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**PROVIDING SUPPORT FOR THE
SCENARIO SELECTION PROBLEM:
AN INTELLIGENT ASSISTANT FOR
DEMOGRAPHIC PROJECTIONS**

by

RONALD DAWSON, B.B.A.

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

Masters of Management Studies

School of Business

**Carleton University
Ottawa, Ontario
April 22, 1994
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**"PROVIDING SUPPORT FOR THE
SCENARIO SELECTION PROBLEM:
AN INTELLIGENT ASSISTANT FOR
DEMOGRAPHIC PROJECTIONS"**

submitted by

Ronald S. Dawson, B.B.A.

in partial fulfilment of
the requirements for the degree of
Masters of Management Studies

Thesis Co-Supervisors

Director, School of Business

Carleton University
Ottawa, Ontario

May 19, 1994

Abstract

This paper represents research in the application of Expert System methodology to the area of population projections. When government demographic agencies publish a set of population projections, often only a sub-set is published. The reasons for publishing a sub-set include cost, but additionally there are issues associated with the value of a smaller sub-set to the users of population projections. The process of selecting which scenarios to include in a publication is a complex and time consuming process. Artificial Intelligence, and Expert Systems in particular, could potentially provide effective support to demographers in the scenario selection process. This paper outlines this process and discusses research into the applicability of Expert Systems in supporting this process.

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The completion of this thesis would not have been possible without the time, patience and support of a great number of people. It has been a long journey and I'd like to thank my co-supervisors, Professors Wojtek Michalowski and Roland Thomas, for their continued guidance and patience. I would also like to thank Professors David Cray and Vinod Kumar for their insightful comments throughout the process.

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"Prudent men should judge of future events by what has taken place in the past and what is taking place in the present."

- Miguel Cervantes in "Persiles and Sigismunda"

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I INTRODUCTION

Interest in human populations has a long history, but it was not until more recent times that the foundations of modern demography were laid. During the seventeenth century there was an increased interest in the study of human population. In the mid-part of the century, John Graunt carried out a numerical analysis of births and deaths, cumulating in a number of generalizations regarding fertility, mortality, marriage and migration as interrelated population processes. Graunt and his colleague, William Petty, are considered to be the founding fathers of demography (Pollard, 1974).

The advent of the industrial revolution set the stage for the work of Thomas Malthus in 1830. In his "Essay on the Principle of Population" he expressed his theories regarding the inability of food supply to increase as quickly as required to support ever increasing human populations (Malthus, 1960). It was not until nearly 100 years later that modern demography was actually established with the development of a mathematical model for the study of human reproduction by Alfred J. Lotka in 1925 (Cox, 1970).

Importance of Population Projections

The interest in human populations, particularly projections of future populations, is understandable. Users in the public sector are often required to make decisions regarding infrastructure projects such as schools, roadways, railroads, hospitals, airports and the like. The spatial and temporal population distributions that are part of population projections play a critical role in these infrastructure decisions.

Similarly, population projections can influence decisions made in the private sector. For example, the age distribution of future populations is particularly important.

The requirements of decision makers for population projections are fulfilled by different organizations. Many of these organizations are government statistical agencies, such as Statistics Canada.

Population Projections at Statistics Canada

Within Statistics Canada, population projections are generated by the Demography Division. The process followed is a multi-stage one, with demographic assumptions formulated in the early stages, the actual projections performed in the middle stages, and the selection of projection scenarios for publication in the later stages. Of these stages, it is the assumption formulation stage and the scenario selection stage which make the heaviest demands on demographic experts who must apply their knowledge and experience to a complex decision problem. This thesis focuses on the latter stage, the selection of scenarios for publication.

Expert Systems: An Opportunity

The process of projecting human populations is a complex and time consuming task. As is the case in many areas, computers can potentially play a useful role. Currently the computations involved in the middle part of the projection process heavily utilize computer technology. However, the assumption formulation and scenario selection stages do not utilize computer technology to a large extent.

One computer technology that may be useful in supporting the scenario selection decision process is Expert System (ES) technology. ESs have been successfully implemented in a number of other areas; the most notable being the areas of medicine,

engineering and finance (Waterman, 1986). However, there has been no significant work in the area of human population projections. It is possible that the complex interdisciplinary area of demography, and population projections in particular, has simply been overlooked as a field for suitable for ESs.

Research Focus

The focus of this research is an investigation of whether ES technology is appropriate for supporting the scenario selection stage of the population projections problem. A methodology is employed which equates the scenario selection process with a human decision-making situation that can be modelled. All aspects of the decision-making process are modelled. This includes the formal procedures, goals, and individual *expertise* that the demographic experts at Statistics Canada apply while solving the problem.

The resulting model, in its implementation form, is the Population Scenario Selection Assistant (PSSA). The PSSA is implemented as an ES prototype which is used to both assist in validating the model and in assessing the appropriateness of the application of ES technology to the scenario selection problem area. The primary potential users of the PSSA would be those involved in performing population projections at Statistics Canada.

Contents of Thesis

This paper is divided into several sections. Section 2 illuminates important concepts in demography and population projections. This section is particularly important

because it provides the background on population projections that is necessary for an understanding of the problem area.

The topics of Section 3 are Artificial Intelligence (AI) and Expert Systems. The section explores the role that ESs and AI have played in other areas, with a particular focus on ES applications in the social sciences.

Section 4 describes the scenario selection process at Statistics Canada. Sections 5 and 6 follow and outline the research methodology and describe the application of the methodology, respectively.

A presentation of the results is made in Section 7 through the description of a logical model. Section 8 further illustrates the model through the use of an example. This section is followed by a discussion of the implications of the results in Section 9.

II DEMOGRAPHY AND POPULATION PROJECTIONS

The study of human populations has a long history. Ancient Chinese, Arab and Greek philosophers have all concerned themselves with population issues. Subsequently, the work of European scholars such as Graunt, Petty, Malthus and Farr revitalized interest in the study of human populations (Pollard, 1974).

The term "demography" is derived from the Greek words, "δῆμος" (meaning the people) and "γράφειν" (to draw or write) (Cox, 1970). Since the introduction of the term in 1855 by Achille Guillard in his essay *Eléments de statistique humaine, ou démographie comparée*, demography has come to denote the study of human populations by statistical methods (Stockwell, 1976). Bogue (1969) gives a more precise definition of modern demography:

Demography is the statistical and mathematical study of the size, composition, and spatial distribution of human populations, and of changes over time in these aspects through the operation of the five processes of fertility, mortality, marriage, migration, and social mobility. Although it maintains a continuous descriptive and comparative analysis of trends, in each of these processes and in their net result, its long-run goal is to develop a body of theory to explain the events that it charts and compares.

Population Analysis

A number of demographic tools exist for the analysis of population. Chief among these tools is the census. The United Nations (Stockwell, 1976) defines a census as:

the total process of collecting, compiling and publishing demographic, economic and social data pertaining, at a specified time or times, to all persons in a country or delimited territory.

A census is a complete enumeration of the entire population of an area. While a census is theoretically all-encompassing it is, by its very nature, obsolete by the time that

the data is available. Probably the single most important demographic fact about any population is its rate of change (Bogue, 1969). Given that populations are always changing, census data is of minimal use in the analysis of future populations unless a series of past censuses are examined for trends in rates of population change. Demographers place great importance on measuring the rate of change of a population with a view towards projecting future population levels.

This ever-changing nature of population has necessitated the development of additional demographic tools. Among these are sample surveys which are sometimes employed to gather demographic information. These surveys are typically conducted to collect vital statistics where the official registration system is inadequate, collect supplementary demographic data, or to test the accuracy of the traditional sources of demographic data (Pollard, 1974).

There also exist non-survey, or analytical, tools. Chief among these analytical methods are population estimates of which there are several types including intercensal estimates, immediate postcensal estimates, and population projections.

An intercensal estimate is an estimate for a date between two censuses. Both these censuses play an important role in estimating the population. A postcensal estimate is an estimate that applies to a current or past date following a census and utilizes only past censuses. Future estimates, or population projections as they are commonly known, differ in that they typically estimate population levels for future dates. As with postcensal estimates, only earlier censuses are used. This thesis focuses on population projections.

Population Projections and Their Uses

Haub (1987) defines a population projection as a computational exercise with the goal of determining the future size and age/sex distribution of a population. To engage in this exercise, assumptions are required for future fertility, mortality, and migration patterns (Cox, 1970). Population projections present possible futures, and have all the inherent difficulties associated with "prediction" of the future.

This definition brings up an important issue, namely, how population projections are utilized. Romaniuc (1990) addressed this issue by identifying three possible uses: prediction; simulation; and prospective analysis.

As Haub's definition suggests, prediction is one possible use, although demographers generally prefer to avoid the use of this term. Crucial to the employment of population projections as prediction instruments is a framework for forecasting future population. A number of mathematical frameworks were formulated in the past, culminating with logistic growth theory (Petersen, 1975). Logistic growth theory employed a socio-biological rationale and was popular up until World War II. It is a mix of Malthusian exponential growth and the law of diminishing returns and reflects a simple relationship between population growth and the environment (Romaniuc, 1990).

Since World War II, greater emphasis has been placed on a new theory, that being demographic transition. This theory proposes that a modernizing society goes through stages of evolution from a high fertility and mortality equilibrium to a low fertility and mortality equilibrium. This theory shall be discussed in greater detail later in this paper. Despite the greater sophistication of transition theory, it has proven to be little better than

logistic theory as a basis for prediction (Romaniuc, 1990).

Given the uncertainty in the employment of population projections as predictions it is not surprising that demographers emphasize plausibility over prediction (Haub, 1987; Romaniuc, 1990).

Population projections can also be approached from the perspective of an exercise in simulation. In this case simulation models can help illustrate the effect that policies could have on future population, or illustrate what policies must be adopted to achieve certain population goals. There are doubts, however, about the true value of these models as policy instruments (Romaniuc, 1990).

Finally, there is some middle ground between predictions and simulations occupied by prospective analysis in which the chief aim is to unravel demographic tendencies (Romaniuc, 1990). This is the approach followed by most demographers in which the emphasis is on presenting plausible futures, not certain futures (Haub, 1987). This thesis shall, where appropriate, focus on this middle ground, namely the unravelling of demographic tendencies.

Importance of Population Projections

Knowledge regarding future population is vital for effective decision making in many planning functions in both the public and private sectors (Petersen, 1975). Governments have long recognized the importance of economic and social planning.

In general, the logistics of planning requires knowledge of such items as labour supply (both amount and kind), raw materials, capital and capital equipment. Thus, knowledge regarding labour supply, an aspect of a population, is vital for any planning

decisions (United Nations, 1965).

In addition to projections of labour supply, projections of total population, school-age population, education levels and household and family information are required by governments for any sort of effective planning (United Nations, 1965). Families affect housing needs, education level affects labour classification, and school-age population affects such decisions as the construction of new schools. In addition, spatial distribution of population will affect decisions regarding road construction, hospitals and the like.

Within the private sector, knowledge regarding population shifts can directly affect the "bottom line" (Merrick and Tordella, 1988). Changes in age structure, family and household demographics, and population geography are important if long-term business planning is to be effective. For example, a service organization might wish to tailor its services to suit seniors if the age structure of the population was expected to "grey".

Methods for Projecting Populations

Central to an appreciation of the importance and nature of the assumptions required in the projection of populations, is an understanding of the projection methods employed. There are a number of methods by which population projections can be prepared. The simplest methods involve the extrapolation of the past growth of a population. Examples include geometric, exponential, and logistic curve fitting models (Holmberg, 1977). These methods have largely been discontinued due to their reliance on overly simplistic biological rationales (Petersen, 1975). More sophisticated mathematical methods do exist (Keyfitz, 1977, 1985), but are not commonly used; there

are continuing doubts over the ability of a mathematical function to represent population size changes. Cox (1976) identifies several important characteristics of mathematical methods:

the use of formulae involves assumptions of continuity in population progression which may not always be justified by the irregular course of some developments, e.g. scientific advance; but wave-curves can be used to fit cyclical elements;

formulae may be applied in the projection of components of population change, for example mortality, instead of to total numbers;

the application of a given projection formula to the population of each constituent area of a country may not produce the same result as the application of the same formula to the total population of the country.

The popularity of component methods is the main reason for the lesser emphasis placed on mathematical projection methods. The cohort-component method, which is the most popular component method, was introduced by Pascal Whelpton in the 1920s, and projects a population by individual age-sex cohorts and by separate components (Haub, 1987). With this method, the separate effects of changes in the individual components (births, deaths and migration) are calculated for each age and sex cohort, and are then combined to produce the new age/sex cohorts. For example, to project the number of females aged 20-24 over a five year period, the current number of females aged 15-19 is adjusted by the number of expected deaths and the net level of migration.

Although not necessarily more accurate than mathematical methods, the cohort-component method has a number of advantages over other projection methods, including the ability to easily generate future regional and national age-sex distributions (Perreault, 1975). Of particular importance in the cohort-component method is that each component

of population can be analyzed by subject area experts to a greater depth than would otherwise be feasible. It is also possible to analyze the relative impact of each component on the population over time, thus facilitating the generation of policy-oriented projections (Perreault, 1975).

The main weakness of the cohort-component method is its heavier reliance on its component assumptions. Special consideration must be given to the different components of population change, and their associated assumptions, because the plausibility of any cohort-component projection is wholly dependent on these (Haub, 1987).

Population Scenarios

Demographers normally make it very clear that population projections represent possible futures based on clearly defined *assumptions*. Some demographers have gone so far as to argue that instead of announcing new projections, agencies should announce that they are releasing their latest assumptions (Bouvier, 1983). It has been the difficulty in accurately predicting turnarounds in the trends of these assumptions that is most often cited as the main cause of inaccuracies in projections (Haub, 1987). To overcome this problem, demographic agencies often release a series of projection scenarios, each with its own set of assumptions. Statistics Canada, for example, produces eighteen projection scenarios with their regional cohort-component methodology (Perreault, 1990), while the U.S. Bureau of the Census produces thirty projection scenarios (Haub, 1987).

Because of the uncertainties associated with predicting trends in the components of population change (i.e. fertility, mortality and migration), demographers employ several sets of assumptions. In general, the greater the uncertainty associated with a component,

the more desirable it is to consider a greater number of alternate assumptions for that component.

The number of projection scenarios produced is entirely dependent on the number of assumptions for the different components. Consider for example the scenario generation process at Statistics Canada (illustrated in Figure II.1). In this example, the base population for the last census year, or from a recent estimate, is modified according to the different combinations of fertility, mortality, international migration, and internal migration assumptions. In this example, there is one mortality assumption (e_0), two international migration assumptions, three internal migration assumptions, and three fertility assumptions. Each different combination of these assumptions constitutes one projection scenario. For example, a given projection scenario could have the following assumptions: low international migration, internal migration assumption "A", the high fertility assumption of a fertility rate of 2.1, and the one mortality assumption. Altogether, there are eighteen different combinations that can be generated from these nine component assumptions. The mortality assumption is not a factor because it is the same in every scenario set; despite this, the component is included in the discussion because it is an integral part of any general model of the scenario selection problem. It is possible that there could be more than one mortality assumption.

Scenario Generation

FIGURE II.1

If we consider the previous example, the scenario with the listed assumptions would be scenario number 16, or L2.1A. This notation is explained in greater detail in Section IV, but briefly, "L" represents the low international migration assumption, "2.1" represents the high fertility assumption and "A" represents the selection of that particular interprovincial migration assumption. There is also a label called national group name, but its significance shall be explained in the following sections. The one mortality assumption, e_0 , is not included in the notation since it is the same for each scenario.

As Figure II.1 helps to illustrate, population scenarios are entirely dependent on their underlying demographic assumptions. Bouvier (1983), Haub (1987) and others have clearly stated that population scenarios are entirely dependent on their associated

component assumptions. Any choice decision between scenarios must logically involve careful consideration of these underlying assumptions.

The Components of Population Change

Until World War II, it was believed that the analysis of data on population change was sufficient for the development of basic tools for demographic description. However, events after the war caused a rethinking of this position when indices, particularly fertility indices, changed in opposite directions to that which historical trend analysis had predicted. Consequently, more emphasis was placed on the factors that determine fertility (Péron and Strohmenger, 1985) and the other components of population change (mortality, international migration, and internal migration). The determinants of these components, and their possible interaction, were examined in greater detail than previously.

The simplest population is a closed system. In such a system there are only two ways such a population can change, by the birth of new members and by the death of members. These two components, fertility and mortality, must thus be addressed. A number of theories have been postulated for the changes that have occurred in these components over the ages, but probably the most important theory to date is that of demographic transition.

Demographic and Epidemiological Transition Theories

Demographic transition postulates that as a country urbanizes and industrializes, birth and death rates both decline (Bogue, 1969). In essence, the transition is one from

an equilibrium position where both fertility and mortality are high to another in which fertility and mortality are both low (Romaniuc, 1990). Of particular interest is the interaction between the two variables and with the social and economic environment.

A closely related mortality transition theory, epidemiologic transition theory, also exists. If we consider mortality transition, there are three obvious stages (Omran, 1980). The first is the *Age of Pestilence and Famine* which lasted up to the eighteenth century in Europe. The second stage is the *Age of Receding Pandemics* during which major infections started to decline. This stage lasted up to the earlier twentieth century. Finally, we have the *Age of degenerative and Man-Made Diseases* during which the causes of death shifted from the infectious diseases that typically affect the young to other diseases such as cancer, stroke, and heart problems that typically affect elderly people thus resulting in a shift upwards in average age of death (Jones, 1990).

Some researchers have postulated that Canada has entered a fourth stage of epidemiological transition (Bah and Rajulton, 1991). Mortality in this fourth stage is characterized by the interactions between micro-level determinants such as individual behaviour and social lifestyles; and macro-level determinants such as health care and health promotion programs. Mortality declines in this stage are primarily dependent upon prevention strategies, health promotion, and changes in individual behaviour (Bah and Rajulton, 1987).

Similar to shifts in mortality, fertility also declined, but this decline lagged some fifty to seventy-five years behind declines in mortality. Initially, fertility actually increased thanks largely to the better health of men and women and the resultant decline

in secondary sterility (Omran, 1980). Also, with couples living longer, the likelihood of pregnancy was increased on average (Jones, 1990).

These changes accompanied significant social, economic, and technological change as Europe moved through both the Agricultural and Industrial Revolutions to our modern society. Jones (1990) summarizes the overall transition in four steps:

- High stationary stage, with high fertility and high mortality providing little growth;
- Early expanding stage, with high fertility, but declining mortality as a result of sanitary and agricultural improvements;
- Late expanding stage, still showing significant population growth, but with fertility declining as the growth of an urban-industrial society makes the rearing of children more burdensome for parents;
- Low stationary stage, with fertility and mortality levelling out to re-establish a fairly stable population.

It should be mentioned that this is the classical, or western model. Demographic transition has been different in developing countries where fertility decline has been delayed. In some countries, such as the U.S.S.R. and Japan, the model is an accelerated model in which fertility drops rapidly.

Transition theory is very important since it forms a basis for the analysis of populations and its components, particularly fertility and mortality.

Fertility

Fertility is the term used to indicate the number of children born alive. This differs from fecundity, the physiological ability to reproduce. Fertility is thus the realization of this potential (Pollard, 1974).

Factors that can influence fertility include urban/rural status, pronatalist movements, ethnicity, strength of the family unit, and social status (Petersen, 1975;

Rostum, 1988). Although these factors all do affect fertility, the influence is not always direct. There are two basic categories of determinants: those that operate in the background indirectly (cultural, socioeconomic, environmental); and a set of biological and behavioural factors which serve as intermediate determinants (Jones, 1990).

Although the demographic transition theory is sufficient for describing the fertility decline that occurred as Europe moved from a pre-industrial to a modern society, the logic proposed for this scheme has not satisfied everyone. A number of supplementary theories have arisen to explain this transition. Of these, the theory of inter-generational wealth flows has proven to be particularly interesting (Caldwell, 1980). This theory postulates that there are two basic kinds of society - one in which high fertility is advantageous and one where it is not. The transformation from one of these types to the other is a quick one and occurs when there is a change in net direction of the flow of wealth between parents and children.

This theory, however, is not as useful for explaining post-transition fertility trends. Becker (Jones, 1990) utilized neo-classical consumer behaviour models to explain fertility fluctuations in developed countries. The core of Becker's framework is that fertility is determined by the household's attempt to maximize satisfaction by balancing its subjective *tastes* (desire for children relative to goods) against the opportunities offered by *resources* and constrained by *costs*.

The focus of research in fertility has thus been, until recently, on socioeconomic determinants (Smith, 1989). In addition, most research has focused on the macro, or aggregate, level (Jayachandran, 1986 ; Smith, 1989), but work by Bagozzi and Van Loo

(1978), Jayachandran (1986) and others have examined psychological and socioeconomic factors at the micro, or individual, level.

With all these theories, many complex, it is no surprise that the process of projecting future fertility can also be quite complex. Simple analysis of national and world trends must be complemented by a thorough analysis of the basic determinants of fertility. Fertility assumptions are thus one of the most uncertain components of population change, and necessitate a greater number of assumptions than for many of the other components.

Mortality

One event that demographers can be reasonably certain of is that all persons born into a population will at some time die, although there is less certainty where people will be when they die. Mortality, then, is a continuous force of attrition that acts to reduce population; it serves as the countervailing force to fertility (Bogue, 1969).

As with fertility, there are a large number of factors that can influence mortality. Nutrition has long been felt to be a factor. Malnutrition can lead to the onset of infectious diseases.

Medical advances are another factor. Currently, cancer is one of the leading causes of death. If medical advances were to occur such that the incidence of cancer would be reduced, this would have the effect of increasing the average life expectancy. However, this increase would likely be by just 1 or 2 years. Health standards play an important role, particularly if we are considering the prevalence and incidence of disease (Gnanasekaran, 1975). Diet and the prevalence of social disorders, such as drug addiction

and alcoholism, also affect mortality. Other factors such as murders, suicide, and accidents (particularly auto accidents) play a role, albeit minor, in mortality (Gnanasekaran, 1975).

Ethnicity can play a role in mortality since different racial/ethnic groups have different inherited longevity (Jones, 1990; Petersen, 1975). Trovato (1985) demonstrated that although a comparison of the mortality rates of native-born and foreign-born Canadians reveals a minimal difference between the two, if these two groups are disaggregated into more specific ethnic and social groups, wide disparities exist.

One of the more basic methods of projecting mortality is the projection from past trends. In addition to trend analysis, a number of mortality models, such as Coale's Princeton method (Stockwell, 1976) or the methods of France's Institut national d'études démographique (Stockwell, 1976), have been developed. These methods are particularly useful when satisfactory statistics regarding mortality are unavailable (Stockwell, 1976).

Of particular importance when considering mortality is a statistical model known as the life table (Bogue, 1969; Pollard, 1974). In essence, a life table portrays conditions of a population at a particular time and facilitates the measurement of longevity for different age segments of the population. Such models are particularly useful in that they show the effects of age distribution on a population. In addition to specific national life tables, more general life tables, called model life tables, have been constructed from the life tables of a large number of countries. Two sets of model life tables commonly referred to by demographers are the United Nations and Coale-Demeny tables (Pollard, 1974).

Finally, it should be noted that mortality levels within national boundaries are not necessarily uniform. This is the case in Canada. Regional differences in mortality do exist, but the differences have been narrowing. This trend is expected to persist for some time (Perreault, 1990). These differing mortality levels must be considered when projecting mortality for different regions. One factor that can contribute to differences within a population is social class; this is because of differences in occupation, health care access, behavioural influences and material deprivation (e.g. good housing, etc). Community of residence can also play a major role (Jones, 1990). For example, proximity to heavy industry could result in the manifestation of various health disorders. In addition, health care facilities may not be evenly distributed and this could cause regional/area differences.

Future mortality improvements in Canada will have to occur in the age groups where the risks of dying are highest, but these gains are expected to be less significant than those recently observed (Perreault, 1990). For example, the recent gains in Canada in the mid 1970s to mid 1980s were largely due to a reduction in the incidence of heart disease among males in the 30-69 years of age group (Jones, 1990). Despite mortality being less crucial than fertility when projecting total population size in developed countries, it still plays a significant role in determining the age-sex structure of a population.

Although a detailed study of mortality trends, patterns and determinants is important for assessing the future population of a country, it is given a low priority status in a developed country like Canada owing to the already low death rates. As a

consequence of these low mortality levels, the policy that has been adopted by the projection agencies of most industrialized countries is to employ a single mortality assumption (Perreault, 1990).

Migration

A problem with many of the early attempts at projecting populations was the assumption of a closed population system. The only way for persons to enter or depart such a system is at birth or death. In the "real" world, population dynamics are rarely so simple. There is always the possibility of migration. Thus, the immigration and emigration component of population change must be part of any realistic population projection method.

There are two types of migration associated with a given population, these being internal migration and international migration. Internal migration has no bearing on the total population of a country as it refers to movement from one area to another. If we considered the world as a population unit, migration would not be a factor at all. But in a large country like Canada, it is important to consider partial populations in the different provinces and this means that both international migration and internal migration are factors. Of the two, international migration is the easiest to deal with as the immigration aspect is highly regulated by governments.

International Migration

As is the case in most countries, immigration in Canada is strongly constrained by the policies of the federal government. When projecting the level of immigration ten

years from the present time, the future policy of government immigration must first be predicted; this is not always an easy task. In addition to immigration quotas, other political events can affect immigration. Two such examples are subsidized migration, such as England's Empire Settlement Act of 1922 (Petersen, 1975), and refugees. Economic considerations are also factors in international migration. Economists have employed both macroeconomic and microeconomic models in the analysis of the determinants of international migration (Wadensjö, 1977). A related determinant is mobility of populations.

When immigrants arrive in a country, they settle in a particular sub-national area. One method of developing sub-national projections is to employ mathematical or ratio methods. Cohort-component methods could also be employed. For example, Statistics Canada first determines the immigrants/emigrants at the national level, and then distributes the immigrants and emigrants across the provinces according to an assumed distribution based on immigration trends for the past three years (George and Perreault, 1985). The projected numbers of immigrants are also distributed by age and sex.

Other components of population growth may have a noticeable impact on the importance of international migration. The low fertility rates in developed countries may result in greater authorized levels of immigrants, thereby giving immigration a greater role in overall population change (Bouvier, 1984).

Internal Migration

In addition to migration between countries, migration occurs within national boundaries. Within western countries, there generally is freedom for the population to move within national boundaries. Economic and mobility issues come to the forefront in any analysis of this internal migration. Economic development is generally regarded as an important driving force behind migration patterns (Karlqvist and Snickars, 1977). There exist two major distinct classes of migration models, the macro- and the micro-analytical models.

Macro-analytical models typically have an ecological basis with the assumption that migration is between areas with different relative powers of attraction (Jones, 1990). These models entail the use of mathematical expressions with the purpose of representing regularities or commonalities in movement between different areas.

Of particular note is the classical gravity model and its derivations (Jones, 1990). The precursor to this model is Ravenstein's (1885) *Laws of Migration*. Ravenstein developed five laws from studying inter-county movements in Britain in the nineteenth century:

- the great body of migrants proceed only a short distance. A universal shifting of populations occurs, a sort of ripple effect;
- the inhabitants of an area undergoing rapid growth flow into it, leaving gaps. These gaps in the surrounding areas are in turn filled by migrants from more distant areas;
- the process of dispersion is the opposite of absorption;
- each main current of migration produces a compensating counter-current;
- migrants proceeding long distances generally go by preference to one of the great centres of commerce and industry.

These hypotheses have since been expanded into what are commonly referred to

as gravity models (Walmsley and Lewis, 1984). These models follow principles similar to that of Newton's Law of Universal Gravitation. The basic concept is that inter-community movement is such that the total "work" of the system is minimized. In other words, the amount of movement between any communities is directly proportional to the product of their two populations and inversely proportional to the distance between them (Jones, 1990). This model has since been refined. One of the more important refinements was Stouffer (1940) and his intervening obstacles hypothesis. Stouffer argued that it was not so much distance that was important, but rather the nature of the space between the communities.

The entire macro-analytic approach, however, concentrates on empirical regularities in aggregate population data without actually considering the basic causes for population migration. This is where micro-analytic theories enter the picture. These models focus on the actual decision making processes involved in the migration process by individuals. Research findings have clearly identified economic pull as one of the chief determinants of migration (Morrison, 1977). The demand for labour attracts immigrants from both healthy and poor economies alike. But the immigration process is much more complicated. In addition to the push and pull factors typically discussed, the actual costs and benefits to the individual migrant must be examined (Bogue, 1969). These will include the usual pull and push factors, such as higher wages, more interesting social life, unemployment in current area and so on, but the costs must also be considered. It costs money to move. Finally, the perceived utility or "happiness" from a move is also an important factor in the migration decision process (Bogue, 1969). This

would include a number of non-job related benefits or costs (Rothenberg, 1977).

