephone switching equipment. Attention now turns to the theoretical strands used in the empirical analysis -- allometry, diffusion, and Retarding Lead. We begin with the undetermined relationship between growth and allometry.

1.2 Growth and Allometry

The absolute rate at which growth takes place varies widely between systems and between parts of a single system. In general systems theory (GST), there exists a concept that describes the regularities that occur in the growth of a part of a system in relation to the whole: it is the law of allometry.

The law relates the changes in the proportionality of the parts of any system to the size of the system as a whole; thus, most broadly, allometry deals with size and its consequences.
(Berry et al., 1976, pp.482-483)

The law applies to animate and inanimate growth (as in the growth of crystals), to social growth (as in the growth of populations and economic growth), and negative growth or decay (as in decomposition of radioactive substances) as well as positive growth.

The law of allometry states that the size of the part is governed by the growth of the whole. For example, the changes in proportions in the growth of a human being proceeds at varying rates in different parts (Fig. 1.2). In the advance from infancy to adult life: the height of the head doubles, length of body triples, weight of heart increases thirteen-fold, and weight proportion of the nervous system decreases to one-eighth of infantile proportion (Hollingworth, 1927, p.10). Thus we can observe that relative growth (positive as well as negative) leads to changes in a variety of proportions (linear, volumetric) and these changes in proportion are governed by the allometric law.

It was not until fifteen years after Thompson's seminal work that J.S. Huxley (1932) re-emphasized the relationship of growth and form. Problems of Relative Growth introduces an algebraic measurement of relative growth which is more tractable than Thompson's, but at the cost of an explicit spatial approach. Huxley (1932, p.4) described it as "the formula of constant differential growth-ratio." The mathematical equation may be expressed by the power formula:

FIGURE 1.2
RELATIVE GROWTH IN MAN

ILLUSTRATING THE CHANGES IN PROPORTIONS
DURING PRENATAL AND POSTNATAL GROWTH

Source: Holligworth, 1927, p.11 (After Stratz)

$$y = bx^{\alpha} \quad (1.1.1)$$

$$\text{or } \log y = \log b + \alpha \log x \quad (1.1.2)$$

(Naroll and Bertalanffy, 1956, p.76),

where the growth of one part of a system (Y) is compared with the growth of another part or with the system itself (X). Huxley (1932) uses the term "growth-coefficient" as a measure of specific growth of a component or process. The term "alpha value" (α) is gaining popularity in the growth literature and is synonymous to Huxley's growth-coefficient. In mathematics, the symbol α generally indicates the first direction of a line or angle with the x-axis or simply delineates acceleration. By definition, the alpha value

... indicates the allometry of the part to the whole, that is, the ratio of their specific growth rates. Where α is less than one, the part grows more slowly than the whole and the allometry is said to be negative. If the allometry of all components is one, the parts grow at the same rate as the whole, and there is no change in shape with increasing size. Where the allometry is greater than one, the part grows faster than the system as a whole, and the allometry is said to be positive. (Ray et al., 1974, pp.342-343)

In the literature, the logarithmic relationship has been interpreted in two ways: (1) as a measurement of relative growth -- that the growth rate of a component is proportional to the growth of the whole -- characterized by differential equations; and (2) as a statistical phenomenon, characterized by stochastic equations. This thesis is

mainly concerned with the first approach.

In addition to Thompson (1917) and Huxley (1932), a third biologist has helped to develop the intellectual foundation for allometry. Ludwig von Bertalanffy (1960), considered to be the father of GST, provided an interdisciplinary focus on the theory of systems and examined the manner in which a systems approach aids in developing allometry as a GST concept.

An important contribution in the social sciences is that of Naroll and Bertalanffy (1956) where the principle of allometry is used as a useful quantitative tool (Fig. 1.3). They have shown that the process of progressive urbanization follows a regular pattern of relative growth.

The concept of allometry has had many applications in geography. Stig Nordbeck (1965) was one of the first to introduce it. He suggests a functional relationship between a temporal process and a spatial form and utilizes the allometric law to show that the area of a city is related to its total population. The literature suggests related applications such as the relative growth of metropolitan areas and the interrelationships between city structure and rates of growth (Bourne and MacKinnon, 1972). Other contributions include making projections, identifying policy levers, and exploring underlying growth processes (Ray and

FIGURE 1.3
URBANIZATION; UNITED STATES, 1790-1950

Source: Naroll and Bertalanffy, 1956, p.86.

Villeneuve, 1975; Ray et al., 1974; Roberge et al., 1975). The last comprehensive work done by a Canadian group is that of the defunct Ministry of State for Urban Affairs which dealt with growth processes at the national, metropolitan, and neighbourhood level (Ray, 1976).

Despite the initial success of allometry as a GST concept, no major work has been published on it in geography within the last decade. As this thesis will indicate, allometric relationships are an important alternative concept that transform different types of geographical systems.

1.3 Diffusion

Diffusion is described in different ways by different disciplines. The simplest definition of diffusion is "the spread of a phenomenon over space and time" (Johnston, 1981, p.82). In geography, the spread of individual phenomena provides clues to the exchange of information among regions. Much to our surprise, our involvement with nature has indicated particular regularities with diffusion patterns. In all cases, adoption is seen to be an important prerequisite to diffusion. Archeologists and anthropologists have been concerned with this diffusion of innovation. The second regularity is that of the rate of growth from the first centre of adoption. This rate of diffusion may be twofold: parallel discovery and/or

successive waves of diffusion.

Diffusion implies the spatial exchange and spread of information, as opposed to independent discovery in each location. The spread may be very slow, as in the Neolithic diffusion of pottery making or very rapid as in the diffusion of insulin treatment for diabetes. Pottery diffusion in Latin America was less than ten miles a year (Berry et al., 1976, p.491) whereas insulin, invented in Canada in 1925, spread throughout the world in less than a year (Hart, 1957, p.51). Geographers have favoured more recent, more rapid diffusion examples.

By far the most frequently studied diffusion process, however, is rapid innovation, "...not because of their intrinsic importance (indeed, they sometimes tend to be trivial), but because we can see the whole cycle of diffusion in a relative brief time period" (Haggett, 1975, p.296). Spatial diffusion modelling as a research specialty has been examined extensively, primarily because the subject yields to a number of already published papers. One geographer, Gatrell (1984, p.443) does not regard spatial diffusion modelling as "exclusively geographical" and he is "...well aware that the papers examined are knitted to a wider literature."

The steady growth of diffusion articles in the geogra-

phical literature has been influenced by pioneers such as Morrill (1968), Gould (1969), Berry (1970), and Brown (1981). Another source of general dynamic modelling is reviewed by the late D.L. Clarke (1968) in Analytical Archeology. These authors emphasize the distributional characteristics of "invention and refinements" leading to the innovations becoming practical" (Brown, 1981, p.1). These characteristics change over time, and indeed, as the Law of the Retarding Lead will testify, there is more than one way of being concerned with change, and its corollary, there is more than one kind of change with which to be concerned.

Diffusion and distribution models have been examined in general terms as useful tools consolidating observed regularities and a synthesis of many accurately documented cases. Many have put forward a number of key spatial diffusion models that have influenced this thesis. The Swedish geographer, Torsten Hagerstrand is an innovator in diffusion modeling. Hagerstrand (1953, 1967) is particularly noted for his general empirical analysis of diffusion at the regional scale and has explored the use of dynamic stochastic simulation models using a Monte Carlo approach. Haggett (1975) investigates profiles of innovation waves by describing four main stages in the passage of an innovation through an area; Yuill's work (1965) expands and develops modifications already begun by Hagerstrand and investigates

diffusion waves and the effect of four kinds of barrier in his simulation model; Gould (1969) grapples with problems of "spatial dynamics" by reviewing theories of spatial diffusion and their use and suggests a cross-classification of some types of diffusion processes; and Berry (1970) responds to the needs of public policy by attempting to monitor and understand the nature of the growth processes and economic advancement in the United States -- of which he discusses the subtlety of television as an "evolutionary" innovation, among others.

More recently an increasing number of articles have begun to appear in major geographical journals (Brown, 1975; Malecki, 1977; Blaikie, 1978; Findley and MacLennan, 1978; Agnew, 1979; Freeman, 1985) culminating in the completion of a major publication in 1981 by L.A. Brown entitled Innovation Diffusion: A New Perspective.

The spatial diffusion model that has influenced most the suggested Law of the Retarding Lead has been the well documented "lead-lag" model. Although lead-lag models and the proposed law have certain commonalities, one must be able to differentiate between one model and the other. Johnston (1981, p.184) defines lead-lag models as "statistical models, for the identification of timing differences ('leads' and 'lags') in the transmission of fluctuation through regions and system of cities." Lead-lag

models are not confined to the discipline of geography (Haggett, 1971) but are also identified in the field of economics (Neftci, 1978), mathematics (Bennett, 1979), archeology (Clarke, 1968), history (Kindleberger, 1964), biology (Huxley, 1932) and various others that have cultural, scientific and economic applications.

The study of the diffusion of innovation has had some shortcomings. Some disciplines have examined growth per se and others have studied the direction it has taken. Biologists for example, have experimented with both growth and direction. This thesis pulls together the interdisciplinary models that help associate the growth of diffusion of innovation to the Law of the Retarding Lead.

1.4 The Law of the Retarding Lead

Diffusion studies describe the first adoption and the rate of growth at each location, but only to establish patterns of adoption rates that are common to all locations. However, in focusing attention on the universality of the learning curve researchers missed the spatial regularities in the rate of change in the parameters of the learning curve. These regularities imply a relationship between the timing of adoption at each successive location and the rate of adoption in each location. That relationship was first identified in the biological sciences as an orderly system of "growth-gradients" (Thompson, 1917; Huxley, 1932).

Huxley introduced the concept of "growth-gradient" whereby growth coefficients are plotted against distance (or time). This study of relative growth has an important bearing upon many other disciplines and has pre-eminently affected the social sciences in particular. More usefully, the social sciences have combined the concepts of diffusion and allometry, forming the notion of "retarding lead" (Hart, 1957; Berry et al., 1976). The Law of the Retarding Lead states that later adopters of innovation "must achieve" higher rates of growth at a later period. Jan Romein, a leading Dutch historian, first coined the "the law of the retarding lead" and as he explains:

Whether or not it is a "law" in the strict sense, there do seem to be recurrent situations in which the historian finds himself suggesting that a nation or other social groups took the lead in a new development precisely because it had lagged behind in the one before. The Italian contribution to Gothic architecture was less outstanding than the French, the Germans, the English; but it was in Italy that the breakthrough to Renaissance architecture occurred, quite suddenly, in the early fifteenth century. During the Enlightenment, Germans thinkers seemed to be lagging behind the French, the English, even the Dutch; but when Enlightenment values were called into question in the eighteenth century, Germans suddenly took the lead. (Romein cited in Burke, 1979, pp.11-12)

Recurrent situations in the humanities and sciences suggest that in essence this "law" is deemed to have

intrinsic interdisciplinary or "universal" applications. Table 1.1 delineates some practical observations of the Law of the Retarding Lead that have been cited in both the humanities and sciences.

Hornell Hart (1959), an authority on acceleration in social change, cites two laws which are easily associated with the Law of the Retarding Lead, namely,

The Law of Cultural Acceleration: Over the long sweep of time, man's power to carry out his purposes, in the material, biological, psychological, and sociological realms, has tended to increase at an accelerating rate (though with recurrent stagnations and setbacks), and the rate of acceleration has itself tended to accelerate.

The Law of Logistic Surges: Progress with respect to specific purposes, as expressed in individual inventions and in the growth of specific social organizations and culture complexes, has tended to take place in the form of surges, progressing slowly at first, then speeding up, and finally slowing down to a stop or a collapse. In scores of instances, the indexes of these surges can be fitted mathematically with logistic curves.
(Hart, 1959, p.201)

The first law is accredited to Merrill and Eldredge (1952) and like the Law of the Retarding Lead both "deal with tendencies rather than with hard-and-fast, invariable phenomena-sequences" (Hart, 1959, p.201). The two laws of social change have been confirmed by extensive testing and vague qualitative references to a mathematical law of

TABLE 1.1

SOME PRACTICAL APPLICATIONS OF
THE LAW OF THE RETARDING LEAD

SOURCE:	APPLICATION:	
1. Gerschenkron (1962)	industrial development	Germany
2. Gerschenkron (1962)	industrial spurt	1890's, Russia
3. Landes (1969)	urban planning (forced westernization)	Peter the Great,
4. Landes (1969)	industrial growth, technological transition	Italy, Hungary, Russia
5. Roberge (1972)	apply alpha value to pulp industry	St. Lawrence Region 1806-1940
6. Ray <u>et al.</u> (1974)	apply alpha value to railroad building	Europe 1826-1916
7. Cloudsley- Thompson (1977)	zoology, Irish Elk	Ireland
8. Romein cited in Burke (1979)	architecture	Renaissance, Europe
9. Romein cited in Burke (1979)	philosophy	Enlightenment, Europe

Source: Compiled by the author.

cultural acceleration have been made in 1937 (Sutherland and Woodward), 1940 (Ogburn and Nimkoff) and 1956 (Chase).

There are two other views of the Law of the Retarding Lead that are based on similar assumptions. Two economic historians, Alexander Gerschenkron (1962) and David Landes (1969), have investigated the hypothesis that the differences between the economic growth of various countries, including Russia and Germany, can be explained by differences in what one anonymous writer has called "the tension between their existing state and their potentialities."

Gerschenkron's essays are dominated by the general hypothesis that,

...very significant interspatial variations in the process of industrialization are functionally related to the degree of economic backwardness that prevailed in the countries concerned on the eve of their "great spurts" of industrial growth.

(Gerschenkron, 1962, p.1)

Gerschenkron suggests an array of persuasive examples that are parallel to Romein's notion of retarding lead. Gerschenkron (1962, p.16) states that Germany's industrial development derived full advantages from being a relatively late arrival and argues that Germany benefitted mainly from Britain's early lead in industrialization.

- Gerschenkron (1962, pp.46-47) states that in order to achieve such high rates of industrial development, a certain

"prerequisite" must exist before deriving full advantages of backwardness.

One thing is obvious. Illiteracy and low standards of education, and the resulting difficulty in training skilled labour and efficient engineers, can be overcome to some extent by immigration from more advanced countries and to some extent by using the training facilities of those countries. The same is true, even more importantly, of the lack of a store of technical knowledge. It can be imported from abroad.
(Gerschenkron, 1962, p.46)

It is in this sense that Gerschenkron (1962, p.47) can say that industrial development is dependent upon a reservoir of technical assistance, trained skilled labour, and a legacy of capital goods. Individual elements of Russia's industrial spurts of 1890's have been also viewed as determined by the backwardness of the Russian economy. Gerschenkron argues for instance that,

...the Russian favored producers' goods as against consumers' goods because of the importance of technological borrowings to a very backward country in conjunction with the accidental circumstance that technological progress in the immediately preceeding period had been more vehement in the production of capital goods. This lopsidedness in the industrial structure, natural in conditions of backwardness, is said to have been merely accentuated by the policies of the Russian government.
(Gerschenkron. 1962, p.360)

Landes (1969), in his study of technological change and industrial development in western Europe, agrees with

Gerschenkron that Russia benefitted by state planning under Peter the Great, in its industrial development.

It was Europe's good fortune that technological change and industrialization preceded or accompanied pari passu the other components of modernization, so that on the whole she was spared the material and psychic penalties of unbalanced maturation. The instances of marked discrepancy that come to mind -- the effort of Peter to force the westernization of a servile society in Russia, the exploitation of population in Ireland in a primitive and poor agricultural environment, the urbanization of Mediterranean Europe in the context of a pre-industrial economy -- yielded a harvest of death, misery, and enduring resentment.
(Landes, 1969, p.7)

Landes and Gerschenkron strongly associate a country's degree of backwardness and its potential economic growth with the increased responsibility of the State to act as an accelerator.

...the more backward a country -- the bigger the gap between its economic performance and possibilities -- the more necessary the intervention of authority in promoting growth.
(Landes, 1969, p.548)

Russia assimilated limited modern technology and slowly advanced thereby breaking the "...tenacious backwardness of most branches of economic activity" (Landes, 1969, p.236). Russia's industrial growth, like that of Italy and Hungary "...was generally more rapid in this period than that of the advanced countries, even Germany" (Landes, 1969, p.237).

An important technological diffusion study that has

affected diffusion modeling with regards to the Law of the Retarding Lead is that of the sociologist C.M. Coughenour. Coughenour (1964) has systematically investigated the relative rate of diffusion of recommended farm practices in twelve Kentucky localities. Parallel to the Law of the Retarding Lead, Coughenour (1964, p.325) indicated that much of the sociological research on cultural diffusion has been stimulated by what Gerschenkron (1962) and Landes (1969) referred to as the relative "backwardness," technologically, of one area compared to another.

Only a handful of geographers have seriously attempted to join formal and functional approaches in describing a number of empirical regularities pertaining to diffusion and retarding lead. By utilizing the concept of allometry, a trio of economic geographers have examined three examples of diffusion and allometry of innovations (Ray et al., 1974). The first example demonstrated that allometric growth coefficients (alpha values) increased with distance from the origin of a French Canadian settlement in Vancouver. Second, with respect to the diffusion of the pulp and paper industry in the St. Lawrence Region, regional allometric growth rates were explained by procurement costs, and a clear growth gradient was identified. The final example is the familiar case of railroad building in Europe (Fig. 1.4). It has been observed that an increase of

FIGURE 1.4

THE DIFFUSION AND GROWTH GRADIENT OF
RAILROAD BUILDING IN EUROPE, 1826 - 1916

Source: Rey et al., 1974, p.348.

railroad mileage was accompanied by a "lagged outward spread" from the original center of the innovation, Great Britain and at an accelerating rate. The growth gradient found in Fig. 1.4 seems to support the notion of retarding lead.