In addition to the effect of migration on individuals, whether in terms of real wealth or happiness, migration has an effect on the communities themselves. An area undergoing rapid growth from immigration will have an increasing demand for labour in service industries, thus reinforcing the demand for more immigrants (Morrison, 1977). In turn, there is a similar relationship between out-migration and stagnation. Morrison (1977) offers several explanations for this correlation including the degradation of the overall workforce as those more-qualified and mobile members of the workforce migrate. These two self-feeding mechanisms will result in richer areas becoming richer and poorer areas becoming poorer (Morrison, 1977).

This leads to yet another way of viewing migration, namely the political economy perspective. These models address the criticism that the micro and macro-analytical models fail to address the fundamental determinants that lead to uneven development in spatial terms (Jones, 1990).

Of particular interest is Zelinsky's (1971) early work in this area; Zelinsky developed a parallel model to the demographic transition model for migration. The model hypothesizes that there is a steady transition from a condition of severely restricted spatial mobility to higher rates that accompany the modernization process.

These models often employ Marxist-based interpretations of migration evolution. These studies have demonstrated the relationship between the development of capitalism and migration patterns. Migration is regarded as a socio-economic process, not just a demographic component or aggregation of migrants (Jones, 1990). These models thus

consider the complicated processes that are going on as a society modernizes and capitalism evolves, matures, and restructures. The strength of these models is that they consider the interaction between a number of factors that are usually treated separately.

Given the complexity of internal migration, it is no surprise that within Canada, internal migration is the most unstable of the components of population change (Perreault, 1990). It is susceptible to large and abrupt fluctuations, and even reverses in direction. This is illustrated by the westward movement towards Alberta in the early 1980s that abruptly reversed itself a few years later (George and Perreault, 1985). This flow is generally accepted to be the result of primarily economic factors (Perreault, 1990), but there are other factors at work in this system such as retirees returning to their place of birth, people moving out of cities for lifestyle reasons, and so on. These factors must all be considered.

Finally, if we look at Zelinsky's transition model in terms of the effects that modernization and capitalism have had on spatial population levels, the process that led towards the concentration of capital and population in urban centres may now be changing; telecommunication advances have worked to reduce the need for concentrating capital and labour. This counter-urbanization movement has been clearly observed in other countries (Jones, 1990) and may already be starting in Canada.

Interaction Between the Components

As the discussion of the components suggests, there is a significant interaction effect between them. For example, if we consider migration alone, the settlement patterns of international migrants can affect internal migration. If migrants all settle in large

metropolitan areas, this could lead to a greater demand for services in these areas, thus drawing migrants from other areas. In turn, it has been demonstrated that first generation international migrants from certain ethnic groups have higher fertility than the Canadian average (Rostum, 1988). If this extends down to second and later generations, it could affect fertility projections. Fertility also affects immigration policy which in turn will determine the number of international migrants. It is therefore obvious that the components of population change cannot be considered in isolation from each other and that they must be looked at as a system.

Implications

As stated earlier, population scenarios are entirely dependent on their associated component assumptions. Any choice between scenarios must logically involve careful consideration of these underlying assumptions and the components cannot be considered in isolation.

Statistics Canada served as the vehicle for the study. Consequently, the procedures followed by the Demography Division for both scenario selection and the underlying assumption formulation were examined to provide the proper background for the research.

III HUMAN DECISION MAKING AND EXPERT SYSTEMS

Computers have had a profound influence in most areas of society. In particular, computers have provided much needed support to decision-makers. The use of AI in a supporting role to human decision makers has been increasing in many areas (Harmon and King, 1985; Holsapple and Whinston, 1987; Waterman, 1986). Before discussing AI, it is useful to consider the nature of human decision making.

Human Decision Making

A number of studies have been made of human decision making and computer-assisted decision making (CADM) in particular. Simon (1965) presented a particularly useful taxonomy of decision problems (see Table III.1).

In Simon's taxonomy, decisions were classified as programmed or non-programmed. Programmed decisions were essentially very structured and routine or repetitive whereas non-programmed refers to unstructured, more complex or abstract decision requiring deep analysis, judgemental input, and evaluation of risk (Mitra, 1986). Simon also identified different techniques, both traditional and modern, used in decision making.

In addition, Simon defined three main phases in the decision-making process. These include the **intelligence phase** (finding occasions for making a decision), the **design phase** (finding possible courses of action), and the **choice phase** (choosing among alternative courses of action). Simon (1977) also defined a fourth phase, that of carrying out the decision and **reviewing** past choices. This last phase is often referred to as the **implementation phase** (Sprague, 1980).

Traditional and Modern Techniques of Decision Making

Types of Decisions	Decision-Making Techniques	
	Traditional	Modern
Programmed: Routine, repetitive decisions. Organization develops specific processes for handling them.	1. Habit 2. Clerical routine: Standard Operating procedures 3. Organization structure: Common expectations System of sub-goals Well-defined informational channels	1. Operations Research: Mathematical analysis Models Computer simulation 2. Electronic data processing
Non-programmed: One-shot, ill-structured novel, policy decisions Handled by general problem-solving processes	1. Judgement, intuition, and creativity 2. Rules of thumb 3. Selection and training of executives	Heuristic problem solving techniques applied to: (a) training human decision makers (b) constructing heuristic computer programs

TABLE III.1

Adapted from Mitra (1986)

Computers have played an important role in supporting the decision techniques classified by Simon as modern. At the most basic level, electronic data processing (EDP) and Management Information Systems (MIS) have played major roles in the automation of programmed decisions. But it is the non-programmed or unstructured type of decision

that is particularly of interest. One interesting technology applied to this type of decision is that of decision support systems.

Decision Support Systems

A decision support system (DSS) is a computer system purported to serve decision makers in making unstructured types of decisions (Mitra, 1986). The purpose of a DSS is defined (Keen et al., 1978) as:

- a system to assist decision makers in their decision processes in semi-structured tasks;
- to support, rather than replace, decision makers' judgement, and;
- to improve the effectiveness of decision making as opposed to its efficiency.

The semi-structured criterion is particularly important as the decision process being assisted must be one of which there is *sufficient* structure for computer and analytic aids, yet must still be one where the decision maker's judgement is essential (Keen et al., 1978).

DSSs are not limited to just the later phases of Simon's decision-making process. Unlike EDP and MIS, which are applicable to just the "intelligence" phase, and Management Science/Operations Research (MS/OR), which are limited to the "choice" phase, DSSs can serve a useful function in all three stages (Sprague, 1980).

Sprague (1980) describes a DSS as combining the use of models or analytic methods with conventional data retrieval techniques. Building on this basic definition, Sprague defines a DSS as consisting of three principal software subsystems, these being the database management software (DBMS), the model base management software

(MBMS) and the user interface software, or dialogue generation and management software (DGMS).

MBMS and DBMS technologies still are in Simon's "programmed" category. Simon foresaw the use of "heuristic" programs to assist the more unstructured types of decisions. Thus of the different branches of computer science, artificial intelligence (AI), and expert systems (ESs) in particular, have great potential for enhancing the support for the more non-programmed types of decisions. (Keen et al., 1978).

Artificial Intelligence

AI can be defined as the capability of a device, such as a computer, to perform tasks or functions that would reasonably be regarded as intelligent if they were observed in humans (Mockler, 1989). This process of "mimicking" human intelligence involves research from the disciplines of computer science, cognitive psychology, and philosophy. Within AI, there are three major branches:

- Robotics and Sensory Subsystems
- Natural Language Systems
- Expert Systems

Robotics research seeks to emulate human visual and tactile senses with the goal of creating functional robots that can interpret and react to their environment. Natural language systems involves research into the understanding of human speech and writing. Finally, ESs involve the creation of computer-based systems capable of representing and reasoning about knowledge-rich domains with a view to problem solving and giving advice (Jackson, 1986). The purpose of such systems is to emulate human experts (Mockler, 1989).

It is ESs that have the most potential for applications in Simon's unstructured decision types. Initially ESs and AI were thought of as adjuncts to DSSs, but ESs have come to be regarded as something separate from DSSs. The principal differentiation between modern ESs and DSSs are the components of the system, and differences in purpose (Turban, 1990).

Components of Expert Systems

Similar to a DSS, an ES has three major components, but these components differ from those of a DSS. An ES consists of a user interface, an inference engine, and a knowledge base (Holsapple and Winston, 1987). Harmon and King (1985) also define an ES as containing two additional subsystems: the knowledge acquisition subsystem, and; the explanation subsystem (See figure III.1).

FIGURE III.1
Adapted from Harmon and King (1985)

The user interface is the most visible component of any ES since it interacts with the user. It is the role of the user interface to facilitate the interaction of the user with the ES.

Of particular note is the relationship between the user interface and the explanation subsystem. The explanation subsystem contains an explanation and justification mechanism which provides the user of the ES with some detail of the system's reasoning processes. This explanation capability is one of the most important features of ESs (Turban, 1990).

The inference engine contains the reasoning methods used to search the knowledge base and solve the problem. This component is analogous to the reasoning and inferential capabilities of human experts.

The knowledge base contains information relevant to the problem at hand. This knowledge is a distillation of the expertise of the human expert. The knowledge acquisition subsystem of the ES facilitates the process of knowledge engineering, that is, the capturing of the expert's knowledge and its representation in the knowledge base. Several knowledge-representation methods do exist, but it is the use of rules that is the most common approach to representing knowledge (Harmon and King, 1985; Jackson, 1986; Mockler, 1989). This study concentrates on rule-based knowledge representation which uses rules of the format: "IF x THEN y." As an example of a rule, consider:

IF area is Prince Edward Island
THEN assume valid range is small province range

As this example demonstrates, there are two basic parts to a rule: a premise, also known as an antecedent, following the IF operator, and a conclusion, also known as a

consequent, following the THEN. If the premise of a rule is true, the inference engine will "reason" that the conclusion must also be true. A premise is determined to be true if the condition, or the combination of conditions, stated in the premise is met. Thus, the above rule implies that if the actual area being considered is Prince Edward Island, the valid range that should be used is the "small province range". More complex rules can be created through the use of AND, OR and NOT logical operators. Rules can also capture uncertainty through the use of certainty factors. For example, consider:

**IF economic boom in west, AND
 economic recession in east
THEN assume internal westward migration CF .8**

In this example, if the premise of both an economic slump in eastern Canada and an economic boom in western Canada is met, a conclusion is derived such that the westward internal migration assumption should be accepted with a confidence level of .8. Certainty factors thus represent the uncertainty that is inherent within many areas of expertise. It should be noted that certainty factors do not represent probabilities as there is no requirement for the certainty factors of the alternatives to sum to 1 (Jackson, 1986); they represent the relative levels of confidence associated with the occurrence of the consequent given the premise.

Rule-based ESs can be made more complex by the inclusion of meta-rules, or rules about rules, in the knowledge base. (Jackson, 1986). These meta-rules are particularly important in representations of dynamic knowledge, as is often the case in simulations.

As the methodology section (Section V) shall explain, there are intermediate steps towards building an ES in which a formal model is created. For purposes of this

research, the formalism referred to as propositional logic, and its associated predicate calculus (Jackson, 1986; Lemmon, 1965), shall be used. A brief explanation shall be given, but the reader is directed to a logic text such as Lemmon's *Beginning Logic* (1965).

Logic revolves around the soundness and unsoundness of arguments. An argument is analogous to a rule, and consists of statements, or propositions, called a premise, and a following proposition, called a conclusion (Lemmon, 1965; Luger and Stubblefield, 1989). The notation is of the form:

$$A \rightarrow B$$

In this example, **A** is the premise and **B** is the consequent. Given **A**, **B** is concluded to be true. The rule based notation of the same argument would be:

If A then B

The " $\rightarrow$ " operator is thus analogous to the **then** operator and it denotes the direction of reasoning. Similarly, the " $\neg$ " is analogous to the NOT operator, "&" to the AND operator and so on.

To illustrate the propositional form of the earlier example rule associated with internal migration, assume that the proposition **B_w** represents an economic boom in the west, **D_e** represents an economic recession in the east, and **M_w** represents westward internal migration. An analogous argument in propositional calculus to the westward migration rule is:

$$(B_w \& D_e) \rightarrow M_w$$

This example demonstrates that although the notation appears different at first glance it

is similar in terms of function.

The inference engine in an ES reasons typically employs this type of logic. Consider the following arguments:

A -> B
B -> C

If the proposition **A** is true, the inference engine will conclude that **B** must also be true. Similarly, once **B** has been determined to be true, **C** will likewise be concluded to be true. The knowledge base of any ES will thus consist of such arguments, rules, or similar structures.

Although ESs offer a number of benefits, they are not necessarily suited to all problems. In general, ESs lend themselves to the decision-making areas that Simon (1977) defined as semi-structured and unstructured problems (Harmon and King, 1985). There is thus considerable overlap between the traditional DSS and ES problem areas.

There exist opportunities for the integration of ESs and DSSs (Macklem, 1990; Turban, 1990). In particular, the addition of knowledge bases and other "qualitative" AI tools can readily enhance a DSS. Turban (1990) describes two basic approaches of integrating ESs into a DSS. The first is integrating ESs into the different DSS components (e.g. ES interacting with the model-base to perform such tasks as sensitivity analysis, identifying problem types, etc). The second is by including the ES as a separate subsystem, much as the DBMS and MBMS are in the traditional DSS.

There is no reason why DSS technology could not be integrated within an ES. Although ESs generally have a narrower range than DSSs (Turban, 1990), certain ESs could benefit from the more "quantitative" type of analysis typically associated with DSSs

or MS/OS. One architecture that is ideal for this coupling of "symbolic" and "numeric" reasoning is that of Blackboard Systems.

There are three basic parts to the blackboard model (Englemore and Morgan, 1988; Nii, 1986), these being the knowledge sources, the blackboard data structure, and the control mechanism. The knowledge sources are the sources of knowledge needed to solve the problem. The sources can be procedures, groups of heuristics (rules), and so on. These sources are independent of other knowledge sources, thus allowing portability between blackboard systems. The blackboard data structure is the global data store. The blackboard functions as a sort of knowledge exchange centre. As the different knowledge sources (or modules) are called upon, the blackboard is used as a common data storage area for each of them. Thus the different knowledge sources use the blackboard to communicate with each other. For example, one knowledge module in a blackboard system could be called upon to perform some sensitivity analysis on some data in the blackboard. The results of this analysis would be stored in the blackboard as well. In turn this sensitivity data would be available for other knowledge modules. The only communication between the knowledge sources is via the blackboard. It is the control mechanisms that must coordinate the different knowledge sources with the blackboard.

Benefits and Feasibility of Expert Systems

As with any technology, ESs must be proven to be beneficial before the technology will be adopted. There are a number of advantages that are typically associated with the use of ESs (Beerel, 1987):

- the dissemination of knowledge
- easing the work load of busy experts
- providing expertise where it is in short supply
- to assist in the provision of expert training
- the development of a knowledge bank of explicit knowledge inherent in members of the organization.

As mentioned earlier, ESs are most suitable for unstructured types of decision-making problems. Within the ES literature, a number of common characteristics of problem areas suitable for ES development can be identified (Beerel, 1987; Newquest, 1986; Prerau, 1985):

- the task does not require any imagination or common sense.
- experts can articulate their knowledge
- genuine experts are available and are cooperative
- the task requires cognitive skills
- the nature of the task is clearly understood
- the problem solving required is not too easy and is considered to be a serious one.

The determination of whether ES development is appropriate for a particular problem area is thus very important. Some problem areas are more suitable candidates for ES applications than are others.

Expert Systems Applications

A number of classification schemes exist in the literature for ES problem areas (Beerel, 1987; Mockler, 1989; Waterman, 1986; Turban, 1990). These schemes are useful

in that they highlight the different types of problems for which ESs have been developed. In addition, they also highlight some characteristics of the applications. Waterman's classification scheme is presented in Table III.2.

Classification of ESs

Category	Problem Addressed
Interpretation	Inferring situation descriptions from sensor data
Prediction	Inferring likely consequences of given situations
Diagnosis	Inferring system malfunctions from observables
Design	Configuring objects under constraints
Planning	Designing actions
Monitoring	Comparing observations to expected outcomes
Debugging	Prescribing remedies for malfunctions
Repair	Executing plans to administer prescribed remedies
Instruction	Diagnosing, debugging, and modifying student behaviour
Control	Governing overall system behaviour

TABLE III.2
Adapted from Waterman (1986)

Expert Systems have been used in a wide variety of fields including chemistry,

computer systems, geology, mathematics, and medicine (Jackson, 1986). The earliest applications of ESs include DENDRAL, which determined the molecular structure of unknown organic compounds, and MYCIN, which diagnosed blood infections (Jackson, 1986). DENDRAL is an example of an interpretation ES, while MYCIN is a diagnostic ES. An interpretation system is one which builds a description of a situation from the data it receives. A diagnostic system uses situation descriptions, behaviour characteristics and the like to infer probable causes of system malfunctions. Other examples of ESs include PROSPECTOR for geology (interpretation ES), XCON for configuring VAX/VMS computers (Design ES), and MACSYMA in the area of mathematics (Mockler, 1989). It must be noted that not all ES applications fall clearly into a single category; some ES applications share the characteristics of two or more categories (e.g. SPE *diagnoses* inflammatory conditions by first *interpreting* waveforms from a scanning densitometer).

Expert Systems in the Social Sciences

Humans are social creatures. They normally spend their entire lives in association with other human beings. Social Science is the study of the group life of humankind (Hunt, 1966). As such, social scientists are interested in all human relationships, especially those that occur in organized groups. However, all aspects of human culture are interrelated, so social science encompasses a number of sub-fields including history, anthropology, economics, political science and sociology. In addition many consider disciplines such as psychology and social psychology to be social sciences. The social sciences, of course, include demography. Demography is a cross-disciplinary area

involving anthropology, sociology, economics, and other disciplines (Bogue, 1969).

Social science as a whole has not had the plethora of ES research that other areas have had. For example, in the natural sciences, there are numerous systems, particularly in the biomedical area, but also in chemistry and geology. If we discount the legal and financial ESs, there have been very few ESs developed in the social sciences.

One example of an ES in the social sciences is an application in political science. The application of ESs as Elite Foreign Policy Advisors was demonstrated by Tamashiro et al. (1985). The prototype developed was required to infer the intentions of governments from their behaviour. Meta-knowledge (meta-rules) were required in the implementation of this system.

Banerjee (1985) developed an ES representation of an anthropological model. In this case, the intent was to model the phases of the Chinese Revolution. An important question addressed was "what kind of trans-individual cognitive processes give rise to stable social structure?" This simulation required the modelling of the interactions between the principal actors in the revolution (i.e. Chinese Communist Party, KMT, soldiers, and peasants). Like the Elite Policy advisor, this ES also employed meta-knowledge.

Another example is the ES designed by Olson et al. (1989) for Policy Analysis and Decision Aids for Energy Crisis Management. This Planning ES considered geographic, economic and political factors. National disasters, hostile acts and economic factors were evaluated in both domestic and international terms. This ES was actually an example of ES-DSS integration. Of particular importance was the integration of the

system to a database for the retrieval of relevant laws, location and names of nuclear reactors, and so on.

Expert Systems in Demography

Although there have been some ESs developed within the social sciences, demography, and population projections in particular, have not enjoyed the benefits of ESs. Computer applications have been used extensively in population projections, however. The entire process of projecting populations relies heavily on computers. Greenberg et al. (1973) developed a system to prepare population projections for minor civil divisions in the United States. This system employed already existing projections at the state and national levels to generate predictions for smaller areas. The work was essentially a combination of Newling's curve fitting models combined with cohort-survival analysis (Greenberg et al., 1973). This system was not an ES and was primarily a mathematical exercise in which the different factors were considered as multipliers to the population equations.

Haub (1987) briefly describes a number of programs for performing demographic projections, but these do not employ ES technology, nor do they examine the actual assumption-formulation processes. The different national projecting agencies employ their own projection programs. For example, Statistics Canada utilizes the Statistics Canada Projections Model (SCPM) which is build on a regional cohort component approach (Perreault, 1975).

One attempt at implementing an ES in demography was undertaken by Conley (1988). Conley's SIMPOP system employed a blackboard architecture and was thus was

able to integrate different experts, both in the form of symbolic and numeric modules. One advantage of coupling the numeric modules through the blackboard architecture is that it allows the numeric modules to update their conclusions based on recent results from other modules rather than have the modules serve as just data generators. In many ways, this architecture is akin to multiple experts sharing information and undertaking new reasoning based on recent input provided by the other experts. Conley's SIMPOP employs Prism, an OPS-5 based development platform, but the interface between Prism and the Fortran-based simulation models proved to be a limiting constraint. Although Conley's system has much potential for future development, it presently deals mainly with population simulation employing a simple biological model and as such is useful for teaching purposes, but lacks the sophistication necessary for application to real world problems (Conley, 1988). So far there have been no attempts to develop an ES to support scenario selection problem area.

Opportunities in Demography

Despite the lack of research in the application of ESs to population projections, the area does appear suitable for ES development in that it exhibits many of the characteristics (Beerel, 1987; Newquest, 1986; Ferau, 1985) considered important for ES development. The field has a large body of theory and expertise associated with it.

Perhaps one reason for the lack of significant ESs applications in the field may be related to the complexity associated with modelling a problem area which involves many inter-related areas of expertise. As discussed in Section II, demography is an interdisciplinary field. If we look at the process of population change in Canada in general,

it is a very complex process. Selecting one section of this overall process would perhaps yield positive results.

IV THE SCENARIO SELECTION PROCESS AT STATISTICS CANADA

The process of preparing population projections at Statistics Canada follows the regional cohort component methodology (Perreault, 1990). There are several steps involved in the implementation of this approach to projecting human population.

Statistics Canada Population Projections Process

The first step in this process entails the formulation of assumptions associated with the basic components of population change; these being mortality, fertility, external migration and interprovincial migration. As noted in section II, there are a large number of factors that must be considered in formulating these assumptions, making this a complex process.

With the latest set of released projections (Perreault, 1990), there are two external migration assumptions, three fertility assumptions, three interprovincial migration assumptions, and one mortality assumption.

These assumptions are used to generate the different population scenarios. Each different combination of assumptions yields a separate population scenario. The current mix of assumptions thus yields eighteen separate projection scenarios. It is important to note that as part of a regional component method, populations are calculated separately for each region.

The notation used for these population scenarios is straightforward. Each scenario is represented by a sequence of letters and numbers that describes the demographic characteristics of that scenario in terms of the assumptions associated with each of its components. The symbols used for international migration are H or L, representing the

which of the previously generated scenarios are most suitable to the request, given changes in trends since publication.

Of these stages in the projection process, scenario selection was chosen as the specific problem area to model.

Scenario Selection

The final step in the projection process at Statistics Canada is the selection of scenarios for publication. This would not be an issue if all scenarios were published, but this is not the case for a number of reasons.

One of the more obvious disincentives for the publishing of all scenarios is the cost. A document that contains all 18 scenarios and associated analyses would cost more to print than one which contained 4 scenarios. However, this is not the only consideration for deciding to publish just a subset of the scenarios. Users generally do not wish to be presented with what they feel is an excessive number of scenarios, but rather a single scenario (Haub, 1987). This must be balanced against the fact that releasing a single scenario would be the equivalent to making a prediction, and projection agencies such as Statistics Canada prefer to avoid making such predictions. Therefore a range of scenarios is presented with a view to perspective analysis (Romaniuc, 1990).

The optimum number of scenarios is generally felt to be three, allowing for the presentation of high, medium and low scenarios. However, a fourth medium scenario is often included. The inclusion of this fourth scenario helps to deter the user of the published projections from assuming that the medium scenario is a prediction for the future (Perreault, 1990). In addition, four scenarios are more likely to satisfy certain goals.

There are a number of goals that must be achieved when selecting the four scenarios for publication:

- The offering of a high, medium, and low population scenario for each province and territory, in addition to at the national level;
- The provision of a suitable population range at the national and provincial levels;
- The offering of a scenario that best represents a continuation of current trends at the national level.

It is important to note that the final goal is not intended as a "prediction". Its inclusion is simply to ensure that the most recent trends are included in the range of plausible scenarios. The scenario which best represents recent trends is not guaranteed to be the medium scenario, although that often is the case.

The process of reconciling all these goals can be a complex and often convoluted process. It is this process that is modelled in this project. Several experts from different areas come together to participate in the process, and it is their expertise that must be captured in any ES model.

V METHODOLOGY

The methodology for the research was derived primarily from the KADS methodology (Hickman et al., 1989). The KADS methodology was intended for the development of large scale expert systems. The scope of this project was not on the same scale, however, much of the methodology was still appropriate. Consequently, changes were made to the standard KADS methodology to create a more suitable methodology for this project.

The KADS Methodology

The KADS methodology originated as an ESPRIT project in 1983. The usual approach for ES development has been via the use of rapid prototyping (Hickman et al., 1989). Rapid prototyping is an iterative approach consisting of a number of ad-hoc methods with the aim of implementing systems as quickly as possible. KADS takes a more traditional software engineering approach to the problem. Within KADS, prototyping still does occur, but as a technique to assist in particular aspects of modelling.

The KADS philosophy is that ES development is primarily a modelling activity (Hickman et al., 1989). An ES is therefore an operational model of some real life activity. Viewing an ES as an operational model implies that there are other more abstract models that may be useful in the process of developing the operational model of a decision processes.

KADS relies heavily on the work of Brachman (Brachman, 1979); the development process involved a series of models at different levels of abstraction. Breuker and Wielinga (1987) outlined five levels of abstraction (see Figure V.1). The

FIGURE V.1

first level was the linguistic level. At this level, the raw data is gathered from text books, interviews with experts, and other sources. There is no formal model of the decision process at this level, just an identification of knowledge elements.

The next level of knowledge abstraction is the conceptual level. At this level, knowledge is formalised by the identification of conceptual relations, basic structures and conceptual models (Hickman et al., 1989). These basic structures are linked together in a coherent conceptual framework.

The third level is the highest level of data abstraction. At this level, the structural properties of the conceptual knowledge are identified. The specific domain knowledge is not important at this level; it is the structures associated with the knowledge that are important. Thus the basic structures at this level represent roles of concepts, reasoning

strategies, types of knowledge sources, structuring relations and so on (Hickman et al., 1989).

The fourth level of data abstraction is the logical level. At this level, the inferencing methods are described through the use of logic formalisms. For example, propositional and predicate calculus are used (see Section III).

The final level is the implementation level, which is the goal of the KADS methodology. The model at this level consists of the primitives that are used in describing an AI program (Hickman et al., 1989). In the case of a rule-based ES shell, this model would consist of the actual rules as they would be implemented in the ES.

KADS achieves this data modelling through the use of a modified "waterfall life-cycle model" (Hickman et al., 1989). This approach is based on the conventional systems development life cycle model of analysis, design and implementation. The basic stages were as follows:

- Analysis
- Design
- Implementation
- Installation
- Use
- Maintenance
- Knowledge Refinement

A number of tools, including prototyping, are used within the KADS development methodology. As mentioned previously, the methodology is intended for the construction of large deliverable systems and their maintenance; this is beyond the scope of the research outlined in this paper. Consequently, a modified version of the KADS methodology was employed.

The Modified KADS Methodology

The modified research methodology consisted of four main parts, which followed each other consecutively. The process was not strictly linear though. As Figure V.2 presents, the four stages include analysis, design, prototype development, and implementation and validation. The validation component of the last stage can result in several iterations of all the stages as the knowledge is refined.

Modified KADS Methodology	
Stage	Task
Analysis	Identification and Knowledge Acquisition Literature Technical Knowledge Documents Elicitation
Design	Formalisation of Knowledge Transformation to Conceptual and Logical Models
Prototype Development	Transformation of Model from Logical to Implementation
Implementation & Validation	Implementation of a Prototype Model and Validation of Model

FIGURE V.2

Analysis

The first step in the methodology is to clearly identify and define the problem area. This generally entails a number of preliminary meetings with experts, coupled with the knowledge engineer's own efforts to become familiar with the problem area. The

goal of this preliminary stage is to focus the problem.

Once the problem has been clearly defined, the knowledge engineer is required to gather the knowledge and expertise associated with the decision problem. The knowledge gathering process is commonly referred to as knowledge acquisition. The knowledge acquisition for this project relied on three primary sources. The first of these sources was the general literature in the area of human population dynamics. Although the specific problem area was the selection of scenarios for publication, the review included an examination of the literature on closely related areas such as scenario component assumption formulation. The purpose was to establish the key concepts of the problem area. This familiarisation with the basic concepts laid a foundation that would later facilitate the acquisition of expert knowledge in the problem domain.

A second aspect of knowledge acquisition was the analysis of the technical documents of the Demography Division of Statistics Canada regarding scenario selection and formalisation of scenario component assumptions. These documents included both internal and published reports related to previous scenario projection and selection situations. This aspect of knowledge acquisition was particularly important as it allowed the creation of a preliminary framework of the decision process. This framework assisted in preparation for the next step, that being knowledge elicitation from the domain experts.

Knowledge elicitation methods (Cordingley, 1989) were employed to directly acquire expertise from the domain experts within the Demography Division of Statistics Canada. This was important because written sources rarely contained detailed information on how knowledge is used (Breuker and Wielinga, 1987). Knowledge elicitation from

the experts was thus necessary as it would assist in capturing how the experts screened and filtered information in an incisive manner (Beerel, 1987).

The end result of this stage was a linguistic framework of the knowledge and processes required in solving the decision problem. This linguistic representation was transformed in later stages.

Design and Formalisation

This second stage involved the transformation of the linguistic framework, developed in the analysis stage, through a series of models. The purpose was to eventually create a rule-based logical model. The analysis employed in this stage was based on Brachman's (1979) knowledge representation scheme. The model was thus transformed from the linguistic level to the conceptual, epistemological and finally logical level of abstraction. To accomplish the transformation, the knowledge conceptualization tools described by Mockler (1989) were employed. These tools included structure diagrams of the knowledge and dependency diagrams (Mockler, 1989).

This stage thus converted the knowledge and expertise from its initial linguistic state as communicated by the experts to a conceptual model which was eventually refined into a logical model. Predicate calculus (see Section III) was used as the representation notation for the logical model. The logical model underwent a final transformation in the next stage.

Prototype Development

The final step in knowledge abstraction and transformation was the transformation

of the logical model to an implementation model. Once the platform, both in terms of hardware and software, was selected, the model was transformed into the appropriate format for the platform implementation. The implementation model would then be implemented as an ES system prototype in the final stage of the methodology.

Implementation And Validation

Once the implementation model was developed, it was transferred to the ES platform. The primary purpose of this operational implementation model was two fold. One important aspect was validation of the model. The model was primarily evaluated through the analysis of expected results with model produced results. In addition, the results of past scenario selections at Statistics Canada were compared with model selected scenarios given similar input to the model as would have been the case at the time the experts made their decisions. This form of validation is referred to as predictive validation (O'Keefe et al., 1990).

Although much validation occurred at this stage, model validation occurred at all stages. The validation process involved the input from several experts at Statistics Canada as the model went through its different transformations. This form of validation is referred to as face evaluation and is a useful preliminary approach to validation (O'Keefe et al., 1990). Thus additional refinements were possible throughout the transformation process, resulting in the appropriate changes in all the models (linguistic through implementation).

The second aspect is related to the primary purpose of the research which was to determine whether an ES modelling methodology was appropriate to the scenario

selection decision problem. The ES prototype was thus intended as a verification tool for the evaluation of the appropriateness of the model.

VI MODEL DEVELOPMENT AND VALIDATION

As the previous section indicated, the research was undertaken using a modified KADS methodology. The process of model development consisted of transforming the experts' *expertise* through several levels of knowledge abstraction. The approach followed was a waterfall approach, thus the stages followed one another consecutively. It must be noted that the methodology involved prototyping; as a result of the inherent iterative nature of prototyping, some steps were repeated as the model was further refined. As outlined in the methodology, the primary stages were analysis, design, prototype development and implementation and validation.

Analysis

As a first step, several ideas were discussed with Statistics Canada personnel. These discussions centred on the nature of the population projection process, and the decision making problems associated with each. From these deliberations, the selection of scenarios for publication was selected as the portion of the process to model. The problem was thus identified.

There were three distinct parts to the second portion of the analysis phase. The first of these was a consultation of the **population projection literature**. Initially, this review of the literature encompassed the entire field of demography. Once the basic demographic foundations were established, the focus narrowed to population projections focusing on cohort-component methods. A number of demographic sources were consulted. Concepts presented by Haub (1987) and Bouvier (1983) were particularly useful in developing the initial groundwork required for this phase.

The next step was the consulting of technical literature and documents specific to the process that Statistics Canada employs in projecting Canadian populations. These documents were particularly useful in developing a framework from which to prepare for the knowledge elicitation sessions.

Finally, the knowledge elicitation sessions occurred. These sessions were conducted on the premises of Statistics Canada and consisted a series of interviews with persons within or associated with the Demography Division. Multiple experts were consulted throughout the knowledge elicitation and validation processes. For an example of the format of the interviews, refer to Appendix 1.

The knowledge elicitation process was essentially an iterative process. The initial interviews consisted entirely of open-ended questions; the purpose of this open-ended format was to learn enough about the problem to better refine or replace the initial that model had been constructed from the technical documents. From the first two interviews, a linguistic framework of the problem area was constructed. Later interviews were more focused as their goal was usually to validate and clarify different aspects of the model. In addition, several technical documents were made available that shed further light on the process that was followed in past projection rounds at Statistics Canada.

As with any knowledge engineering process, further information and clarification was needed as the model was refined. Thus the model passed from the linguistic through conceptual and logistic stages, and then back to the linguistic stage as clarification was required. The interviews and feedback sessions occurred over an extended period.

A complication with this knowledge acquisition stage was the existence of

multiple experts. With multiple experts, different views existed regarding how certain parts of the process "worked". Despite such differences, there tended to be a strong convergence of views. It was also interesting to note that, in a few cases, all the experts had difficulty in articulating certain aspects of their expertise. For example, the experts all had difficulty explaining the point at which a high scenario would be considered too high.

In the case of conflicting knowledge, the experts involved were re-consulted and presented with the differing view. In most cases, this resulted in a clarification. When a conflict remained, the views of the senior expert were given precedence. Seniority was determined based on how much an expert had been involved in the scenario selection task. As noted above, such situations were not common.

Design

The methodology outlined a process of transforming knowledge through different levels of abstraction. The goal of this stage of the methodology was to transform the knowledge from the linguistic framework to a more formal logical model. As Section VI outlined, a number of tools were utilized to accomplish this.

The first transformation was from the linguistic framework to a conceptual model. The first step in this initial transformation was the construction of structure diagrams of the problem area. These structure diagrams broke the large problem down into logical parts. At the most basic level, the model consists of two sub-models. These sub-models were referenced as *the National Segment* and *the Provincial Segment*. These two basic logical blocks can in turn be subdivided into additional blocks. Figure VI.1 illustrates the

FIGURE VI.1

basic structure diagram for the completion of the National segment. As can be seen in the figure, there are three upper level tasks that must be resolved.

This basic structure diagram was expanded into a larger, more detailed dependency diagram. The complete set of dependency diagrams can be found in Appendix 2. As illustrated in Figure VI.1, each task involves a number of sub-tasks. These in turn have lower level tasks that must be completed before the upper level tasks. Of the three upper level tasks in Figure VI.1, the selection of the medium national scenario involves the greatest number of branching sub-tasks.

Figure VI.2 on the following page is an example of a dependency diagram of one section of the medium national scenario task. This particular task is the evaluation of

FIGURE VI.2

recent international migration trends. This task is further subdivided into three lower level tasks: economic-political evaluation; refugee evaluation; and an evaluation of recent trends. Each of these is in turn subdivided into even lower level tasks.

This process of subdividing each task into its dependent parts was carried out recursively for both the *National and Provincial Segments*. As was mentioned earlier, the complete dependency diagrams are laid out in Appendix 2. In addition to the dependency and structure diagrams, HIPO charts were also developed. The purpose of these charts was to trace the flow of data through the process by tracking input, output

and the processes which operate on the data.

This formalization process eventually led to the construction of a logical model utilizing predicate calculus. The complete model is given in Appendix 3. This step thus saw the initial linguistic framework of the expertise transformed through several states of knowledge abstraction with the goal of the creation of the logical model. The rules in this model are in the notation of predicate calculus. This notation is briefly explained in section III.

Figure VI.3 highlights one small section of the logical model that was created.

Refugee Evaluation Example, Propositional Calculus

```
Increasing_refugees_trend -> Refugee_trend,
Increased_world_refugees -> Refugee_world,
Decreased_world_refugees -> Refugee_world,
(Refugee_trend, & Refugee_world,) -> R8,
(Refugee_trend, & Refugee_world,) -> R15
```

Explanation of Propositions:

```
Increasing_refugees_trend = Refugee trend towards large increases.
Decreased_world_refugees = Recent world events suggest decrease in refugees
Increased_world_refugees = Recent world events suggest large increase in refugees
Refugee_trend, = Long term refugee trend assigned a value of 8
Refugee_world, = World refugee evaluation assigned value of 7
R8 = Overall evaluation of refugees assigned a value of 8
R15 = Overall evaluation of refugees assigned a value of 15
```

FIGURE VI.3

This particular section represents some of the rules associated with the refugee evaluation task from figure VI.2. If we assume that the trend in refugee applicants has been increasing, and that recent world events suggest that there is likely to be an increase in refugee producing situations, then the consequents of rules 1 and 2 will also be considered to be true. These reasoned conclusions are the antecedent of rule 5, thus resulting in the consideration of this rule's antecedent also being considered true, namely that the refugee situation evaluation should be assigned a value of 15.

A slightly different final conclusion would have been the case with a different assumption for the short term world refugee situation. If recent events in fact suggested that recent world events were likely to result in a decrease in the number of refugees in the near future, then the antecedent of rule 2 would not be true. Instead the consequent of rule 3 would be considered true. This in turn would result in the consequent of rule 4 being considered true rather than that of rule 5. In this case, a lower value would be assigned to the refugee situation evaluation. This reflects less confidence of large refugee levels applying to Canada than in the earlier case.

The next step was the implementation of this model on a computer platform. This required a further transformation. The logical model had to be converted to an implementation level model.

Prototype development

The third stage involved the implementation of the rule-based model in an ES prototype. The first step in this stage was the selection of an appropriate ES tool for development. The literature suggested that the use of an ES shell dramatically reduces the development time (Luger and Stubblefield, 1989). This was one of the factors which led to the selection of Expertech's XiPlus shell (Expertech, 1986) as the primary development platform. Other factors were that it ran on the IBM PC platform, and that it had sufficient flexibility including the fact that it reportedly interfaced well with external data sources. In addition, the inference engine appeared to be more powerful than many of the other IBM PC shells available, and it had the ability to access data in a wide variety of formats.

Writing the system in the Prolog programming language was considered as an option but was not followed due to the increased development time requirements that would have been involved. The advantages of using an ES shell included: a shell comes with a user interface, thus reducing the need for the knowledge engineer to develop one; additionally, a number of inferencing techniques are available readily that would take longer to develop within a non-shell. However, there were disadvantages as well. The principal disadvantage was that shells tend to be more limited in terms of overall capabilities. This is because a shell has to be able to perform a number of functions; in addition, a shell typically sacrifices a level of detail to achieve a "friendly" development environment.

After the choice of the development tool was made, the logical model was transformed to an implementation model. Initially this model was in a format compatible with XiPlus. Difficulties arose during the implementation stage, resulting in a final implementation model with two distinct sections. These two sections corresponded with the national and provincial segments of the model which shall be explained in Section VII. The national segment implementation model is XiPlus compatible, while the provincial segment is compatible with C.

As mentioned earlier, the methodology was applied in an iterative manner. This led to refinements throughout the modelling exercise.

Implementation and Validation

Some difficulties were encountered in the implementation of the national model. These difficulties were apparently related to the effective size of a knowledge base which XiPlus could handle. This problem was overcome by dividing the national segment into two parts. The first part involved the user query functions and some preliminary reasoning utilizing the user provided data, while the second part utilized the conclusions of the first in its own reasoning. It was thus possible to reduce the overhead required at any point of the reasoning process for the national segment.

This problem hinted at more serious problems which were to arise with the implementation of the provincial segment model. In many ways, the memory requirements of this complex segment were more demanding. Despite similar attempts at modularisation as occurred with the national segment implementation, XiPlus yielded disappointing results. The main problems appeared to be:

- The model entailed comparisons between different scenario groups and the interactions between the attributes of the groups. The scenario groups and their associated scenarios had a number of attributes that had to be represented within XiPlus memory structures. XiPlus proved unsatisfactory in fulfilling these requirements. Attempts at subdividing the task proved insufficient in overcoming these difficulties.
- Some other tasks associated with the decision problem were difficult to efficiently implement in XiPlus. Examples of this type of task included sort routines and the like. These tasks were more easily and efficiently implemented in procedural languages such as Pascal or C.
- The use of other ES shells would likely result in similar experiences. ES shells are good for the development of non-complex decision problems, but have proven to be less successful for the implementation of decision problems with complex interactions between sub-problems (McNurlin and Sprague, 1989).

The solution for the successful implementation of the provincial segment was achieved through the use of the C programming language. The implementation model for the provincial segment was redesigned to be compatible with the C language development platform, but at its core, it remained a rule based system. As mentioned earlier, development using a non-shell is much more involved. Consequently, a sub-set of the logical model was implemented in C.

The C implementation of the provincial segment utilized the data generated by the national segment, which continued to be implemented in XiPlus. The two segments functioned as desired, both together and separately. The two segments were linked through the use of data files. The results generated by the prototype implementation when compared with expected results, and with previous scenario selection problems solved by the experts (see Section IX), confirmed that the model of the knowledge represented to a very high degree the scenario selection decision process.

An important part of this stage was the validation of the prototype of the model by the domain experts. This validation involved the soliciting of the experts for feedback during both the model development and implementation process. Feedback was solicited in follow-up interviews and written requests. This procedure of soliciting feedback from the experts helped to clarify different aspects of the acquired knowledge and generally helped to refine the quality of the knowledge base. This refinement process was thus an iterative one and resulted in changes at both the logical and implementation levels of the model.

In addition, there was a formal presentation of the model to the experts and other

demographers at Statistics Canada. Feedback from that seminar was especially important in evaluating the validity of the model.

VII THE MODEL

A logical model was developed from the knowledge acquired from the domain experts at Statistics Canada. Although this knowledge existed within the experts, the process had not until this point been modelled employing expert system formalisms. The complete formal model can be found in Appendix 2 and Appendix 3.

The model is divided into two principal components which shall be referred to as the National and Provincial segments respectively. The following text is a description of this model.

National Segment

When a population is considered from the national perspective, there are but three components of population change that must be considered, these being fertility, mortality and external migration. The fourth component, interprovincial migration, is not a factor at the national level. Of these components, mortality has but a single assumption; therefore, it is not a factor in determining which scenarios should be selected because the mortality assumption is identical for each scenario.

Within the model there are six national scenarios. Referring to Figure II.1, the national scenarios are H1.2, H1.7, H2.1, L1.2, L1.7, and L2.1. This notation is explained in Section IV, but briefly, the first letter represents the migration assumption, and is either H (igh) or L (ow) and the following number is the fertility rate.

The six national scenarios were thus created from the two immigration assumptions (high and low), the one mortality assumption, and the three fertility assumptions (1.2, 1.7 and 2.1). Each of these national scenarios can in turn be expanded

into three provincial scenarios through the addition of the interprovincial migration assumption. These provincial scenarios, however, do not play a role in this segment; within the national segment, only the national scenarios (the groups in Figure III.1) are considered.

The basic goal of this segment is to pare the number of national scenarios. By paring the number of national scenarios in half, their associated provincial level scenario groups are halved. This reduces the number of scenario groups from 3060 to 126. Although the final goal of the **national segment** is to select three scenarios, under certain circumstances four will be selected.

There are a number of criteria that must be considered. There exist certain situations, however, where these criteria can not all be satisfied without including an additional national scenario. This would result in four scenarios being selected instead of the preferred three.

The criteria which must be fulfilled in the paring process are:

- The inclusion of an appropriate high scenario
- The inclusion of a suitable medium scenario
- The inclusion of an appropriate low scenario
- The inclusion of a scenario that approximates recent demographic trends at the national level
- Ensuring that all the associated "national level" component assumptions are represented (i.e. the three fertility assumptions, the two migration assumptions and the single mortality assumption) in the selected scenarios.

To accomplish these tasks, the model of the decision process requires several inputs from different sources. In addition, the model makes use of data variables as part of the reasoning process. A useful summary of the variables and input required by the system can be found in Appendix 7.

The *selection of the high scenario* is a simple process. To select the high scenario, the combination of the **high assumptions** is selected. This is the high fertility rate assumption and the high international migration level assumption. As mentioned earlier, there is only one mortality assumption, so it is not a factor. In the event that an additional mortality assumption was added, the assumption associated with the highest life expectancy at birth would be used for determination of the mortality assumption for the *high scenario*.

Likewise, the *selection of the low scenario* is a non-difficult task. The scenario which combines the **low assumptions** for fertility and international migration is selected.

The final three criteria must be considered together, and after the high and low scenarios have already been selected. In certain instances, it is possible that not all of these criteria can be satisfied through the selection of a third scenario, thus necessitating the selection of a fourth scenario.

The procedure of choosing this third, and possibly fourth, scenario while meeting the three final criteria (i.e. *the inclusion of a suitable medium scenario, the utilization of all the national level assumptions, and the inclusion of the scenario which best represents recent trends*) is a more complicated task than selecting either the *high* or *low scenarios*.

The first step in selecting the final scenario(s) is determining the *fertility assumption that most closely approximates recent trends*. Knowledge about the **expected short term fertility rate within Canada** and **recent fertility trends in other western industrialized countries** is required. These two data elements are compared with each other to make a determination if the fertility associated with the *scenario which best*

represents recent trends should be low, medium or high. If the expected short term fertility rate in Canada is expected to increase and the trend in other western countries is either steady fertility rates or increasing rates, the high fertility rate assumption is selected as the fertility rate which most closely approximates recent trends. If the recent fertility trends in Canada indicate decreasing fertility rates in the short term, the fertility assumption best approximating recent trends shall be determined to be the low fertility assumption. If the expected short term fertility rate in Canada is expected to be a continuation of the current fertility rate while the trend in other western countries is decreasing rates, the fertility rate best matching recent trends shall be determined to be low. Any other combination results in the selection of the medium fertility rate assumption for the fertility rate that best approximates recent trends.

The next step is the determination of the *migration assumption that most closely approximates recent immigration trends*. There are three sub-problems that must be tackled in this decision process. These three tasks are the *determination of likely government policy, an analysis of the likely refugee situation, and an examination of recent immigration trends*.

These sub-problems have several variables associated with them which essentially function as holding places for ordinal data representing the solution of each task. These ordinal values are eventually combined to generate a value between 0 and 100. The decision process the experts follow differs from procedure; the experts do not think in terms of ordinal scales, but the different sub-problems have different associated levels of importance which are represented by the different sized ranges allowed for each variable

within the model. The scales are thus an attempt within the model to represent the relative importance of all of these different factors.

The actual relative sizes of the different scales were determined through questioning the experts as to importance of the different factors relative to each other. For example, if a particular evaluation involved three factors, and the experts indicated that one of these factors was particularly important relative to the others, the more important factor would be assigned a greater weight. Additionally, the experts were consulted as to how the two lesser factors were weighed in relation to each other. If the experts considered the two lesser factors to be of equal importance, they would both be assigned the same weight. The weights of these three example factors might be 60, 20 and 20. The actual size of the weight was arbitrary, but the relation of the different weights to each other was an interpretation of the relationships expressed by the experts. The sizes were selected such that the weights of the factors that were part of significant tasks would total 100; this was primarily for convenience of interpretation.

It must be noted that other mechanisms could have been used in place of the scaled values. One such mechanism is certainty factors. As discussed in section III, certainty factors are values associated with expertise which may represent any inherent uncertainty. In essence, the scaled values are performing a role similar to that of certainty factors, with higher values representing higher levels of certainty.

The first of the migration sub-tasks that must be examined is the determination of *likely government policy*. Information regarding three factors plays a role in this analysis. The information required includes trends in the setting of **recent federal immigration**

quotas, the results of recent **government immigration studies**, and the possible impact of recent **economic and political events**. Each item of information is ranked on an ordinal scale. The scale runs from 0 to 20 for both the **recent government immigration studies** evaluation and the **recent economic and political events** evaluation. The scale is from 0 to 10 for the evaluation of **recent federal immigration quotas**. In the case of each, the higher the number on the scale, the greater the indication that particular analysis suggests a likely increase in immigration. For example, a 0 value for the evaluation of government immigration studies would indicate that recent studies suggest that federal immigration quotas are likely to be lowered. The results of all these analyses are summed yielding an overall ordinal value on a scale of 0 to 50.

The second sub-task that must be undertaken is the evaluation of the *refugee situation*. Information concerning the **world wide refugee situation** and recent **Canadian trends in accepting refugees** is needed. Both factors are evaluated using an ordinal scale. The two resulting values are summed, giving a final number on an ordinal scale running from 0 to 15.

The final sub-task in the determination of the migration assumption that most closely approximates recent trends is the evaluation of *recent immigration trends*. This requires knowledge about the **actual recent immigration numbers** compared to **expected levels** and **recent immigration trends in other "western" industrialized countries**. The recent immigration numbers have an associated variable which can have a value from 0 to 25 depending on the difference between actual immigration levels and past expected levels. The larger the difference, the larger this value. The information

about other western countries has a similar associated variable which can have an ordinal value from 0 to 10. These two variables are added to produce an value between 0 and 35 for the evaluation of recent immigration trends.

The three sub-task scales are combined to create a total ordinal number between 0 and 100. If the number is greater than 50, the migration assumption that most closely approximates recent trends is determined to be the higher assumption. Otherwise the lower assumption is selected. Note that there are only two immigration assumptions. If an additional assumption were to be added at a later time, the model could be expanded to allow for the possibility of one or more medium assumptions.

Once the fertility and international migration assumptions best representing recent trends have been selected, decisions must be made regarding which fertility and immigration assumptions would be appropriate for the medium scenario. The first decision addressed is the medium fertility assumption.

The first step in the fertility assumption decision process is to check to see if all the *fertility assumptions* have been **utilized**. If they have not, the unselected fertility assumption should be selected as the fertility assumption for the medium scenario. In the case of three fertility assumptions, the medium fertility assumption will always be selected for the medium scenario because the high and low fertility assumptions have already been utilized in the high and low national scenarios respectively. Unless the number of fertility assumptions increases to more than four, there will never be a need to choose from two or more unutilized fertility assumptions. After the medium migration assumption has been selected, it is necessary to check if all the *migration*

assumptions have been **utilized**. If one has not been utilized, the unutilized migration assumption is selected. In the event of multiple unutilized scenarios, the unutilized scenario that most closely approximates recent trends is selected. Similarly, if all the migration assumptions have already been employed (i.e. there are two or fewer assumptions being employed for international migration), the **migration assumption** that best approximates recent trends as the migration assumption for the medium scenario is selected.

Finally, *after determining the associated migration and fertility assumptions* for the medium scenario, the scenario that contains both of these assumptions is selected as the **medium scenario**.

After the selection of the medium scenario, three scenarios will have been selected. Usually one of these will be the *scenario which best represents recent trends*. **In the case of the scenario which best represents recent trends not being included in the selected scenarios, a fourth scenario is selected.** The selected scenario is the scenario that has the **migration and fertility assumptions that best represent recent trends**. It is important to add this scenario because one of the original criteria was that one of the published scenarios must be the scenario which best represents recent trends.

After following these steps, three or four national scenarios will have been selected. This leads into the second principal segment of the model, that being the provincial segment.

Provincial Segment

The purpose of the national segment was to pare down the total number of

scenarios. It achieved this by reducing the number of scenarios at the national level prior to the inclusion of the interprovincial migration assumptions.

Figure II.1 was an illustration of how the different component assumptions generated eighteen provincial level scenarios and six national level scenarios (scenario groups in Figure II.1). The national segment reduced the number of national scenarios from six to three, thus halving the provincial level scenarios from 18 to 9 as the provincial scenarios associated with the eliminated national scenarios were also eliminated. While a reduction from 18 to 9 provincial scenarios may not seem significant, consider that there are over 3000 combinations of four scenarios that can be created from 18 scenarios, while there are but 126 combinations of four scenarios that can be created from 9 scenarios.

FIGURE VII.1

Figure VII.1 is a representation of an example where the national segment has pared the number of national groups in two. When the internal migration assumptions are combined with the three remaining national groups (i.e. H1.7, H2.1, and L1.4), nine provincial level scenarios are created. The primary goal of the provincial segment, and of the entire decision process, is to select four provincial level scenarios for publication. It is important to note that this goal is different from the goal of the national segment which was to select three national level groups. The national segment goal was just one step towards satisfying the principal goal of the selection of four provincial level scenarios.

As is the case with the national segment, there are a number of variables and inputs that the model utilizes as it reasons. Appendix 8 contains a summary table of the different variables and inputs that this segment utilizes.

The first stage in the provincial segment is to *generate the provincial scenarios*. This is accomplished by adding the three different internal migration assumptions to each of the selected national scenarios. For example, consider national scenario H2.1. If the internal migration assumptions are labelled A, B and C, this single national scenario yields three provincial scenarios: H2.1A, H2.1B, and H2.1C. This process of adding the interprovincial migration assumptions is duplicated for each of the selected national scenarios from the National Segment, thus creating **nine or twelve provincial scenarios**.

After the provincial scenarios are created, it is necessary to *rank the scenarios for each province*. This ranking is by order of population size. Thus, the scenario ranked number 1 for a particular province is the scenario that has the lowest associated

population level for that province. For purposes of this ranking, **all eighteen possible** provincial scenarios are used. Thus both the scenarios which were rejected and selected as a consequence of the national segment are considered for ranking purposes. The logic for this will be apparent later when the scenarios are evaluated as being *high, medium or low* for a particular province.

The next step is to *create the different scenario groups*. Each of these groups will contain four scenarios since that is the preferred number for publication. This is a simple combinatorial exercise. Assuming that there are nine elements in the set of scenarios, there are 126 combinations, or groups of four scenarios, that can be generated. If the number of scenarios is 12, there would be a total of 495 groups. There will be no more than 495 groups because of the paring down of scenarios in the national stage.

The user must provide additional information to the model. The first of these is **information regarding historic demographic trends** for each province and territory. This information relates to trends in the flow of people to and from that particular province. The second required item of information also applies to each province. Each province's **short term economic and political situation** must be rated. Internal migration is closely tied to economic conditions for most provinces. Each province is ranked in terms of the expected short term economic growth or decline. A third item of required information concerns **which internal migration assumption best approximates recent trends within Canada**.

The next step is the *rating of strength of each scenario group*. To accomplish this, several criteria are applied to each group. The application of these criteria will lead

to an ordinal value between 0 and 100 for each group. Once all the scenario groups are rated, the **group that has the highest ordinal value** is selected as the group most appropriate for publication. In the case of a tie, the earliest value shall be selected. It must be noted that it is theoretically possible that no group will be selected. This issue of a possible non-selection result shall be dealt with later.

The first criterion, or sub-task, is that each group be *examined to see if it includes the scenario which best represents recent trends*. This scenario would have fertility and immigration component assumptions that best reflect recent trends; these assumptions were determined in the national stage. The scenario which best represents recent trends must also contain the interprovincial migration assumption that best reflects recent inter-province population changes within Canada. This was determined in a preceding section within this provincial segment. If a particular group does not contain the scenario which best represents recent trends, it is immediately rejected and assigned a value of 0; the next group is then examined. This procedure is necessary because although the scenario which best represents recent trends is in the set of filtered scenarios, not all of the combinations of these provincial level scenarios will contain that particular scenario.

The next several tasks employ the use of scales. These scales are utilized by different variables in the process of determining which scenario group best matches the goal and criteria of the selection process. The values are combined to achieve an overall score for each scenario group.

Assuming that the scenario group contains the scenario which best represents recent trends, the next step is to check to see *if the group contains a high scenario for*

each province. The process of evaluating the high scenario requires the scenario rankings for each province that were determined earlier in this segment. If one of the four scenarios in the group is a scenario that is in the upper six provincial rankings by population, it is considered a high scenario. The scenario group is assigned an ordinal value from 0 to 5 depending on how representative that scenario is as a high scenario for that province. 0 represents a non-high scenario, while 5 is a particularly high scenario. If there are several high scenarios, the scenario with the highest ranking is the one considered. This process is repeated for each province and territory. The values are all totalled and then converted to a scale running from 0 to 20.

A similar process to the above is followed to determine *if the group contains a low scenario for each province.* If one of the four scenarios in the group is a low scenario for that particular province, it is assigned an ordinal value from 1 through 5 depending on how close it is to being one of the lowest scenarios. If no low scenario exists, that province is assigned a value of 0 for that scenario group. As is the case with the high scenario check above, these strength ratings are totalled and then converted to a scale running from 0 to 20.