The processes associated with the Law of the Retarding Lead can also be seen in the biological literature. Cloudsley-Thompson (1977) examines in detail influences on the processes of biological growth and development. It is generally recognized that the study of growth and development in animals distinguished two homogeneous processes:

As an animal grows up, ...(1) it increases in weight until mature size is reached; this we shall call Growth, and (2) it changes in its body conformation and shape and its various functions and faculties come into full being; this we shall call Development.
(Batt, 1980, p.1)

The organ undergoes varied growth rates during the process of maturation and its relative size is determined as a function of body size. Here we find that these various organs, experiencing differential growth, have periods in which some parts "lead" (with respect to growth and development); while others "lag" behind.

In extremes cases, the linear dimensions of certain parts change during growth proportionately very much more than do the dimensions of the whole body. Thus the antlers are so large in the extinct Irish elk (Cervus magaceros) because there had been an increase in body size

and the antlers, in order to keep their positive allometric ratio to body size, had become disproportionately large.
(Cloudsley-Thompson, 1977, p.22)

In this particular situation, the antlers of the Irish elk -- in terms of their rate of growth -- overcompensated and became a nuisance to the animal. It has been suggested in the literature that the animal became extinct primarily due to the incredible disproportionate weight of the antlers and the elks' inaptitude to cope with its body size.

The Law of the Retarding Lead is concerned with change, and in some circumstances with the absence of change. By definition the Law of the Retarding Lead consolidates observed regularities and a synthesis of many accurately documented cases which researchers in general suggest that "...a nation or social groups took the lead in a new development precisely because it has lagged behind in the one before" (Romein cited in Burke, 1979, pp.11-12). Although, as we have examined, the basis of these growth processes need not have solely economic or historic applications. As Cloudsley-Thompson demonstrated, the nature of the growth processes may be applied to the biological sciences.

1.5 Regulation and Control: Cybernetics

This thesis assumes that growth may be modelled as a learning system. The rate of growth increases in time and

space up to some saturation level. Spatial processes are complex systems that few have attempted to analyze mathematically. R.J. Bennett, a geographer and mathematician is one of them. Bennett in his book entitled Spatial Time Series (1979), describes system operations and has developed an understanding of the way in which the behaviour of systems is governed by their structure. Other important contributions were made by the late C.H. Waddington. The subject is highly abstract, solutions of practical problems are complex and theoretical ideas and intuitive discussions are often inadequate.

There are fundamental growth processes which need to be described within the context of GST. Two terms that have always created some confusion are "steady state" and "homeostasis." Naturally enough, this confusion then carries over into understanding "homeorhesis."

In general, four types of systems have been commonly identified: closed no-growth systems, self-maintaining systems, open developing systems, and growing open systems -- although in this thesis we are mainly concerned with the last of these. Bertalanffy (1968b, p.156) describes open systems as "...systems maintaining themselves in a continuous exchange of matter with environment." Space-time systems have been known to follow various forms of growth, reaching a saturation point where the system generates

little incremental growth. This saturation level is directly associated with the dynamic state of a system; in fact, the two terms are considered to be readily interchangeable. Moreover, Bertalanffy believes that

The steady state of open systems is characterized by the principle of equifinality; that is, in contrast to equilibrium states in closed systems which are determined by initial conditions, the open system may attain a time-independent state independent of initial conditions and determined only by the system parameters.

(Bertalanffy, 1968a, p.18)

Considering the general notions of feedback systems -- feedback may be either positive or negative. Positive feedback is a reinforcing, self-stimulating type of process, which through a number of steps, leads to an increase in the rate of growth (Waddington, 1977, pp.83-84). "Negative feedback is a central theme of cybernetics, the science of communication and control" (Berry et al., 1976, p.480). With negative feedback the system is maintained in a steady state by a process of self regulation known as homeostasis. Waddington (1977, p.98) defines homeostasis as "the technical word for the process of returning to a steady state system after it has been disturbed (from two Greek words, meaning 'the same' and 'state').". The steady state is the central tendency value of a state variable primarily maintained by negative feedback loops. "A classic example is provided by the process of competition in space which

leads to a progressive reduction in excess profits until the spatial system is in equilibrium" (Harvey, 1969, p.460).

In Tools for Thought, Waddington (1977, pp.104-105) dealt with modeling system dynamics. He argues that some systems are progressive and rather than maintaining a stable or stationary value, or homeostatic; they are instead homeorhetic. Homeorhesis is, similarly, a process of steady state growth that maintains a growing component of a system in balance with the growing system. Homeorhesis, "a word which means preserving a flow," ensures continual change along a certain canalized pathway of growth (Waddington, 1977, p.105). The pathway itself is called a chreod and the patterns which various possible chreods map out during development can be pictured in terms of an epigenetic landscape (Waddington, 1977, pp.106,109). Waddington's study of these processes has conceptually much in common with Rene Thom's (1972) work on catastrophe theory.

Continuous parameter models are structures with internal linkages that balance between the constraints on system operation and the control mechanisms which direct the system. Open systems in particular, have shown remarkable characteristics of homeostasis, in which three patterns of return to steady state predominate. Figure 1.5 illustrates basic types of homeostasis as described by Bertalanffy (1968b) -- asymptotic, false start correction, and

FIGURE 1.5
OPEN SYSTEM APPROACHES TO STEADY STATE

Source: L.V. Bertalanffy, 1968b, p.143

overshoot. The graph illustrates homeorhesis at work and all three approaches maintain the structure of the system in equilibrium. Moreover, the graph illustrates controls on growth and hence the catch-up growth is part of Waddington's homeorhesis process in operation.

One cannot draw a graph and say "that part of the line is homeorhesis," because by definition, homeorhesis is a process by which deviations from the pathway of growth are controlled. An important relationship exists between homeorhesis and the saturation level of a system though no work concerning this relationship has been published. In progressive open systems (versus terminating ones) it is assumed that such systems are capable of generating incremental growth while at the same time the saturation level may itself grow slowly, thus representing the system (or supra-system) dynamic state. In trying to describe the homeorhetic process, the complication is to identify the appropriate system level. Homeorhesis operates and controls the sub-system growth rates within each of these sub-systems. The catch-ups, (which tend to vary from sub-system to sub-system) illustrate sub-system homeorhesis. Conversely, phenomena of homeorhesis and dynamic steady state, (as frequently found in open systems), may indicate that we are dealing with general trends that may have wide applications in system problems.

Figure 1.6 illustrates the homeorhetic rate for the Law of the Retarding Lead. The Law of the Retarding Lead is capable of dealing with a conglomeration of sub-systems, as opposed to identifying the growth pattern of a single system or sub-system, and has the ability to indicate general growth trends. In addition, the "catch-up rate" is an important part of the process itself and increases over time and space (Fig. 1.6). A good example is the resources required to support world population. As world population increases, the nature of resources also changes. Food resources, energy, minerals, and other earth resources are being used at a growing rate. Technology may help either by stretching out the life of resources or by conserving the existing supply.

A hypothetical pattern, that distinguishes between system growth and sub-system growth can be derived from system principles (Fig. 1.7). The pattern indicates that the time of adoption of innovation plays a decisive role. Firms, groups, nations adopting innovations at an early stage, do so with smaller growth rates than later adopters. The Law of the Retarding Lead assumes that a system is constantly learning, thereby imparting faster growth rates to each successive sub-system.

1.6 Conclusion

Utilization of spatial diffusion modeling discussed in

HOMEORHESIC RATE LAW OF THE RETARDING LEAD

Where Q = Quantity
 T = Time or Distance
 ● = Adoption of Innovation

FIGURE 1.7
HYPOTHETICAL PATTERN
ALLOMETRIC GROWTH TRENDS
LAW OF THE RETARDING LEAD

this introductory chapter ~~generally~~ involves integrating observed epidemic characteristics of the Law of the Retarding Lead. Can it just be coincidence that we observe diffusion of: new development, ideas, industrial and technological growth, and allometric growth? Some would argue that these processes of growth involves an implicit segmentation of spatial diffusion modeling.

This introductory chapter has examined the preconditions and mechanisms of diffusion, focusing upon applications of the Law of the Retarding Lead. Processes of growth and homeorhesis have been investigated with respect to technological development. Homeorhesis is explained and is related to the Law of the Retarding Lead.

Two main characteristics of diffusion -- direction and rate of growth -- concern both the ways in which the level of development affects the Law of the Retarding Lead. Indeed, what are the basic elements and how do they help explain continuity and change? How has the Law of the Retarding Lead been applied to geographical problems? Is the Law of the Retarding Lead a general or universal proposition? Lastly, how can the Law of the Retarding Lead be applied and interpreted in terms of investigating technological growth? The succeeding chapters attempt to answer these questions.

CHAPTER 2

COMPONENT OF GROWTH

Economic growth implies the expansion of a system as a whole producing a change of its existing parts. Economic development implies a positive change in economic life through production, exchange, transfer, and consumption of goods and services. The Law of the Retarding Lead states that if growth in part of the system is delayed, growth will catch up in that part once the impediments are removed. Thus, an attempt is made to maintain the growing component of the system in balance with the growing supra-system.

How is diffusion of technology relevant to the growth of our society? This is a question that many have attempted to answer but we still lack a comprehensive understanding of how growth and technology are interrelated. This chapter examines the rate at which communication technologies are being developed and their potential for quick and wide diffusion. Today, "...one of the distinguishing marks of the new technologies is 'the great speed with which innovations are being made' " (Vitta, 1985, p.243).

"The growth of spatial systems and the development of spatial organization are linked by three interrelated

processes: invention, innovation, and diffusion" (Berry et al., 1976, p.484). More specifically, processes of growth in the communications sector are influenced by three key components: (1) invention and innovation; (2) a product life cycle; and (3) diffusion reaching a saturation level. Various analytical tools -- which are commonly used in the analysis of communication strategies -- underly the discussion of growth. Each is discussed separately below.

2.1 Invention and Innovation

As Darwin (1982, p.14) points out, to better understand telecommunications, our potential use of them, and their effects on us, "... we should understand the process of diffusion/adoption of new technologies." By examining the process of diffusion of telecommunication technologies such as cable television and telephone switching equipment, we can better understand the changes (tangible and intangible) around us, and what may happen in the near future.

There are several terms that will require an explanation and/or definitions. The first term that needs to be expanded is that of "invention." Two others that will also require further investigation or re-definition are "innovation" and "diffusion." "The creative act or process itself is called invention and can include ideas, procedures, types of organization, products and technology" (Darwin, 1982, p.14).

Parallel to this idea, "the innovation process is the acceptance, adoption, and application of inventions" (Darwin, 1982, p.15). It has been evident that it takes place in areas other than the place of origin (and of course, some time after the invention). Thus, innovations are based primarily on a combined time and spatial sequence. The study of the spread of innovation and adoption of inventions is simply called diffusion.

The literature on invention and innovation indicates that innovation and growth are closely interrelated. An American task group has recently made implicit assumptions that industrial innovation is a positive factor in producing economic growth. Their comprehensive study of ten cases of innovation indicated that

There is convincing evidence that innovation and capital formation are the primary elements in stimulating growth ... Therefore society ought to be motivated to stimulate innovation.
(Industrial Research Institute, 1981, p.1)

Solow (1957), a pioneer in calculating the contribution of technical innovation to growth in GNP in the U.S., has estimated that between 1909 and 1949, 87.5 percent of the increase is attributable to technical change and that the remaining 12.5 percent to increased use of capital (Solow, 1957, p.320). Although his estimate is presently known to be high (Denison, 1967; Jorgenson, 1979), it is largely of interest because it drew attention to the relationship of

technical innovation and growth.

Gertler and Crowley (1977), have also addressed this important question and feel that

Innovations, whether they take the form of providing new products, involving the use of new production processes or the restructuring of an organization, all stimulate city growth.
(Gertler and Crowley, 1977, p.150)

They believe that the account of growth forces is mainly embedded in large metropolitan areas and that they are intensified by the innovation diffusion process. Moreover, this concentration of power is deemed to have profound implications for the growth of the urban system (Gertler and Crowley, 1977, p.153).

2.2 Product Life Cycles

The product life cycle is a well established concept for projecting growth rates and analyzing marketing strategies (Fig. 2f1). A new product or innovation may be seen to pass through four general stages: introduction, growth, maturity, and decline (Kotler, 1972, pp.429-31; Wasson, 1974, Rink and Swan, 1979; Brown, 1981). Such product life cycles may vary in length of time, typically having a duration of 30 years. However, it is to be noted that product life cycles in high technology industrial firms are much shorter -- perhaps only five years. CB radio and

FIGURE 2.1
STAGES IN THE PRODUCT LIFE CYCLE

Source: Kotler, 1972, p.430, Price Waterhouse Associates, 1981, p.17

telegrams are examples which appear to be well into the decline phase. "The telephone, on the other hand, remains in the early part of the maturity phase, with volume continuing to grow appreciably faster than population" (Price Waterhouse Associates, 1981, p.18).

The Law of the Retarding Lead is in effect based indirectly on cycles of invention and innovation. That is, as products or services are developed and put into production, profit margins attain an equilibrium and inevitably decline to a point where the product is gradually becoming obsolescent or simply dropped from production.

The Law of the Retarding Lead has certain implications regarding a rapid rate of innovation. Shorter product life cycles mean that their frequency will be greater, as more technologies are introduced or improved at an accelerated rate. A similar relationship is offered by Vitta: "...since the new technologies now find their way into the market faster than before, they displace old technologies also faster than previously" (Vitta, 1985, p.243). Vitta has inferred a corollary between rate of innovation and rate of obsolescence. It is further suggested from this corollary that if the rate of innovation slows down, so should the rate of obsolescence. Obsolescence can be avoided either by modifying the original product or by developing a new product which is not recognizable from the

original. Hence, the timing of adoption of innovation is crucial. Agencies will have to choose to either remain with a certain technology and decide for how long, or, alternatively decide (based on differentiated marketing) to discontinue its use and concentrate on a new product or innovation that will provide rapid subsequent growth.

Figure 1.6 illustrates this point well. The homeorhetic rate is composed here of three cycles: T0, television; T1 cable television; and T2 pay television. The saturation level or maximum market penetration (in this case) is known. We can observe that as the first cycle (TV) approaches its saturation level, the second innovation (CATV) comes into the market and subsequently, as it reaches in turn its maximum penetration, the third cycle (pay TV) begins. Similarly, by trying to "jump" from T0 to T2 without the intermediary of T1, a certain predicament of obsolescence is avoided and the innovation continually attempts to re-embark on the overall homeorhetic rate (for that specific technology).

There is a marked difference between cycles for products and cycles for technologies. A technology is often referred to an "evolutional" innovation that has primary applications. The example in Figure 1.6 illustrates television as the primary technology, while cable and pay television are seen as secondary products. Although it is often

difficult to differentiate between a technology and a product, the Law of the Retarding Lead assumes that catch up rates for subsequent products will be greater than the growth rate of the evolutionary innovation. The ability of subsequent products to spread their high fixed costs over a long period of time is a primary factor for its higher rate of growth. This point is amplified in sub-section 2.3.1.

The catch-up rate of each individual innovation tends to increase over time, according to the Law of the Retarding Lead. Hence, the alpha value should be greater as further innovations are introduced to the market. Naturally, these further innovations are linked technologically. Cable TV requires an ordinary television and pay television requires cable TV. Retarding Lead applies within any given technology and any given innovation. Whether it applies between different technologies and products is a different question which has also promoted a lot of discussion -- e.g. Hornel Hart (1957). Nevertheless, a tautology seems to exist between Retarding Lead and accelerating acceptance.

2.2.1 Growth-Share Portfolio

A growth-share portfolio model has been developed by the Boston Consulting Group (cited by Price Waterhouse Associates, 1981). It conveniently combines the concepts of the product life cycle and economies of scale, and the development of product standardization.

Berry (1970) argues that impulses of technological change are transmitted down the urban and regional hierarchy. Diffusion of innovation is a direct function of distance from the first centre of adoption and reaches "troughs of economic backwardness" (Hagerstrand, 1953; Berry, 1970). Darwin (1982, p.15) also argues that the adoption of communications technology is hierarchical. That is, telecommunication innovation is expected to occur first in large firms. Geographers accept the notion that the first to adopt telecommunication technology are large firms in large central cities (Berry, 1970; Brown, 1981). The same technology is adopted by smaller firms in the same geographical area by the process of trickling down. Large firms are known to be first because they have to meet the (functional) prerequisites to adopt the invention. These prerequisites and threshold conditions determine the dates of adoption of innovation and subsequent rates of growth in each adopting location. There are two measures of threshold that commonly appear in the literature. They are exposure to the innovation or the number of times a potential adopter has to be contacted before adopting, and the minimum size of the adopting organization (Ray et al., 1974, p.341; Darwin, 1982, p.15).

Actual threshold values depend on the nature of the innovations as well as on the character of the adopter. Threshold conditions are much higher in the case of entrepreneurial innovations which

usually involve a greater risk than household innovations.
(Pedersen, 1970, p.20)

• It is in understanding the process of hierarchical diffusion that economies of scale and product life cycle come about as a growth-share model. As the name of the model explains, growth is shared between these two elements.

2.2.2 Standardization

This diffusion of technological change results in specialization and standardization. The process of growth, innovation and diffusion, is characteristic of a contemporary life cycle, each stage being associated with various forms of ideas, technology, supply and demand, products and standardization.

One authority on economic growth and standardization, Charles P. Kindleberger, described the growth-share portfolio model from a different perspective in his study of Economic Growth in France and Britain (1964). Nevertheless, he has clearly identified two salient features of this model: the notion of saving time and economies of scale.