Once again, a similar process occurs in evaluating *whether the group contains a medium scenarios for each province.* The process yields an ordinal value between 0 and 5 for each province. This number is 0 when there is no medium scenario for that province. These values for each province are again totalled and converted to a scale running from 0 to 20.

Finally, the *population range of the scenario groups is examined for each*

province. This analysis yields an ordinal value between 0 and 40. There are several ranges that are examined as part of this analysis. The first range is the difference in population between the scenario that yields the highest population for that province and the scenario that yields the lowest population level. The second is the range between the median population level and the scenario yielding the highest population level. The final range is the difference between the median and lowest population. From the interviews, it was determined that ideal ratio (I_r) of the total range over the median population was approximately .30, where

$$I_r = \frac{\text{high population value} - \text{low population value}}{\text{median population.}}$$

The minimum acceptable ratio value was about half the value of I_r . It was found through testing of the model on real data that the ratio which had been gleaned from the interviews was too large. It resulted in no scenario being selected. A more workable range appeared to be in the neighbourhood of .10 as the maximum ratio for the total range over the median population. If I_r proved to be over .10, but not over .30, the scenario group was defined as a "flat scenario". These desired ratios, flat and otherwise, could be scaled up or down depending on the demographic uncertainty associated with a province. The greater the uncertainty, the higher the optimum range for that province. Demographic uncertainty was determined by comparing the historic demographic trends for that province with the near term political and economic situation. If the near term economic situation differed significantly from the historical trend, greater uncertainty was assumed, hence the desire to present a broader range. The acceptable maximum and minimum range are adjusted appropriately. In addition, there were some slight

differences in how smaller provinces are treated. After the application of these **range analyses**, a final ordinal value is arrived at between 0 and 40 for that scenario group.

Each group at this stage now has the following attributes and ordinal scales associated with it:

- High Scenario Analysis 0-20
- Medium Scenario Analysis 0-20
- Low Scenario Analysis 0-20
- Range Analysis 0-40.

The ordinal values assigned from these scales are totalled for each scenario group giving a total between 0 and 100. *The scenario group with the highest rating is selected for publication.* In the event of a tie rating, the scenario that was examined first is selected. It is possible that no scenario will be selected. Also of particular importance is the "flat scenario" designation. If a selected scenario is a "flat scenario", it will be identified as such.

As was mentioned earlier, it is possible that no scenario group will be selected for publication in certain circumstances. Although the current model does not deal with this eventuality, there are two addition steps that could be added. The first option is to repeat the provincial segment of the model utilizing all eighteen scenarios instead of the nine or twelve originally used. The second option is to increase the number of scenarios in the selected set from four to five.

VIII IMPLEMENTATION AND EXAMPLE

The implementation model was divided into two principal segments like the previous logical model. However, there were significant differences owing to the development platform used for each (see Section V). The entire implementation model is in Appendices 4 and 5.

From the perspective of the user, he/she would have to answer some questions after which the system would go through a reasoning process to determine which the national scenarios would be selected. The system would then prompt the user for additional information regarding provincial demographics, and then would select the scenario group best suited for publication, assuming such a group existed.

An example should help to better illustrate how the system works. For the sake of simplicity, a four province model is assumed. There are three different fertility assumptions: 2.1, 1.7 and 1.2; these numbers represent possible fertility rates for Canada. There are two immigration assumptions: a high assumption of 200,000¹ immigrants a year by 1994 and a low assumption of 140,000 per year; there is a single mortality assumption; finally, there are three interprovincial migration assumptions. The first interprovincial migration assumption, A, represents a population flow towards Ontario. Under this scenario, British Columbia experiences some small population gains, while Ontario experiences particular large gains. The rest of the provinces experience population losses. The second internal migration assumption, B, reflects long term trends

¹ This **high** immigration assumption was exceeded in reality. The original high immigration assumption of 200,000 immigrants has proven to be 50,000 lower than the actual 250,000 level for 1994.

in Canada since the 1960s. This assumption is the scenario which results in the most positive migration pattern for the Atlantic Provinces and is a medium scenario for most of the other provinces. The third assumption, C, represents a resumption of the large flow of interprovincial migrants to British Columbia and Alberta. These assumptions are the same as those employed in Statistics Canada's 1989 population projection series.

1996 Population Data						
National Group	Scenario Name	Canada	Populations (100s)			
			Nfld.	Que.	Ont.	B.C.
H1.2	H1.2A	306473	5638	77295	117915	36411
	H1.2B	306612	5868	75823	115702	35794
	H1.2C	306538	5486	74655	114885	38590
H1.7	H1.7A	316816	5820	79572	122005	37707
	H1.7B	316949	6059	78044	119698	37063
	H1.7C	316903	5661	76843	118432	32987
H2.1	H2.1A	323793	5964	81864	124677	38422
	H2.1B	323886	6210	80284	122305	37765
	H2.1C	323797	5799	79044	121016	40743
L1.2	L1.2A	293333	5585	72528	114000	34690
	L1.2B	293471	5813	71064	111818	34083
	L1.2C	293397	5430	69961	110623	36830
L1.7	L1.7A	303243	5766	74674	117949	35923
	L1.7B	303375	6003	73157	115674	35290
	L1.7C	303328	5603	72020	114432	38153
L2.1	L2.1A	309892	5908	76818	120520	36599
	L2.1B	309985	6152	75250	118182	35953
	L2.1C	309896	5740	74076	116916	38879

TABLE VIII.1

The combination of these assumptions yields eighteen possible provincial level scenarios. The population level for Canada and the four modelled provinces are presented in Table VIII.1.

National Segment

As the model suggests, the first stage is the national segment. In this segment,

internal migration assumptions are not considered. There are but six national level scenarios (see Table VIII.2).

1996 Population Table by National Groups	
Scenario Name	Population (100,000s) Canada
H1.2	306
H1.7	317
H2.1	324
L1.2	293
L1.7	303
L2.1	310

TABLE VIII.2

The first task is the selection of the high national scenario. The system selects the scenario as was described in section VII. The combination of the high fertility and high immigration assumptions is selected as the high national scenario. Thus, the scenario which has the high immigration assumption of 200,000 immigrants and a fertility rate assumption of 2.1 is selected. These are the assumptions associated with national scenario H2.1 and it is thus selected as the high national scenario. As can be seen in Table VIII.2, this scenario has the highest associated population level.

A similar task is involved in the selection of the low national level scenario. In this example, that is scenario L1.2. This scenario combines both the low fertility and low international migration assumptions, and of course the one mortality assumption.

The selection of the remaining scenario(s) is a more complicated matter. The model must be provided with information before it can make this determination. The prototype implementation poses questions to the user to obtain some of this information. Figure VIII.1 displays an example question where the model is requesting information

Example Question, National Segment

Application: PSSA National Segment
Knowledgebase: National Questions

What trends in immigration are suggested by recent government white papers?

Select one of..

- >> Very favourable to increase
- Somewhat favourable to increase
- Opposed to increase

FIGURE VIII.1

regarding possible future federal immigration policies, particularly as addressed by recent government documents or announcements.

Let's assume that the user provides the information that is displayed in Table VIII.3. This information is necessary for determining the fertility and immigration assumptions for the scenario which best represents recent trends.

2

PM-1 3½"x4" PHOTOGRAPHIC MICROCOPY TARGET
NBS 1010a ANSI/ISO #2 EQUIVALENT

PRECISIONSM RESOLUTION TARGETS

Example Demographic Data

Immigration:	
White Papers:	Suggest no increase
Recent Quotas:	Have been some increases
Recent events:	Argue Against increase
<hr/>	
Canadian refugee trend:	Some Increases in accepting
World Refugee Situation:	Highly likely to increase
Other Western trends:	Decreases
Actual vs. Set Quota:	About the same
<hr/>	
Fertility:	
Canadian Fertility rate:	Near term status quo
Other Western countries:	Recently at status quo

TABLE VIII.3

This series of inputs yields a low migration assumption and a medium fertility assumption (1.7) for the scenario which best represents recent trends. The medium national scenario is thus L1.7. Note that if the fertility of the scenario which best represented recent trends had been high (2.1), there would have been four selected scenarios (i.e. L1.7, H2.1, L1.2 and L2.1). The addition of the fourth scenario would have been necessary because one of the criteria is that the scenario which best represents recent trends be included amongst those selected for publication.

Provincial Segment

The three selected scenarios (i.e. L1.2, L1.7, H2.1) are passed to the provincial segment where they are disaggregated into their provincial forms by incorporating the three internal migration assumptions. Nine provincial level scenarios are thus created: L1.2A, L1.2B, L1.2C, L1.7A, L1.7B, L1.7C, H2.1A, H2.1B and H2.1C.

All of these scenarios generated from the national scenarios selected in the

Sorted Populations for Newfoundland by Scenario					
Scenario	Populations (100s)	Rank	High Strength	Medium Strength	Low Strength
<i>L1.2C</i>	<i>5430</i>	1	0	0	5
H1.2C	5486	2	0	0	5
<i>L1.2A</i>	<i>5585</i>	3	0	0	5
<i>L1.7C</i>	<i>5603</i>	4	0	0	5
H1.2A	5638	5	0	1	4
H1.7C	5661	6	0	2	3
L2.1C	5740	7	0	3	2
<i>L1.7A</i>	<i>5766</i>	8	0	5	1
<i>H2.1C</i>	<i>5799</i>	9	0	5	0
<i>L1.2B</i>	<i>5813</i>	10	0	5	0
H1.7A	5820	11	1	5	0
H1.2B	5868	12	2	3	0
L2.1A	5908	13	3	2	0
<i>H2.1A</i>	<i>5964</i>	14	4	1	0
<i>L1.7B</i>	<i>6003</i>	15	5	0	0
H1.7B	6059	16	5	0	0
L2.1B	6152	17	5	0	0
H2.1B	6210	18	5	0	0

Note: Scenarios in italics are those eligible for inclusion in a group. Non-italicised scenarios are created from rejected national scenarios.

TABLE VIII.4

previous segment, and the scenarios generated from the non-selected, are then sorted and ranked in terms of population for each province. Table VIII.4 contains the results of this procedure applied to Newfoundland.

Groups of four of scenarios are then generated from the scenarios that are eligible for inclusion in a group. An example of a group is the following set of scenarios: [H2.1A, L1.7B, L1.7C, L1.2C].

The next step is the rating of each of the different groups. Before this can be accomplished, several inputs are required regarding the economic outlook and past demographic migration patterns for each province. Information is also required regarding

which internal migration assumption best represents recent trends; this example will assume that this internal migration assumption is determined to be "C" (the westward migration). For Newfoundland, the economic situation will be assumed to be particularly bleak. The long range demographic position will be assumed to be a long term trend of movement away from the province. Similar input is required for each province.

Each group is then checked to see if it contains the scenario which best represents recent trends. From the national segment, it is already known that the scenario which best represents recent trends has a fertility of 1.7 and the low international migration assumption. We have also determined that this scenario should have internal migration of "C". The scenario which best represents recent trends is therefore L1.7C. Our example group contains this scenario, so it is further examined. If it had not contained the reference scenario, that group would have been assigned a value of 0, and the next group would then be looked at.

The next step is to check the group for a good high, medium and low scenario. For Newfoundland, scenario L1.7B yields a high strength rating of 5 (see Table VIII.4). The best medium scenario is provided by L2.1A with a strength of 1. The best medium value is provided by L1.2C with a strength of 5. These ratings are carried out for each province.

Each scenario group is rated in terms of its ability to provide a good range of scenarios for each province. The provincial economic future and the provincial demographic history information play an important role in this decision. For the example, we assume for Newfoundland that the demographic history and economic future both

suggest outflows of people from the province to a high degree. The fact that both indicate a similar future population implies that there should be a level of certainty in projecting Newfoundland's future population levels. This level of greater certainty is reflected in the acceptability of a smaller population range for Newfoundland. This is tempered by the small province adjustments. The final result is a strength of 7 out of a possible 10 for Newfoundland's population ranges.

When the other provinces are considered, the final total value for this scenario group is 86 (see Figure VIII.2). If this value proves to be the highest of the 126 scenarios groups, this scenario group is selected for publication purposes. One observation of note is that this scenario group is that it is a "flat scenario". This means that while it does satisfy the range criteria with an overall strength of 37, it does not satisfy the ideal range criteria which is a higher value.

Solution Screen, Provincial Segment		
Scenario 86		
Scenario 1:	H2.1A	
Scenario 2:	L1.7B	
Scenario 3:	L1.7C	
Scenario 4:	L1.2C	
High Scenario Value:	20	
Medium Scenario Value:	9	
Low Scenario Value:	20	
Range Value:	37	
	--	
Total Strength	86	(Maximum possible = 100)
	==	

FIGURE VIII.2

It turns out that this is the best group and is selected as the group for publishing. For a complete example of all the screens associated with the prototype computer implementation, please refer to Appendix 6.

IX DISCUSSION AND CONCLUSIONS

In Section III of this document, Simon's decision making dichotomy (Simon, 1965) was introduced. In this dichotomy, decision making processes were classified as either programmed or non-programmed. The scenario selection decision process proved to be a combination of these. Aspects of it are of a programmed, or structured, nature; there is a clear system of sub-goals which must be solved as part of the process. For example, there are criteria for the inclusion of an appropriate high, medium and low scenario. Other aspects of the decision process are less structured and fit Simon's non-programmed category. These include the rules of thumb, or heuristics, that the experts apply in reaching their decision goals.

The problem is therefore of a semi-structured nature. Mitra (1986) writes that one purpose of a DSS is to assist decision makers in semi-structured tasks. The scenario selection task fits this facet of Mitra's DSS scheme. Although the distinction between ESs and DSSs is blurred, it is clear that there are a number of differences in terms of the components and structures inherent in an ES (Turban, 1990). This has led to a body of literature for evaluating the suitability of a problem area for ES in particular.

ES Success Factors

As Section III outlined, there are a number of factors typically associated with problem areas suitable for ES development (Beerel, 1987; Newquest, 1986; Prerau, 1985).

These factors include:

- the task does not require any imagination or common sense.
- experts can articulate their knowledge
- genuine experts are available and are cooperative
- the task requires cognitive skills
- the nature of the task is clearly understood
- the problem solving required is not too easy and is considered to be a serious one.

The first of these factors is important because common sense is not easily modelled. Expert systems are most suitable for knowledge rich domains with specific expertise (Jackson, 1986). The scenario selection problem is such a decision task; it is a problem requiring specific expert analysis related to demography. The process is not a creative one; it does not create new theory. Instead, it analyzes an existing situation utilizing a method drawing on specific expert knowledge.

The next two ES success factors were also associated with the scenario selection problem. The experts within the Demography Division of Statistics Canada were helpful and readily available. Their co-operation was vital to the success of this research. In addition, in having the ability to articulate their expertise, they satisfied the second factor. Through a series of structured and semi-structured elicitation techniques, it was possible to capture much of the expertise and knowledge the experts applied to the decision problem.

The fourth factor is the requirement that the task involve cognitive skills. This is certainly true with the scenario selection decision problem. The decision problem involves a number of cognitive processes that require expert reasoning. The model is an effort to capture these cognitive processes.

The nature of the tasks required for solving the scenario selection problem was clearly understood by the experts. Although a semi-structured decision problem, there were definite specific tasks which had to be undertaken as part of solving the problem. The developed model clearly illustrated the structured nature of the decision processes involved.

The final factor was that the task not be too easy and that it be considered a serious one. If the task were of a trivial nature, there would have been little benefit to modelling the decision process. The scenario selection process, however, was undeniably complex, as the experts clearly articulated (George, 1991). This complexity was readily evident in the model.

The analysis of these success factors as they apply to the scenario selection problem indicate that the problem area is appropriate for the application of ES modelling methodology. A comparison of the decisions made by the model with those of the experts is a useful exercise in the evaluation of the model itself.

Comparison of Model and Expert Solutions

One must be mindful that the prototype implementation utilized a sub-set of the logical model. Despite this, a comparison between the scenarios selected by the prototype and by the experts during the 1990 projections round revealed a strong similarity in the results.

When population data and other demographic and economic indicators that were appropriate for 1989/90 were utilized in conjunction with the implementation of the

model, the results were very similar to the scenarios selected by the experts. The scenarios selected by the prototype implementation were:

- L1.7A: Low immigration, medium fertility, internal migration focused towards Ontario
- L1.2A: Low immigration, low fertility, internal migration focused towards Ontario
- H2.1B: High Immigration, high fertility, internal migration close to long term general trend
- H2.1C: High immigration, high fertility, internal migration focused towards Alberta and BC

These selections compare favourably with those selected by the 1990 projections round:

- L1.7A: Low immigration, medium fertility, internal migration focused towards Ontario
- L1.2C: Low immigration, low fertility, internal migration focused towards Alberta and BC
- H2.1B: High Immigration, high fertility, internal migration close to long term general trend
- H1.7C: High immigration, medium fertility, internal migration focused towards Alberta and BC.

Both the implemented prototype of the model and the experts selected scenarios L1.7A and H2.1B. A third choice was very close between the two, this being scenarios L1.2A by the model and L1.2C by the experts. In this case, the two national level components, the low fertility and low immigration were identical. The difference was in the internal migration component. This difference in the internal migration assumption may be due to the limited scope of the implementation; a sub-set of four provinces was used. This sub-set included Newfoundland, Quebec, Ontario and British Columbia. The model selected and expert selected scenarios were very close, suggesting that even with the simplification in the prototype, the model was very close to the knowledge that the experts use.

The fourth selected scenario was H2.1C. This compared to H1.7C which was selected by the experts in 1989. Both scenarios had the same internal migration assumption, and the same international migration assumption. The sole difference was the national level fertility component assumption. One possible explanation for this divergence is related to the "criss-cross" effect. This effect occurs when high fertility is combined with low international migration, or when low fertility is combined with high immigration. Several of the experts revealed that they considered such scenarios undesirable for inclusion in the set of scenarios to be published. The reason for the undesirability was related to how criss-cross scenarios tend to be medium scenarios which are less desirable than the other possible medium scenarios. It appeared that the experts selected all the national level combinations for publication except for those which were affected by the criss-cross effect. An analysis of previous projection releases (Statistics Canada, 1979; George and Perreault, 1984) reveals similar findings.

The implementation model differs from the strategy of disregarding criss-cross scenarios. If a user of the implementation model selects a near term scenario which has the characteristics of a criss-cross scenario, the selection is permitted. Essentially, the user is given greater latitude in determining acceptable scenario component combinations. It would not be difficult to incorporate the criss-cross logic in a future implementation of the model, perhaps as an option.

Despite the four province simplification and the possible criss-cross effect, the selected scenarios were very similar to those selected by the experts. This suggests that the model well represents the knowledge associated with the decision process. It also

suggested that the four provinces selected for the implementation may have collectively embodied many of the internal migration dynamics within Canada.

Implementation Issues

The research was successful in modelling the scenario selection decision process and in the creation of a framework for ES development. Following the completion of the model, an ES prototype was developed utilizing the XiPlus ES Shell. An ES shell was selected as the development platform because the use of such a platform was supposed to have the effect of significantly reducing the design and implementation time required.

Because of the complexity of the model, the implementation model developed on the XiPlus platform did not function as desired. After experimentation and study, it was decided to implement part of the model using the programming language C. This approach did prove successful. The scaled down C language implementation, coupled with XiPlus, performed according to expectations.

The principal explanation for the unsatisfactory performance of the XiPlus platform lay in the computer memory overhead required for the storage of the information associated with the decision process. In particular, the problem required that all the different possible combinations of scenarios, after having been filtered at the national level, be compared with each other. Each comparison involved a number of sub-problems making the process particularly complex. As was discussed in Section VII, there were either 126 or 495 different combinations of the scenarios, depending on how many national level scenarios were filtered out. XiPlus' database could not properly accommodate the memory structures associated with the different sub-problems that are

an integral part of the comparison of scenario groups. Although XiPlus was very flexible, it proved to not behave satisfactorily given a complex model. The C language implementation, however, required less memory overhead for the storage of information associated with the problem; the utilization of C allowed much greater control over the structures used. In addition, there were certain functions, particularly those which involved iteration, which were managed more efficiently.

This experience confirms that, when modelling and supporting a complex decision process, ES shells may not be the most appropriate avenue to development (McNurlin and Sprague, 1989) . A more appropriate avenue for complex problem areas appears to be programming languages like Lisp, Prolog, or as with this experience, C. This approach was initially excluded because of the large programming requirements associated with such an undertaking using this type of platform; the scope of such a programming project was beyond the scope of this project, particularly given that the ES prototype was not the primary goal of the research.

The primary goal of the research was to build a theoretical model and test it through implementation. The model was developed and, despite the XiPlus shortcomings, was successfully tested. The goal was therefore achieved.

Summary and Conclusions

This research involved the analysis and modelling of a real decision process that proved to be particularly complex. As such, it was not a trivial problem area and contributed to the body of knowledge in both the demography and expert systems fields.

The decision problem was successfully analyzed through the application of a modified KADS methodology and associated ES tools. The acquired knowledge was structured and then formally modelled both conceptually and as a logical model utilizing predicate calculus, thus demonstrating that it was possible to model this problem area.

The model was validated through series of follow-up sessions at Statistics Canada including a formal presentation of the model. In addition, an ES prototype was implemented and this implementation of the model yielded a very similar selection to that selected by the experts, thus assisting in validating the model.

The resulting model is of potential benefit to Statistics Canada. It represents a formal model of a process which to date has not previously been modelled in such great depth. This formal model can be useful in a number of ways, including allowing non-experts to gain insight on the decision processes associated with this problem. In addition, the modelling of the expertise may reveal facets of the process that the experts had not consciously realized because the knowledge had not previously been formally modelled. It must also be remembered that this model captured the knowledge from multiple experts, and can also contribute to expanding the knowledge of the individual experts.

An implementation of the model can serve a valuable role in an advisory position to the demographers involved in the process of selecting the group of scenarios for publication. In particular, the model implementation could be used to assist in evaluating the possible effect that different changes in demographic and economic variables could have on the appropriateness for selection of different scenario groups. In other words,

an implementation could be used as a simulation experiment. The inclusion of a detailed explanation facility in a full-fledged implementation would be of particular usefulness to anyone learning about the decision process.

Finally, as alluded to previously, the research demonstrated the appropriateness of the application of an ES modelling methodology to the complex and unstructured scenario selection problem, thus adding to the body of knowledge in the fields of demography and decision support. In addition, similar types of decision problems in other fields, both within and beyond the social sciences, should possibly be successfully modelled through the application of ES modelling methods.

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APPENDIX 1: KNOWLEDGE ACQUISITION

The knowledge acquisition stage of the ES methodology consisted of several components. The most important of these components was the knowledge elicitation process. The process consisted primarily of a series of interviews conducted with the domain experts of the Demography Division of Statistics Canada. Multiple experts were consulted including M.V. George, R. Costa, M. Declos, and J. Perreault. Additional input was given by V. Kawka.

Most of the interviews were conducted in June and July of 1991. Some follow-up interviews were conducted in September, 1991 and in February of 1992. In addition to the major interviews, a number of shorter discussions transpired with the experts during the duration of the modelling exercise. These discussions assisted in clarifying or validating different aspects of the knowledge domain.

The interviews were semi-structured, with the earlier interviews more open-ended and the later interviews more focused. In the initial stages, the goal was to develop a rough framework of the problem area. The later interviews thus focused on expanding different aspects of the framework. This framework would eventually be transformed into the conceptual and logical models.

The following sample interview session may be of interest. This was the second knowledge elicitation session and was therefore of a somewhat open-ended nature. The main questions and topics were prepared in advance, but the expert was allowed much leeway in answering the prepared questions.

JULY 12th INTERVIEW

The interview presented here was with Ms. J. Perreault. Ms Perreault was the author of the principal report that was utilized in the preparation of the initial set of questions. Because this was one of the earliest interviews it was primarily exploratory.

Answer Sheet

Comments of the interviewer are contained within []. All other text is a paraphrase of the answers received during the interview sessions. The questions are in italics.

I. Empirical/Theoretical Methods Debate

In your 1984 paper, you said that the scenario selection process considered empirical arguments only. Theoretical models were not considered. The example used was that lower fertility theoretically could lead to higher levels of international migration to "make-up" for the shortfall below replacement. Are all theoretical considerations dismissed?

This effect referred to is substitution theory and it can be found throughout the literature. But as the paper explains, this was not used. [See later sections for more]. Jeanine expressed some dismay at the very idea of theoretical considerations having a role at this stage. The implication is that these theories are used primarily at the initial stages (ie. assumption formulation).

Are long term theoretical models not considered at this stage? (The example goes on to justify not using this theory because of the long-range nature of the model). What about the effects of pro-natalist measures? Urbanization?

[The article referred to the trade-off between fertility and international migration - the lower the fertility rate, the greater the level of immigration and the opposite is true - high fertility = low immigration]. This effect is a long term effect, thus the time it takes for fertility to affect migration is far too long term an affair for it to be considered at this point. As for urbanization, Ms. Perreault did not think it really received much attention. Definitely not at this point of the process.

On an unrelated matter, Ms Perreault explained the coding system for scenarios.

eg.	H22A	L14D
High Immigration	<—	—>
2.2 Fertility Rate	<—	—>
Internal Migration Assumption A	<—	—>

Internal Migration
Assumption D
1.4 Fertility Rate
Low Immigration

II. Plausible Scenarios

How would you define a plausible scenario? What makes one scenario plausible and another not?

Plausibility is to a large extent determined in the choice of assumptions, and as indicated earlier, substitution effect and similar ideas are not considered. At this point, Perreault indicated that highest assumption combination was always chosen as the highest [at the national level that is. At the provincial level, things are different as later parts of the interview suggest.]

There is something known as the "criss-cross" effect. This effect is what determines redundancy [see later section.]

Criteria?

Criteria is not really a question since plausibility is not considered at this point. Range [see later sections] seems to be the real key. But getting back to the substitution effect, it does not hold up in all cases. Consider what happened in the early 80s. Fertility was dropping but immigration stayed very low. There were other factors at work. There was the recession. There is also the matter of refugees, the family-reunion effect, and the time it takes for government policies to be formulated.

Supposing you were to look at a scenario, what would you do to decide if it was "plausible" or not?

Other than criss-cross effect, plausibility does not play a role. The "range" question is the key to the process. [Again, plausibility is determined in the assumptions...]

What role does theory have in this? What role do

empirical considerations, such as short-term trends have?

Again, theory is in the assumptions. As are the long term trends. Effects such as the gradual movement of people to the west coast and the likelihood of a strong Pacific economy are considered, but in the assumption formulation process.

III. Suitable Range of Scenarios

How do you define a suitable range? Plausible Range?

This question was answered through the use of a series of diagrams. Basically, there is a desire to have a suitable mix and range for the low, medium and high. Consider:

The first "mix" is not as good as the second since the medium in the first is too close to the high scenario.

In addition, the magnitude of the range is important. The range for Canada is something like 3 1/2 million. The range for provinces will vary, depending upon the history of "sudden" and dramatic changes in population (eg. Quebec, Alberta). Also, range is of course relative to the size of the provinces.

The process of choosing the proper range involves consideration of the population in both absolute and "percentage" terms. [not sure how important that last statement was...it was said towards the end of the interview as Perreault was looking through her papers to see if we had missed anything].

Highest Plausible?

The high point is preferably the highest scenario, but not necessarily. There is a range of high scenarios that are suitable.

Lowest Plausible?

Similar process to that which occurs in choosing the highest plausible end of the range.

Mid-point?

This appears to be the trickiest part as the diagrams above suggest. It must be noted that Stats Can tries to present at least four scenarios so as to avoid the habit of taken the middle scenario as a prediction (although some provinces do in fact do this).

Most Likely? Is the most likely always the medium? In the 1984 projections, I believe it was the lowest...

No, most likely is not always the "medium" scenario. It is also important to note that the entire phrase is "most likely in the SHORT TERM". The entire concept of a most likely scenario is frowned upon and it is referred to as a "reference scenario" in much of the literature. Trends in each assumption are looked at. Want to make sure that the most likely scenario is indeed offered. Depending on the stage in the process, either add the most likely scenario or choose something that is close. As for trends that are looked at, this includes trends among subgroups in Canada (eg. Montreal Jewish communities very low fertility of 1.2) and trends elsewhere. Sometimes it is not possible to satisfy all the provinces. 9 out of 12 last time.....

IV. The Process

I was wondering if you could go over the process that is followed with me. From what I have read, and learned from talking with others, is that initially the scenarios are looked at from the national level only. This involves six scenarios. The scenarios are ranked. Is the ranking simply the highest being the national high, the lowest, the national low, and the rest as medium scenarios?