Standardization can produce physical economies as well as savings in transactions, though not necessarily in total cost. In production, the saving may lie in economies of scale through repetitive production and in the reduction of down time for changing patterns and shifting materials. In use -- more often perhaps of intermediate than of final goods -- the benefit is of

interchangeability of equipment.
(Kindleberger, 1983, p.384)

Verman (1973) has also thoroughly documented the concept of standardization as a "new discipline." Standards are treated within this thesis as a "...category of documents whose function is to control some aspect of human endeavor" (Sullivan, 1983, p.2). Notably, the earliest controls (standards) were originated to "keep people honest." The historical development in the realm of standardization is infinitely complex, but with a clear distinction between voluntary and mandatory standards. Voluntary standards are developed by people for the use of people, while mandatory standards are obligatory and are generally imposed, usually by standards organizations or governments. Governments have standardized products, production process, and institutions, including banking, legal, labour, education, professional and technical certification, and transportation.

A classical example is that of the railways and the "Battle of the Gauges." Both in England in the early 1800's and later in Canada in the mid 1850's, the distance that separated the rails varied from a rail gauge of 4 feet 8 1/2 inches to 7 feet. Legget (1970, pp.16-17) and Kindleberger (1964, pp.149-51; 1983, pp.384-85) refer to this familiar case and stress that it is inevitable that in most situations

there is only room for a single standard. Hence the idea of standardization not only protects the consumer, but it can also be utilized as an effective instrument for guiding production and thus constitutes a means to properly evaluate and identify the various stages of the product life cycle.

The concept of standardization pervades all parts of the growth-share portfolio model. It illustrates well how economies of scale affect the Law of the Retarding Lead. Kindleberger explains that,

It is a general phenomenon that the first major firm in the field in a country has a relatively free hand in setting the standard. This may, however, prove later to be less than optimal but at such time difficult to displace.
(Kindleberger, 1983, p.386)

"Standardization achieves economies of scale in production" (Kindleberger, 1978, p.229). Indeed, economies of scale are important, particularly for larger firms, because large organizations are able to spread their resources (i.e. research and development, marketing and overhead costs) over a large number of units (Price Waterhouse Associates, 1981, p.20). This kind of strategic analysis increases profits (in absolute dollars, as well as on a percentage basis) and allows large firms to secure the distribution channels for their products.

Where a company is far in the lead, as the American Telephone and Telegraph company or IBM in computers, there is strong pressure on the rest of the

industry to make its equipment compatible, leading to the private and collective good of standardization, although for the lead company which may be partially displaced, the standardization might be regarded as a private bad.
(Kindleberger, 1983, p.387)

Kindleberger (1978) has pointed to numerous examples in the work of Michel Chevalier, a distinguished economist in 19th century France, of how standards interface with time and economies of scale. Chevalier, was primarily concerned with economic growth. Chevalier undertook a two-year journey in North America from 1834 to 1835 and reflected particularly on the public works of the U.S. One of his insights was the different use Americans made of time.

The American was preoccupied with saving time, in contrast with the French for whom the problem was how best to spend it.
(Kindleberger, 1978, p.127)

Chevalier commented that French railway standards on grades, curves of track, double-tracking, and types of materials were much higher than those of the U.S., "...where absolute engineering standards were qualified by a tradeoff between technical performance and cost" (Kindleberger, 1978b, p. 129). Chevalier admired the fact that Americans were not held back by rigid standards.

An interesting comparison is afforded by the size of canals (width and depth, especially of locks, and length of locks). The British adopted standards that proved to be too small, and kept them. French standards were originally too large, thus tying up capital that

might have better been utilized in more productive projects. The Americans started with an economical standard, as noted, and rebuilt when forced to.
(Kindleberger, 1978b, p.129)

Chevalier cites numerous works throughout the U.S. which demonstrated American ingenuity, simplicity, and efficiency. Chevalier was most impressed with the speed with which the Erie Canal was built, "...and the speed with which boats were put through it, locks working, for those that paid extra, night and day" (Kindleberger, 1978b, p.128).

One last point concerning the difficulty of changing standards is that of workers' attitudes and motivation and the role of historical memory in a nation. Chevalier conjectures that young countries have shorter memories than old. That is, countries with shorter memories (fifty-years old) are able to play stronger roles in shaping current macro-economic policies (Kindleberger, 1978b, pp.135-136). In addition, Kindleberger suggests that economic aging (as opposed to economic growth) may be the result of interference from associations.

Economic aging, ...may be marked by associations which dig in, instead of intermediating between the parts of the whole, to such degree that they prevent the whole from functioning.
(Kindleberger, 1978b, p.142)

Kindleberger (1978b, p.142) postulates, although indirectly, that, if nations are to grow, economically, individual countries must determine their own separate fates, rather

than "... leave their fortunes in the hands of a particular association." Chevalier did not adequately explain the term "association." However, it has been interpreted to represent groups, brotherhoods, and in a larger perspective, associations in terms of allied nations or organizations. Apparently, a long historical memory of a nation coupled with preconceived ideas and rigid standards limit initiative and impede a natural diffusion of invention and innovation. Once established, standards set national economic growth rates that seem almost impervious in the long run to short-run droughts, recessions, war, and booms.

Specialization is another fundamental prerequisite for success in small markets. Economies of scale dictate that,

High up-front costs for research, development, marketing and production start-up give large-scale operations an important advantage. A small country can only achieve this scale if it has industries which are specialized, export oriented and generally outside the areas in which major countries have already established a strong position.

(Price Waterhouse Associates, 1981, p.167)

The Law of the Retarding Lead is intrinsically intertwined with the two elements that compose the growth-share portfolio model. By nature, the Law of the Retarding Lead implies a sequential progression from an "old" standard to a "newer" one. The country setting the new standard becomes the leader. Economic growth does not necessarily follow a

hierarchical pattern and "large" groups or nations do not necessarily lead the way with higher growth rates. Standardization and specialization are processes which are deeply rooted insofar as the Law of the Retarding Lead is concerned. It is by standardizing and specializing that smaller firms/nations can lead in technological change. "Troughs of economic backwardness" may in turn dictate the pace of repetitive production rather than to wait for some other company or other nation to lead the way.

Standardization and specialization have been associated with the introduction of new technologies at an accelerated rate. Consider the explosive growth of Computer-Aided Engineering (CAE) technology. The technology has been on the market for only two years and yet already vendors indicate that a lack of standards constrains CAE. The near-total absence of standards poses problems for the user and causes high prices and confusion in the market place (Weissman, 1986, p.55). A pre-defined growth philosophy would allow, as more innovations are introduced, for continual adaptation to technical changes and works towards standardization. The learning curve is intensified as knowledge is increased and additional skills are assimilated. That is, new knowledge is adopted to a level where it is considered general and basic.

2.3 Saturation Level

The application of learning curves is another concept that is frequently used in diffusion studies. Learning curves are applied particularly in high technology industries.

Learning curves are dependent on the assumption that, "...the cost of completing a given task or unit of a product will be less each time the task is undertaken" (Price Waterhouse Associates, 1981, p.22). The number of adopters of innovation increases as price decreases with time. It is in this sense that learning curves graphically describe the rate of adoption of innovation. This S-shaped diffusion curve is dependent upon human behavior and it is commonly known as a "logistic" curve. Gould (1969, p.19) has described this symmetrical distribution and the equation that links the proportion of adopters to diffusion time.

It will be noticed that we are now confining the use of the term "learning curve" to those elemental components of diffusion innovation which equate with elements of human adaptability. The behavioural significance of diffusion of innovation can be further appreciated if we can conceptualize the individual innovation as occupying the common focus of growth and the availability of technological hindsight. This property is simply expressed in Figures 2.2 and 2.3.

Figure 2.2 is a simple graph depicting the cumulation

FIGURE 2.2
THE LOGISTIC CURVE OF INNOVATION ADOPTION

Source Gould, 1969, p.20

FIGURE 2.3
LEARNING CURVE

Source After Price Waterhouse Associates, 1981, p.23

of innovation acceptors with time. The upper limit of the curve is the saturation level of the innovation. The maximum is one hundred percent adoption, but this level is seldom reached in the real world. The Law of the Retarding Lead implies a rapid acceptance of potential adopters and the curves of innovation adoption vary as there are different rates of entry into a market. The learning curve depicted in Figure 2.3 is based on the logistic curve. It can be observed that unit cost drops to some minimum value or steady state.

In economic applications, the "learning curve" was originally thought of in terms of maximizing cumulative production and developing a cost advantage (Price Waterhouse Associates, 1981, p.22). It is seen as a maturation process whereby certain morphological changes take place. This is achieved in several ways (Price Waterhouse Associates, 1981, p.22). First, as labour becomes more productive, this will inevitably increase the overall experience of the entering industry. Second, as the Law of the Retarding Lead suggests, further technological improvements are triggered by individual innovations. Lastly, additional savings may be due to administrative intergration and a better organization of production.

Experience is important both for labour and for new technologies. Without experience, new entrants have

difficulty in overcoming the initial financing of a new innovation. This cost advantage may be earned by adopting experience gained by an industrial leader as its methods are known. The new entrant may also have access to "immediate" technological capability by recruiting experienced personnel from the leader. This expertise puts the new entrant on a higher learning curve and can initiate higher rates of return on investment. In short, higher learning curves denote faster adoption rates.

2.3.1 Breakeven Analysis,

Breakeven analysis, a standard economic concept, is useful in examining the sensitivity of profit margins to changes in volume.

Breakeven analysis relates the size of the profit or loss on a product to the sales volume in units. The term derives from the breakeven point, which is the level of volume when revenues are exactly equal to costs.

(Price Waterhouse Associates, 1981, p.24)

Figures 2.4 and 2.5 compare two hypothetical products. For simplicity, they have the same breakeven point. Figure 2.4 demonstrates low fixed costs, while Figure 2.5 indicates high fixed costs and relatively small variable costs. The second product shows an extreme profits or losses situation. Innovations with high initial development costs result in high fixed-cost products.

FIGURE 2.4
BREAK-EVEN ANALYSIS

Source: Price Waterhouse Associates, 1981, p.25.

FIGURE 2.5
BREAK-EVEN ANALYSIS

Source: Price Waterhouse Associates, 1981, p.25.

Much of the communications ... sector resembles the high fixed cost example. This is true of telephone and cable systems and computer service bureaus, because they require large investments in capital equipment.

(Price Waterhouse Associates, 1981, p.24)

The profitability of products with high fixed costs is particularly sensitive to demand. The demand of any product is unpredictable. Hence, high fixed-costs products are often viewed as high risk. The readiness of companies to take chances on a new process is at best seen as skeptical.

The Law of the Retarding Lead implies that a system is capable of generating incremental growth while at the same time the saturation level slowly increases (where demand is stable or growing at a steady rate). Predictability of demand translates into predictability of profitability. Telephone and cable systems are two such examples.

Another source for the overall success of the telephone and cable systems is their ability to spread high fixed costs over a long period of time. In their infancy the telephone and television were seen as "evolutionary" products. Today, their products are constantly adapting to technical changes because they have been able to widen their economic base. The sequential diffusion process involved has helped enormously the success of these two innovations. The term "sequential" refers to an "evolutionary" product that diversifies itself into various other sub-

products/services.

For example the telephone now offers such services as emergency dialing and answering capabilities; the cable system offers a wide range of additional programs, and two-way systems such as a household security system and on-line computer services. That is, once the "evolutional" product is well established on the market, the Law of the Retarding Lead predicts higher rates of growth. If for any reason the introduction of a specific product fails, the fixed costs will not be as high as the evolutionary product, primarily because the basic infrastructure of the innovation has already been laid out. Increasing efficiency is important in prolonging the life of old technologies (Brown, 1981, p.186). Hence, the tradeoff between technical performance and cost is a viable characteristic in the breakeven analysis.

2.4 Retarding Lead and Accelerating Acceptance

We have observed that technology, standards and the Law of the Retarding Lead are closely interrelated. Innovation offers the opportunity for change: canals replace turnpike roads, railways supercede canals, and roads compete with railways. Each innovation offers an opportunity to correct problems created by past decisions. But the window of opportunity is short-lived. In particular, product life cycles in high technology tend to be short. Short product

life cycles have a more dramatic impact upon the timing of adoption of innovation as they provide less time for maximum market penetration.

The success of an innovation is often measured by the speed and extent to which it has been adopted by a population. The literature argues that the diffusion of technology must be hierarchical (Berry, 1970; Brown, 1981). Moreover, threshold conditions (minimum size and exposure required to support a particular innovation) must be met before a particular innovation is considered secure.

Standards must be set de jure, or they will occur de facto. Some standards are almost impossible to change, particularly if they have become institutionalized. Transportation facilities (canal, rail and road) are obvious examples. Consider the example of how the U.K.'s Great Western Railway changed to a "standard" gauge over-night. One standard which has been very difficult to change is that of countries with cars driving on the left side of the road (e.g. U.K. and New Zealand). The use of metric versus imperial measures is another current issue.

The Law of the Retarding Lead is dependent on ever-increasing rapid acceptance of products/services. Retarding Lead implies accelerating acceptance whereby the catch up rate of each individual innovation tends to increase over

time. Retarding Lead applies within any given technology and any given innovation. Hence, the timing of the adoption of the innovation can be explained in terms of functional prerequisites determining: (1) the rate of growth in the total system, or (2) sub-system growth relative to that of the total system. Standardization and specialization are processes which are deeply rooted insofar as the Law of the Retarding Lead is concerned. It is by standardizing and specializing that smaller firms/nations can lead with respect to technological change. Gould's logistic curve of innovation adoption has been redefined in terms of learning curves denoting faster adoption rates.

Now that we have examined how technical growth is based on the dynamic theory of Retarding Lead, we are ready to investigate the diffusion and allometry for two current innovations: cable television and telephone switching equipments.

CHAPTER 3

THE DIFFUSION OF CABLE TELEVISION

The extensive literature on television and cable television has surprisingly few references to the diffusion and adoption rates of new technologies. This chapter measures the diffusion and allometry of cable television, within the constraints of the data available. The application of the Law of the Retarding Lead to this communication technology is explored to test if whether later adopters achieve faster adoption rates. We begin with a capsule history of cable television in Canada.

3.1 Cable Television in Canada

Cable television, or community antenna television (CATV) as it was initially known, developed in Canada some 35 years ago. Large community antennas improved the reception and diversity of television signals. A number of entrepreneurs were providing service across the country by the early 1950's.

1952 -- E.R. Jarman began by experimenting with a rhombic antenna in the back yard of his London, Ontario home. His company eventually grew to become London Cable TV. Throughout the 1950's, cable TV was developing in Quebec and by 1952 Rediffusion de Grand-Mère and Télédistribution

Asbestos were operational. On the west coast, Tru Vu Television was opened by George Chandler in Vancouver B.C.

1957 -- Cable operators formed a national Association to represent their views to government, telephone companies and other public. Cable licences were issued by the federal Department of Transport and the industry operated with minimum regulation.

1968 -- Parliament passed the Broadcasting Act creating the Canadian Radio-television and Telecommunications Commission (CRTC) with authority to regulate the broadcasting system, including cable television.

1976 -- The CRTC's cable television regulations came into force in April and set out general guidelines for the industry. The Regulations established classes of cable systems based on the number of subscribers served, set priority carriage requirements, and outlined requirements for community channel programming, allocation of television channels and simultaneous signal substitution.

1979 -- Proceedings of the House of Commons became the first full-time satellite service delivered via cable.

1980 -- In the spring of 1980 the industry's first home security service was launched in the nation's capital by Ottawa Cablevision.

1981 -- Montreal's Videotron Communications and La Presse introduced the first electronic newspaper via cable.

1983 -- Cable television systems launched Canada's first pay television services on February 1. A sixth regional Pay TV company received a licence on February 21.

CANCOM's licence was amended to allow distribution of the 3 + 1 U.S. television services (three commercial and one non-commercial networks) to its "core" market of remote communities as well as its new "extra-cable" market which included cable systems where the full 3 + 1 service is not available.

3.2 How A Cable Television System Works

A cable television system distributes television, radio and data signals from one or more central originating locations to subscribers by means of a system of cables and

in-line amplifiers instead of electromagnetic waves. According to the Canadian Cable Television Association (1983), systems consist of three main elements.

First is the "headend" which is the point at which all signals are received, assembled and processed. Second is the "distribution network" consisting of coaxial cable, amplifiers and associated hardware used for the transportation of signals throughout a particular area. Third is the "subscriber drop" which consists of the coaxial cable going from the street to the subscriber's home or business and the related equipment required to interface with the subscriber's television receiver or other apparatus.

A simplified diagram of a cable television system appears as Figure 3.1.

There are a variety of broadcasting signals. Local signals are received over-the-air within 50 to 100 miles of a radiating antenna, while those coming from great distances are periodically strengthened by the use of amplifiers along the route or are received via microwave or satellite earth stations (dishes).

Broadcasting signals provide a variety of services to the subscriber. The processing and combining of signals throughout the cable network to the subscriber drop ensure that the cable system is compatible with the subscriber's home entertainment equipment. These signals cannot be received without the installation of interface equipment.

FIGURE 3.1
TYPICAL CABLE TELEVISION SYSTEM

Source: Canadian Cable Television Association (1983), Cablestats

such as a cable converter.

3.3 The Diffusion of Television

The diffusion of black and white TV and colour TV has been examined by several authors. An important diffusion study by Berry (1970) examined the percentage of households having black and white or colour receivers. He has established that after 1940, the U.S. television industry experienced logistic growth in terms of market penetration. Berry calculated that by 1964 the percentage of cities having television broadcasting or repeating facilities was reaching the ninety-nine percentile. Market penetration is closely associated with city size: the hierarchical diffusion pattern is clearly evident. His maps show the spatial diffusion over time, and both national hierarchy and local spread effects are evident. Berry estimated that by 1965, only a few areas lacked TV reception. It was found that the receiving pattern was quite different from the broadcasting pattern: colour receivers were more common in the expanding areas of the nation where there were more affluent households prepared to innovate.

The successful diffusion of an innovation can be measured in various ways. Let us now examine that of cable television.

3.4 Diffusion of Cable TV in Southern Ontario

Easton (1980) elaborately describes the early developments of CATV in Canada. The large cable television system in Montreal started before any television broadcasts were available elsewhere in Canada. It evolved into a wired television system based on similar principles of the radio relay system established in the U.K. Easton states that this occurred from 1948 to the commencement of Canadian services in 1952.