- (1) Make a small table and first choose the highest combination of factors at the national level.
- (2) Choose the lowest combination as the low scenario.
- (3) All the rest are medium scenarios

One of the six scenarios was eliminated because it was redundant. What makes a scenario redundant? [specifically,

why was the high fertility, low international migration combination redundant?]

This depends on whether 3 or 4 scenarios are chosen. We would like to have one as a medium and one other. Four scenarios is thus a goal (min, max, + 2 med.). Suppose 75,000 is very likely for international immigration. We would like to make sure that 75,000 is included in the medium scenarios. We might also like to include the most likely fertility. These factors influence the choice of the two medium scenarios.

Is the process then to rank the six scenarios, and eliminate redundancies? Anything else happen at this stage?

Yes. It must be noted that "redundancies" are those scenarios that are eliminated due to 'criss-cross' effect. This effect refers to the fact that in the short term, a low fertility-high migration and a high fertility-low migration scenario are equivalent in terms of population, so one is eliminated.

Eliminated scenarios are not initially considered when internal migration is added to the equation, but they are put on "standby" and less emphasis is given to them....

The next step is to expand the remaining scenarios by including internal migration [5 to 15 scenarios]. These scenarios are ranked. How are they ranked? In terms of high, medium and low?

Ranked by importance and for each province.

The chart in the document lists several high scenarios for some provinces. What then is the criteria for a scenario to be considered a high scenario?

This is a good question. When is a "high" scenario still a high scenario and not a medium scenario? There are indeed several high scenarios which are generally "close" to each other. It is hard to say where you draw the cut off line. It is a matter of personal judgement.....

What is the criteria for a low scenario?

Similar to above. Consider multiple scenarios... (H1, H2, H3....)

What is the criteria for a medium scenario?

Intuitive Range...

What is the criteria for a "most-likely scenario"?

[Discussed earlier]

What is the exact process? Charts and graphs are looked at. What charts and what graphs?

The goal is to provide a good range for as many provinces as is possible. After choices are made at the National level, the complicated process of "satisfying" provinces begins. This provincial round involves the addition of the component of internal migration to the mix. This multiplies the number of scenarios by 3 (currently 3 internal migration assumptions). The inclusion of internal migration is the key to the problem since internal migration is the most volatile component in the equation. As was indicated earlier in the interview, this process involves the creation of a number of graphs for each province given different combinations. A mixing and matching process starts of which the final product is hopefully a set of 4 or 5 scenarios that provide a suitable range (including placement of medium and "most likely" scenarios) for each province. Unfortunately, it is hard to satisfy every province which is why 3 of the 12 provinces and territories were not entirely satisfied.

Currently, these graphs are generated via lotus. The graphs are "eyeballed" to see if they look good. In addition, population ranges are considered in terms of people in both absolute and relative terms. [It has occurred to me since the time of the interview that this range can vary significantly depending on how far in the future the migration is. This is particularly significant when you consider the effect that fertility has in the long term - a much greater impact than migration. It would be useful to know when this range is measured....]

V. Provincial Involvement

What role do the provinces have in the process? Are there preferences considered in choosing scenarios? (In other words, is this a factor that is also considered in the process above?)

Internal Migration is a very important factor in population dynamics in Canada and it affects all provinces, unlike international migration which affects

principally only four provinces (or four principal cities....). The provinces really want to have a say and they complain if they feel they are not consulted.

So, the provinces are consulted at the start of the assumption formulation phase, this is two years before the release of projections. However, Stats Can would prefer to talk to them when they have more to say since some provinces are less sophisticated than others.

Perreault mentioned the closing of C.F.B. Summerside (as did George) and the effects that this closing had on their talks with PEI. PEI really was leaning towards the lower scenarios. Because of their insistence, Stats Can considered having two low scenarios for PEI if they could prove that there would be a strong likelihood of dramatic negative consequences.

As another example, Perreault listed the dramatic swings in migration in both Ontario and Alberta. In the early 80s where Alberta went from a net 30,000 out-migrant situation to a positive 30,000 situation and in the 70s when Ontario went from positive net 40,000 in-migrants to a net 40,000 out-migrant situation two years later. Because of this type of change, it is important to talk to the provinces, particularly those where population movement is very volatile.

VI. Other Information Sources

Are other information sources considered? Tax records? Family Allowance? Recent trends in other countries? Etc? Where does this fit in the process?

Yes, Income Tax records are indeed used. These records are yearly records and they include change of address records. More important though are monthly records that are obtained from things such as family allowance payments. These payments are used to calculate monthly mobility estimates.

Other sources include birth registers and new policies of government ministers. Both of these are used to compute and predict future fertility (mainly registers) and migration (policy).

Manpower and Immigration are also consulted. Manpower was particularly interested in international migration in the last round. They wished to consider much higher levels of migration up around 300,000. They wanted more

immigration assumptions (5 instead of 3). Upon reflection, maybe they knew more about what was going to happen given the governments recent decision to dramatically increase immigration quotas.

On a note regarding dramatic changes, the change results in a change in the beginning point, not the end points (predictions). The curve is just "smoothed" out. [Despite this, it does stand to reason that it ought to affect the choice of a range and especially influence the 4th scenario (ie. put it in the more likely section of the range).]

The ultimate goal is to present a nationally consistent picture. This differs from what Manpower does. Manpower has their COPS system (Canadian Occupation Projection System). In this design, the provinces are consulted and are asked for their preferences. The provinces choose, and then 2 sets of projections are made. The first projection is the "Nationally Consistent" projection and it does not consider the provincial "wish list". The second projection is the "Nationally INCONSISTENT" projection. In this run the provinces are all considered in a vacuum and their wish list is considered in full. The result is a set of scenarios that do not fit together into a national whole. The advantage though is that there is no headache and no debate.

[Other]

Finally, Ms. Perreault went on to mention that there are three types of projections. [This is largely along the lines of Romaniuc's paper - (1) prediction (2) simulation (3) perspective analysis.] It is the third type, "conditional", that the national agency (Stats Can) produces. This does not mean that all the provinces do the same. Some use it as a prediction by just accepting one scenario for their province.

Comments

This interview provided a tremendous amount of insight into the process. Although Ms. Perreault was no longer involved directly in the scenario selection process, she had more experience in this area than anyone else interviewed. It was her articles that had formed the basis of the early working model of the process. This particular

interview more than any other allowed the enriching of the model with the expertise of the domain experts.

The next step was to talk with the domain experts currently working within the demography division of Statistics Canada in this problem area. Through a series of such interviews and follow-up discussions, the framework which evolved into the logical model was synthesized.

I am grateful to all the personnel in the Demography Division for their patience and time without whom this study would have been impossible.

APPENDIX 2: CONCEPTUAL MODEL

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Key to Codes in Structure and Dependency Charts

Code	Meaning
M-1	Combination of recent fertility and immigration trends
M-2	Criterion that all assumptions are used
M-3	Criss-cross effect
M-4	International migration assumption which best represents recent trends
M-5	Fertility assumption which best represents recent trends
M-6	Interprovincial migration assumption which best represents recent trends
N-H	Selection of high national scenario
H-1	High international migration assumption
H-2	High fertility assumption
N-L	Selection of low national scenario
L-1	Low international migration assumption
L-2	Low fertility assumption
N-R	National scenario which best represents recent trends
N-M	Selection of medium national scenario
N-S	Selection of national level scenarios
C-1	All assumptions used criterion
C-2	Scenario which best represents recent trends criterion
C-3	Preparation of scenarios and scenario groups
C-4	Evaluation of scenario groups
F-A	Scenarios which are accepted after the national filtering
F-R	Scenarios which are rejected after the national filtering
P-F	Final conclusions of provincial segment
R	Recommend scenario group
S-9	Ranking of scenarios
S-8	Classification of scenarios as high, medium or low
S-7	Creation of scenario groups
S-6	Scenario combination concerns
S-5	Focal Point Concerns
S-4	Acceptable low for province
S-3	Acceptable medium for province
S-2	Acceptable high for province
S-1	Acceptable range for province
P-1..P-12	Rank each group for province/territory 1-12

Dependency Structure Diagram

* Not Implemented

Provincial Segment Dependency Diagram

Provincial Segment Dependency Diagram - A

Provincial Segment Dependency Diagram - B

HIPO Chart

Input

Scenario/Assumption
Characterization

User Provided
Partially Data

User Provided
Immigration Data

Accepted Scenario

Partly and
Immigration Data

User Provided
Data on Immigration
Trends

Immigration Situation
for each province

Net Migration
for each province

Process

Read
Assumption
Data

National
Filtering
Segment

Start
Filtered
Scenario
and Trend
Trend Results

Read
National Segment
Data Scenario
and Trend Trends

Test
Immigration

Classify
Scenario
as High, Medium
or Low

Class
Value
Change
Change

Immunize
for each
province

All
Other
Data

Final
Scenario

Recommended
as Final
Scenario
Group

Recommended
Scenario
Group

Output

Accepted Scenario

Rejected Scenario

Recent Immigration
Trend

Recent Partially
Trend

Recommended
Scenario Group

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APPENDIX 3: LOGICAL MODEL

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MODEL FORMAT

Predicate Calculus

The model is presented in a notation based on the propositional and predicate calculus as defined by Lemmon (1965). An explanation of propositional calculus was presented in Section III. A brief explanation of the predicate calculus notation shall be presented here.

With propositional calculus, there is no way to access the individual components of an assertion; predicate calculus does allow this. For example, instead of having a single proposition, say HS, denote the sentence "H2.1 is a high scenario", we could instead have the predicate *high_scenario(H2.1)* to describe this particular relationship. This is an example of a function expression. A function expression consists of function constant (e.g. *high_scenario*) followed by one or more terms enclosed in parentheses and separated by commas. A term can be a variable, constant or function. H2.1 is a constant in this example.

As mentioned, variables are possible within predicate calculus. Consider the following concept:

If any scenario has the most likely fertility assumption for the short term and the most likely international migration assumption for the short term future, then it is the scenario which best represents the recent trends.

This concept can be represented in predicate calculus as:

$(x)(Likely_fertility(x) \ \& \ Likely_mortality(x)) \rightarrow Recent_trends(x)$

This literally can be translated as for any x, if x has the properties of likely fertility and likely mortality, then x also has the property of representing recent trends. In this

example, x is a variable symbol.

The abbreviation $(\forall x)$ is called the universal quantifier and indicates that the sentence is true for all values of the variable x . The universal quantifier is alternatively denoted as $\forall x$, but this text shall use the former notation. In addition to the universal quantifier, there is the existential quantifier, denoted as $(\exists x)$, which means the sentence is true for some values of x .

Other symbols of note are the following operators:

$\&$: logical and
 $\parallel$: logical or
 $\neg$: negation


```

(GWP25 & GQT25 & GPE25) -> GP25
(GWP25 & GQT25 & GPE25) -> GP25
(GWP25 & GQT25 & GPE25) -> GP25
(GWP25 & GQT25 & GPE25) -> GP25
(GWP25 & GQT25 & GPE25) -> GP25
(GWP25 & GQT25 & GPE25) -> GP25
(GWP25 & GQT25 & GPE25) -> GP25
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(GWP25 & GQT25 & GPE25) -> GP25
(GWP25 & GQT25 & GPE25) -> GP25
(GWP25 & GQT25 & GPE25) -> GP25
(GWP25 & GQT25 & GPE25) -> GP25

```

Explanation of Propositions:

White_Paper_Increase = Government white papers suggest large increase in immigration quotas
 White_Paper_Somewhat = Government white papers suggest some small increase in immigration quotas
 White_Paper_Against = Government white papers suggest no increases in immigration quotas
 Quota_High_Increase = Trend has been large increases in immigration quotas
 Quota_Some_Increase = Trend has been small increases in immigration quotas
 Quota_Same = Trend has been in immigration quotas remaining at same level
 Quota_Decreases = Trend has been decreasing immigration quotas
 Political_Economy_Increase = Recent political and economic events suggest quotas may see large increases
 Political_Economy_Some = Recent political and economic events suggest quotas may increase somewhat
 Political_Economy_Same = Recent political and economic events suggest no change in immigration quota
 Political_Economy_Decreases = Recent political and economic events suggest decrease in immigration quota
 GWP_(25,25,25) = Evaluation of Government White Papers.
 GQT_(25,25,25) = Evaluation of trends in Government Set Quotas
 GPE_(25,25,25) = Evaluation of impact of recent Political and Economic Events on Immigration
 GP_(25,25,25) = Evaluation of Government and Political Indicators regarding Immigration

Recent Migration

```

Actual_Canadian_immigration_much_higher -> CMT25
Actual_Canadian_immigration_somewhat_higher -> CMT25
Actual_Canadian_immigration_same -> CMT25
Actual_Canadian_immigration_lower -> CMT25

```

```

Western_immigration_larger -> WMT25
Western_immigration_same -> WMT25
Western_immigration_no -> WMT25

```

```

(CMT25 & WMT25) -> RMT25
(CMT25 & WMT25) -> RMT25
(CMT25 & WMT25) -> RMT25
(CMT25 & WMT25) -> RMT25
(CMT25 & WMT25) -> RMT25
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(CMT25 & WMT25) -> RMT25
(CMT25 & WMT25) -> RMT25
(CMT25 & WMT25) -> RMT25

```

Explanation of Propositions:

Actual_Canadian_immigration_much_higher = Canadian immigration significantly greater than expected quotas
 Actual_Canadian_immigration_somewhat_higher = Canadian immigration somewhat larger than expected quotas
 Actual_Canadian_immigration_same = Canadian immigration matches expected quotas
 Actual_Canadian_immigration_lower = Canadian immigration lower than expected quotas
 Western_immigration_larger = Immigration has been increasing in other western countries
 Western_immigration_same = Immigration levels have been remaining the same in other western countries
 Western_immigration_no = Immigration levels have been declining in other western countries
 CMT_(25,25,25) = Evaluation of Actual versus expected immigration levels in Canada
 WMT_(25,25,25) = Evaluation of immigration trends in other western countries
 RMT_(25,25,25) = Evaluation of recent trends in immigration quotas in Canada and other countries

Immigration Which Best Represents Recent Trends

```

(RMT25 & GP25 & R25) -> Recent_Immigration_High
(RMT25 & GP25 & R25) -> Recent_Immigration_High
(RMT25 & GP25 & R25) -> Recent_Immigration_High
(RMT25 & GP25 & R25) -> Recent_Immigration_High

```


$R_{(11,11,1,1,1,1)}$ = Overall evaluation of refugee impact on immigration
 Recent_Immigration_High = Immigration in short term likely to be high
 Recent_Immigration_Medium = Immigration in short term likely to be medium
 Recent_Immigration_Low = Immigration in short term likely to be low

NOTE:

The number of rules presented in the immigration which best represents recent trends group could have been reduced through the use of the appropriate predicate functions and variables. The model as described in Section VII does just that, as does the implementation in XISPR. However, presenting the rules in this format helps illustrate the advantage of converting the information to the scaled variable format.

Criterion for scenario which best represents recent migration trends

(x)(LM(x) & Recent_Immigration_Low) -> likely_migration(x)
 (x)(LM(x) & Recent_Immigration_Medium) -> likely_migration(x)
 (x)(HM(x) & Recent_Immigration_High) -> likely_migration(x)
 (x)(HM(x) & Recent_Immigration_Medium) -> likely_migration(x)

Explanations:

x = a scenario

LM(x) = x has the low international migration assumption

HM(x) = x has the high international migration assumption

Recent_Immigration_High = Immigration in short term likely to be high

Recent_Immigration_Medium = Immigration in short term likely to be medium

Recent_Immigration_Low = Immigration in short term likely to be low

Fertility Review

Canadian_Fertility_Increasing -> CFI_(11,11,1)

Canadian_Fertility_Same -> CFI_(11,11,1)

Canadian_Fertility_Decreasing -> CFI_(11,11,1)

Western_Fertility_Increasing -> WFI_(11,11,1)

Western_Fertility_Same -> WFI_(11,11,1)

Western_Fertility_Decreasing -> WFI_(11,11,1)

Explanations:

Canadian_Fertility_Increasing = Canadian fertility has been increasing in recent years

Canadian_Fertility_Same = Canadian fertility rate has been remaining the same in recent years

Canadian_Fertility_Decreasing = Canadian fertility rate has been declining in recent years

Western_Fertility_Increasing = Fertility rates in other western countries have been increasing

Western_Fertility_Same = Fertility rates in other western countries have been remaining the same

Western_Fertility_Decreasing = Fertility rates in other western countries have been declining

CFI_(11,11,1) = Evaluation of recent Canadian fertility

WFI_(11,11,1) = Evaluation of recent fertility trends in other western nations

Fertility which best represents recent trends

(CFI_(11,11,1) & WFI_(11,11,1)) -> Fertility_trend_high
 (CFI_(11,11,1) & WFI_(11,11,1)) -> Fertility_trend_high
 (CFI_(11,11,1) & WFI_(11,11,1)) -> Fertility_trend_high
 (CFI_(11,11,1) & WFI_(11,11,1)) -> Fertility_trend_medium
 (CFI_(11,11,1) & WFI_(11,11,1)) -> Fertility_trend_medium
 (CFI_(11,11,1) & WFI_(11,11,1)) -> Fertility_trend_low
 (CFI_(11,11,1) & WFI_(11,11,1)) -> Fertility_trend_low
 (CFI_(11,11,1) & WFI_(11,11,1)) -> Fertility_trend_low
 (CFI_(11,11,1) & WFI_(11,11,1)) -> Fertility_trend_low

Explanations:

CFI_(11,11,1) = Evaluation of recent Canadian fertility

WFI_(11,11,1) = Evaluation of recent fertility trends in other western nations

Fertility_trend_high = Fertility trends indicate high assumptions

Fertility_trend_medium = Fertility trends indicate medium assumptions

Fertility_trend_low = Fertility trends indicate low assumptions

Criterion for scenario which best represents recent fertility trends

(x)(HF(x) & Fertility_trend_high) -> likely_fertility(x)
 (x)(MF(x) & Fertility_trend_medium) -> likely_fertility(x)
 (x)(LF(x) & Fertility_trend_low) -> likely_fertility(x)

Explanations:

x = a scenario

Fertility_trend_high = Fertility trends indicate high assumptions

Fertility_trend_medium = Fertility trends indicate medium assumptions

Fertility_trend_low = Fertility trends indicate low assumptions

HF(x) = scenario x has the high fertility assumption

MF(x) = scenario x has the medium fertility assumption

LF(x) = scenario x has the low fertility assumption

Selection of a possible fourth scenario

```
(w)(x)(y)(z) (HS(x) & MS(y) & LS(z) Recent_trends(w) & ~(Recent_trends(x) || Recent_trends(y) || Recent_trends(z)) -> FS(w)
```

Explanations:

w,x,y,z = national level scenarios
 HS(x) = scenario x is selected as the high national level scenario
 LS(y) = scenario y is selected as the low national level scenario
 MS(z) = scenario z is selected as the medium national level scenario
 FS(w) = select a fourth scenario, w, which matches recent trends
 Recent_trends(x) = scenario x's assumptions match recent trends

Combination Check for use of all assumptions

```
(x)(y)(z) (FC(x,y,z) & MC(x,y,z)) -> CC(x,y,z)
```

```
(x)(y)(z) (HF(y) & LF(z) & MF(x)) -> FC(x,y,z)
(x)(y)(z) (HF(x) & LF(y) & MF(z)) -> FC(x,y,z)
(x)(y)(z) (HF(z) & LF(x) & MF(y)) -> FC(x,y,z)
(x)(y)(z) (HF(y) & LF(x) & MF(z)) -> FC(x,y,z)
(x)(y)(z) (HF(x) & LF(y) & MF(z)) -> FC(x,y,z)
(x)(y)(z) (HF(x) & LF(z) & MF(y)) -> FC(x,y,z)
```

```
(x)(y)(z) (HM(x) & HM(y) & LM(z)) -> MC(x,y,z)
(x)(y)(z) (HM(x) & LM(y) & HM(z)) -> MC(x,y,z)
(x)(y)(z) (LM(x) & LM(y) & HM(z)) -> MC(x,y,z)
(x)(y)(z) (LM(x) & HM(y) & HM(z)) -> MC(x,y,z)
(x)(y)(z) (LM(x) & HM(y) & LM(z)) -> MC(x,y,z)
(x)(y)(z) (HM(x) & LM(y) & HM(z)) -> MC(x,y,z)
```

Explanations:

x,y,z = national level scenarios
 FC(x,y,z) = criterion that scenarios x, y and z represent all possible fertility assumptions is met
 MC(x,y,z) = criterion that scenarios x, y, and z represent all possible international migration assumptions is met
 CC(x,y,z) = scenarios x, y, and z meet all assumptions combination criteria
 HF(x) = scenario x contains the high fertility assumption
 MF(x) = scenario x contains the medium fertility assumption
 LF(x) = scenario x contains the low fertility assumption
 HM(x) = scenario x contains the high international migration assumption
 LM(x) = scenario x contains the low international migration assumption

Selection of Medium Scenario

```
(x)(y)(z) (Recent_trends(x) & LS(y) & HS(x) & CC(x,y,z)) -> MS(x)
(x)(y)(z) (likely_migration(x) & LS(y) & HS(x) & CC(x,y,z)) -> MS(x)
(x)(y)(z) LS(y) & HS(x) & (CC(x,y,z)) -> MS(x)
```

NOTE:

The second rule in this rule group only fires if the first does not. Thus, an attempt is made to include the recent trends in the reference scenario. If that fails, the second rule is fired. If this rule also fails, the third more general rule is fired.

Explanations:

x,y,z = national level scenarios
 Recent_trends(x) = scenario x matches recent fertility and international migration trends
 likely_migration(x) = scenario x matches recent migration trends
 CC(x,y,z) = Scenarios x, y and z contain all the component assumptions
 LS(x) = Scenario x is the low scenario
 HS(x) = Scenario x is the high scenario
 MS(x) = Scenario x is selected as the high scenario

Scenario that represents recent trends

```
(x)(likely_migration(x) & likely_fertility(x)) -> Recent_trends(x)
```

Explanations:

x = a national level scenario
 likely_migration(x) = scenario x approximates recent international migration trends
 likely_fertility(x) = scenario x approximates recent fertility trends
 Recent_trends(x) = scenario x approximates recent international migration and fertility trends

PROVINCIAL SEGMENT

Check for Valid Groups

```
(w)(x)(y)(z) (combinations(w,x,y,z) & national(w,x,y,z) & all_recent_trends(w,x,y,z)) -> group(w,x,y,z)
```

Explanations:

w,x,y,z = scenarios
 combinations(w,x,y,z) = scenarios w,x,y,z use all the different assumptions
 national(w,x,y,z) = scenarios w,x,y,z are derived from the national assumptions. This information is passed from the national segment.
 recent_trends(w,x,y,z) = one of scenario w, x, y, or z will represent recent trends
 group(w,x,y,z) = scenario group w,x,y,z is a valid scenario group

Recent Trends

```
(w)(x)(y)(z) (recent_trend(w) & recent_interprovincial(w)) -> all_recent_trends(w,x,y,z)
(w)(x)(y)(z) (recent_trend(x) & recent_interprovincial(x)) -> all_recent_trends(w,x,y,z)
(w)(x)(y)(z) (recent_trend(y) & recent_interprovincial(y)) -> all_recent_trends(w,x,y,z)
(w)(x)(y)(z) (recent_trend(z) & recent_interprovincial(z)) -> all_recent_trends(w,x,y,z)
```

```
(3x) recent_interprovincial(x)
```

Explanations:

w,x,y,z = scenarios
 recent_trend(x) = scenario x represents recent fertility and international migration trends. This is determined in the national segment.
 recent_interprovincial(x) = scenario x represents recent interprovincial migration trends.
 all_recent_trends(x) = scenario x represents recent fertility, international migration and interprovincial migration trends.

Check Combinations of Scenario Group

```
(w)(x)(y)(z) ( ( CC(w,x,y) || CC(w,x,z) || CC(w,y,z) || CC(x,y,z) ) & IPM(w,x,y,z) ) -> combinations(w,x,y,z)
```

```
(w)(x)(y)(z) (HIFM(w) & MIFM(x) & LIFM(y)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(w) & MIFM(y) & LIFM(x)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(y) & MIFM(w) & LIFM(x)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(y) & MIFM(x) & LIFM(w)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(x) & MIFM(y) & LIFM(w)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(x) & MIFM(w) & LIFM(y)) -> IPM(w,x,y,z)
```

```
(w)(x)(y)(z) (HIFM(w) & MIFM(x) & LIFM(z)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(w) & MIFM(z) & LIFM(x)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(z) & MIFM(w) & LIFM(x)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(z) & MIFM(x) & LIFM(w)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(x) & MIFM(z) & LIFM(w)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(x) & MIFM(w) & LIFM(z)) -> IPM(w,x,y,z)
```

```
(w)(x)(y)(z) (HIFM(w) & MIFM(y) & LIFM(z)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(w) & MIFM(z) & LIFM(y)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(z) & MIFM(w) & LIFM(y)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(z) & MIFM(y) & LIFM(w)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(y) & MIFM(z) & LIFM(w)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(y) & MIFM(w) & LIFM(z)) -> IPM(w,x,y,z)
```

```
(w)(x)(y)(z) (HIFM(x) & MIFM(y) & LIFM(z)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(x) & MIFM(z) & LIFM(y)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(z) & MIFM(x) & LIFM(y)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(z) & MIFM(y) & LIFM(x)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(y) & MIFM(z) & LIFM(x)) -> IPM(w,x,y,z)
(w)(x)(y)(z) (HIFM(y) & MIFM(x) & LIFM(z)) -> IPM(w,x,y,z)
```

```
(3x) HIFM(x)
```

```
(3x) MIFM(x)
```

```
(3x) LIFM(x)
```

Explanations:

w,x,y,z = scenarios
 CC(x,y,z) = scenarios x, y and z utilize all the fertility and international migration assumptions. CC is defined in the national segment.
 IPM(w,x,y,z) = scenarios w,x,y and z utilize all the interprovincial migration assumptions
 HIFM(x) = scenario x has the high interprovincial migration assumption
 MIFM(x) = scenario x has the medium interprovincial migration assumption
 LIFM(x) = scenario x has the low interprovincial migration assumption

Value ranking rules

```
(w)(x)(y)(z) w_highest(w,x,y,z) -> highest(w,x,y,z,w)
(w)(x)(y)(z) x_highest(w,x,y,z) -> highest(w,x,y,z,x)
(w)(x)(y)(z) y_highest(w,x,y,z) -> highest(w,x,y,z,y)
(w)(x)(y)(z) z_highest(w,x,y,z) -> highest(w,x,y,z,z)
```

```
(3w)(x)(y)(z) w_highest(w,x,y,z)
```



```

(w)(3x)(y)(z) x_highest(w,x,y,z)
(w)(x)(3y)(z) y_highest(w,x,y,z)
(w)(x)(y)(3z) z_highest(w,x,y,z)

(w)(x)(y)(z) w_lowest(w,x,y,z) -> lowest(w,x,y,z,w)
(w)(x)(y)(z) x_lowest(w,x,y,z) -> lowest(w,x,y,z,x)
(w)(x)(y)(z) y_lowest(w,x,y,z) -> lowest(w,x,y,z,y)
(w)(x)(y)(z) z_lowest(w,x,y,z) -> lowest(w,x,y,z,z)

(3w)(x)(y)(z) w_lowest(w,x,y,z)
(w)(3x)(y)(z) x_lowest(w,x,y,z)
(w)(x)(3y)(z) y_lowest(w,x,y,z)
(w)(x)(y)(3z) z_lowest(w,x,y,z)

```

Explanation:

w,x,y,z = any value
w_highest(w,x,y,z) = value w is equal to the highest value of w,x,y,z. This does not preclude it from being equal to x, y, or z.
x_highest(w,x,y,z) = value x is equal to the highest value of w,x,y,z. This does not preclude it from being equal to any of the others.
y_highest(w,x,y,z) = value y is equal to the highest value of w,x,y,z. This does not preclude it from being equal to any of the others.
z_highest(w,x,y,z) = value z is equal to the highest value of w,x,y,z. This does not preclude it from being equal to any of the others.
highest(w,x,y,z,w) = scenario w is equal to the highest value of the set w, x, y and z.
w_lowest(w,x,y,z) = value w is equal to the lowest value of w,x,y,z. This does not preclude it from being equal to x, y, or z.
x_lowest(w,x,y,z) = value x is equal to the lowest value of w,x,y,z. This does not preclude it from being equal to any of the others.
y_lowest(w,x,y,z) = value y is equal to the lowest value of w,x,y,z. This does not preclude it from being equal to any of the others.
z_lowest(w,x,y,z) = value z is equal to the lowest value of w,x,y,z. This does not preclude it from being equal to any of the others.
lowest(w,x,y,z,w) = scenario w is equal to the lowest value of the set w, x, y and z.