During this time television transmissions were available across the Ontario/U.S. border from stations broadcasting in Detroit, Cleveland, and Buffalo which had opened prior to 1949 when the FCC freeze halted further expansion for the next four years. As a result there was a trickle of purchases of receivers in Southern Ontario, but only a trickle because very few Canadians were close enough to these stations to obtain reliable reception using the relatively simple antennas then available for home installation. Nevertheless, these transmissions were an inducement to several entrepreneurs to devise the means of improving their entertainment first to their families, then to their neighbours, and later to their communities.
(Easton, 1980, p.71)

One of the first entrepreneurs was Ed Jarmain living in London, Ontario. Easton (1980) recounts his experiences in the early days and describes cable television as "the hobby that got out of hand" (Easton, 1980, p.72).

London (1951) was the first city to adopt cable TV

(Fig. 3.2). From there, it spread east towards Guelph (1953) and Stoney Creek (near Hamilton -- 1956), north to Midland (1955), east to Cornwall (1957), and west to Peterborough (1956) and Oshawa (1966). Some of the larger urban centres adopted cable television service surprisingly late. For example, Toronto and Ottawa did not admit cable service until thirteen years after London's starting date. Kingston did not receive service until twenty-two years later.

Three interrelated elements aid in explaining the spread of cable television in Southern Ontario. First is distance away from Detroit, Cleveland, and Buffalo (Easton, 1980). Second is the availability of non-cable channels to larger urban centres. The more non-cable channels ("free" of costs) available, the less is the need for cable service. Third is the "psychological barrier" of quantitative versus qualitative change in television signals. Cable television will not be adopted merely to increase channel capacity unless it also provides a clearer picture (either by improved resolution or by infiltrating colour). The stark choice was black and white TV versus colour cable television. Cable subscription is relatively cheap compared with the cost of a colour television set.

3.5 The National Pattern

Berry (1970) demonstrated that market penetration is

FIGURE 3.2
DIFFUSION OF CABLE TELEVISION IN SOUTHERN ONTARIO

closely associated with city size producing a hierarchical diffusion pattern which is clearly evident (Fig. 3.3). The diffusion of TV and CATV in Canada portrays quite a different picture from that of the Americans (Figs. 3.4, 3.5).

The diffusion pattern of twenty-five Canadian metropolitan television cities appears to be almost instantaneous. Within a period of four years, eighty percent of Canadian metropolitan areas had television. The diffusion of CATV across Canada was a little slower taking thirty-five years instead of twenty years. A television city has an operational television station that originates telecasts. Similarly, a cable television city is capable of providing original programming. Cities with low repeaters, satellites or rebroadcasting stations only are not included. The distribution of cable signal is based on localized areas. Television and CATV Yearbooks confirm that there are more cable systems than television. Ontario and Quebec alone account for sixty three percent of all CATV cities in Canada.

The growth of cable television in Canada (Fig. 3.6) does not resemble the pattern identified by Berry (Fig. 3.3). The diffusion seem to be almost instantaneous. Cities of various size adopt the cable TV service within a thirty year period. The composite growth of cable TV has been subdivided by regions from a sample of 175 cities: the Atlantic Provinces, British Columbia, Ontario, the Prairie

FIGURE 3.3
HIERARCHICAL DIFFUSION OF THE U.S. TV NETWORK

Source: Berry (1970)

FIGURE 3.4
DIFFUSION OF TELEVISION IN CANADIAN METROPOLITAN AREAS

FIGURE 3.5
DIFFUSION OF CABLE TELEVISION IN CANADIAN METROPOLITAN AREAS

FIGURE 3.6
COMPOSITE GROWTH OF CABLE TV: 1951-1984^o

Source: Broadcasting/Cablecasting - Yearbook 1984; 1981 Census of Canada.

Provinces and Quebec. It can be concluded from the graph that the Atlantic Provinces (with the exception of their larger cities) developed their cable service during the later part of the cycle; the cycle originating in 1951 and terminating approximately in 1982. The Prairie Provinces have a bi-modal distribution, 1962 and 1977 representing key periods. The remaining regions: British Columbia, Ontario and the Province of Quebec, display a uniformly distributed pattern.

3.6 Allometric Growth Trends

Figure 3.7 illustrates the number of cable television subscribers by province. The year that Statistics Canada began to collect data and information related to cable television was 1970. In Canada, the number of cable television subscribers increased from 408,853 in 1967 to 5,140,262 in 1983. As expected, the larger populated provinces (Ont., B.C., and Que.) lead in the number of cable TV subscribers. Quebec and B.C. are very closely parallel to each other. Following the "central core," the Prairie provinces and lastly the Atlantic region fall into their subsequent order, P.E.I. and Newfoundland being lowest in the rank order. Quebec differs from Ontario because of the language barrier (Fulford, 1985; Melody, 1985).

Additional insights have been obtained by studying rates of adoption using relative growth measures.

FIGURE 3.7
NUMBER OF CABLE TV SUBSCRIBERS BY PROVINCE

Source: Statistics Canada, Catalogue 56-205, Annual, Cable Television

Provincial allometries of the number of subscribers are positive for Alberta, Manitoba, New Brunswick, Newfoundland, Nova Scotia, P.E.I., and Saskatchewan (Fig. 3.8, Table 3.1). British Columbia has a negative allometry. Lastly, the central provinces of Ontario and Quebec follow the Canadian rate. The "economically disadvantaged provinces" tended to have the highest allometric growth trends from 1951 to 1984 (Fig. 3.9).

Canadian cable companies served over five million subscribers in 1983, or nearly sixty percent of the total television households in the country (Fig. 3.10). The growth rate of the total households tends to be closely parallel to that of the number of cable television subscribers and the gap between the two appears to be narrowing. Indeed, the potential market for cable TV subscribers may reach the seventy percentile by the year 1990. It has been apparent that the number of households with TV (either black and white or colour) remained relatively the same. The number of households without TV is fluctuating from slightly over 150 to slightly under 180 thousand households between 1979 and 1983.

It is only after 1950 that the Canadian cable television industry experienced logistic growth in terms of market penetration. Figure 3.11 compares the growth of television cities to that of CATV cities from 1950 on. Out of a sample of 323 cable cities, 197 cities with a population over 5,000

FIGURE 3.8

ALLOMETRIC GROWTH TRENDS IN
NUMBER OF CABLE TELEVISION SUBSCRIBERS

Source: Statistics Canada, Catalogue 56-205, Annual, Cable Television

TABLE 3.1
CABLE TELEVISION ALLOMETRIES

PROVINCE:	ALLOMETRY:
Alberta	2.11
British Columbia	0.84
Manitoba	1.19
New Brunswick	1.73
Newfoundland	4.33
Nova Scotia	1.88
Ontario	0.90
Prince Edward Island	2.36
Québec	1.04
Saskatchewan	5.14

Source: Calculated from Figure 4.8.

FIGURE 3.9
THE PROVINCIAL GROWTH RATES OF CABLE TELEVISION: 1951 - 1984

FIGURE 3.10
POTENTIAL MARKET FOR CABLE TELEVISION

Source: Statistics Canada, Catalogue 56-205, Annual Cable Television

FIGURE 3.11

LOGISTIC GROWTH OF TV
AND CATV CITIES: 1950 - 1985

account for 18.4 out of a possible 24.3 million Canadians having cable TV service within their own city in 1981. Moreover, this sample of 18.4 million Canadians is 75.4 percent of Canada's population and this represents Canada's urban population in 1981, estimated at 18,435,935. This coincidence implies that the sample tentatively represents all of Canada's urban population and an additional 126 cities with a population less than 5,000 people.

The overall growth of cable cities tends to be somewhat clustered (Fig. 3.12). This M-shaped development peaked during the years of 1955-1957. A plateau of growth between 1962-1968 is later followed by another smaller summit during the mid 1970's. It is estimated that by 1980 the percentage of cities (not subscribers) over 5,000 population receiving TV and/or CATV reached the ninety-five percentile. The relationship between date of adoption and city size displays quite a different picture in spite of the growth of the CATV being typically logistic.

Berry's model of hierarchical growth takes into account that innovations are normally accepted in larger urban centres first. Different population groups indicate various rates of growth (Fig. 3.13). Two mainstreams appear to be present. First, extremely high growth rates exist in the first four years, reaching alpha values as high as 4.7 (for cities less than 5,000) and 9.5 (for cities between 5,000 -

FIGURE 3.12
GROWTH OF CABLE TV CITIES: 1950-1985

FIGURE 3.13
THE SPREAD OF CABLE TELEVISION 1951-1984⁰

29,999). All indicates a major shift toward the adoption of cable television in small cities during the period 1955-1959. As well, it is within the same period that the largest total number of cities (82 cities or one quarter of all cable TV cities) admitted cable television. Two smaller concentrations for cities between 5,000 and 29,000 population appear within the years 1967-68, and 1977-78.

Second, all other Canadian cities experienced negative allometries of 0.8 (for cities between 30,000 - 99,999), 0.5 (for cities between 100,000 - 499,999), and 0.6 (for cities over 500,000) within the first five years of the CATV cycle. The last major city over 100,000 to adopt CATV was the city of Windsor in 1984. Five to six years after the introduction of CATV, four out of five population groups reembarked on a similar homeorhetic rate varying between an alpha value of 0.9 to 1.2 (1.0 represents the Canadian norm). Medium size cities (30,000 - 99,999), however, carried on with a slightly higher rate of 1.5. In short, larger cities (over 30,000) seem to experience negative allometries for a longer period of time. Hence, larger cities are not necessarily indicative of early, higher rates of growth.

3.7 Factors Affecting the Rate of Diffusion

It is relatively difficult to identify factors that positively shape and determine the rate of adoption, but it has been possible to suggest a number of them. The composite

growth of cable TV at the national level is difficult to interpret. Although we do not necessarily understand how, we are forced to believe that growth is indeed systematically related to size. Berry's (1970) hypothesis postulated that market penetration is closely associated with city size.

Distance to larger cities and a number of socio-economic factors were expected to account for the variance in light of the diffusion of cable television across Canada. A stepwise multiple regression analysis was performed on the twenty-four Census Metropolitan Areas to help determine which independent variables were statistically most significant in this regard. In total, nine independent variables were chosen (Appendix D). To ensure a normal distribution of data and linearity of relationships, it was necessary to use the logarithm of the population and distance variables.

The first set of multiple regressions examined the significance of the date of adoption of cable television (CATV) (Table 3.2). CATV was thought to be a function of distance from Montreal, Toronto, and Vancouver (DISTLG), percentage of dwellings with colour television (COLOURTV), and the ratio of English to French as their mother tongue (ENGFR). The logarithmic distance from the three major metropolitan cities is the primary factor and has a multiple correlation coefficient of .389. The variable DISTLG is

2 OF 2

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

TABLE 3.2

SUMMARY OF STEPWISE REGRESSION ANALYSIS OF CABLE TELEVISION

A. CATV: f (DISTLG, COLOURTV, ENGFR)

Step	Variable Entered	Beta	Significance Test Statistic	Significance Level	Multiple Correlation Coefficient r	Coefficient of Determination r^2	F Statistic	Significance Test Level
------	------------------	------	--------------------------------	--------------------	---	---------------------------------------	-------------	----------------------------

1 DISTLG .389 1.980 0.0603 .389 .151 3.92 0.0603

B. CATV: f (INCOME, DISTLG, POPLG)

1	DISTLG	.389	1.980	0.0603	.389	.151	3.92	0.0603
2	POPLG	-.431	-2.408	0.0253	.579	.335	5.29	0.0138

C. CATV: f (COLOURTV, INCOME, HOUSING, FORGBORN, DISTLG, POPLG, ENGFR)

1	DISTLG	.389	1.980	0.0603	.389	.151	3.92	0.0603
2	POPLG	-.431	-2.408	0.0253	.579	.335	5.29	0.0138

Variable Key:

CATV: Year cable began operation in individual city.

DISTLG: Log of distance in km to closest of Mtl/Tor/Van.

COLOURTV: % Dwellings with colour TV, 1971.

ENGFR: % English divided by % French as mother tongue, 1971.

INCOME: Average total family income, 1971

POPLG: Log of city population, 1971.

HOUSING: % Construction of dwellings, 1946-1960.

FORGBORN: % Foreign born, 1971.

indicative of an isolation factor and COLOURTV and the ENGFR variables are unimportant to the timing of cable. The second regression compares CATV with INCOME, DISTLG and POPLG (city population). Again, the isolation factor comes through: DISTLG is re-affirmed and POPLG (not INCOME) is seen as another measure of isolation and the multiple r has increased to .579 in the second step. The last regression found in Table 3.2 includes HOUSING (percentage of construction of dwellings) and FORBORN (percentage of foreign born). The equation indicates that with the exception of DISTLG and POPLG, there are no other significant factor. DISTLG is the primary factor determining the date of adoption and POPLG is secondary in importance and is negatively correlated (i.e. smaller populated areas tend to have higher rates of growth).

Table 3.3 examines the rate of growth (ALPHA) to the same variables found in Table 3.2. Once again, DISTLG and POPLG come in first and the only difference is that INCOME is seen to be important in determining an alpha value. The second regression in Table 3.3 includes all but the CATV variable. In addition to DISTLG, COLOURTV and the ENGFR variables have progressed to a multiple r value of .751.

Table 3.4 compares ALPHA with all variables, this time it includes the timing of adoption variable. The first step in the multiple regression analysis (CATV) accounted for

TABLE 3.3

SUMMARY OF STEPWISE REGRESSION ANALYSIS OF CABLE TELEVISION

A. ALPHA: f (INCOME, DISTLG, POPLG).

Step	Variable Entered	Beta	Significance Test T Statistic	Significance Level	Multiple Correlation Coefficient r	Coefficient of Determination r^2	Significance Test F-Statistic	Significance Level
1	DISTLG	.517	2.834	0.0097	.517	.267	8.03	0.0097
2	POPLG	-.347	-2.022	0.0561	.622	.387	6.62	0.0059
3	INCOME	-.212	-1.032	0.3146	.646	.418	4.78	0.0114

B. ALPHA: f (COLOURTV, INCOME, HOUSING, FORGBORN, DISTLG, POPLG, ENGFR).

1	DISTLG	.517	2.834	0.0097	.517	.267	8.03	0.0097
2	COLOURTV	-.381	-2.270	0.0339	.641	.412	7.35	0.0038
3	ENGFR	.335	2.077	0.0509	.718	.516	7.11	0.0019
4	POPLG	-.229	-1.452	0.1628	.751	.564	6.16	0.0024

Variable Key: ALPHA: Provincial alpha value for CATV city.

TABLE 3.4

SUMMARY OF STEPWISE REGRESSION ANALYSIS OF CABLE TELEVISION

A. ALPHA: f (COLOURTV, INCOME, HOUSING, FORGBORN, DISTLG, POPLG, ENGFR, CATV).

Step	Variable Entered	Beta	Significance Test T Statistic	Significance Level	Multiple Correlation Coefficient r	Coefficient of Determination r^2	Significance Test F Statistic	Significance Level
1	CATV	.597	3.493	0.0021	.597	.357	12.19	0.0021
2	ENGFR	.372	2.349	0.0287	.700	.491	10.11	0.0008
3	COLOURTV	-.335	-2.350	0.0292	.775	.601	10.03	0.0003
4	DISTLG	.255	1.699	0.1056	.808*	.653	8.96	0.0003

35.7 percent of the variance in determining the rate of growth in that city. ENGFR accounted for an added 13.4 percent of the variance, while COLOURTV contributed another 11.0 percent. Altogether, the distance closest to Montreal, Toronto, and Vancouver, the rate of adoption, the penetration rate and the language background accounted for 65.3 percent of the variance in determining an alpha value. A multiple correlation coefficient of .597 confirms that later adopters tend to have higher rates of growth.

Table 3.5 indicates the simple correlation of the variables in the regression analysis. Multiple correlation coefficients of 0.2 to 0.6 are explained by the influence of urban hierarchy, metropolitanism, and cultural values. Significant correlations are present, however, it is apparent that with the exception of the ALPHA and CATV variables, the remaining variables are forcibly competing among themselves. In summary, the rate of growth for cable television is highly dependent upon the date of acceptance within the limits of the city.

3.8 Conclusion

The concept of allometry and the Law of the Retarding Lead appear to be closely associated. The receiving pattern of acceptance of subscribers is quite different from the broadcasting pattern (growth of television and cable television cities).

TABLE 3.5

CORRELATION MATRIX

	COLOURTV	INCOME	HOUSING	FORGBORN	DISTLG	POPLG	ENGFR	CATV	ALPHA
COLOURTV	1.000	.474	.011	.197	-.081	.199	-.084	-.114	-.421
INCOME	.474	1.000	.128	.521	-.254	.464	-.262	-.362	-.448
HOUSING	.011	.128	1.000	.114	.069	.130	-.148	.051	.036
FORGBORN	.197	.521	.114	1.000	-.097	.503	-.104	-.238	-.300
DISTLG	-.081	-.254	.069	-.097	1.000	.105	.259	.389	.517
POPLG	.199	.464	.130	.503	.105	1.000	-.147	.385	.289
ENGFR	-.084	-.262	-.148	-.104	.259	-.147	1.000	.184	.469
CATV	-.114	-.362	.051	-.238	.389	.385	.184	1.000	.597
ALPHA	-.421	-.448	.036	-.300	.517	.289	.469	.597	1.000

Southern Ontario portrays a representative picture of the diffusion of cable television across Canada. The diffusion pattern is explained by a synthesis of individual contributions of certain entrepreneurs, the proximity of large economies of scale outside our international boundary, and a series of socio/economic factors. This explains why certain large cities such as Toronto and Ottawa, and Kingston did not admit cable service until thirteen and twenty-two years after London's starting date in 1951.