Ranking of High Scenarios by Each Province

```

(w)(x)(y)(z) (group(w,x,y,z) & high_prov(MFLD, w, u1) & high_prov(MFLD, x, u2) & high_prov(MFLD, y, u3) & high_prov(MFLD, z, u4) & highest(u1,u2,u3,u4,u5)) -> MFLD_high_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & high_prov(NS, w, u1) & high_prov(NS, x, u2) & high_prov(NS, y, u3) & high_prov(NS, z, u4) & highest(u1,u2,u3,u4,u5)) -> NS_high_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & high_prov(MD, w, u1) & high_prov(MD, x, u2) & high_prov(MD, y, u3) & high_prov(MD, z, u4) & highest(u1,u2,u3,u4,u5)) -> MD_high_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & high_prov(PEI, w, u1) & high_prov(PEI, x, u2) & high_prov(PEI, y, u3) & high_prov(PEI, z, u4) & highest(u1,u2,u3,u4,u5)) -> PEI_high_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & high_prov(QUE, w, u1) & high_prov(QUE, x, u2) & high_prov(QUE, y, u3) & high_prov(QUE, z, u4) & highest(u1,u2,u3,u4,u5)) -> QUE_high_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & high_prov(ONT, w, u1) & high_prov(ONT, x, u2) & high_prov(ONT, y, u3) & high_prov(ONT, z, u4) & highest(u1,u2,u3,u4,u5)) -> ONT_high_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & high_prov(MAN, w, u1) & high_prov(MAN, x, u2) & high_prov(MAN, y, u3) & high_prov(MAN, z, u4) & highest(u1,u2,u3,u4,u5)) -> MAN_high_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & high_prov(SASK, w, u1) & high_prov(SASK, x, u2) & high_prov(SASK, y, u3) & high_prov(SASK, z, u4) & highest(u1,u2,u3,u4,u5)) -> SASK_high_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & high_prov(ALTA, w, u1) & high_prov(ALTA, x, u2) & high_prov(ALTA, y, u3) & high_prov(ALTA, z, u4) & highest(u1,u2,u3,u4,u5)) -> ALTA_high_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & high_prov(BC, w, u1) & high_prov(BC, x, u2) & high_prov(BC, y, u3) & high_prov(BC, z, u4) & highest(u1,u2,u3,u4,u5)) -> BC_high_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & high_prov(YUK, w, u1) & high_prov(YUK, x, u2) & high_prov(YUK, y, u3) & high_prov(YUK, z, u4) & highest(u1,u2,u3,u4,u5)) -> YUK_high_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & high_prov(NWT, w, u1) & high_prov(NWT, x, u2) & high_prov(NWT, y, u3) & high_prov(NWT, z, u4) & highest(u1,u2,u3,u4,u5)) -> NWT_high_rank(w,x,y,z,u5)

```

```

(x) (prov_pop_rank(province, x, 1) -> high_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 2) -> high_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 3) -> high_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 4) -> high_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 5) -> high_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 6) -> high_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 7) -> high_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 8) -> high_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 9) -> high_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 10) -> high_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 11) -> high_prov(province, x, 1)
(x) (prov_pop_rank(province, x, 12) -> high_prov(province, x, 2)
(x) (prov_pop_rank(province, x, 13) -> high_prov(province, x, 3)
(x) (prov_pop_rank(province, x, 14) -> high_prov(province, x, 4)
(x) (prov_pop_rank(province, x, 15) -> high_prov(province, x, 5)
(x) (prov_pop_rank(province, x, 16) -> high_prov(province, x, 5)
(x) (prov_pop_rank(province, x, 17) -> high_prov(province, x, 5)
(x) (prov_pop_rank(province, x, 18) -> high_prov(province, x, 5)

```

Explanations:

w,x,y,z = scenarios

u1,u2,u3,u4,u5 = any values
 province = a province or territory
 prov_pop_rank(province,x,Number)= scenario x has an associated population projection for province that is ranked Number, where 18 is the highest population and 1 is the lowest

high_prov(province, x, Number) = scenario x is assigned a value of Number for this province
 prov_pop_rank(province,x,u1) = scenario x is ranked number u1 of the scenarios when ranked by ascending population order for province

NFLD_high_rank(w,x,y,z,u5) = the NFLD high evaluation for scenarios w,x,y, and z yields the number u5
 NS_high_rank(w,x,y,z,u5) = the NS high evaluation for scenarios w,x,y, and z yields the number u5
 NB_high_rank(w,x,y,z,u5) = the NB high evaluation for scenarios w,x,y, and z yields the number u5
 PEI_high_rank(w,x,y,z,u5) = the PEI high evaluation for scenarios w,x,y, and z yields the number u5
 QUE_high_rank(w,x,y,z,u5) = the QUE high evaluation for scenarios w,x,y, and z yields the number u5
 ONT_high_rank(w,x,y,z,u5) = the ONT high evaluation for scenarios w,x,y, and z yields the number u5
 MAN_high_rank(w,x,y,z,u5) = the MAN high evaluation for scenarios w,x,y, and z yields the number u5

SASK_high_rank(w,x,y,z,u5) = the SASK high evaluation for scenarios w,x,y, and z yields the number u5
 ALTA_high_rank(w,x,y,z,u5) = the ALTA high evaluation for scenarios w,x,y, and z yields the number u5
 BC_high_rank(w,x,y,z,u5) = the BC high evaluation for scenarios w,x,y, and z yields the number u5
 YUK_high_rank(w,x,y,z,u5) = the YUK high evaluation for scenarios w,x,y, and z yields the number u5
 NWT_high_rank(w,x,y,z,u5) = the NWT high evaluation for scenarios w,x,y, and z yields the number u5

Notes:

prov_pop_rank is determined outside of the rule based logical model.

Ranking of Low Scenarios by Each Province

(w)(x)(y)(z) (group(w,x,y,z) & low_prov(NFLD, w, u1) & low_prov(NFLD, x, u2) & low_prov(NFLD, y, u3) & low_prov(NFLD, z, u4) & highest(u1,u2,u3,u4,u5)) -> NFLD_low_rank(w,x,y,z,u5)
 (w)(x)(y)(z) (group(w,x,y,z) & low_prov(NS, w, u1) & low_prov(NS, x, u2) & low_prov(NS, y, u3) & low_prov(NS, z, u4) & highest(u1,u2,u3,u4,u5)) -> NS_low_rank(w,x,y,z,u5)
 (w)(x)(y)(z) (group(w,x,y,z) & low_prov(NB, w, u1) & low_prov(NB, x, u2) & low_prov(NB, y, u3) & low_prov(NB, z, u4) & highest(u1,u2,u3,u4,u5)) -> NB_low_rank(w,x,y,z,u5)
 (w)(x)(y)(z) (group(w,x,y,z) & low_prov(PEI, w, u1) & low_prov(PEI, x, u2) & low_prov(PEI, y, u3) & low_prov(PEI, z, u4) & highest(u1,u2,u3,u4,u5)) -> PEI_low_rank(w,x,y,z,u5)
 (w)(x)(y)(z) (group(w,x,y,z) & low_prov(QUE, w, u1) & low_prov(QUE, x, u2) & low_prov(QUE, y, u3) & low_prov(QUE, z, u4) & highest(u1,u2,u3,u4,u5)) -> QUE_low_rank(w,x,y,z,u5)
 (w)(x)(y)(z) (group(w,x,y,z) & low_prov(ONT, w, u1) & low_prov(ONT, x, u2) & low_prov(ONT, y, u3) & low_prov(ONT, z, u4) & highest(u1,u2,u3,u4,u5)) -> ONT_low_rank(w,x,y,z,u5)
 (w)(x)(y)(z) (group(w,x,y,z) & low_prov(MAN, w, u1) & low_prov(MAN, x, u2) & low_prov(MAN, y, u3) & low_prov(MAN, z, u4) & highest(u1,u2,u3,u4,u5)) -> MAN_low_rank(w,x,y,z,u5)
 (w)(x)(y)(z) (group(w,x,y,z) & low_prov(SASK, w, u1) & low_prov(SASK, x, u2) & low_prov(SASK, y, u3) & low_prov(SASK, z, u4) & highest(u1,u2,u3,u4,u5)) -> SASK_low_rank(w,x,y,z,u5)
 (w)(x)(y)(z) (group(w,x,y,z) & low_prov(ALTA, w, u1) & low_prov(ALTA, x, u2) & low_prov(ALTA, y, u3) & low_prov(ALTA, z, u4) & highest(u1,u2,u3,u4,u5)) -> ALTA_low_rank(w,x,y,z,u5)
 (w)(x)(y)(z) (group(w,x,y,z) & low_prov(BC, w, u1) & low_prov(BC, x, u2) & low_prov(BC, y, u3) & low_prov(BC, z, u4) & highest(u1,u2,u3,u4,u5)) -> BC_low_rank(w,x,y,z,u5)
 (w)(x)(y)(z) (group(w,x,y,z) & low_prov(YUK, w, u1) & low_prov(YUK, x, u2) & low_prov(YUK, y, u3) & low_prov(YUK, z, u4) & highest(u1,u2,u3,u4,u5)) -> YUK_low_rank(w,x,y,z,u5)
 (w)(x)(y)(z) (group(w,x,y,z) & low_prov(NWT, w, u1) & low_prov(NWT, x, u2) & low_prov(NWT, y, u3) & low_prov(NWT, z, u4) & highest(u1,u2,u3,u4,u5)) -> NWT_low_rank(w,x,y,z,u5)

(x) (prov_pop_rank(province, x, 1) -> low_prov(province, x, 5)
 (x) (prov_pop_rank(province, x, 2) -> low_prov(province, x, 5)
 (x) (prov_pop_rank(province, x, 3) -> low_prov(province, x, 5)
 (x) (prov_pop_rank(province, x, 4) -> low_prov(province, x, 5)
 (x) (prov_pop_rank(province, x, 5) -> low_prov(province, x, 4)
 (x) (prov_pop_rank(province, x, 6) -> low_prov(province, x, 3)
 (x) (prov_pop_rank(province, x, 7) -> low_prov(province, x, 2)
 (x) (prov_pop_rank(province, x, 8) -> low_prov(province, x, 1)
 (x) (prov_pop_rank(province, x, 9) -> low_prov(province, x, 0)
 (x) (prov_pop_rank(province, x, 10) -> low_prov(province, x, 0)
 (x) (prov_pop_rank(province, x, 11) -> low_prov(province, x, 0)
 (x) (prov_pop_rank(province, x, 12) -> low_prov(province, x, 0)
 (x) (prov_pop_rank(province, x, 13) -> low_prov(province, x, 0)
 (x) (prov_pop_rank(province, x, 14) -> low_prov(province, x, 0)
 (x) (prov_pop_rank(province, x, 15) -> low_prov(province, x, 0)
 (x) (prov_pop_rank(province, x, 16) -> low_prov(province, x, 0)
 (x) (prov_pop_rank(province, x, 17) -> low_prov(province, x, 0)
 (x) (prov_pop_rank(province, x, 18) -> low_prov(province, x, 0)

Explanations:

w,x,y,z = scenarios
 u1,u2,u3,u4,u5 = any values
 province = a province or territory
 prov_pop_rank(province,x,Number)= scenario x has an associated population projection for province that is ranked Number, where 18 is the highest population and 1 is the lowest

```

low_prov(province, x, Number) =
prov_pop_rank(province,x,u1) =
  lowest
  scenario x is assigned a value of Number for this province
  scenario x is ranked number u1 of the scenarios when ranked by
  ascending population order for province
  the NFID low evaluation for scenarios w,x,y, and z yields the number
  u5
  the NS low evaluation for scenarios w,x,y, and z yields the number u5
  the NB low evaluation for scenarios w,x,y, and z yields the number u5
  the PEI low evaluation for scenarios w,x,y, and z yields the number u5
  the QUE low evaluation for scenarios w,x,y, and z yields the number u5
  the ONT low evaluation for scenarios w,x,y, and z yields the number u5
  the MAN low evaluation for scenarios w,x,y, and z yields the number u5
  the SASK low evaluation for scenarios w,x,y, and z yields the number
  u5
  the ALTA low evaluation for scenarios w,x,y, and z yields the number
  u5
  the BC low evaluation for scenarios w,x,y, and z yields the number u5
  the YUK low evaluation for scenarios w,x,y, and z yields the number u5
  the NWT low evaluation for scenarios w,x,y, and z yields the number u5

```

Note:

prov_pop_rank is determined outside of the rule based logical model.

Ranking of Medium Scenarios by Each Province

```

(w)(x)(y)(z) (group(w,x,y,z) & medium_prov(NFID, w, u1) & medium_prov(NFID, x, u2) & medium_prov(NFID,
y, u3) & medium_prov(NFID, z, u4) & highest(u1,u2,u3,u4,u5)) ->
NFID_medium_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & medium_prov(NS, w, u1) & medium_prov(NS, x, u2) & medium_prov(NS, y,
u3) & medium_prov(NS, z, u4) & highest(u1,u2,u3,u4,u5)) -> NS_medium_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & medium_prov(NB, w, u1) & medium_prov(NB, x, u2) & medium_prov(NB, y,
u3) & medium_prov(NB, z, u4) & highest(u1,u2,u3,u4,u5)) -> NB_medium_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & medium_prov(PEI, w, u1) & medium_prov(PEI, x, u2) & medium_prov(PEI,
y, u3) & medium_prov(PEI, z, u4) & highest(u1,u2,u3,u4,u5)) ->
PEI_medium_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & medium_prov(QUE, w, u1) & medium_prov(QUE, x, u2) & medium_prov(QUE,
y, u3) & medium_prov(QUE, z, u4) & highest(u1,u2,u3,u4,u5)) ->
QUE_medium_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & medium_prov(ONT, w, u1) & medium_prov(ONT, x, u2) & medium_prov(ONT,
y, u3) & medium_prov(ONT, z, u4) & highest(u1,u2,u3,u4,u5)) ->
ONT_medium_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & medium_prov(MAN, w, u1) & medium_prov(MAN, x, u2) & medium_prov(MAN,
y, u3) & medium_prov(MAN, z, u4) & highest(u1,u2,u3,u4,u5)) ->
MAN_medium_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & medium_prov(SASK, w, u1) & medium_prov(SASK, x, u2) & medium_prov(SASK,
y, u3) & medium_prov(SASK, z, u4) & highest(u1,u2,u3,u4,u5)) ->
SASK_medium_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & medium_prov(ALTA, w, u1) & medium_prov(ALTA, x, u2) & medium_prov(ALTA,
y, u3) & medium_prov(ALTA, z, u4) & highest(u1,u2,u3,u4,u5)) ->
ALTA_medium_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & medium_prov(BC, w, u1) & medium_prov(BC, x, u2) & medium_prov(BC, y,
u3) & medium_prov(BC, z, u4) & highest(u1,u2,u3,u4,u5)) -> BC_medium_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & medium_prov(YUK, w, u1) & medium_prov(YUK, x, u2) & medium_prov(YUK,
y, u3) & medium_prov(YUK, z, u4) & highest(u1,u2,u3,u4,u5)) ->
YUK_medium_rank(w,x,y,z,u5)
(w)(x)(y)(z) (group(w,x,y,z) & medium_prov(NWT, w, u1) & medium_prov(NWT, x, u2) & medium_prov(NWT,
y, u3) & medium_prov(NWT, z, u4) & highest(u1,u2,u3,u4,u5)) ->
NWT_medium_rank(w,x,y,z,u5)

```

```

(1) (prov_pop_rank(province, x, 1) -> medium_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 2) -> medium_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 3) -> medium_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 4) -> medium_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 5) -> medium_prov(province, x, 1)
(x) (prov_pop_rank(province, x, 6) -> medium_prov(province, x, 2)
(x) (prov_pop_rank(province, x, 7) -> medium_prov(province, x, 3)
(x) (prov_pop_rank(province, x, 8) -> medium_prov(province, x, 4)
(x) (prov_pop_rank(province, x, 9) -> medium_prov(province, x, 5)
(x) (prov_pop_rank(province, x, 10) -> medium_prov(province, x, 5)
(x) (prov_pop_rank(province, x, 11) -> medium_prov(province, x, 5)
(x) (prov_pop_rank(province, x, 12) -> medium_prov(province, x, 3)
(x) (prov_pop_rank(province, x, 13) -> medium_prov(province, x, 2)
(x) (prov_pop_rank(province, x, 14) -> medium_prov(province, x, 1)
(x) (prov_pop_rank(province, x, 15) -> medium_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 16) -> medium_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 17) -> medium_prov(province, x, 0)
(x) (prov_pop_rank(province, x, 18) -> medium_prov(province, x, 0)

```

Explanations:

w,x,y,z = scenarios

u1,u2,u3,u4,u5 = any values

province = a province or territory

prov_pop_rank(province,x,Number)= scenario x has an associated population projection for province that is ranked Number, where 18 is the highest population and 1 is the lowest

medium_prov(province, x, Number) = scenario x is assigned a value of Number for this province

```

prcv_pop_rank(province,x,u1) = scenario x is ranked number u1 of the scenarios when ranked by
                                ascending population order for province
NPLD_medium_rank(w,x,y,z,u5) = the NPLD medium evaluation for scenarios w,x,y, and z yields the number
                                u5
MS_medium_rank(w,x,y,z,u5) = the MS medium evaluation for scenarios w,x,y, and z yields the number
                                u5
NB_medium_rank(w,x,y,z,u5) = the NB medium evaluation for scenarios w,x,y, and z yields the number
                                u5
PEI_medium_rank(w,x,y,z,u5) = the PEI medium evaluation for scenarios w,x,y, and z yields the number
                                u5
QUE_medium_rank(w,x,y,z,u5) = the QUE medium evaluation for scenarios w,x,y, and z yields the number
                                u5
ONT_medium_rank(w,x,y,z,u5) = the ONT medium evaluation for scenarios w,x,y, and z yields the number
                                u5
MAN_medium_rank(w,x,y,z,u5) = the MAN medium evaluation for scenarios w,x,y, and z yields the number
                                u5
SASK_medium_rank(w,x,y,z,u5) = the SASK medium evaluation for scenarios w,x,y, and z yields the number
                                u5
ALTA_medium_rank(w,x,y,z,u5) = the ALTA medium evaluation for scenarios w,x,y, and z yields the number
                                u5
BC_medium_rank(w,x,y,z,u5) = the BC medium evaluation for scenarios w,x,y, and z yields the number
                                u5
YUK_medium_rank(w,x,y,z,u5) = the YUK medium evaluation for scenarios w,x,y, and z yields the number
                                u5
NWT_medium_rank(w,x,y,z,u5) = the NWT medium evaluation for scenarios w,x,y, and z yields the number
                                u5

```

Note:

prcv_pop_rank is determined outside of the rule based logical model.

Addition of Rank Scores

```

(u1)(u2)(u3)(u4)(u5)(u6)(u7)(u8)(u9)(u10)(u11)(u12)(3sum) ->
add_scores(u1,u2,u3,u4,u5,u6,u7,u8,u9,u10,u11,u12,sum)

```

Explanations:

u1,u2,u3,u4,u5,u6,u7,u8,u9,u10,u11,u12 = numeric values

sum = numeric value which is the summation of u1..u12.

add_scores(u1,u2,u3,u4,u5,u6,u7,u8,u9,u10,u11,u12,sum) = sum has the characteristic that it is the arithmetic sum of u1..u12

Overall High Rank for each Scenario Set

```

(w)(x)(y)(z) (group(w,x,y,z) & NPLD_high_rank(w,x,y,z,u1) & MS_high_rank(w,x,y,z,u2) &
NB_high_rank(w,x,y,z,u3) & PEI_high_rank(w,x,y,z,u4) & QUE_high_rank(w,x,y,z,u5) &
ONT_high_rank(w,x,y,z,u6) & MAN_high_rank(w,x,y,z,u6) & SASK_high_rank(w,x,y,z,u8) &
ALTA_high_rank(w,x,y,z,u9) & BC_high_rank(w,x,y,z,u10) & YUK_high_rank(w,x,y,z,u11) &
NWT_high_rank(w,x,y,z,u12) & add_scores(u1,u2,u3,u4,u5,u6,u7,u8,u9,u10,u11,u12,sum)) ->
overall_high_raw(w,x,y,z,sum)

```

Explanations:

u1,u2,u3,u4,u5,u6,u7,u8,u9,u10,u11,u12 = numeric values

sum = numeric value which is the summation of u1..u12.

overall_high_raw(w,x,y,z,sum) = overall high ranking score for scenario set w,x,y,z is value sum

Overall Medium Rank for each Scenario Set

```

(w)(x)(y)(z) (group(w,x,y,z) & NPLD_medium_rank(w,x,y,z,u1) & MS_medium_rank(w,x,y,z,u2) &
NB_medium_rank(w,x,y,z,u3) & PEI_medium_rank(w,x,y,z,u4) & QUE_medium_rank(w,x,y,z,u5) &
ONT_medium_rank(w,x,y,z,u6) & MAN_medium_rank(w,x,y,z,u6) & SASK_medium_rank(w,x,y,z,u8) &
ALTA_medium_rank(w,x,y,z,u9) & BC_medium_rank(w,x,y,z,u10) & YUK_medium_rank(w,x,y,z,u11) &
NWT_medium_rank(w,x,y,z,u12) & add_scores(u1,u2,u3,u4,u5,u6,u7,u8,u9,u10,u11,u12,sum)) ->
overall_medium_raw(w,x,y,z,sum)

```

Explanations:

u1,u2,u3,u4,u5,u6,u7,u8,u9,u10,u11,u12 = numeric values

sum = numeric value which is the summation of u1..u12.

overall_medium_raw(w,x,y,z,sum) = overall medium ranking score for scenario set w,x,y,z is value sum

Overall Low Rank for each Scenario Set

```

(w)(x)(y)(z) (group(w,x,y,z) & NPLD_low_rank(w,x,y,z,u1) & MS_low_rank(w,x,y,z,u2) &
NB_low_rank(w,x,y,z,u3) & PEI_low_rank(w,x,y,z,u4) & QUE_low_rank(w,x,y,z,u5) & ONT_low_rank(w,x,y,z,u6) &
MAN_low_rank(w,x,y,z,u6) & SASK_low_rank(w,x,y,z,u8) & ALTA_low_rank(w,x,y,z,u9) &
BC_low_rank(w,x,y,z,u10) & YUK_low_rank(w,x,y,z,u11) & NWT_low_rank(w,x,y,z,u12) &
add_scores(u1,u2,u3,u4,u5,u6,u7,u8,u9,u10,u11,u12,sum)) -> overall_low_raw(w,x,y,z,sum)

```

Explanations:

u1,u2,u3,u4,u5,u6,u7,u8,u9,u10,u11,u12 = numeric values

sum = numeric value which is the summation of u1..u12.

overall_low_raw(w,x,y,z,sum) = overall low ranking score for scenario set w,x,y,z is value sum

Range Evaluation for each Scenario Group by Province

```
(w)(x)(y)(z) (WFLD_range_rank(w,x,y,z,u1) & NS_range_rank(w,x,y,z,u2) & NB_range_rank(w,x,y,z,u3) &
PEI_range_rank(w,x,y,z,u4) & QUE_range_rank(w,x,y,z,u5) & ONT_range_rank(w,x,y,z,u6) &
MAN_range_rank(w,x,y,z,u7) & SASX_range_rank(w,x,y,z,u8) & ALTA_range_rank(w,x,y,z,u9) &
BC_range_rank(w,x,y,z,u10) & YUK_range_rank(w,x,y,z,u11) & NWT_range_rank(w,x,y,z,u12) &
add_scores(u1,u2,u3,u4,u5,u6,u7,u8,u9,u10,u11,u12,sum)) -> overall_range_score_raw(w,x,y,z,sum)
```

```
(w)(x)(y)(z) ((group(w,x,y,z) & prov_range_rank(WFLD,small,w,x,y,z,Ranking)) ->
WFLD_range_rank(w,x,y,z,Ranking))
(w)(x)(y)(z) ((group(w,x,y,z) & prov_range_rank(NS,small,w,x,y,z,Ranking)) ->
NS_range_rank(w,x,y,z,Ranking))
(w)(x)(y)(z) ((group(w,x,y,z) & prov_range_rank(NB,small,w,x,y,z,Ranking)) ->
NB_range_rank(w,x,y,z,Ranking))
(w)(x)(y)(z) ((group(w,x,y,z) & prov_range_rank(PEI,small,w,x,y,z,Ranking)) ->
PEI_range_rank(w,x,y,z,Ranking))
(w)(x)(y)(z) ((group(w,x,y,z) & prov_range_rank(QUE,large,w,x,y,z,Ranking)) ->
QUE_range_rank(w,x,y,z,Ranking))
(w)(x)(y)(z) ((group(w,x,y,z) & prov_range_rank(ONT,large,w,x,y,z,Ranking)) ->
ONT_range_rank(w,x,y,z,Ranking))
(w)(x)(y)(z) ((group(w,x,y,z) & prov_range_rank(MAN,large,w,x,y,z,Ranking)) ->
MAN_range_rank(w,x,y,z,Ranking))
(w)(x)(y)(z) ((group(w,x,y,z) & prov_range_rank(SASX,large,w,x,y,z,Ranking)) ->
SASX_range_rank(w,x,y,z,Ranking))
(w)(x)(y)(z) ((group(w,x,y,z) & prov_range_rank(ALTA,large,w,x,y,z,Ranking)) ->
ALTA_range_rank(w,x,y,z,Ranking))
(w)(x)(y)(z) ((group(w,x,y,z) & prov_range_rank(BC,large,w,x,y,z,Ranking)) ->
BC_range_rank(w,x,y,z,Ranking))
(w)(x)(y)(z) ((group(w,x,y,z) & prov_range_rank(YUK,small,w,x,y,z,Ranking)) ->
YUK_range_rank(w,x,y,z,Ranking))
(w)(x)(y)(z) ((group(w,x,y,z) & prov_range_rank(NWT,small,w,x,y,z,Ranking)) ->
NWT_range_rank(w,x,y,z,Ranking))
```

```
(province)(province_size)(w)(x)(y)(z) (highest(population(province,w), population(province,x),
population(province,y), population(province,s),high_pop) & lowest(population(province,w),
population(province,x), population(province,y), population(province,s),low_pop) &
(overall_prov_range(high_pop, low_pop, province_size, economic(province),
demographic(province),rankscore)) & upper_lower_range(high_pop, low_pop, w,x,y,z, economic(province),
demographic(province), upper_lower_score) & add_two(over_score, upper_lower_score,sum)) ->
prov_range_rank(province, prov_size, w, x, y, z, sum)
```

Note:

The following rules have the same quantifier:
(high_pop)(low_pop)(province_size)(economic_picture)(long_demographic)

```
(high_pop)(low_pop)(province_size)(economic_picture)(long_demographic) (size_equal(prov_size,small) &
high_uncertainty(economic_picture, long_demographic) & high_total_ratio(high_pop,low_pop)) ->
overall_prov_range(high_pop, low_pop, economic_picture, long_demographic, province_size, 5)
```

```
(high_pop)(low_pop)(province_size) ((high_ratio(high_pop,low_pop) & high_uncertainty(economic_picture,
long_demographic) & (size_equal(prov_size,small) & (assign(orank,5)))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orank)
```

```
(medium_ratio(high_pop,low_pop) & high_uncertainty(economic_picture, long_demographic) &
(size_equal(prov_size,small) & (assign(orank,0)))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orank)
```

```
(low_ratio(high_pop,low_pop) & high_uncertainty(economic_picture, long_demographic) &
(size_equal(prov_size,small) & (assign(orank,0)))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orank)
```

```
(high_ratio(high_pop,low_pop) & some_uncertainty(economic_picture, long_demographic) &
(size_equal(prov_size,small) & (assign(orank,5)))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orank)
```

```
(medium_ratio(high_pop,low_pop) & some_uncertainty(economic_picture, long_demographic) &
(size_equal(prov_size,small) & (assign(orank,5)))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orank)
```

```
(low_ratio(high_pop,low_pop) & some_uncertainty(economic_picture, long_demographic) &
(size_equal(prov_size,small) & (assign(orank,0)))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orank)
```

```
(high_ratio(high_pop,low_pop) & low_uncertainty(economic_picture, long_demographic) &
(size_equal(prov_size,small) & (assign(orank,5)))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orank)
```

```
(medium_ratio(high_pop,low_pop) & low_uncertainty(economic_picture, long_demographic) &
(size_equal(prov_size,small) & (assign(orank,5)))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orank)
```

```
(low_ratio(high_pop,low_pop) & low_uncertainty(economic_picture, long_demographic) &
(size_equal(prov_size,small) & (assign(orank,0)))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orank)
```

```
(high_pop)(low_pop)(province_size)((high_ratio(high_pop,low_pop) & high_uncertainty(economic_picture,
long_demographic) & (size_equal(prov_size,large) & (assign(orank,5)))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orank)
```

```

(medium_ratio(high_pop,low_pop) & high_uncertainty(economic_picture, long_demographic) &
(size_equal(prov_size,large)) & (assign(orange,2))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orange)

(low_ratio(high_pop,low_pop) & high_uncertainty(economic_picture, long_demographic) &
(size_equal(prov_size,large)) & (assign(orange,0))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orange)

(high_ratio(high_pop,low_pop) & some_uncertainty(economic_picture, long_demographic) &
(size_equal(prov_size,large)) & (assign(orange,0))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orange)

(medium_ratio(high_pop,low_pop) & some_uncertainty(economic_picture, long_demographic) &
(size_equal(prov_size,large)) & (assign(orange,5))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orange)

(low_ratio(high_pop,low_pop) & some_uncertainty(economic_picture, long_demographic) &
(size_equal(prov_size,large)) & (assign(orange,0))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orange)

(high_ratio(high_pop,low_pop) & low_uncertainty(economic_picture, long_demographic) &
(size_equal(prov_size,large)) & (assign(orange,2))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orange)

(medium_ratio(high_pop,low_pop) & low_uncertainty(economic_picture, long_demographic) &
(size_equal(prov_size,large)) & (assign(orange,5))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orange)

(low_ratio(high_pop,low_pop) & low_uncertainty(economic_picture, long_demographic) &
(size_equal(prov_size,large)) & (assign(orange,2))) ->
overall_rank(high_pop,low_pop,prov_size,economic_picture, long_demographic, orange)
End of block of rules with same quantifier.

(economic)(demographic) close_trends(economic, demographic) -> low_uncertainty(economic,demographic)
(economic)(demographic) not_close_or_divergent_trends(economic, demographic) ->
medium_uncertainty(economic,demographic)
(economic)(demographic) divergent_trends(economic, demographic) -> high_uncertainty(economic,demographic)

(high_pop)(low_pop)(economic)(demographic)(w)(x)(y)(z) (small_upper_lower_ratio(high_pop,low_pop,w,x,y,z)
& positive_demographic(economic,demographic) & assign(upper_lower_score,5)) ->
upper_lower_range(high_pop,low_pop,w,x,y,z,economic,demographic,upper_lower_score)

(high_pop)(low_pop)(economic)(demographic)(w)(x)(y)(z) (medium_upper_lower_ratio(high_pop,low_pop,w,x,y,z)
& positive_demographic(economic,demographic) & assign(upper_lower_score,3)) ->
upper_lower_range(high_pop,low_pop,w,x,y,z,economic,demographic,upper_lower_score)

(high_pop)(low_pop)(economic)(demographic)(w)(x)(y)(z) (large_upper_lower_ratio(high_pop,low_pop,w,x,y,z)
& positive_demographic(economic,demographic) & assign(upper_lower_score,0)) ->
upper_lower_range(high_pop,low_pop,w,x,y,z,economic,demographic,upper_lower_score)

(high_pop)(low_pop)(economic)(demographic)(w)(x)(y)(z) (small_upper_lower_ratio(high_pop,low_pop,w,x,y,z)
& neutral_demographic(economic,demographic) & assign(upper_lower_score,2)) ->
upper_lower_range(high_pop,low_pop,w,x,y,z,economic,demographic,upper_lower_score)

(high_pop)(low_pop)(economic)(demographic)(w)(x)(y)(z) (medium_upper_lower_ratio(high_pop,low_pop,w,x,y,z)
& neutral_demographic(economic,demographic) & assign(upper_lower_score,5)) ->
upper_lower_range(high_pop,low_pop,w,x,y,z,economic,demographic,upper_lower_score)

(high_pop)(low_pop)(economic)(demographic)(w)(x)(y)(z) (large_upper_lower_ratio(high_pop,low_pop,w,x,y,z)
& neutral_demographic(economic,demographic) & assign(upper_lower_score,2)) ->
upper_lower_range(high_pop,low_pop,w,x,y,z,economic,demographic,upper_lower_score)

(high_pop)(low_pop)(economic)(demographic)(w)(x)(y)(z) (small_upper_lower_ratio(high_pop,low_pop,w,x,y,z)
& negative_demographic(economic,demographic) & assign(upper_lower_score,0)) ->
upper_lower_range(high_pop,low_pop,w,x,y,z,economic,demographic,upper_lower_score)

(high_pop)(low_pop)(economic)(demographic)(w)(x)(y)(z) (medium_upper_lower_ratio(high_pop,low_pop,w,x,y,z)
& negative_demographic(economic,demographic) & assign(upper_lower_score,0)) ->
upper_lower_range(high_pop,low_pop,w,x,y,z,economic,demographic,upper_lower_score)

(high_pop)(low_pop)(economic)(demographic)(w)(x)(y)(z) (large_upper_lower_ratio(high_pop,low_pop,w,x,y,z)
& negative_demographic(economic,demographic) & assign(upper_lower_score,5)) ->
upper_lower_range(high_pop,low_pop,w,x,y,z,economic,demographic,upper_lower_score)

```

Explanations:

high_pop,low_pop = population numbers
 economic,demographic = economic and demographic picture
 province = a province or territory
 w,x,y,z = scenarios
 orange = score for evaluation of total range
 upper_lower_score = score for evaluation of upper and lower ranges

Overall Score for each Scenario Group

```

(w)(x)(y)(z) (group(w,x,y,z) & overall_high_raw(w,x,y,z,high_score) &
normal_high(high_score,normal_high_score) & overall_medium_raw(w,x,y,z,medium_score) &

```

```

normal_medium(medium_score,normal_medium_score) & overall_low_raw(w,x,y,z,low_score) &
normal_low(low_score,normal_low_score) & overall_range_score_raw(w,x,y,z,range_score) &
normal_range(range_score,normal_range_score) &
normal_add(normal_low_score,normal_high_score,normal_medium_score,normal_range_score,total_score) ->
group_score(w,x,y,z,total_score)

```

Explanations:

This set of rules normalizes the different scores and adds them. The different components are thus given different weights. The range score is assigned a weight of 40 while the three other scores are assigned weights of 20.

Best Overall Score

The highest group_score is an indicator of the scenario group best suited for publication. Note that it is possible to not select a scenario group.

Final Note:

A number of predicates in the provincial segment draw on functions which were developed elsewhere using non-logical formalisms. One example is `prov_pop_rank`. This predicate would return a value reflecting the rank of the scenario for that province in terms of population relative to the other scenarios.

APPENDIX 4: PSSA: NATIONAL SEGMENT

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PSSA Design Introduction

The logical model was converted into an implementation model in the form of an ES prototype. This ES prototype of the PSSA was an amalgamation of two different logical segments which performed two different, but inter-related tasks. The first was the national segment; its primary task was to select the scenarios which best suited several national criteria. Essentially, it filtered the scenario set using these criteria. This segment was developed on the XiPlus platform.

The second segment was the provincial segment. This segment used the filtered data from the national segment, and produced the final selection of which scenarios are most appropriate for publication purposes. The primary communication between the two segments was via the use of the "natchoic.txt" ascii file. The development platform for the provincial segment was the C language.

The details of the national segment are presented here in the XiPlus rules format.

The National Segment

HIPO Chart

National File Segment File Structures

File: scenario

Purpose: This is a comma delimited file that contains some basic data about the national scenarios. The national scenarios just include the fertility, mortality and external migration assumptions. This file is read by national.cmp

Structure: The file has the following record structure:
 scenario_name, fertility assumption, external migration e.g. scenario1, High, High, scenario2, High, Low

The fertility and the migration fields describe the respective assumptions associated with each particular scenario.

File: natchoic.txt

Purpose: This file is the final result of the National segment. It contains the selected national level scenarios.

Structure:

Scenario_type, scenario_number, fertility, migration

Scenario_type is one of [High, Medium, Low]

scenario_number is one of [scenario1, scenario2, scenario3, scenario4, scenario5, scenario6]

fertility is one of [high, medium, low]

migration is one of [high, low]

e.g. High , scenario1 , high , high

XiPlus Module: Natques.cmp

Purpose: The purpose of this module is to query the user regarding trends in Canada to assist in determining which scenarios will best represent Canada at the National level. Once the questions are asked, and the module reasons some conclusions, control is passed to another XiPlus module, national.cmp. The results of the reasoning are passed to national.cmp via the agenda database.

XiPlus Rules:

```

if  government policy is evaluated
  and immigration trend is evaluated
  and refugee situation is evaluated
  and migration certainty factor >= 50
then migration outlook is high

if  government policy is evaluated
  and immigration trend is evaluated
  and refugee situation is evaluated
  and migration certainty factor < 50
  and migration certainty factor >= 35
then migration outlook is medium

if  government policy is evaluated
  and immigration trend is evaluated
  and refugee situation is evaluated
  and migration certainty factor < 35
then migration outlook is low

if  government white paper is evaluated
  and recent government event is evaluated
  and recent government trend is evaluated
then government policy is evaluated

if  recent government tendency is high increases
then recent government trend is evaluated
  and migration certainty factor = migration certainty
factor + 10

if  recent government tendency is some increases
then recent government trend is evaluated
  and migration certainty factor = migration certainty
factor + 5

if  recent government tendency is no increases
then recent government trend is evaluated

if  recent government event outlook is very favorable to
increase

```

then recent government event is evaluated
 and migration certainty factor = migration certainty
 factor + 20

if recent government event outlook is somewhat favorable
 to increase
 then recent government event is evaluated
 and migration certainty factor = migration certainty
 factor + 10

if recent government event outlook is against increase
 then recent government event is evaluated

if government white paper outlook is very favorable to
 increase
 then government white paper is evaluated
 and migration certainty factor = migration certainty
 factor + 20

if government white paper outlook is somewhat favorable
 to increase
 then government white paper is evaluated
 and migration certainty factor = migration certainty
 factor + 10

if government white paper outlook is opposed to increase
 then government white paper is evaluated

if current refugee status is evaluated
 and recent refugee event is evaluated
 then refugee situation is evaluated

if actual refugee status is large increases
 then current refugee status is evaluated
 and migration certainty factor = migration certainty
 factor + 8

if actual refugee status is some increases
 then current refugee status is evaluated
 and migration certainty factor = migration certainty
 factor + 4

if actual refugee status is no increases
 then current refugee status is evaluated

if recent refugee outlook is strongly favorable for
 increase
 then recent refugee event is evaluated
 and migration certainty factor = migration certainty
 factor + 7

if recent refugee outlook is somewhat favorable for

```

increase
  then recent refugee event is evaluated
  and migration certainty factor = migration certainty
  factor + 3

  if recent refugee outlook is unfavorable for increases
  then recent refugee event is evaluated

  if other governments migration is evaluated
  and actual migration is evaluated
  then immigration trend is evaluated

  if other governments migration status is large increases
  then other governments migration is evaluated
  and migration certainty factor = migration certainty
  factor + 10

  if other governments migration status is slight increases
  then other governments migration is evaluated
  and migration certainty factor = migration certainty
  factor + 5

  if other governments migration status is decreases or no
  increases
  then other governments migration is evaluated

  if actual migration status is actual immigration much
  higher
  then actual migration is evaluated
  and migration certainty factor = migration certainty
  factor + 25

  if actual migration status is actual immigration somewhat
  higher
  then actual migration is evaluated
  and migration certainty factor = migration certainty
  factor + 15

  if actual migration status is actual immigration about
  the same
  then actual migration is evaluated
  and migration certainty factor = migration certainty
  factor + 5

  if actual migration status is actual immigration lower
  then actual migration is evaluated

  if recent fertility is evaluated
  and fertility trend in other countries is evaluated
  and fertility certainty factor >= 70
  then fertility outlook is high
  and report Fertility is High

```

```

if recent fertility is evaluated
  and fertility trend in other countries is evaluated
  and fertility certainty factor < 70
  and fertility certainty factor >= 45
then fertility outlook is medium
  and report fertility is medium

if recent fertility is evaluated
  and fertility trend in other countries is evaluated
  and fertility certainty factor < 45
then fertility outlook is low
  and report Fertility is Low

if fertility trend status is expect near term fertility
increase
  then recent fertility is evaluated
  and fertility certainty factor = fertility certainty
factor + 70

if fertility trend status is expect fertility at status
quo
  then recent fertility is evaluated
  and fertility certainty factor = fertility certainty
factor + 30

if fertility trend status is expect near term fertility
decline
  then recent fertility is evaluated

if other country fertility status is recent increases
  then fertility trend in other countries is evaluated
  and fertility certainty factor = fertility certainty
factor + 30

if other country fertility status is remain at status quo
  then fertility trend in other countries is evaluated
  and fertility certainty factor = fertility certainty
factor + 15

if other country fertility status is recent decreases
  then fertility trend in other countries is evaluated

if migration outlook is high or medium or low
  and fertility outlook is high or medium or low
then outlook stuff is satisfied
  and command save dbs natques
  and command load national

default      migration certainty factor = 0
default      fertility certainty factor = 0

```

query outlook stuff

Module: National.cmp

Purpose: The purpose of this module is to select the scenarios that best fit the national situation. To make the decision, the questions posed in the preceding segment, natques.cmp, are used in conjunction with the data read from the scenario file. The scenario file contains basic information regarding each scenario such as fertility assumptions, mortality assumptions, scenario name, etc.

Once the decision is made, the user is notified and the results are displayed. The results are also written to the file "natchoic.txt" which is used later in the provincial segment.

XiPlus Rules:

```
fact      scenario1 is a national scenario
fact      scenario2 is a national scenario
fact      scenario3 is a national scenario
fact      start is true
fact      scenario4 is a national scenario
fact      scenario5 is a national scenario
fact      scenario6 is a national scenario
fact      number of scenario1 is 1
fact      number of scenario2 is 2
fact      number of scenario3 is 3
fact      number of scenario4 is 4
fact      number of scenario5 is 5
fact      number of scenario6 is 6

    when scenario data is loading
    then cells1 is a1.c1
      and file is nation.cdf
      and do read cdf using ( file , cells1 ) giving ( scenario1
, fertility of scenario1 , migration of scenario1 )

    when scenario data is loading
    then cells2 is a2.c3
      and file is nation.cdf
      and do read cdf using ( file , cells2 ) giving ( scenario2
, fertility of scenario2 , migration of scenario2 )

    when scenario data is loading
    then cells3 is a3.c3
      and file is nation.cdf
      and do read cdf using ( file , cells3 ) giving ( scenario3
, fertility of scenario3 , migration of scenario3 )

    when scenario data is loading
```

```

    then cells4 is a4.c4
      and file is nation.cdf
      and do read cdf using ( file , cells4 ) giving ( scenario4
, fertility of scenario4 , migration of scenario4 )

    when scenario data is loading
      then cells5 is a5.c5
        and file is nation.cdf
        and do read cdf using ( file , cells5 ) giving ( scenario5
, fertility of scenario5 , migration of scenario5 )

    when scenario data is loading
      then cells6 is a6.c6
        and file is nation.cdf
        and do read cdf using ( file , cells6 ) giving ( scenario6
, fertility of scenario6 , migration of scenario6 )

    if    scenario data is loading
      and low filter is selected
      and high filter is selected
      and medium filter is selected
    then national is selected
      and report High Scenario is [high scenario]
      and report Medium Scenario is [medium scenario]
      and report Low Scenario is [low scenario]
      and report to file natchoic.txt High , [high scenario] ,
[fertility of high scenario] , [migration of high scenario]
      and report to file natchoic.txt Medium , [medium scenario]
, [fertility of medium scenario] , [migration of medium
scenario]
      and report to file natchoic.txt Low , [low scenario] ,
[fertility of low scenario] , [migration of low scenario]
      and command reset kb
      and command load pei2

    if    start is true
      then scenario data is loading

    if    Scenario is a national scenario
      and fertility of Scenario is high
      and migration of Scenario is high
      and fertility of Scenario is Fertility
      and migration of Scenario is Migration
    then high scenario is Scenario
      and high filter is selected
      and fertility of high scenario is Fertility
      and migration of high scenario is Migration

    if    Scenario is a national scenario
      and fertility of Scenario is low
      and migration of Scenario is low

```

```

then low scenario is Scenario
  and low filter is selected
  and fertility of low scenario is low
  and migration of low scenario is low

if Scenario is a national scenario
  and most likely criteria of Scenario is satisfied
  and assumption combination criteria of Scenario is
satisfied
  and migration of Scenario is Migration
  and fertility of Scenario is Fertility
  and criss_cross criteria of Scenario is satisfied
then medium filter is selected
  and medium scenario is Scenario
  and migration of medium scenario is Migration
  and fertility of medium scenario is Fertility

if Scenario is a national scenario
  and fertility of high scenario is high
  and fertility of low scenario is low
  and fertility of Scenario is medium
  and high scenario is not Scenario
  and low scenario is not Scenario
then fertility assumption criteria of Scenario is satisfied

if Scenario is a national scenario
  and fertility of high scenario is high
  and fertility of low scenario is medium
  and fertility of Scenario is low
  and high scenario is not Scenario
  and low scenario is not Scenario
then fertility assumption criteria of Scenario is satisfied

if Scenario is a national scenario
  and fertility of high scenario is low
  and fertility of Scenario is medium
  and fertility of low scenario is high
  and high scenario is not Scenario
  and low scenario is not Scenario
then fertility assumption criteria of Scenario is satisfied

if Scenario is a national scenario
  and fertility of high scenario is low
  and fertility of Scenario is high
  and fertility of low scenario is medium
  and high scenario is not Scenario
  and low scenario is not Scenario
then fertility assumption criteria of Scenario is satisfied

if Scenario is a national scenario
  and fertility of high scenario is low
  and fertility of Scenario is medium

```

```

    and fertility of low scenario is high
    and high scenario is not Scenario
    and low scenario is not Scenario
    then fertility assumption criteria of Scenario is satisfied

    if  Scenario is a national scenario
    and fertility of high scenario is medium
    and fertility of Scenario is high
    and fertility of low scenario is low
    and high scenario is not Scenario
    and low scenario is not Scenario
    then fertility assumption criteria of Scenario is satisfied

    if  Scenario is a national scenario
    and fertility assumption criteria of Scenario is satisfied
    and migration assumption criteria of Scenario is satisfied
    then assumption combination criteria of Scenario is
satisfied

    if  Scenario is a national scenario
    and low scenario is not Scenario
    and high scenario is not Scenario
    and migration of high scenario is high
    and migration of Scenario is low
    and migration of low scenario is low
    then migration assumption criteria of Scenario is satisfied

    if  Scenario is a national scenario
    and low scenario is not Scenario
    and high scenario is not Scenario
    and migration of high scenario is high
    and migration of Scenario is high
    and migration of low scenario is low
    then migration assumption criteria of Scenario is satisfied

    if  Sceanrio is a national scenario
    and low scenario is not Scenario
    and high scenario is not Scenario
    and migration of high scenario is low
    and migration of Scenario is high
    and migration of low scenario is low
    then migration assumption criteria of Scenario is satisfied

    if  Scenario is a national scenario
    and low scenario is not Scenario
    and high scenario is not Scenario
    and migration of high scenario is low
    and migration of Scenario is high
    and migration of low scenario is high
    then migration assumption criteria of Scenario is satisfied

    if  Scenario is a national scenario

```

and low scenario is not Scenario
 and high scenario is not Scenario
 and migration of high scenario is low
 and migration of Scenario is low
 and migration of low scenario is high
 then migration assumption criteria of Scenario is satisfied

if Scenario is a national scenario
 and low scenario is not Scenario
 and high scenario is not Scenario
 and migration of high scenario is high
 and migration of Scenario is low
 and migration of low scenario is high
 then migration assumption criteria of Scenario is satisfied

if Scenario is a national scenario
 and most likely migration of Scenario is satisfied
 and most likely fertility of Scenario is satisfied
 and preferred combinations of Scenario is satisfied
 then most likely criteria of Scenario is satisfied

if fertility outlook is high
 and fertility of Scenario is high
 and Scenario is a national scenario
 then most likely fertility of Scenario is satisfied

if fertility outlook is medium
 and fertility of Scenario is high
 and Scenario is a national scenario
 then most likely fertility of Scenario is satisfied

if fertility outlook is high
 and fertility of Scenario is medium
 and Scenario is a national scenario
 then most likely fertility of Scenario is satisfied

if fertility outlook is medium
 and fertility of Scenario is medium
 and Scenario is a national scenario
 then most likely fertility of Scenario is satisfied

if fertility outlook is low
 and fertility of Scenario is medium
 and Scenario is a national scenario
 then most likely fertility of Scenario is satisfied

if fertility outlook is medium
 and fertility of Scenario is low
 and Scenario is a national scenario
 then most likely fertility of Scenario is satisfied

if fertility outlook is low

```

    and Scenario is a national scenario
    and fertility of Scenario is low
    then most likely fertility of Scenario is satisfied

```

```

if    migration outlook is high
    and Scenario is a national scenario
    and migration of Scenario is high
then most likely migration of Scenario is satisfied

```

```

if    migration outlook is medium
    and Scenario is a national scenario
    and migration of Scenario is high
then most likely migration of Scenario is satisfied

```

```

if    migration outlook is low
    and Scenario is a national scenario
    and migration of Scenario is low
then most likely migration of Scenario is satisfied

```

```

if    migration outlook is medium
    and Scenario is a national scenario
    and migration of Scenario is low
then most likely migration of Scenario is satisfied

```

```

default    fertility of scenario1 is not_known
default    fertility of scenario2 is not_known
default    fertility of scenario3 is not_known
default    migration of scenario1 is not_known
default    migration of scenario2 is not_known
default    migration of scenario3 is not_known
default    migration of scenario4 is not_known
default    fertility of scenario4 is not_known
default    migration of scenario5 is not_known
default    fertility of scenario5 is not_known
default    migration of scenario6 is not_known
default    fertility of scenario6 is not_known
default    most likely criteria of scenario1 is unsatisfied
default    most likely criteria of scenario2 is unsatisfied
default    most likely criteria of scenario3 is unsatisfied
default    most likely criteria of scenario4 is unsatisfied
default    most likely criteria of scenario5 is unsatisfied
default    most likely criteria of scenario6 is unsatisfied
default    criss_cross criteria of scenario1 is satisfied
default    criss_cross criteria of scenario2 is satisfied
default    criss_cross criteria of scenario3 is satisfied
default    criss_cross criteria of scenario4 is satisfied
default    criss_cross criteria of scenario5 is satisfied
default    criss_cross criteria of scenario6 is satisfied
default    most likely fertility of scenario1 is unsatisfied
default    most likely fertility of scenario2 is unsatisfied
default    most likely fertility of scenario3 is unsatisfied

```

default	most likely fertility of scenario4 is unsatisfied
default	most likely fertility of scenario5 is unsatisfied
default	most likely fertility of scenario6 is unsatisfied
default	most likely migration of scenario1 is unsatisfied
default	most likely migration of scenario2 is unsatisfied
default	most likely migration of scenario3 is unsatisfied
default	most likely migration of scenario4 is unsatisfied
default	most likely migration of scenario5 is unsatisfied
default	most likely migration of scenario6 is unsatisfied
default	preferred combinations of scenario1 is satisfied
default	preferred combinations of scenario2 is satisfied
default	preferred combinations of scenario3 is satisfied
default	preferred combinations of scenario4 is satisfied
default	preferred combinations of scenario5 is satisfied
default	preferred combinations of scenario6 is satisfied
query	national

APPENDIX 5: PSSA: PROVINCIAL SEGMENT

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HIPO Chart

File Structures

FILE: NATCHOIC.TXT

This file is generated by the national segment. It contains the selections made at the national level. The file consists of but three records. The format of each record is:

Scenario_type, scenario_number, fertility, migration

Scenario_type is one of [High,Medium,Low]

scenario_number is one of [scenario1,scenario2,scenario3,
scenario4,scenario5,scenario6]

fertility is one of [high,medium,low]

migration is one of [high,low]

e.g. High , scenario1 , high , high

The commas are required, and the variables are variable length, thus requiring a bit more sophisticated "read" routine.

FILE: PROVINCE.TXT

This file contains the population data for the different provinces and territories. These numbers are in units of "10,000 persons".