A similar pattern becomes evident at the national level. The growth of CATV is seen to be typically logistic and it is suspected that its growth follows the normative hierarchical form. This is not necessarily so. We have seen that unlike the U.S. experience, its composite growth is nearly instantaneous and not necessarily hierarchical at all levels. Moreover, allometric growth trends for cable TV subscribers indicate that as opposed to the "core" regions, the more "peripheral," "economically disadvantaged provinces" tended to lead. Hence, we find that the Atlantic provinces have very high rates in the adoption of cable television and that the "central" provinces (Ont., Que., and B.C.) tended to follow the same rate as the whole of Canada.

Two patterns of growth exist when we examine different population size groups. One group of cities swiftly accelerate with early growth rates and then resumes more

moderate development. Another, larger group of cities begins with lower growth rates but they eventually increase, as it must "catch up" with the remainder of Canada. Hence, catch up rates are an important factor describing different rates of growth. The Law of the Retarding Lead defines higher rates for more "peripheral," "backward," "economically disadvantaged areas" first. According to the Law of the Retarding Lead, later adopters of innovation must achieve higher rates of growth at a later period. Hence, this aftergrowth is the result of an attempt to keep up with the national pattern and as a consequence, higher adoption rates (after introduction) are present in cities and regions at the lower end of the hierarchical scale.

CHAPTER 4

TELEPHONE SWITCHING EQUIPMENT

A CONTINUOUS ADOPTION OF INNOVATION

Alexander Graham Bell completed the world's first definitive tests of the telephone in Brantford, Ontario in March, 1876. An Act of Parliament incorporated the Bell Telephone Company of Canada (today known as Bell Canada), soon after in 1880, and by 1885 independent telephone companies were allowed to offer service in direct competition with Bell. Several hundred independent companies have come into existence since then, and as early as 1908 the responsibilities of ownership and regulatory jurisdiction were shared among municipal, provincial and federal government agencies.

A considerable number of factors influence the adoption rates of new telephone switching technologies, both directly and indirectly. This chapter examines these factors and explains their relevance to the Law of the Retarding Lead by sketching the significance of telephone companies and understanding telephone systems.

4.1 Introduction

Telephone services have become a major income

generating activity and an important segment of the Canadian economy since the pioneer years. Today the telecommunications sector accounts for nearly two percent of Canada's Gross National Product. About 8.3 million households (98 percent of the total) had at least one telephone in 1983. Twenty-nine billion telephone calls were made in 1982, an average 1,640 calls per telephone; 95 percent were local calls, 5 percent were long distance calls (Statistics Canada). Canada ranks fourth in the world (behind Sweden, the U.S., and Switzerland) with regards to the number of telephones per capita (Table 4.1).

4.2 Telephone Companies

There were approximately 119 telephone companies operating in Canada in 1983. However, 17 major companies accounted for nearly one hundred percent of the 16.6 million telephones in service (Table 4.2, Fig. 4.1).

Bell Canada is the largest, accounting for 57 percent of the telephones in Canada. Bell is privately owned. It operates in most of Ontario and Quebec and the eastern part Northwest Territories (N.W.T.). Bell served not only Ontario and Quebec but also the Prairie Provinces and the Maritimes until the turn of the 20th century. Today, Bell maintains substantial equity interest in Newfoundland Telephone, MT&T, NBTel and Island Tel. Parts of Ontario and Quebec continue to be served by Bell subsidiaries, chiefly

TABLE 4.1
 TWENTY-FOUR LEADING COUNTRIES
 BY TELEPHONES IN SERVICE
 (AT JANUARY 1, 1983)*

RANK	COUNTRY	TELEPHONES PER 100 POPULATION
1	Sweden	86
2	U.S.A.	84
3	Switzerland	78
4	Canada	74
5	Denmark	72
6	Australia	59
7	Netherlands	57
8	United Kingdom	55
9	France	54
10	Japan	53
11	West Germany	53
12	Austria	44
13	Belgium	40
14	Italy	37
15	Spain	35
16	Taiwan	23
17	Czechoslovakia	22
18	East Germany	20
19	Korea	12
20	South Africa	11
21	U.S.S.R.	10
22	Poland	10
23	Mexico	8
24	Brazil	7

*Estimated

Source: Northern Telecom Product Handbook (1983), p.182.

TABLE 4.2.

MAJOR CANADIAN TELEPHONE OPERATING COMPANIES

(JANUARY 1, 1983)

COMPANY	TELEPHONES ¹ (THOUSANDS)	TELEPHONE AS PERCENT TOTAL
1. Bell Canada	9,432	56.7
2. British Columbia Telephone Company (B.C. Tel)	1,963	11.8
3. Alberta Government Telephones (AGT)	1,303	7.8
4. Manitoba Telephone System (MTS)	748	4.5
5. Saskatchewan Telecommunications (Sask Tel)	678	4.1
6. Maritime Telegraph and Telephone Company, Limited (MT & T)	532	3.2
7. Edmonton telephones	497	2.9
8. The New Brunswick Telephone Company, Limited (NB Tel)	411	2.5
9. Québec-Téléphone	285	1.7
10. Newfoundland Telephone Company Limited (Newfoundland Telephone)	200	1.3
11. Télébec Ltée	170	1.0
12. Canadian National Telecommunications (CN) (includes Terra Nova Telecommunications and Northwest Tel)	104	0.6
13. Thunder Bay Utilities	99	0.6
14. Northern Telephone Limited (Northern Tel)	77	0.5
15. The Island Telephone Company Limited (Island Tel)	73	0.4
16. Téléphone du Nord de Québec	**	(0.4)
17. Ontario Northland Telecommunications	**	(0.4)
TOTAL	16,581	99.7*
TOTAL (CANADA) ²	16,630	100.0

*May not add exactly owing to rounding.

**Data not available, telephone as % total estimated to be less than 0.4.

Source: 1. Northern Telecom Product Handbook (1983).

2. Statistics Canada. Telephone Statistics, Catalogue 56-203 (Annual), 1984.

FIGURE 4.1
BOUNDARIES OF TELEPHONE COMPANIES

MAJOR TELEPHONE COMPANIES

1. Newfoundland Telephone
2. Terra Nova Tel (CN)
3. MT & T
4. Island Tel
5. NB Tel
6. Telebec
7. Quebec Telephone
8. Telephone du Nord de Quebec
9. Bell Canada
10. Northern Telephone
11. Ontario Northland Telecommunications
12. MTS
13. Sask Tel
14. AGT
15. Edmonton Telephones
16. BC Tel
17. North West Tel (CN)

Source: CRIC Fact Digest (1994)

by Télébec Ltée and Northern Telephones Limited (both nearly one hundred percent owned by Bell). As of January 1, 1983, Bell and its subsidiaries accounted for approximately 66 percent of the telephones in Canada and the vast majority of the telephones east of Manitoba. With the exception of Bell Canada, which is federally incorporated and regulated by the CRTC, these companies are all provincially incorporated and regulated.

British Columbia Telephone Co. (B.C. Tel) is the second largest telephone company with approximately 12 percent of the country's telephones. It serves all of B.C. apart from the city of Prince Rupert, which is served by a municipally owned system. B.C. Tel is federally incorporated and regulated by the CRTC, with General Telephone and Electronics Corporation (U.S.A.) being the principal shareholder.

Half of all provincial Crown corporations are located in the prairie region and are represented by three large telephone companies: AGT, MTS and Sask Tel. Together, these three companies account for slightly under one fifth of all telephones in Canada. AGT and MTS are regulated by their respective public utility boards. Sask Tel, together with numerous co-operatively owned systems, is responsible to the provincial legislature.

The other major Canadian telephone companies are

Edmonton Telephones and Thunder Bay Utilities which are two of seventeen municipal telephone systems across Canada controlled by their respective city councils. Canadian National Telecommunications (a division of Canadian National Railways) has two subsidiary telephone companies, Terra Nova Telecommunications Inc. and Northwest Telecommunications, which operate in Newfoundland and the Northwest Territories respectively and are regulated by the CRTC.

4.3 Understanding Telephone Systems

A simple conversation between two persons involves a transmission of information from one person to another. The basic unit of A.G. Bell's invention consisted of a transmitter, a receiver, and a single connecting wire. Today's modern telephone system has greatly improved since Bell's original idea and has become increasingly more sophisticated. Moreover, the Public Switched Telephone Network (PSTN) is the most extensive among all Canadian telecommunication systems and is the one carrying most of the telecommunication traffic. PSTN includes data and voice capabilities, the former being the major user. The following will attempt to briefly introduce some of the basic terms and philosophies behind different types of technology that telephone systems are associated with.

4.3.1 Telephone Networks

A telecommunication network generally has three

functions: the origination and reception of signals carrying information, the transmission of signals and the switching or routing of signals from one transmission link to another. These telecommunication signals are either an analogue format or a digital format. Analogue signals are based on a continuous range of values of amplitude and duration in time. Digital signals can be identified with the use of binary coding of information. New systems and replacement portions of existing telecommunication systems, particularly telephone systems, are becoming predominantly digital.

A telephone network involves switching equipment and transmission facilities (Fig. 4.2). The terminal is represented by a telephone set and the wire and cable infrastructure corresponds closely to that of the cable television system discussed earlier. A central office carries a switching system whereby it establishes temporary connections between terminal equipment and switching equipment, or between sets of switching equipment for the duration of the connection. Terminal equipment and switching equipment is normally connected by a particular device referred to as a "subscriber loop."

The telephone set is the most common of all end-user equipment available for voice communications. A distinction is made between those which are connected to a single telephone (transmission) line, as are most of the telephone

FIGURE 4.2
A TYPICAL TELEPHONE NETWORK

WHEREBY IT CAN BE EASILY INTERCONNECTED WITH
VARIOUS TRANSMISSION SYSTEMS AND EQUIPMENT

Source: Northern Telecom Product Handbook (1983), p.2.

sets installed in residences, and those which are connected to a multiple of telephones and perhaps other, telecommunication facilities. These multiple telephone lines not only have all the features found with a single-line set but also permit access to more than one transmission path into a network. Among the types of equipment required to provide these additional features are key telephone systems (KTSs) and private branch exchanges (PBXs).

The term KTS is derived from the buttons commonly referred to as "keys" on the main body of the telephone set; these are separate from the dialing mechanisms. Such a telephone set is frequently called a "key telephone set." The keys have access to one of a number of transmissions lines and are also used to provide further features, such as intercom and line hold. KTSs can also be used together with PBX equipment.

The telephone is not restricted to single-line residential use. There are times when the communication needs are mostly internal, particularly in an office environment such as in a business or hospital. The use of a "private exchange system" is viewed as an economic solution to an internal communication problem without making use of the telephone company's central office which might be several kilometers away. Switching equipment is therefore provided on the user's premises and may be configured so

that it is located in one building and connected via direct cable or a multiple of telephone sets to a group of external lines. The switching technologies and controlling techniques incorporated in PBX equipment parallel those found in the switching equipment located in central offices.

Switching equipment provides temporary connections among various transmission facilities, within a local exchange or toll (long-distance) exchange. It also permits a large number of lines, or subscriber loops to access a lesser number of paths between exchanges, called "trunks." A subscriber's line is used only ten percent of the time, and allows the facilities (trunks) between exchanges to be shared among subscribers (Northern Telecom, 1983, p.87). Figure 4.3 examines the basic voice network components of a telephone system.

A hierarchy of switching offices exists for North America (Figs. 4.3, 4.4). The local switching offices (to which telephone sets are connected) are called Class 5 (end) offices. The first level of toll switching offices are called Class 4 (toll center of toll points). To cover larger geographical areas there are three levels of toll switching codes (Control Switching Points - CSPs). These CSPs are designated as Class 3, 2 and 1, representing primary, sectional and regional centers respectively.

FIGURE 4.3
BASIC VOICE NETWORK COMPONENTS

Source: Control Data (1982).

FIGURE 4.4
NORTH AMERICAN SWITCHING HIERARCHY

Source Control Date (1982).

A local call is switched within the same office, or between Class 5 offices. The NPA number (or area code) on a telephone determines if the call is within close geographical proximity. Calls made in the Ottawa area are generally restricted to the area code 613. Once a central office receives a call, it breaks down the seven digit number, described as an NNX number. The first two out of seven digits can be represented by a two through nine number (and not zero or one). An NNX number may have as few as a hundred telephones connected to it or it may have as many as 10,000. A typical urban example is that in a central office building, 50,000 lines may be served by 5 NNX's or equivalent to five central office codes.

A toll call typically is routed through the hierarchy of offices, such as Class 5 (local) to Class 4 to Class 3, 2, or 1 then back down to Class 4 and then the called Class 5 office. The call may skip one or more of the toll offices, such as Class 3 to Class 1 if network facilities permit and if no blocking is encountered.

Long distance calls to countries other than the U.S. are handled through "international switching system" or "gateway offices." The three largest metropolitan cities (Toronto, Montreal and Vancouver) are the gateway offices which handle all telephone traffics for Canada to other countries.

4.3.2 Switching Technologies

The switching function can be performed either manually or automatically. The early telephone system was a centrally located switchboard controlled by an operator acting on verbal instructions to establish the desired linkage. The connection was established by operators who manually connected the keys, plugs and jacks in the switchboard.

Automatic switching technology allows telephone lines access to any other telephone line without an operator. There are three major generations (placed in their chronological order of development): step by step (SXS), crossbar (XBAR) and electronic (Fig. 4.5).

SXS, introduced into service in 1923, was a major system for local and toll offices for almost thirty years, and still serves more than half of all the telephones in the world (Northern Telecom, 1983). This system is based on electromechanical switching whereby as its name implies, telephone connections are made in steps or stages. Electromechanical switches must establish a path (circuit) through which a signal passes. The sequential call is set up as the digits are dialed by the subscriber. The signalling is done by rotary dial and the switching equipment is actuated by the pulse of the dial and under its control.

FIGURE 4.5
MAJOR SWITCHING TECHNOLOGIES

STEP BY STEP (SXS)

A SERIES OF GATES

CROSSBAR (XBAR)

ELECTRONIC

The crossbar switching system, introduced in 1956, is highly reliable and is a well proven electromechanical system. XBAR technology involves a considerably smaller amount of mechanical movement of components to establish a path and uses XBAR switches and wire spring relays arranged in a grid or matrix as main elements. A common control logic looks at the total number dialed and sets up the routing between the calling and the called party.

Electronic switching has been on the market since 1967. The control functions are performed by electronic circuits. The switching matrix uses either electromechanical switches (e.g. crossbar) or solid state crosspoints. Its advantages are system flexibility, high speed, reliability, space saving, and its ease of maintenance.

Most modern switches are currently electronic, computer controlled and utilize digital technology for both transmission and switching. Digital transmission is favoured by the lower cost of integrated circuitry, very high bandwidth channels, and lastly, the superior voice quality.

4.4 Perspective of Telephone Trends

Statistics Canada monitors the provincial changes in the number of telephones operated by central energy and automatic switchboards. Statistics Canada had recognized

only two types of switching technologies (manual and automatic) up until 1971. It has taken them more than a decade after the introduction of the XBAR system to correctly identify the three current switching technologies (SXS, XBAR, electronic).

Hence, telephone statistics were not good indicators of past trends prior to 1971 as the definition of types of central offices have changed with time. Secondly, Statistics Canada can describe changes that occur within the provinces and territories and not the telephone companies themselves. The difficulty is that some telephone companies have jurisdiction over a number of provinces. For example, Bell Canada's boundary extends over the N.W.T., Ontario and Quebec. Provincial trends can be easily deceived by telephone statistics affected by inter-company policies, and new laws and regulations. A recent decision of the CRTC allowing subscribers to connect their own phones (other than "Bell" telephones) in their households for example, does not necessarily reflect a higher market penetration within Bell's system.

4.4.1 National Distribution

The highest number of telephones per capita are found in the Yukon Territory (.78), Alberta (.74), and Manitoba (.72). The lowest rates are located in the N.W.T. and the Atlantic Region and vary between .48 and .64 (Fig. 4.6).

FIGURE 4.6
TELEPHONES PER 100 POPULATION, BY PROVINCE, 1983

Source: Statistica Canada Telephone Statistics Catalogue 56 203 (Annual) 1984, p.11, Text Table 1.

Ontario and Quebec were expected to lead primarily because of their urban population (Fig. 4.7). However, they recorded rates of only .68 and .62 respectively. In addition, the larger companies (e.g. Bell and B.C. Tel), located in the most populous regions (Fig. 4.8) do not necessarily have higher adoption rates (Fig. 4.6).

4.4.2 Central Office Technology

Growth is normally viewed in absolute terms (how many more telephones have been added to the total?). This however does not give us an indication of how much technological progress has been made relative to the dynamic steady state of the population. An attempt is made to show change of technology or technological growth rate versus a change of adoption by the population.

The telephones connected to central offices indicate subscriber's use. Telephone subscribers indirectly accept these newer types of switching technologies as they have little other choice but to make use of the system as it is set up. It is, however, the individual telephone companies which attempt to counter technological obsolescence and diminishing returns. It is with this view that central offices are utilized as an indicator of growth and help to explain innovation adoption and its affects on the Law of the Retarding Lead.

FIGURE 4.7
PERCENT URBAN POPULATION, BY PROVINCE, 1981

Source: 1981 Census of Canada, Population (Age, Sex and Marital Status),
Catalogue 92-901-1982 Table G pp. 61 to 79.

FIGURE 4.8
DISTRIBUTION OF COMPANY TELEPHONES

Source Data Northern Telecom Product Handbook (1983)
Map CRTC Fact Digest (1984).

Three general observations have been made concerning the present use of major switching technologies (Table 4.3). First, some provinces/territories are highly dependent upon a single type of technology. Second, some regions have used all three types of technologies. Lastly, some of them share two out of three technologies, leaving the third as relatively insignificant.

At the lower order of technological development, SXS's five major consumers are B.C. (54 percent) followed close by the N.W.T., Manitoba and lastly the Yukon and P.E.I. having equally 46 percent.

Crossbar, the "in between" technology, has the greatest variance within its users. This technology ranges from less than 0.03 percent of all telephones being connected to XBAR central offices (B.C.) to a maximum of slightly over half (Newfoundland has 52 percent of all its telephones on the XBAR system). It appears to be that the provinces of Ontario and Quebec and the provinces immediately surrounding this central core (most of the maritime provinces and the prairie provinces of Manitoba and Saskatchewan) are dependent more or less on an equal basis on this XBAR technology. At the other extremity, the Territories and the western Pacific region (B.C. and Alberta) use this system very little.

TABLE 4.3

PERCENT TELEPHONES CONNECTED TO
CENTRAL OFFICES, BY PROVINCE, 1983

PROVINCE	CENTRAL OFFICE TYPE		
	STEP BY STEP	CROSSBAR	ELECTRONIC
Newfoundland	32.2	52.4	16.3
Nova Scotia	33.6	44.3	21.9
New Brunswick	42.5	33.6	23.9
Prince Edward Island	45.9	33.1	20.9
Quebec	37.4	36.4	25.2
Ontario	33.0	40.0	26.8
Manitoba	49.6	30.1	20.2
Saskatchewan	40.2	33.7	25.8
Alberta	16.1	17.6	64.2
British Columbia	53.7	0.03	46.1
North West Territories	51.6	6.7	41.6
Yukon	45.6	10.0	44.4

Source: Derived from Statistics Canada, "Telephone Statistics,"
Catalogue 56-203 (Annual) 1984, p.24, Table 10.

The use of electronic switching central offices has a similar pattern to that of the SXS system. The higher proportion of adopters are in northern and western Canada. The province of Alberta leads with 64 percent; slightly under twenty percent more than any other province or territory. B.C., Yukon and the N.W.T. are the other major users.

Market penetration and switching technologies appear to be somewhat associated. Is it coincidence that most of the regions which have the highest number of telephones per capita also make use of the most recent technology? Indeed, the Yukon, B.C., and Alberta are regions that infer this association. Furthermore, it is apparent that these regions have tended to opt out of the intermediary XBAR system and have succeeded in attaining considerable growth. This has enabled them to make fewer changes to their overall telephone structure and has given them the opportunity to make a more concentrated effort to change over by "jumping" from a lower technology to a higher one.

We have seen the stages that individual provinces and territories have reached with respect to switching technologies. Let us examine how these different types of switching technologies are interrelated and how they are affected by the Law of the Retarding Lead.

Figure 4.9 is assembled from a survey by the author of

FIGURE 4.9

CENTRAL OFFICES BY TYPE: 1965-1983

Canada's major telephone companies, and examines the "development" of central offices, by type, from 1965 to 1983 and includes both manual and automatic switching technologies. This survey of nine major telephone companies represents a sample of 90.2 percent or nearly fifteen out of a possible 16.6 million telephones in 1983.

Central offices, as opposed to number of telephones, helps explain adoption of innovation primarily because the type and number of central offices are indicative of: (1) technological progress; and (2) the incremental growth of telephone subscribers as population increases.

Two significant patterns are evident. The first concerns allometric growth rates and the second describes how learning curves affect the Law of the Retarding Lead. The allometric growth rates for the four switching technologies are described as follows. The SXS system has had relative decline up until 1975 and has since been in absolute decline. The XBAR system, up until 1965, has had a maximum growth rate of 0.5 and has been slowing down at a rate slower than that of the SXS.

The two remaining central office types appear to be diametrically opposed to each other. Statistics Canada indicates that as of 1983, there were a total of 333 telephones (located in N.S. and Quebec) connected to manual

office units; the last manual central office code disappeared in Canada in 1979 with B.C. Tel. The technology has been used extensively for almost sixty years and this closure completes the formal termination of the manual system.

Bell Canada first used the electronic central office in 1967. Electronic offices carried over alpha values as high as 3.4 for the first five years after introduction, but have slowed down since 1973 to half its early rate or approximately 1.4.

4.4.3 Learning Curves

The expected pattern is that more telephones can be connected to fewer central offices. Moreover, costs will tend to decrease for every technological alteration/change done to that particular type of central office. The number of telephones connected to that central office does not necessarily indicate an increase in the use of that technology as it does not necessarily reflect the decreasing structural size of the network that telephones are intimately based on. Hence, number of central offices indicate limits of technology versus limits of adoption of innovation.

The three remaining switching technologies (SXS, XBAR, electronic) are associated with certain limits. The earlier central office technology is capable of handling the least

amount of telephone lines and the most up to date system is still trying to increase its relative capacity to a maximum that is yet unknown. It is known however that in 1965 it had taken Canada slightly over 1900 central office codes to be able to sustain all telephone traffic. In 1983, it had increased by 400 and the numbers will remain to increase, primarily at the fate of losing the SXS and XBAR system at some future time.

Figure 4.10 is typical of how learning curves are applied to the diffusion of technology. The B.C. Tel example compares the declining costs of electromechanical and ESPC (an electronic type) toll equipment. It appears to be that although the electromechanical equipment has a higher learning curve, the ESPC equipment is more favourable due to its lower initial costs (which are approximately a fifth of the electromechanical upkeep costs).

4.5.4 Electronics: A Growing Network

Allometric growth trends support the Law of the Retarding Lead within the electronic type of switching equipment. Figure 4.11 is based on Bell Canada (1984) information, and confirms earlier national trends. The three power trends in the figure are three separate types of electronic switching equipment. ESS and SP1 are stored-program-controlled switching systems that utilize a special purpose digital computer for the control and processing of

FIGURE 4.10
ANNUAL UPKEEP COSTS PER TRUNK LINE
Termination Comparison Between
Electromechanical & ESPC Toll Equipment
(Note: In Constant 1980 Dollars)

Source: British Columbia Telephone Company, General Rate Increase Application, October 26, 1984.

FIGURE 4.11
BELL CANADA CENTRAL OFFICES AT END OF YEAR

Source: Bell Canada (1984), Bell Annual Charts 1965-1983 (Abridged)

telephone calls. DMS is a compact "digital multiples system" designed to handle subscribers' lines at a point remote from the central office. The trend is that later technologies (even within the same type) are adopted much more rapidly than the previous one. Note the changes from ESS to SP1 to DMS in the Bell example.

Bell is not the only company utilizing this type of equipment. In 1981, NB Tel (1983, p.7), spent \$14 million on a digital switching and transmission system and has at present 26.7 percent of the equipped capacity as electronic switching (1985). Manitoba's first digital switch was installed in 1980 and the utility has been gradually modernizing its telephone network. Edmonton Telephones (1982, p.8) programs to retire its existing SXS switching system began in 1979 and will be completed by 1987. Telebec (1985) has had electronic technology since 1974 and according to its present plans, another ten electronic switchers will be installed over the next five years. By the end of 1983, over 40 percent of B.C. Tel lines were served by electronic switching. B.C. Tel claims to have the highest percentage of all investor-owned telephone companies in Canada and that by 1988, 92 percent of its system will be electronic, of which two-thirds will be digital (B.C. Tel., 1984, p.65).

The question of how many innovations will appear until

the beginning of the next century is difficult to answer. Marchetti's (1980) analysis indicates that the crucial years appear to be between 1984 and 2000, when eighty percent of the basic innovations will have been introduced. Northern Telecom, a leading telecommunications industry, does not expect any revolutionary new technologies between now and 1990. The basic technologies are known, and any changes that occur will be evolutionary. Noble, a vice-president of Northern Telecom, made a prediction similar to that of Marchetti.

We are confident that we know the kinds of products that will be introduced in our industry ... the hard thing is to gauge the timing of their introduction and the rates of development of various markets.

(Noble, 1984, p.8)

It is strongly believed that with this in mind, no major technological breakthroughs will be made concerning the discovery of other switching technologies. Major growth of existing electronic switching equipment is nevertheless anticipated within the next five years.

4.6 Conclusion

The number of telephones will probably continue to increase at the present rate until saturation level is achieved. However, technology is ever changing and will undoubtedly offer alternate and additional services that are connected/associated with the use of the telephone (e.g.,

banking, home shopping). The allometric growth trends for telephone switching equipment by central office type are indicated in Figure 4.12. Furthermore, once this saturation level has been reached (every adult and child having at least a telephone), the growth of telephone services can continue to increase at a phenomenal rate, primarily because of these "additional" services offered by telephone companies (e.g. stopping crank telephone calls; Kennedy, 1984), cable companies and associated firms.

It is clear from the data obtained from the major ~~telephone~~ companies that the three early generations of switching technology (manual, SXS and XBAR) are being overtaken by more modern switches that are totally electronic and computer controlled. Moreover, rates of growth for several geographic regions do not appear to follow the normative hierarchical model that has been associated with similar types of technologies. The general trend indicates that later adopters achieve faster adoption rates.

FIGURE 4.12
ALLOMETRIC GROWTH TRENDS FOR
TELEPHONE SWITCHING EQUIPMENT
BY CENTRAL OFFICE TYPE

CHAPTER 5

GEOGRAPHY AND THE LAW OF THE RETARDING LEAD

- SUMMARY AND PROSPECTS -

The Law of the Retarding Lead has been frequently asserted but never rigorously tested. The Law states that later adopters of innovation achieve higher rates of growth. This thesis reviews the theoretical underpinning required for a comprehensive restatement of the Law of the Retarding Lead.

The GST literature argues that universal laws describe all growth. General Systems Theory makes a distinction between absolute growth and relative growth. Absolute growth is examined through time, while relative growth or allometric growth, describes the regularities that occur in the growth of a part of a system in relation to the whole. A number of laws of growth are suggested (Thompson, Huxley, Bertalanffy) of which the law of allometry provides a link between growth and form.

Nevertheless, a relationship is sought between dynamic growth and diffusion of innovation. The Law of the Retarding Lead has been placed within the context of

geography and the social sciences literature; hence, the Law is deemed to have an interdisciplinary nature. Moreover, broad regularities come to light when the rate of adoption by a region is measured against the system total. The two empirical regularities are allometry and the Law of the Retarding Lead.

Like diffusion, allometry and the Law of the Retarding Lead have made important contributions to the understanding of geography. Historians did not test the idea of Retarding Lead mathematically, and did not attempt to explain the process. Biologists have researched the law of allometry and confirmed that this law of growth holds widely. Social scientists have experimented with both these concepts (diffusion and allometry).

Geographers in particular, examine growth across space through time. Key ideas concerning diffusion of innovation have been made by Hagerstrand, Berry and Brown, among others. An underlying process is present in various stages of invention and innovation: Marchetti has suggested a cyclical behavior and Kindleberger advocates a process of product standardization and specialization. Geographers have applied the concept of allometry within a spatial context. Research on diffusion on the other hand have not incorporated the concept of allometry. The main barrier is that academics were too concerned with interconnecting

growth and form in a purely spatial context. For example, Nordbeck's interrelationship between the area of a city and its total population. There are certain deficiencies with this approach. In diffusion research, only the date of first adoption in each location is considered -- but not the subsequent growth at each location. In turn, growth through time obscures interdependencies in growth rates among locations competing for growth.

This thesis investigates the diffusion, allometry and growth gradients for two important current innovations: cable television and telephone switching equipment. The first case examines rates of diffusion of innovation of cable television. The growth of cable television in the country as a whole is typically logistic. However, the more peripheral, economically disadvantaged regions have tended to have faster rates than the core regions. Furthermore, catch up rates are seen to be an important factor in determining different rates of growth. Smaller population size cities swiftly accelerate with early growth rates. Larger cities begin with lower growth rates but eventually increase. The Law indicates that the core regions (the slower growth areas will eventually "catch up" with the periphery.

The second case study investigates the technological diffusion of telephone switching equipment. We can observe

that Retarding Lead applies not only within any given technology and any given innovation, but may also apply between different technologies and products. Allometric growth trends indicate that the three early generations of technology (manual, SXS, XBAR) are being overtaken by more modern switches that are totally electronic and computer controlled. Moreover, rates of growth within the electronic technology appear to be even more rapid as their products are increasingly ameliorated.

The Law of the Retarding Lead is proposed as an integration of the various types of growth that are presently known to general systems theorists. If a nation's or social groups' development is delayed, it will catch up once the impediments to growth are removed. Thus, an attempt is made to maintain the growing component of the system (social, economic, etc.) in balance with the growing supra-system (the nation as a whole or world dynamics).

This thesis has opened up many avenues and questions that require further exploration on the Law of the Retarding Lead. The Law could potentially be used as an alternative research tool that has never been tested in the past. The Law of the Retarding Lead has strong potential to influence decisions made by policy oriented organizations. This may in turn lead to the accurate timing of adoption of innovation. Without a doubt, more in-depth research is

required to examine how and why later adopters of innovation achieve higher rates of growth.

APPENDIX A
CANADIAN
TELEVISION AND CATV CITIES

		1	1	2	3
	PROVINCE	POP	TYPE	CABLE	TELEVISION
ABBOTSFORD	BC	12745	DM	67	
AGASSIZ	BC	< 3000		78	
AJAX	ONT	25475	T	68	
ALLISTON	ONT	< 5000		71	
ALMA	QUE	26322	V	77	
ALSASK	MAN	< 5000		69	
AMHERST	NS	9684	T	72	
AMOS	QUE	9421	V	57	80 S
ANTIGONISH	NS	5205	T	78	
ARGENTIA	NFLD	< 5000			57
ARNPRIOR	ONT	5828	T	76	
ASBESTOS	QUE	7967	V	54	
ASCOT	QUE	8848	CT	71	
ATHABASCA	ALTA	5974	CM	75	
ATIKOKAN	ONT	< 5000		55	
AURORA	ONT	16267	T	65	
AYERS CLIFF	QUE	< 5000		63	
AYLMER	ONT	5254	T	66	
BAGOTVILLE	QUE	< 5000		55	
BAIE ST-PAUL	QUE	< 5000		56	
BAIE-COMEAU	QUE	12866	V	78	
BANCROFT	ONT	< 5000	VL		74
BANFF	ALTA	< 5000		80	
BARRIE	ONT	38423	C	63	55 S
BATHURST	NB	15703	C	78	
BEARDMORE	ONT	< 5000		65	
BEAUCEVILLE EST	QUE	< 5000		55	
BELLEGARDE	SASK	< 5000			80
BELLEVILLE	ONT	34881	C		56
BELOEIL	QUE	17540	V	62	
BLACK LAKE	QUE	5148	V	56	
BLAIRMORE	ALTA	< 5000	T	76	
BOLTON	ONT	< 5000		69	
BONNE BAY	NFLD	< 5000			67
BOUCHERVILLE	QUE	29704	V	65	
BRACEBRIDGE	ONT	9063	T	63	
BRAMPTON	ONT	149030	C	65	
BRANDON	MAN	36242	C	77	55 S
BRANTFORD	ONT	74315	C	65	
BROCKVILLE	ONT	19876	C	62	
BROMPTONVILLE	QUE	< 5000	T	58	
BROOKS	ALTA	9421	T	79	
BUCKINGHAM	QUE	7992	V	67	
BURLINGTON	ONT	114853	C	66	
BURNABY	BC	136494	DM	62	
CABANO	QUE	< 5000	T	78	
CALGARY	ALTA	592743	CMA	71	54 S
CAMPBELLFORD	ONT	< 5000	T	66	
CAMPBELL RIVER	BC	15832	DM	56	
CAMPBELLTON	NB	9818	C		76
CAMROSE	ALTA	12570	C	77	
CAP-DE-LA-MADELEINE	QUE	32626	C	63	
CARLETON	QUE	< 5000	T		59
CASTLEGAR	BC	6902	C	57	
CFB SHILO	MAN	< 5000		71	
CFS MOISIE	QUE	< 5000		71	

CHANDLER	QUE	< 5000	T		61
CHAPAIS	QUE	< 5000	T	60	
CHAPLEAU	ONT	< 5000		58	
CHARLOTTETOWN	PEI	15282	C	76	68 S
CHATHAM	NR	6779	T	78	
CHATHAM	ONT	40952	C	67	76
CHIBOUGAMAU	QUE	10732	V	60	
CHICOUTIMI--(JONQUIERE)	QUE	135172	CMA	75	63 S
CHILLIWACK	BC	40642	DM	64	
CLERMONT	QUE	< 5000		66	
COATICOOK	QUE	6271	V	57	
COLERAINE	QUE	< 5000		66	
COLGATE	SASK	< 5000	VL		62
COLLINGWOOD	ONT	12064	T	63	
COOKSHIRE	QUE	< 5000	T	65	
COQUITLAM	BC	61077	DM	65	
CORNER BROOK	NFLD	24339	T	77	59 S
CORNWALL	ONT	46141	C	57	58
COWANSVILLE	QUE	12240	V	65	
CRANBROOK	BC	15915	C	54	62
CRESTON	BC	< 5000	T	55	
CYPRESS HILL	SASK	< 5000			79
DALHOUSIE	NR	> 5000	T	79	
DANVILLE	QUE	< 5000	T	59	
DARTMOUTH	NS	62277	C	71	
DAWSON CREEK	BC	11373	C		59 S
DEBDEN	SASK	< 5000	VL		79
DEEP RIVER	ONT	5075	T	67	
DEER LAKE	NFLD	< 5000	T	77	
DELTA	BC	74672	DM	66	
DESERONTO	ONT	< 5000			76
DISRAELI	QUE	< 5000	T	64	
DOLBEAU	QUE	8766	V	56	
DOWNSVIEW	ONT	> 5000		67	
DRUMHELLER	ALTA	6508	C		54
DRUMMONVILLE	QUE	27347	C	55	
DRYDEN	ONT	6640	T	54	
DUNCAN	BC	< 5000	C	74	
EAST ANGUS	QUE	< 5000	T	61	
EAST BRIGHTON	QUE	< 5000		63	
EDMONTON	ALTA	657057	CMA	71	54 S
EDMUNDSTON	NR	12041	C	56	
ELLIOT LAKE	ONT	16723	T	76	
ESTEVAN	SASK	9174	C	63	
FABREVILLE	QUE	> 5000		59	
FERGUS	ONT	6064	T	68	
FERME NEUVE	QUE	< 5000	VL	59	
FERNIE	BC	5441	C	57	
FORESTVILLE	QUE	< 5000	T	79	
FORT McMURRAY	ALTA	31000	C	70	70
FREDERICTON	NR	43723	C	59	
GASPE	QUE	17261	V		81
GATINEAU	QUE	74988	V	67	
GENTILITY	QUE	< 5000		72	
GEORGETOWN	ONT	> 5000		68	
GERALDTON	ONT	< 5000	T	32	
GILLIES BAY	BC	< 5000		77	
GIRARDVILLE	QUE	< 5000		61	
GLACE BAY	NS	21466	T	76	
GLOVERTOWN	NFLD	< 5000	T	81	

GOOSE BAY	NFLD	< 5000			56 S
GRANBY	QUE	38069	V	62	
GRAND FALLS	NFLD	8765	T	77	
GRAND PRAIRIE	ALTA	24263	C	75	54
GRAND'MERE	QUE	15442	V	54	
GRANDE VALLES	QUE	< 5000		63	
GRAVELBOURG	SASK	< 5000	T		80
GUELPH	ONT	71207	C	53	
HALIFAX	NS	277727	CMA	71	54 S
HAMILTON	ONT	542095	CMA	58	54 S
HANDOVER	ONT	6316	T	68	
HAWKESBURY	ONT	9877	T	63	
HINTON	ALTA	8342	T	59	
HOPE	BC	< 5000	T	77	
HULL	QUE	56225	V		55 S
HUNTSVILLE	ONT	11457	T	56	
IBERVILLE	QUE	8587	V	76	
JASPER	ALTA	< 5000		79	
JONQUIERE	QUE	60364	V		55 S
KAMLOOPS	BC	64048	C	74	57 S
KASLO	BC	< 5000	VL	59	
KELOWNA	BC	59196	C	57	57 S
KENTVILLE	NS	> 5000	T	74	
KESWICK	ONT	< 5000		75	
KIMBERLEY	BC	7375	C	54	
KINCARDINE	ONT	5778	T	71	
KINGSTON	NS	< 5000		75	
KINGSTON	ONT	52616	C	73	54 S
KITCHENER	ONT	287801	CMA	62	54 S
KITIMAT	BC	12811	DM	73	
L'ANNOUCCIATION	QUE	< 5000	VL	62	
LA BELLE	QUE	< 5000		56	
LA PATRIE	QUE	< 5000	VL	74	
LA POCAITIERE	QUE	< 5000	T	56	
LA SERRE	QUE	< 5000		76	
LA TUQUE	QUE	11556	V	68	
LABRADOR CITY	NFLD	11538	T		65 S
LAC AUX SABLES	QUE	< 5000		56	
LAC ROUCHETTE	QUE	< 5000	VL	56	
LAC CARRE	QUE	< 5000	VL	57	
LAC DES ECORCES	QUE	< 5000	VL	77	
LAC EDOUARD	QUE	< 5000		59	
LAC ETCHEMIN	QUE	< 5000	T	71	
LAC MEGANTIC	QUE	6119	V	56	
LACOMBE	ALTA	5591	T	78	
LANGFORD	BC	> 5000		66	
LEAKINGTON	ONT	12528	T	69	
LEREL-SUR-QUEVILLON	QUE	< 5000	T	67	
LENNOXVILLE	QUE	< 5000	T	60	
LETHBRIDGE	ALTA	54072	C	64	55 S
LINDSAY	ONT	13596	T	66	
LISTOWEL	ONT	5026	T	75	
LIVERPOOL	NS	< 5000		75	
LLOYDMINSTER	SASK	6034	C		58 S
LLOYDMINSTER	ALTA	8997	C	78	60 S
LONDON	ONT	283668	CMA	51	53 S
LUNENBURG	NS	24593	MD	75	
MADOC	ONT	< 5000	VL	66	
MAFEKING	MAN	< 5000			78

MAGOG	QUE	13604	C	58	
MALARTIC	QUE	> 5000	T	60	
MANIWAKI	QUE	5124	V	56	
MARQUIS	SASK	< 5000	VL		64
MARSOUI	QUE	< 5000	VL	59	
MARYSTOWN	NFLD	6299			65
MATAGAMI	QUE	< 5000	T	64	
MATANE	QUE	13612	V		58 S
MATTICE	ONT	< 5000		72	
MEDECINE HAT	ALTA	40380	C		57 S
MELFORT	SASK	6010	C		73
MERRIT	BC	6110	C	61	
MIDLAND	ONT	12132	T	55	
MILK RIVER	ALTA	< 5000	T	76	
MISSISSAUGA	ONT	315056	C	68	
MITCHEL	ONT	< 5000	T	75	
MONCTON	NB	54743	C	75	54 S
MONT APICA	QUE	< 5000		70	
MONT TREMBLANT	QUE	< 5000		62	
MONT-LAURIER	QUE	8405	V		62
MONTMAGNY	QUE	12105	C	79	
MONTREAL	QUE	2828349	CMA	6 SEP 52	52 S
MOOSE JAW	SASK	33941	C	78	69
MYNARSKI PARK	ALTA	< 5000		66	
McADAM	NB	< 5000	VL	76	
NACKAWIC	NB	< 5000	T	69	
NANAIMO	BC	47069	C	64	
NANOOSE BAY	BC	< 5000		80	
NELSON	BC	9143	C	53	
NEW GLASGOW	NS	10464	T	71	
NEW LISKEARD	ONT	5551	T	59	
NEW WESTMINSTER	BC	38550	C	65	
NEWMARKET	ONT	29753	T	65	
NIPAWIN	SASK	< 5000	T		78
NORANDA	QUE	8767	C		57 S
NORMANDIN	QUE	< 5000	VL	52	
NORTH BATTLEFORD	SASK	14030	C	75	
NORTH BAY	ONT	51268	C	62	72 S
NORTH HATLEY	QUE	< 5000	VL	66	
NORTH VANCOUVER	BC	33952	C	58	
NOTRE DAME DU LAUS	QUE	< 5000		77	
NOTRE-DAME-DE-LA-ROSE	QUE	< 5000		56	
NOTRE-DAME-DES-ANGES	QUE	< 5000		70	
OAKVILLE	ONT	75773	T	70	
OLIVER	BC	< 5000	VL	63	
ORANGEVILLE	ONT	13740	T	68	
ORILLIA	ONT	23955	C	63	
OSHAWA	ONT	154217	CMA	66	53*
OTTAWA-HULL	QUE	170579	CMA	63	
OTTAWA-HULL	ONT	547399	CMA	64	53 S
OWEN SOUND	ONT	19883	C	57	
PARIS	ONT	7485	T		74 S
PARKSVILLE	BC	5216	T	75	
PARRY SOUND	ONT	6124	T	61	
PEMBROKE	ONT	14026	C	67	77 S
PENTICTON	BC	23181	C	56	70
PETERBOROUGH	ONT	60620	C	56	55 S
PICKERING	ONT	37754	T	71	
PICTON	ONT	< 5000	T	68	
PINCHER CREEK	ALTA	< 5000	T	77	

PLESSIVILLE	QUE	7249	V	61	
PONOKA	ALTA	5221	T	78	
PONTEIX	SASK	< 5000		70	79
PORT ALBERNI	BC	19892	C	56	
PORT ALFRED	QUE	< 5000		66	
PORT REXTON	NFLD	< 5000			65
PORT-AUX-BASQUES	NFLD	< 5000		78	
POWEL RIVER	BC	13423	DM	55	
PRINCE ALBERT	SASK	31380	C		58
PRINCE GEORGE	BC	67559	C	75	61 S
PRINCE RUPERT	BC	16197	C	71	
PRINCEVILLE	QUE	< 5000	T	61	
QUAMISH	BC	10272	DM	57	
QUEBEC	QUE	576075	CMA	61	54 S
RED DEER	ALTA	46393	C		57 S
REGINA	SASK	164313	CMA		54 S
RENFREW	ONT	8283	T	76	
REVELSTOKE	BC	5544	C	57	
RICHMOND	QUE	< 5000	T	55	
RIMOUSKI	QUE	29120	V		54 S
RIVIERE DU LOUP	QUE	13459	C	72	62 S
RIVIERE-A-PIERRE	QUE	< 5000		56	
ROBERTSONVILLE	QUE	< 5000	VL	68	
ROCK ISLAND	QUE	< 5000	T	56	
ROCKLAND	ONT	3961	T	68	
ROUYN	QUE	17224	C	74	57 S
SAANICH	BC	78710	DM	71	
SAGUENAY-LAC ST JEAN	QUE	> 5000			82 S
SAINT JOHN	NR	114048	CMA	74	54 S
SARNIA	ONT	50892	C	67	
SASKATOON	SASK	154210	CMA	78	51 S
SAULT STE MARIE	ONT	82697	C	72	53 S
SAWYERVILLE	QUE	< 5000	VL	67	
SCARBOROUGH	ONT	443353	BOR	70	
SCHREIBER	ONT	< 5000		55	
SECHLT	BC	< 5000	VL	70	
SELKIRK	MAN	10037	T	78	
SEPT ILES	QUE	29262	V	58	73 S
SHAWINIGAN	QUE	23011	C	55	
SHELROSE PARK	NS	< 5000		74	
SHERBROOKE	QUE	74075	V	55	56 S
SIDNEY	BC	7946	T	65	
SIDNEY	NS	< 5000			54
SIMCOE	ONT	14326	T	68	
SLAVE LAKE	ALTA	< 5000	T		81
SMITH FALLS	ONT	8831	T	68	
SOREL	QUE	20347	C	62	
SPRINGHILL	NS	< 5000		78	
SQUAMISH	BC	10272	DM	57	
STAR CITY/HELFORT	SASK	> 5000			73 S
ST BENOIT-LABRE	QUE	< 5000		66	
ST CATHERINES-NIAGARA	ONT	304353	C	66	53*
ST COME	QUE	< 5000		64	
ST DONAT	QUE	< 5000		57	
ST EVARISTE	QUE	< 5000		55	
ST FELICIE	QUE	> 5000	V	56	
ST GEDEON	QUE	< 5000		57	
ST GEORGES DE BEAUCE	QUE	< 5000		55	
ST GREGOIRE	QUE	< 5000	VL	57	
ST HUBERT	QUE	60573	V	75	

ST HYACINTHE	QUE	38240	V	61	
ST JEROME	QUE	25123	C	65	
ST JOHN'S	NFLD	154820			64 S
ST JOSEPH	QUE	< 5000		65	
ST JOVITE	QUE	< 5000	VL	55	
ST LAZARE	MAN	< 5000	VL	75	
ST LUDGER	QUE	< 5000	VL	55	
ST MARTIN	QUE	< 5000		55	
ST MARY'S	ONT	> 5000	T	68	
ST METHODE	QUE	< 5000		76	
ST MICHEL	QUE	< 5000		62	
ST PAMPHILE	QUE	< 5000	T	55	
ST PROSPER	QUE	< 5000		55	
ST RAYMOND	QUE	< 5000		54	
ST THEOPHILE	QUE	< 5000		56	
ST THOMAS	ONT	28165	C	62	
ST TITE	QUE	< 5000	T	55	
ST VICTOR	QUE	< 5000	VL	79	
ST ZACHARIE	QUE	< 5000		58	
STE ADELE	QUE	< 5000	T	62	
STE-ANGELE-DE-LAVAL	QUE	< 5000		59	
STE-ROSE-DU-LAC	MAN	< 5000	VL		76
STEPHEENVILLE	NFLD	8876	T	77	67
STETTLER	ALTA	5136	T	78	
STONE CREEK	ONT	36762	T	56	
STRATHMORE	ALTA	< 5000		79	
SUDBURY	ONT	91829	C	75	53 S
SUMMERSIDE	PEI	7828	T	77	
SUSSEX	NB	< 5000		74	
SWASTIKA	ONT	< 5000		58	
SWIFT CURRENT	SASK	14747	C	82	57 S
SYDNEY	NS	29444	C	77	54 S
TABER	ALTA	5998	T	74	
TERRACE	BC	10914	DM	72	62 S
TERRACE BAY	ONT	< 5000		52	
TERRE BONNE	QUE	11769	V	76	
THETFORD MINES	QUE	19965	V	56	
THOMPSON	MAN	14268	C	61	
THUNDER BAY	ONT	121379	C	60	54 S
TIMMINS	ONT	46114	C	75	56 S
TORONTO	ONT	2998947	CMA	61	8 SEP 52 S
TRAIL	BC	9599	C	55	76
TROIS-RIVIERES	QUE	111453		56	58 S
TRURO	NS	12552	T	67	
UXBRIDGE	ONT	11207	TP	72	74
VAL D'OR	QUE	21371	V	58	80 S
VALLEYFIELD	QUE	< 5000		31	
VANANDA	BC	< 5000		57	
VANCOUVER	BC	1268183	CMA	58	53 S
VEGREVILLE	ALTA	5251	T	78	
VERNON	BC	19987	C	74	
VICTORIA	BC	233481	CMA	59	56 S
VICTORIAVILLE	QUE	21838	V	64	
VILLE MARIE	QUE	< 5000	T	57	
WALLACEBURG	ONT	11506	T	68	
WARWICK	QUE	< 5000	T	53	
WATERLOO	QUE	< 5000	T	60	
WEEDON	QUE	< 5000	VL	66	
WELLAND	ONT	45448	C	74	
WESTLOCK NO. 92	ALTA	7059	ND	78	

WEYBURN	SASK	9523	C	63	
WHITE ROCK	RC	13550	C	67	
WHITECOURT	ALTA	5583	T	75	
WHITEHORSE	YUK	14814	C	58	
WILLOW BUNCH	SASK	< 5000	T		63
WINDSOR	NS	< 5000	T	76	
WINDSOR	QUE	5233	V	56	
WINDSOR	ONT	246110	CMA	84	54 S
WINGHAM	ONT	< 5000	T		55 S
WINNIPEG	MAN	584842	CMA	68	54 S
WOBBURN	QUE	< 5000		67	
WOODSTOCK	NR	< 5000	T	58	
WOODSTOCK	ONT	26603	C	63	
YARMOUTH	NS	7475	T	77	
YELLOWKNIFE	NWT	9483	C	72	68
YORKTON	SASK	15339	C		58 S
YOUNG	BC	< 5000		52	
ZENON PARK	SASK	< 5000	VL		79

Legend:

BOR	Borough
C	City
CM	County
CMA	Census Metropolitan Area
CT	Canton (Municipalité de)
MD	Municipal District
P	Paroisse (Municipalité de)
R	Indian Reserve
SCM	Subdivision of County Subdivision
SD	Sans Designation (Municipalité)
T	Town
VL	Village
S	Broadcasting Station

- Source:
- 1a. Statistics Canada (1983), 1981 Census of Canada, Catalogue 95-943, "Census Metropolitan Areas With Components," Ottawa: Minister of Supply and Services Canada;
 - b. 1981 Census of Canada, Catalogue 95-945, "Census Subdivisions of 5,000 Population and Over."
 2. Sol Taishoff, ed., (1983), Broadcasting/Cablecasting -- Yearbook 1983. U.S.: Broadcasting Publications Inc.
 - 3a. Albert Warren, ed., (1984), Television & Cable Factbook Vol.1: Stations Volume, Television Digest, Inc.;
 - b. C.B.C. (1982), CBC Background: English Television Stations; French Television Stations.;
 - c. Also to include source 2.

APPENDIX B

CANADIAN METROPOLITAN AREAS

CENSUS METROPOLITAN AREA ¹	YEAR BEGAN OPERATION			POPULATION ⁴ (1981)
	TELEVISION ²	CABLE ³	CHANGE (YR)	
1. St. John's	1964	1977	13	154 820
2. Halifax	1954	1971	17	277 727
3. Saint John	1954	1974	20	114 048
4. Chicoutimi-Jonquière	1963	1975	12	135 172
5. Québec	1954	1961	7	576 075
6. Trois-Rivières	1958	1956	- 2	111 453
7. Montréal	1952	1952	0	2 828 349
8. Ottawa-Hull	1953	1963	10	717 978
9. Oshawa	1953*	1966	13	154 217
10. St. Catharines-Niagara	1953*	1966	13	304 353
11. Toronto	1952	1964	12	2 998 947
12. Hamilton	1954	1958	4	542 095
13. Kitchener	1954	1962	8	287 801
14. Sudbury	1953	1975	22	149 923
15. London	1953	1951	- 2	283 668
16. Windsor	1954	1984	30	246 582
17. Thunder Bay	1954	1960	6	121 379
18. Winnipeg	1954	1968	14	584 842
19. Regina	1954	1978	24	164 313
20. Saskatoon	1954	1978	24	154 210
21. Edmonton	1954	1971	17	657 057
22. Calgary	1954	1971	17	572 743
23. Vancouver	1953	1958	5	1 268 183
24. Victoria	1956	1959	3	233 481

* Author's estimate of when they began receiving television signals, as they do not have a television broadcasting station in their home city.

APPENDIX B (CONTINUED)

- Source:
1. Statistics Canada (1983), 1981 Census of Canada, Catalogue 95-943, "Census Metropolitan Area With Components."
 - 2a. Albert Warren, ed., (1984). Television & Cable Factbook, Vol. 1: Stations Volume.
 - b. C.B.C. (1982). CBC Background: English Television Stations; French Television Stations.
 - c. Also to include source 3.
 3. Sol Taishoff, ed., (1983). Broadcasting/Cablecasting -- Yearbook 1983.
 4. Same as source 1.

APPENDIX C

GROWTH OF TV AND
CATV CITIES: 1950-1984

Year	TELEVISION ¹						CABLE TELEVISION ²					
	Number of Cities	Population Size					Number of Cities	Population Size				
		A	B	C	D	E		A	B	C	D	E
1951	0						1				1	
1952	2					2	4	3				1
1953	7			2	3	2	3	1	1	1		
1954	19	1	4	2	7	5	6	1	5			
1955	8	1		7			20	14	5	1		
1956	5	1		3	1		23	9	12	1	1	
1957	8	1	3	4			16	6	8	2		
1958	6		3	2	1		12	5	4	1		2
1959	3	1	2				11	6	3	1	1	
1960	1		1				6	3	2		1	
1961	2	1		1			10	4	4	1		1
1962	5	1	4				13	5	4	2	2	
1963	2	1		1			14	4	7	2	1	
1964	2	1		1			9	3	1	3		2
1965	3	1	2				13	3	6	3	1	
1966	0						13	8	2	1	2	
1967	2	1	1				13	3	7	3		
1968	2		2				15	3	10		1	1
1969	1			1			4	3	1			
1970	2		1	1			7	4		2	1	
1971	0						14	4	4	3	1	2
1972	1		1				8	2	5	1		
1973	3		3				2		1	1		
1974	3	1	2				11	4	4	2	1	
1975	0						18	5	7	5	1	
1976	5	2	2	1			13	6	7			
1977	1		1				15	6	8	1		
1978	2	2					17	4	11	1	1	
1979	4	4					7	4	3			
1980	4	2	2				2	2				
1981	2	1	1				1	1				
1982	1		1				1		1			
1983	0						0					
1984	0						1				1	
<hr/>												
Total												
Number of												
Cities:	106						323					

Population Size Groups:

- A. Less 5,000
- B. 5,000-29,999
- C. 30,000-99,999
- D. 100,000-499,999
- E. 500,000 and over

- Source: 1a. Television & Cable Factbook, Vol. 1: Stations Volume (1984).
 b. CBC Background: English Television Stations; French Television Stations (1982).
 c. Also to include source 2.
 2. Broadcasting/Cablecasting - Yearbook 1983.

APPENDIX D

STEPWISE REGRESSION VARIABLES

	1	2	3	4	5	6	7	8	9	10	11	12
	INCOME	ENG	FR	FORCHURN	COLOURTV	HOUSING	DISTCITY	POP81	DISTLC	POP10	CATV	ALPHA
1	8468	98.9	0.1	1.0	14.0	32.2	2602	154820	*	*	*	*
2	10176	94.3	1.0	7.1	25.8	32.8	1249	227727	*	*	*	*
3	8821	91.7	7.0	4.8	11.7	21.9	940	114068	*	*	*	*
4	9162	3.5	96.0	1.4	11.7	60.4	476	135172	*	*	*	*
5	10159	3.8	95.4	7.3	17.8	29.6	270	576025	*	*	*	*
6	8992	2.8	96.8	1.8	15.9	15.1	145	111453	*	*	*	*
7	10292	21.7	66.1	14.8	12.4	16.4	539	2878160	*	*	*	*
8	12010	56.5	16.6	12.6	22.0	11.9	190	217978	*	*	*	*
9	10192	84.1	2.7	20.0	11.1	17.2	20	154217	*	*	*	*
10	9997	76.4	5.5	21.0	21.9	15.8	115	104153	*	*	*	*
11	11841	73.0	1.7	14.1	19.7	15.1	539	2998947	*	*	*	*
12	10757	79.5	1.9	26.6	14.7	14.1	68	542095	*	*	*	*
13	10661	80.6	1.8	21.7	13.6	29.9	110	287801	*	*	*	*
14	11219	54.4	11.9	12.5	21.1	41.4	400	149923	*	*	*	*
15	12763	87.8	1.1	20.0	19.1	29.7	190	281668	*	*	*	*
16	11281	71.9	8.9	21.4	21.1	31.4	169	246587	*	*	*	*
17	10165	71.8	2.1	21.1	15.2	15.3	1184	171179	*	*	*	*
18	9989	70.8	5.7	29.9	18.1	31.4	2099	584842	*	*	*	*
19	9617	81.6	1.6	11.2	17.8	15.9	1822	164311	*	*	*	*
20	9479	79.2	2.2	14.9	0.6	15.0	1677	154210	*	*	*	*
21	10460	76.1	1.7	18.1	15.7	41.2	1244	657057	*	*	*	*
22	10943	84.0	1.3	20.5	19.7	40.4	1057	572743	*	*	*	*
23	10664	81.5	1.7	26.4	17.1	15.5	4491	1268183	*	*	*	*
24	9921	90.5	1.2	21.7	20.5	12.9	105	211681	*	*	*	*

CENSUS METROPOLITAN AREA (CMA) KEY:

1. St. John's	13. Kitchener
2. Halifax	14. Sudbury
3. Saint John	15. London
4. Chicoutimi-Jonquière	16. Windsor
5. Québec	17. Thunder Bay
6. Trois-Rivières	18. Winnipeg
7. Montréal	19. Regina
8. Ottawa-Hull	20. Saskatoon
9. Oshawa	21. Edmonton
10. St. Catharines-Niagara	22. Calgary
11. Toronto	23. Vancouver
12. Hamilton	24. Victoria

VARIABLE KEY:

- CMA: One of the 24 Census Metropolitan Areas in Canada
- INCOME: Average total family income, 1971
- ENGFR: % English divided by % French as mother tongue, 1971
- FORGBORN: % Foreign born, 1971
- COLOURTV: % Dwellings with colour TV, 1971
- HOUSING: % Construction of dwellings, 1946-1960
- POP81: City population, 1981
- DISTLG: Logarithm of DISTCITY
- DISTCITY: Distance in km to closest of Montréal, Toronto, Vancouver
- POPLG: Logarithm of POP81
- CATV: Year cable began operation in individual city
- ALPHA: Provincial alpha value for CATV city

SOURCE:

1. Statistics Canada (1983), 1981 Census of Canada, Catalogue 95-943, "Census Metropolitan Areas With Components."
2. D. Michael Ray (1976), Canadian Urban Trends, Vol. 1: National Perspective, Table A4.2, pp.170-172.
3. Ray (1976), Table A6.4, pp.271-273.
4. Ray (1976), Table A6.3, pp.268-270.
5. Ray (1976), Table A7.1, pp.300-304.
6. Ray (1976), Table A1.1, pp.32-34.
7. Calculated along main highways and included ferry distances.
8. Same as source 1.
9. Output calculated by SPSSX program.
10. Output calculated by SPSSX program.
11. Appendix B: Canadian Metropolitan Areas.
12. Table 3.1.

APPENDIX E
SURVEY OF MAJOR
TELEPHONE COMPANIES

Includes:

- List of Correspondance
- Sample Letters
- Author's Tabulation of Data

TELEPHONE COMPANIES

COMPANY:	RECEIVED LETTER DATED:
1. British Columbia Telephone Company Mr. T.F. Meenan President & Chief Operating Officer 3777 Kingsway Burnaby, B.C. V5H 3Z7	5 Feb 85
2. Manitoba Telephone System Mr. B.A. Gordon Director - Engineering & Corporate Information Services Box 6666, 489 Empress St. Winnipeg, Manitoba R3C 3V6	11 Feb 85
3. Newfoundland Telephone Company Limited Mr. G.A. Martin Network Planning Manager Fort William Building P.O. Box 2110 St John's, Newfoundland A1C 5H6	18 Feb 85
4. Têlêbec Ltée M. Gilles Leclerc Vice-président Exploitation 3232, rue Bélanger est Montréal, Québec H1V 1B7	19 Feb 85
5. Alberta Greater Telephones Mr. H.M. Naldner President P.O. Box 2411 Edmonton, Alberta T5J 2S4	22 Feb 85
6. Québec-Têlêphone M. Gilles Laroche Vice President - Business Development Department 300 Rimouski, Québec G5L 7E4	27 Feb 85
7. The New Brunswick Telephone Company Limited Mr. P.G. Jollymore Chief Engineer One Brunswick Square P.O. Box 1430 Saint John, N.B. E2L 4K2	4 Mar 85
8. edmonton telephones Mr. K.E. Digweed Network Operations Manager P.O. Box 20500 Edmonton, Alberta T5J 2R4	19 Mar 85

January 10, 1985

Mr. Terence F. Heenan,
President & Chief Operating Officer,
British Columbia Telephone Company,
3777 Kingsway,
Burnaby, B.C. V5H 3Z7.

Dear Mr. Heenan:

One of my full time graduate students, Mr. André Levesque, is presently working on a Master's thesis on the timing of adoption of innovations in cable television and telephone switching equipment.

One company Bell Canada has provided us with data on telephone switching equipment. Our primary interest is examining the various types and numbers of central offices (by year from 1965 to the present time) for several geographic regions. Your 1984 Facts Book (p. 65) indicate that "by the end of 1983, over 40% of customer lines were served by electronic switching, the highest percentage of all investor-owned telephone companies in Canada and that by 1988, 92% of the system will be electronic...". Hence, based on Bell Canada's information and the statement found in your Facts Book, it appears that there are different rates of growth with respect to electronic switching equipment and that possibly this difference may be explained by the proposed lagging lead theory.

In order to complete the thesis we are presently canvassing other telephone companies for comparable data. An appendix that has been made available by Bell Canada is attached. This letter requests the data needed for completion of a similar table for your company. Should you have any questions please contact me collect at (613) 231-2641. Thank you for your consideration in this matter and I anticipate hearing from your Company soon.

Yours sincerely,

D. Michael Ray,
Professor

DMR:mo
c.c. Mr. André Levesque
attach.

CENTRAL OFFICES¹

Year	Manual	Step-by-Step	Crossbar	Electronic			Remote Line Module	Total
				ESS	SPI	DMS		
1965	44	766	296					1 106
1966	35	783	341					1 159
1967	26	797	382	1				1 206
1968	25	802	424	1				1 252
1969	30	823	466	6				1 326
1970	15	826	514	12				1 367
1971	9	831	538	23				1 401
1972	8	834	558	31	1			1 432
1973	5	826	584	38	4			1 457
1974	1	798	606	48	19			1 472
1975	xxx	784	621	47	46			1 498
1976	xxx	778	628	47	80			1 533
1977	xxx	774	639	48	104			1 565
1978	xxx	762	645	48	125	1		1 581
1979	xxx	749	654	49	144	2		1 598
1980	xxx	756	658	52	157	23		1 646
1981	xxx	728	658	52	163	80		1 681
1982	xxx	706	653	51	170	143	2	1 725
1983	xxx	681	650	48	174	181	3	1 737

1. Represents Central Office Codes.

Source: Bell Canada (1984). Bell Annual Charts 1965-1983 (Abridged).

March 1, 1985

Mr. T.F. Heenan,
President & Chief Operating Officer,
British Columbia Telephone Company,
3777 Kingsway,
Burnaby, B.C. V5H 3Z7

Dear Mr. Heenan:

I would like to thank you for responding to our request for data on your Company's telephone switching network. The information that you have kindly made available will be integrated with that of other major telephone companies and will enable us to complete our research.

Although we have not yet received data from all companies it is clear that the three early generations of switching technology (manual, step by step and crossbar) are being overtaken by more modern switches that are totally electronic and computer controlled. Moreover, rates of growth for several geographic regions do not appear to follow the normative hierarchical model that has been associated with similar type of technologies. The general trend indicated that later adopters achieve faster adoption rates.

Once again, thank you for the assistance you afforded us recently and please extend our thanks to Mr. G.F. Auchinleck as well; his courtesy and cooperation was greatly appreciated by us.

Yours sincerely,

D. Michael Ray,
Professor

DMR:mo
c.c. Mr. André Levesque
attach.

NUMBER OF TOTAL
CENTRAL OFFICE CODES,
BY COMPANY, 1965-1983

TELEPHONE COMPANY	YEAR																		
	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83
Bell Canada	1106	1159	1206	1252	1326	1367	1401	1432	1457	1472	1498	1533	1565	1581	1598	1646	1681	1725	1737
B.C. Tel	270	285	307	320	326	335	344	352	362	372	376	388	404	416	427	429	435	446	450
ACT**	*	*	*	*	*	*	*	*	*	410	425	433	382	370	378	391	363	336	310
MTS	242	244	246	246	248	248	249	249	255	256	257	264	267	273	273	273	273	275	276
edmonton telephones	22	22	22	22	23	25	27	28	30	31	34	36	38	42	42	45	48	49	52
NB Tel	84	93	97	100	104	108	111	110	110	110	107	110	110	110	110	110	113	113	118
Québec-Téléphone	142	137	140	146	144	144	143	142	140	141	140	138	138	137	137	137	136	136	136
Newfoundland Telephone	38	39	46	55	59	63	70	73	80	80	77	80	83	85	90	93	93	98	102
Télébec	*	*	*	*	*	*	*	*	*	*	*	103	103	103	113	115	117	120	120
TOTAL:	1904	1979	2064	2141	2230	2290	2345	2386	2434	2472	2514	2590	2670	2717	2768	2839	2929	3028	3101

Notes: * Data not available.
** Estimate based on number of working lines.

NUMBER OF MANUAL
CENTRAL OFFICE CODES,
BY COMPANY, 1965-1983

TELEPHONE COMPANY:	YEAR																		
	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83
Bell Canada	44	35	26	25	30	15	9	8	5	1	-	-	-	-	-	-	-	-	-
B.C. Tel	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	-	-	-	-
AGT**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MTS	105	97	84	66	59	43	35	27	19	16	9	3	-	-	-	-	-	-	-
edmonton telephones	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NB Tel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Québec-Téléphone	71	60	48	31	20	15	11	10	9	8	3	-	-	-	-	-	-	-	-
Newfoundland Telephone	31	13	12	12	12	11	11	10	10	4	-	-	-	-	-	-	-	-	-
Télébec Ltée	*	*	*	*	*	*	*	*	*	*	*	2	2	2	2	-	-	-	-
TOTAL	325	207	177	136	123	86	67	56	44	30	13	6	3	3	1	-	-	-	-

Notes: - Nil.

* Data not available.

** Estimate based on number of working lines.

NUMBER OF STEP BY STEP
CENTRAL OFFICE CODES,
BY COMPANY, 1965-1983

TELEPHONE COMPANY:	YEAR																		
	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83
Bell Canada	766	783	797	802	823	826	831	834	826	798	784	778	774	762	749	756	728	706	681
B.C. Tel	268	283	305	318	324	333	337	344	353	361	360*	363	365	369	353	349	342	343	342
ACT**	*	*	*	*	*	*	*	*	*	326	329	326	248	216	212	211	155	110	79
MTS	132	135	138	139	139	140	141	143	145	145	147	148	146	147	146	144	144	143	142
edmonton telephones	22	22	22	22	22	22	23	23	25	25	24	23	23	23	23	22	22	22	15
NB Tel	67	65	66	65	65	68	69	69	69	69	66	66	66	66	66	66	65	65	65
Québec-Téléphone	60	60	72	91	93	95	92	88	83	82	80	79	79	77	75	75	72	72	69
Newfoundland Telephone	25	25	31	38	39	41	41	42	43	43	43	43	43	43	44	43	42	37	37
Télébec Ltée	*	*	*	*	*	*	*	*	*	*	*	65	65	65	77	78	79	76	75
TOTAL:	1340	1373	1431	1475	1505	1525	1534	1543	1544	1849	1843	1891	1809	1768	1745	1744	1649	1574	1505

Notes: * Data not available.

** Estimate based on number of working lines.

NUMBER OF CROSSBAR
CENTRAL OFFICE CODES,
BY COMPANY, 1965-1983

TELEPHONE COMPANY:	YEAR																		
	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83
Bell Canada	296	341	382	424	466	514	538	558	584	606	621	628	639	645	654	658	658	653	650
B.C. Tel.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AGT**	*	*	*	*	*	*	*	*	*	74	80	82	88	93	96	101	106	106	101
MTS	5	12	24	41	50	65	73	79	85	89	94	104	110	115	115	115	115	117	117
edmonton telephones	-	-	-	-	1	3	4	5	5	5	5	6	7	8	8	8	8	8	8
NB Tel	16	27	30	34	38	39	40	40	40	40	40	40	40	40	40	39	39	39	39
Québec-Téléphone	12	17	20	24	31	34	40	44	45	46	51	52	52	52	53	53	49	48	47
Newfoundland Telephone	-	1	1	5	8	11	18	21	27	32	32	32	32	33	35	35	35	35	35
Télébec Ltée	-	-	-	-	-	-	-	-	-	-	-	36	36	36	36	37	38	38	38
TOTAL:	329	398	459	528	594	666	713	747	786	892	923	980	1004	1022	1017	1046	1048	1044	1035

Notes: Nil.

* Data not available

** Estimate based on number of working lines.

NUMBER OF ELECTRONIC
CENTRAL OFFICE CODES,
BY COMPANY, 1965-1983

TELEPHONE COMPANY:	YEAR																		
	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83
Bell Canada	-	-	1	1	6	12	23	32	42	67	93	127	152	174	195	232	295	364	403
B.C. Tel	-	-	-	-	-	-	6	7	8	10	15	24	38	46	73	80	96	103	108
MTS	*	*	*	*	*	*	*	*	*	10	16	25	46	61	70	79	102	120	130
edmonton telephones	-	-	-	-	-	-	-	-	6	6	7	9	11	11	12	14	14	15	17
NB Tel	-	-	-	-	-	-	-	-	-	1	5	6	8	11	11	15	18	18	28
Québec-Téléphone	-	-	-	-	-	-	-	-	-	-	2	5	5	5	5	5	6	6	7
Newfoundland Telephone	-	-	-	-	-	-	-	-	-	-	5	6	7	8	9	9	15	16	20
Télébec Ltée	*	*	*	*	*	*	*	*	*	*	*	1	1	1	1	1	1	3	4
TOTAL:	-	-	1	1	6	12	29	39	59	100	146	209	276	326	387	450	563	670	745

Notes: Nil.

* Data not available.

** Estimate based on number of working lines.

Has had the electronic technology since 1974.

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