The structure of the files is as follows:

Scen.	Canada	Nfld	N.S.	N.B.	
Name	Pop.	Pop.	Pop.	Pop.	
e.g.					
H1.2B	281299	5848	1392	9334	
H1.2C	281294	5744	1349	9162	
:	:	:	:	:	:
:	:	:	:	:	:

C Language Source Code

```

#define PROV IN LINE 120
#define MAX_INTERNAL 3
#define MAX_EXTERNAL 2
#define MAX_FERTILITY 3

#include "stdio.h"
#include "string.h"
#include "stdlib.h"
#include "math.h"
#include "conio.h"

/* Data Structures */

typedef char string_type[6];

enum internal_type {A, B, C};

struct scenario_data {
    int MAX_SCENARIOS;
};

struct answer_type {
    int afld_economy;
    int afld_demography_trend;
    int que_economy;
    int que_demography_trend;
    int ont_economy;
    int ont_demography_trend;
    int bc_economy;
    int bc_demography_trend;
    char fertility[7];
    enum internal_type recent_internal_trend;
};

struct group_type {
    int group_number;
    struct scenario_type *scenario[4];
    struct group_type *next;
    int high_criteria;
    int medium_criteria;
    int low_criteria;
    int range_criteria;
    int short_term_criteria;
    int overall_rank;
};

struct province_type {
    char scenario_name[6];
    long canada_pop;
    long afld_pop;
    long ns_pop;
    long nb_pop;
    long pei_pop;
    long que_pop;
    long ont_pop;
    long man_pop;
    long sask_pop;
    long alba_pop;
    long bc_pop;
    int yukon_pop;
    int nwt_pop;
    struct province_type *next;
};

struct prov_sort {
    char scenario_name[6];
    struct province_type *pop_ptr;
    int afld_rank;
    int ns_rank;
    int pei_rank;
    int nb_rank;
    int que_rank;
    int ont_rank;
    int man_rank;
    int sask_rank;
    int alba_rank;
    int bc_rank;
    int yuk_rank;
    int nwt_rank;
    struct prov_sort *next;
    struct prov_sort *prev;
};

```

```

};

struct scenario_type {
    char scenario_name[6];
    char internal_migration[7];
    char external_migration[7];
    char fertility[7];
    char mortality[7];
    int prov_rank[12];
    struct prov_sort * ranked;
    struct scenario_type *next;
};

/* National Data Structure:
   Scenario_type: {High, Medium, or Low}
   Scenario_name: Basically a combination of fertility, mortality and
                  external migration codes
   Fertility:     {High, Medium, or Low}
   Mortality:    { Currently not used - but one assumption for mortality
   External      Migration: {High or Low}
*/

struct national_type {
    char scenario_type[7];
    char scenario_name[14];
    char fertility[7];
    char mortality[7];
    char external_migration[7];
    struct national_type *next;
};

/* Prototyping */

void ask_questions(struct answer_type *answers);
void read_fertility(struct answer_type *a);
void read_province(struct province_type *p, struct prov_sort *sorted_prov); /* Read population Data broken down
by province and scenario */
void read_national(struct national_type *n); /* read data from National filter segment */
void generate_scenarios(struct scenario_type *s, struct national_type *n, struct prov_sort *sorted_prov); /*
generate "complete" scenario profiles */
int is_national(int internal, int external, int fertility, struct national_type *n);
void generate_groups(struct group_type *g, struct scenario_type *s, struct scenario_data *SCENARIO_DATA);
struct prov_sort * rank_provinces(struct prov_sort *sorted_prov);
struct group_type * grank(struct national_type *n, struct group_type *g,
                          struct scenario_type *s, struct answer_type *answers);
struct group_type * orank(struct group_type *g);
void prank(struct group_type *g, struct national_type *n, struct scenario_type *s,
           struct answer_type *answers);
int check_high(struct group_type *g);
int check_low(struct group_type *g);
int check_medium(struct group_type *g);
int check_range(struct group_type *g, struct national_type *n,
                struct scenario_type *pr, struct answer_type *answers);
int find_range_rank(string type, prov_size, float upper_range, float lower_range,
                   float total_range, float long_term, float recent_economy);
float find_overall_range(long pop1, long pop2, long pop3, long pop4);
float find_lower_range(long pop1, long pop2, long pop3, long pop4);
float find_upper_range(long pop1, long pop2, long pop3, long pop4);
int check_short(struct group_type *g, struct national_type *n, struct scenario_type *ps, struct answer_type
*answers);
int check_assumptions(struct group_type *g, struct national_type *n, struct scenario_type *ps);
int screen_short(struct national_type *n, struct answer_type *answers, struct scenario_data *SCENARIOS);

void main(void)
{
    /* Set up Variables */

    char pause_char[2];
    int pos; /* For testing scenarios list */

    struct national_type *national, *nat2, *newnat; /* Pointer to National Data */
    struct scenario_type *scenarios, *scen2, *newscen; /* Pointer to Scenario Data */
    struct province_type *prov pops, *prov2, *newprov; /* Pointer to Provincial Population Data */
    struct group_type *scenario_groups, *scengrp2, *newscengrp; /* Pointer to groups data */
    struct prov_sort *sorted_prov, *sort2, *newsort; /* Sorted scenarios for each province */
    struct group_type *choice; /* This is a pointer to the selected Scenario Group */
    struct answer_type *answers;
    struct scenario_data *SCENARIO_DATA;

```



```

printf("Canada: %ld\n",prov2->canada_pop);
printf("Nfld: %ld\n",prov2->nfld_pop);
printf("NB: %ld\n",prov2->nb_pop);
printf("NS: %ld\n",prov2->ns_pop);
printf("PEI: %ld\n",prov2->pei_pop);
printf("Quebec: %ld\n",prov2->que_pop);
printf("Ontario: %ld\n",prov2->ont_pop);
printf("Manitoba: %ld\n",prov2->man_pop);
printf("Sask.: %ld\n",prov2->sask_pop);
printf("Alberta: %ld\n",prov2->alta_pop);
printf("BC: %ld\n",prov2->bc_pop);
printf("Yukon: %ld\n",prov2->yukon_pop);
printf("NWT: %ld\n",prov2->nwt_pop);
printf("----- \n \n \n");
newprov = prov2->next;
prov2 = newprov;
printf("Press any key to continue\n");
gets(pause_char);
}

#endif

sorted_prov = rank_provinces(sorted_prov);
printf("\n");

scenarios = (struct scenario_type *) malloc(18 * (sizeof(struct scenario_type)));
printf("Creating Provincial Scenarios");
generate_scenarios(scenarios,national,sorted_prov); /* Generate Scenarios after National Filtering */
printf("\n");

#ifdef SCENARIO_TRACE

scen2 = scenarios;
while(scen2)
{
    printf("\n<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<\n\n");
    printf("----- \n");
    printf("Scenario Name: %s\n",scen2->scenario_name);
    printf("Fertility: %s\n",scen2->fertility);
    printf("External Migration: %s\n",scen2->external_migration);
    printf("Internal Migration: %s\n",scen2->internal_migration);
    printf("Provincial Rankings: 1 2 3 4 5 6 \n");
    printf(" ");
    for (pos = 0; pos <= 5; pos++) {
        printf("%d ",scen2->prov_rank[pos]);
    }

    printf("\n");
    printf("----- \n \n \n");
    newscen = scen2->next;
    scen2 = newscen;
    printf("Press any key to continue\n");
    gets(pause_char);
}

#endif

printf("Generating Scenarios");
if (SCENARIO_DATA->MAX_SCENARIOS == 3) {
    scenario_groups = (struct group_type *) malloc(126 * (sizeof(struct group_type)));
} else
{
    scenario_groups = (struct group_type *) malloc(495 * (sizeof(struct group_type)));
}

generate_groups(scenario_groups,scenarios,SCENARIO_DATA);
printf("\n");

printf("Selecting Best Scenario Group\n");

choice = grank(national,scenario_groups,scenarios,answers);
printf("\n");

clrscr();

/* Display the Selected Scenario */

#ifdef GROUP_TRACE

scengrp2 = scenario_groups;
while(scengrp2)
{
    printf("\n\n ---- Scenario Groups List ---- \n\n");

```

```

printf("Group No:          %d\n",scengr2->group_number);
scen2 = scengr2->scenario[0];
printf("Scenario 1          %s\n",scen2->scenario_name);
scen2 = scengr2->scenario[1];
printf("Scenario 2          %s\n",scen2->scenario_name);
scen2 = scengr2->scenario[2];
printf("Scenario 3          %s\n",scen2->scenario_name);
scen2 = scengr2->scenario[3];
printf("Scenario 4          %s\n",scen2->scenario_name);
printf("Overall rank:       %d\n",scengr2->overall_rank);
printf("High rank:         %d\n",scengr2->high_criteria);
printf("Medium rank:        %d\n",scengr2->medium_criteria);
printf("Low rank:          %d\n",scengr2->low_criteria);
printf("Range rank:         %d\n",scengr2->range_criteria);
printf("\n\n      ____      ____      ____  \n\n");

newscengr = scengr2->next;
scengr2 = newscengr;
printf("Press any key to continue\n");
gets(pause_char);
}

#endif

printf("\n\n      -- Selected Scenario Group --  \n");
if (choice->overall_rank == 0)
{
    printf(" \n\n\n  ");
    printf("No Scenario Group was selected.\n");
    printf("\n\n\n");
}
else
{
    if (choice->overall_rank > 1000)
        printf("This Scenario group is a Diversified group.\n\n");
    else
        printf("This Scenario group is a Flat group.\n\n");

    printf("Group No:          %d\n",choice->group_number);
    scen2 = choice->scenario[0];
    printf("Scenario 1          %s\n",scen2->scenario_name);
    scen2 = choice->scenario[1];
    printf("Scenario 2          %s\n",scen2->scenario_name);
    scen2 = choice->scenario[2];
    printf("Scenario 3          %s\n",scen2->scenario_name);
    scen2 = choice->scenario[3];
    printf("Scenario 4          %s\n",scen2->scenario_name);
    printf("Scoring Values\n");
    printf("-----\n");
    printf("High value (Max 20) :   %d\n",choice->high_criteria);
    printf("Medium value (Max 20): %d\n",choice->medium_criteria);
    printf("Low value (Max 20) :    %d\n",choice->low_criteria);
    printf("Range Value (Max 40) :  %d\n",choice->range_criteria);
    printf("Total Value (Max 100): %d\n",choice->overall_rank);
    printf("\n\n      ____      ____      ____  \n\n");

    /* Check to give Warnings */

    if (choice->high_criteria == 0)
    {
        printf("!!!! No Provinces have a High Scenario !!!!\n");
    }
    if (choice->medium_criteria == 0)
    {
        printf("!!!! No Provinces have a Medium Scenario !!!!\n");
    }

    if (choice->low_criteria == 0)
    {
        printf("!!!! No Provinces have a Low Scenario !!!!\n");
    }

    if (choice->range_criteria == 0)
    {
        printf("!!!! Range Value not satisfied !!!!\n");
    }
}

printf("Press any key to continue\n");
gets(pause_char);
}
}

```

```

/*****
 *
 * Function: read_national(struct national_type *n)
 * Purpose: This function reads the data from the national segment.
 * Files: The file to be read was created via XiPlus and is an
 *        ASCII file delimited with commas. The format should
 *        be:
 *        <Scenario type> , <scenario n> , <fertility> , <migration>
 *
 * Data
 * Struct: national_type {
 *         char scenario_type[7];
 *         char scenario_name[7];
 *         char fertility[7];
 *         char mortality[7];
 *         char external_migration[7]; }
 *****/

void read_national(struct national_type *n)
{
    FILE *fp;
    char inline[81];
    char *ptr_index,*start;
    int choice_read,pos,ptr_pos;
    struct national_type *old;

    /* Open National Choices File */
    if ((fp = fopen("natchoic.txt","r")) == NULL) {
        printf("Error in reading: natchoic.txt\n");
    } else {
        /* Read one line into buffer */
        fgets(inline,80,fp);

        choice_read = 0;
        /* Read until the three selected national scenarios are read or eof */
        printf(".");
        do
        {
            printf(".");
            ptr_index = inline;
            ptr_pos = 0;

            /* Read in Scenario type */
            pos = 0;
            start = inline;
            do
            {
                pos++;
                ptr_pos++;
                ptr_index++;
            }
            while ((*ptr_index != ',') && (*ptr_index != NULL));
            strncpy(n->scenario_type,start,(pos-1));
            n->scenario_type[pos-1] = '\0';

            /* Skip to after comma */
            ptr_index++;

            /* Read Scenario Name */
            pos = 0;
            start = ptr_index;
            /* skip spaces */
            while(*ptr_index && *ptr_index == ' ')
            {
                start++;
                ptr_index++;
            }
            do
            {
                pos++;
                ptr_index++;
                ptr_pos++;
            }
            while ((*ptr_index != ',') && (*ptr_index != NULL));
            strncpy(n->scenario_name,start,(pos-1));
            n->scenario_name[pos-1] = '\0';

            /* Skip to After Comma */
            ptr_index++;
            start = ptr_index;

            /* Read Fertility Status (High Medium or Low) */
            pos = 0;
            while(*ptr_index && *ptr_index == ' ')
            {
                start++;
                ptr_index++;
            }
        }
    }
}

```



```

do
{
    pos++;
    ptr_index++;
    ptr_pos++;
}
while ((*ptr_index != ',') && (*ptr_index != NULL));
strncpy(n->fertility,start,(pos-1));
n->fertility[pos-1] = '\0';

/* Skip to After Comma */
ptr_index++;
start = ptr_index;

/* Read International Migration Status (High or Low) */
pos = 0;
/* Skip Leading spaces */
while(*ptr_index && *ptr_index == ' ')
{
    start++;
    ptr_index++;
}
do
{
    pos++;
    ptr_index++;
    ptr_pos++;
}
while ((*ptr_index != ',') && (*ptr_index != NULL));
strncpy(n->external_migration,start,(pos-1));
n->external_migration[pos-1] = '\0';

/* Skip to next record */
fgetc(infile,fp);
old = n;
n++;
old->next = n;
}
while (! choice_read && ! feof(fp));
old->next = NULL;
} /* end of else */
}

/*.....*/
*
*  int read_province(struct province_type)
*  This routine reads the population data associated with
*  each scenario and province. It stores this data in a linked
*  list using pointers.
*
*.....*/

int read_province(struct province_type *p, struct prov_sort *ps)
{
    FILE *fp;
    char inline[PROV_IN_LINE];
    char *ptr_index;
    char temp_pop[7];
    struct province_type *old;
    struct prov_sort *ps_old;
    int count1;
    char pause_char[2];

    if ((fp = fopen("2011.txt","r")) == NULL) {
        printf("Cannot Open Provincial Populations File\n");
        return -1; /* -1 for error */
    } else {
        fgetc(infile,(PROV_IN_LINE-1),fp);
        ptr_index = inline; /* move pointer to start of input line */
        strncpy(p->scenario_name,ptr_index,5);
        strncpy(ps->scenario_name,ptr_index,5);
        ps->scenario_name[5] = '\0';
        p->scenario_name[5] = '\0';
        ptr_index += 7;

        /* Canada and Provincial Populations */
        strncpy(temp_pop,ptr_index,7);
        p->canada_pop = atol(temp_pop);
        ptr_index += 7;

        strncpy(temp_pop,ptr_index,7);
        p->nfid_pop = atol(temp_pop);
        ptr_index += 7;

        strncpy(temp_pop,ptr_index,7);

```

```

p->ns_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->nb_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->pei_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->que_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->ont_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->man_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->sask_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->alta_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->bc_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->yukon_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->nwt_pop = atol(temp_pop);
ptr_index +=7;

ps->prev = NULL;
ps->next = NULL;
ps->pop_ptr = p;

fgets(infile,(PROV_IN_LINE - 1),fp); /* move to next line */
)
countl = 1;
countl++;
printf(".");
while (!feof(fp)) {
    printf(".");
    old = p;
    p++;
    old->next = p;
    /* trace stuff for ps array */
    ps_old = ps;
    ps++;
    ps->pop_ptr = p;
    ps->prev = ps_old;
    ps_old->next = ps;

    countl++;

    ptr_index = inline; /* move pointer to start of input line */
    strncpy(p->scenario_name,ptr_index,5);
    p->scenario_name[5] = '\0';
    strncpy(ps->scenario_name,ptr_index,5);
    ps->scenario_name[5] = '\0';
    ptr_index +=7;

    /* Canada and Provincial Populations */
    strncpy(temp_pop,ptr_index,7);
    p->canada_pop = atol(temp_pop);
    ptr_index +=7;

    strncpy(temp_pop,ptr_index,7);
    p->nfld_pop = atol(temp_pop);
    ptr_index +=7;

    strncpy(temp_pop,ptr_index,7);
    p->ns_pop = atol(temp_pop);
    ptr_index +=7;

    strncpy(temp_pop,ptr_index,7);
    p->nb_pop = atol(temp_pop);

```

```

ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->pai_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->que_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->ont_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->ean_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->eak_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->alta_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->bc_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->yukon_pop = atol(temp_pop);
ptr_index +=7;

strncpy(temp_pop,ptr_index,7);
p->nwt_pop = atol(temp_pop);
ptr_index +=7;
p->next = NULL;
pe->next = NULL;
fgets(inline,(PROV_IN_LINE - 1),fp); /* Get next line */
}
fclose(fp);
return 1; /* Eventually have it return 0 if an error occurs */
}

void generate_scenarios( struct scenario_type *s, struct national_type *national,
                        struct prov_sort *ps)
{
    struct scenario_type *temp_s;
    struct prov_sort *ps_start, *ps_temp;
    char *ptr_index;

    int internal,fertility,external,trace_var;

    trace_var = 0;
    for (internal=1;internal<=MAX_INTERNAL;internal++)
        for (external=1;external<=MAX_EXTERNAL;external++)
            for (fertility=1;fertility<=MAX_FERTILITY;fertility++)
                if (is_national(internal,external,fertility,national))
                    {switch(internal)
                        {case 1 : s->internal_migration[0] = 'A';
                            s->internal_migration[1] = '\0';
                            break;
                         case 2 : s->internal_migration[0] = 'B';
                            s->internal_migration[1] = '\0';
                            break;
                         case 3 : s->internal_migration[0] = 'C';
                            s->internal_migration[1] = '\0';
                            break;
                         default : strcpy(s->internal_migration,"Error");
                            s->internal_migration[5] = '\0';
                        }
                    }

    printf(".");

    ptr_index = s->external_migration;
    switch(external)
        {case 1: strcpy(ptr_index,"low");
            s->external_migration[3] = '\0';
            break;
         case 2: strcpy(ptr_index,"high");
            s->external_migration[4] = '\0';
            break;
         default: strcpy(ptr_index,"Error");
            s->external_migration[5] = '\0';
        }
}

```

```

    }
    switch(fertility)
    {case 1: strcpy(s->fertility,"2.1");
      s->fertility[3] = '\0';
      break;
      case 2: strcpy(s->fertility,"1.7");
      s->fertility[3] = '\0';
      break;
      case 3: strcpy(s->fertility,"1.2");
      s->fertility[3] = '\0';
      break;
      default: strcpy(s->fertility,"Error");
      s->fertility[5] = '\0';
    }
    s->scenario_name[0]=s->external_migration[0];
    s->scenario_name[1] = '\0';
    strcat(s->scenario_name,s->fertility);
    strcat(s->scenario_name,s->internal_migration);

/* Redo Fertility to be compaitble with national database */
switch(fertility)
{case 1: strcpy(s->fertility,"high");
  s->fertility[4] = '\0';
  break;
  case 2: strcpy(s->fertility,"medium");
  s->fertility[6] = '\0';
  break;
  case 3: strcpy(s->fertility,"low");
  s->fertility[3] = '\0';
  break;
  default: strcpy(s->fertility,"Error");
  s->fertility[5] = '\0';
}

/* Set appropriate pointer in to matching scenario in
prov_sort array (ps) */
ps_start = ps;

while (ps_start)
{
  if (strcmpi(ps_start->scenario_name,s->scenario_name) == 0)
  {
    s->ranked = ps_start;
    ps_start = NULL; /* trip flag to get out of the loop */
  }
  else
  {
    ps_temp = ps_start->next;
    ps_start = ps_temp;
  }
  temp_s = s;
  s++;
  temp_s->next = s;
  trace_var++;
}
}
temp_s->next = NULL;
}

int is_national(int internal,int external,int fertility,struct national_type *n)
{ int fert_num, ext_num, found;
  char temp_fert,temp_external;
  char pause_char[2];

  found = 0;
  do
  { temp_fert = n->fertility[0];

    switch(temp_fert)
    {case 'h' : fert_num = 1; break;
      case 'm' : fert_num = 2; break;
      case 'l' : fert_num = 3; break;
      default : fert_num = 0;
    }
    temp_external = n->external_migration[0];
    switch(temp_external)
    {case 'l' : ext_num = 1; break;
      case 'h' : ext_num = 2; break;
      default : ext_num = 0;
    }
    if (fertility == 1 && fert_num == ext_num)
      found = 1;
  }
  while (pause_char[0] != '\n');
}

#ifdef IS_NAT_TRACE

```

```

    printf("ts : %d -- %d : %s : %d -- %d --> %d\n", n->fertility, fert_num, fertility, n->external_migration,
ext_num, external, found);
    gets(pause_char);

#endif

    n=n->next;
    } while (n && ! found);
    return found; /* Returns a 1 if a match is found, 0 otherwise */
}

void generate_groups (struct group_type *g, struct scenario_type *s,
                     struct scenario_data *SD)
{ struct scenario_type *start_scen;
  struct group_type *old_g;
  int group_count, j, k, i, l;

  start_scen = s;
  group_count = 1;

  for (i=1; i<=(( SD->MAX_SCENARIOS * MAX_INTERNAL ) -3); i++)
    for (j=i+1; j<=(( SD->MAX_SCENARIOS * MAX_INTERNAL ) -2); j++)
      for (k=j+1; k<=(( SD->MAX_SCENARIOS * MAX_INTERNAL ) -1); k++)
        for (l=k+1; l<=(( SD->MAX_SCENARIOS * MAX_INTERNAL ); l++)
          { s = start_scen;
            s+=(i-1);
            g->scenario[0]=s;

            s=start_scen;
            s+=(j-1);
            g->scenario[1]=s;

            s=start_scen;
            s+=(k-1);
            g->scenario[2]=s;

            s=start_scen;
            s+=(l-1);
            g->scenario[3]=s;

            g->group_number = group_count;
            old_g = g;
            g++;
            old_g->next = g;
            group_count++;

            printf(".");
          }

#ifdef GROUP_TRACE
    printf("%d %d %d %d %d \n", group_count-1, i, j, k, l);
#endif
  }
}

old_g->next = NULL;
}

/*****
* Module : Rank_Province
*
* Purpose: This module ranks the scenarios for each province. It
*          employs a series of bubble sorts to achieve this.
*
*****/

struct prov_sort * rank_province(struct prov_sort *prov_ranking)
{ struct prov_sort *temp_node, *previous_node, *next_node;
  struct prov_sort *current_start, *current_end, *start, *end;
  struct province_type *pop1, *pop2;
  int i;
  char pause_char[2];

  start = prov_ranking;
  /* find end of linked list */
  end = start;
  while (end->next)
    end = end->next;

  /* Newfoundland sort */

  current_start = start;
  while (current_start) {
    printf(".");

```

```

#ifdef SORT_TRACE
    printf("\n Outer while: current_start -> %s \n",current_start->scenario_name);
    gets(pause_char);
#endif

    current_end = end;
    while (current_end && (current_end != current_start)) {

#ifdef SORT_TRACE
        printf("\n Inner while: current_end -> %s \n",current_end->scenario_name);
        gets(pause_char);
#endif
        pop1 = current_start->pop_ptr;
        pop2 = current_end->pop_ptr;

#ifdef SORT_TRACE
        printf("%s : %ld \n",current_start->scenario_name,pop1->nfiled_pop);
        printf("%s : %ld \n",current_end->scenario_name,pop2->nfiled_pop);
        gets(pause_char);
#endif

        if (pop1->nfiled_pop > pop2->nfiled_pop) /* make the switch */
        {
            previous_node = current_start->prev;
            next_node = current_start->next;
            temp_node = current_start->prev;
            if (temp_node)
                temp_node->next = current_end;
            temp_node = current_end->prev;
            if (temp_node && (temp_node != current_start))
                temp_node->next = current_start;
            temp_node = current_start->next;
            if (temp_node && (temp_node != current_end))
                temp_node->prev = current_end;
            temp_node = current_end->next;
            if (temp_node)
                temp_node->prev = current_start;
            if (current_end->prev != current_start)
                current_start->prev = current_end->prev;
            else
                current_start->prev = current_end;
            current_start->next = current_end->next;
            current_end->prev = previous_node;
            if (current_end != next_node)
                current_end->next = next_node;
            else
                current_end->next = current_start;
        }

#ifdef SORT_TRACE
        if (next_node)
            next_node->prev = current_start;
#endif

        if (current_start == start)
            start = current_end;
        temp_node = current_start;
        current_start = current_end;
        if (current_end == end)
            end = temp_node;
        current_end = temp_node;

#ifdef SORT_TRACE
        printf("\n A switch was made \n");
#endif

        /* display the overall list */

#ifdef SORT_TRACE
        temp_node = start;
        printf("\n===== LIST =====\n");
        while (temp_node)
        {
            previous_node = temp_node->prev;
            next_node = temp_node->next;
            if (next_node && previous_node)
                printf("%s : %s : %s \n",temp_node->scenario_name,
                    previous_node->scenario_name,next_node->scenario_name);
            else
                printf("%s : Either prev or next NULL \n",temp_node->scenario_name);
            temp_node = temp_node->next;
        }
#endif

        current_end = current_end->prev;
        current_start = current_start->next;
    }
    /* Assign values */

```



```

if (pop1->ont_pop > pop2->ont_pop) /* make the switch */
{
    previous_node = current_start->prev;
    next_node = current_start->next;
    temp_node = current_start->prev;
    if (temp_node)
        temp_node->next = current_end;
    temp_node = current_end->prev;
    if (temp_node && (temp_node != current_start))
        temp_node->next = current_start;
    temp_node = current_start->next;
    if (temp_node && (temp_node != current_end))
        temp_node->prev = current_end;
    temp_node = current_end->next;
    if (temp_node)
        temp_node->prev = current_start;
    if (current_end->prev != current_start)
        current_start->prev = current_end->prev;
    else
        current_start->prev = current_end;
    current_start->next = current_end->next;
    current_end->prev = previous_node;
    if (current_end != next_node)
        current_end->next = next_node;
    else
        current_end->next = current_start;
    if (current_start == start)
        start = current_end;
    temp_node = current_start;
    current_start = current_end;
    if (current_end == end)
        end = temp_node;
    current_end = temp_node;
}
current_end = current_end->prev;
}
current_start = current_start->next;
}

/* Assign values */
current_start = start;
i = 1;
while (current_start)
{
    current_start->ont_rank = i;
    i++;
    current_start = current_start->next;
}

/* B.C. Sort */
current_start = start;
while (current_start) {
    current_end = end;
    while (current_end && (current_end != current_start)) {
        pop1 = current_start->pop_ptr;
        pop2 = current_end->pop_ptr;
        if (pop1->bc_pop > pop2->bc_pop) /* make the switch */
        {
            previous_node = current_start->prev;
            next_node = current_start->next;
            temp_node = current_start->prev;
            if (temp_node)
                temp_node->next = current_end;
            temp_node = current_end->prev;
            if (temp_node && (temp_node != current_start))
                temp_node->next = current_start;
            temp_node = current_start->next;
            if (temp_node && (temp_node != current_end))
                temp_node->prev = current_end;
            temp_node = current_end->next;
            if (temp_node)
                temp_node->prev = current_start;
            if (current_end->prev != current_start)
                current_start->prev = current_end->prev;
            else
                current_start->prev = current_end;
            current_start->next = current_end->next;
            current_end->prev = previous_node;
            if (current_end != next_node)
                current_end->next = next_node;
            else
                current_end->next = current_start;
        }
        if (current_start == start)
            start = current_end;
        temp_node = current_start;
        current_start = current_end;
        if (current_end == end)
            end = temp_node;
        current_end = temp_node;
    }
}

```



```

    }
    current_end = current_end->prev;
  }
  current_start = current_start->next;
}

/* Assign values */
current_start = start;
i = 1;
while (current_start)
{
  current_start->bc_rank = i;
  i++;
  current_start = current_start->next;
}

return start;
}

/*****
*
* Module: grank
*
* Purpose: This module is the main driving control module for the
*          routines that decide which group of scenarios would be
*          the best to publish. This routine returns a pointer to the
*          "best group".
*
*****/

struct group_type * grank(struct national_type *n, struct group_type *g,
                          struct scenario_type *pr, struct answer_type *answers)
{
  char pause_key(2);

  struct group_type *start, *best;
  start = g;

  while (g)
  { /* Rank Each Individual group */

    prank(g,n,pr,answers);

#ifdef GRANK_TRACE
    printf("Group No:      %d\n",g->group_number);
    printf("Overall rank:    %d\n",g->overall_rank);
    printf("High rank:        %d\n",g->high_criteria);
    printf("Medium rank:       %d\n",g->medium_criteria);
    printf("Low rank:          %d\n",g->low_criteria);
    printf("Range rank:        %d\n",g->range_criteria);
    printf("\n\n      ---      \n\n");
    gets(pause_key);
#endif

    g = g->next;

  }

  /* Get best overall ranked group of scenarios */
  best = orank(start);

  return best; /* Return a pointer to the main program so that the
                "Best" scenario group can be printed out */
}

/*****
*
* Module: orank
*
* Purpose: The purpose of this module is to determine which of the
*          already ranked scenarios had the best "rating".
*
*****/

struct group_type * orank(struct group_type *g)

```

```

{ struct group_type *best;
  int best_so_far;

  best = g;
  best_so_far = g->overall_rank;
  g=g->next;
  while (g)
  {
    if (g->overall_rank > best_so_far)
      (best_so_far = g->overall_rank;
       best = g;
      )
    g=g->next;
  }
  if (best)
    return best;
  else
    return 0; /* An Error has occurred! */
}

/.....
*
* Module: Prank
*
* Purpose: This module co-ordinates the scenario ranking for a single
*          scenario group. It is called repeatedly to evaluate all the
*          scenario groups.
*
*...../

void prank(struct group_type *g, struct national_type *n,
          struct scenario_type *pr, struct answer_type *answers)
{
  /* Check to see if near term scenario is represented. If not, assign a
  rank of 0
  */

  g->short_term_criteria = check_short(g,n,pr,answers);
  g->high_criteria = 0;
  g->low_criteria = 0;
  g->medium_criteria = 0;
  g->range_criteria = 0;

  printf(".");

  if (g->short_term_criteria == 1 && check_assumptions(g,n,pr))
    /* does it meet the short term and assumptions criteria */
    {
      g->high_criteria = check_high(g);
      g->medium_criteria = check_medium(g);
      g->low_criteria = check_low(g);
      g->range_criteria = check_range(g,n,pr,answers);

      g->overall_rank = g->high_criteria +
                      g->low_criteria +
                      g->medium_criteria +
                      g->range_criteria;
    }
  else
    g->overall_rank = 0;
}

/.....
*
* Modules: check_high
*          check_medium
*          check_low
*
* Purpose: These Modules evaluate whether a given scenario group
*          satisfies the requirement that each province has a
*          high, medium and a low scenario. They return different
*          values depending on the strength of the "fit". Since all
*          these routines are nearly identical, just the high_
*          criteria function shall be presented.

```

```

...../

int check_high (struct group_type *g)
{
    struct scenario_type *temp_scenario;
    struct prov_sort *sorted_scenario;
    int rank, i, o_rank, t_rank;
    char get_pause[2];

    o_rank = 0;

    /* Wild */

    /* Rank is being used as a flag to make sure that each province
       contains a high scenario.  If any province does not, then o_rank
       will be demerited by 3.
    */

    rank = 0;

    for (i=0; i<=3; i++)
    {
        temp_scenario = g->scenario[i];
        sorted_scenario = temp_scenario->ranked;
        switch(sorted_scenario->afld_rank)
        {
            case 18 : t_rank = 5; break;
            case 17 : t_rank = 5; break;
            case 16 : t_rank = 5; break;
            case 15 : t_rank = 5; break;
            case 14 : t_rank = 4; break;
            case 13 : t_rank = 3; break;
            case 12 : t_rank = 2; break;
            case 11 : t_rank = 1; break;
            default : t_rank = 0;
        }
        if (rank < t_rank)
            rank = t_rank;
    }

    if (rank == 0)
        rank += -3;
    o_rank += rank;

    /* Quebec */

    rank = 0;
    for (i=0; i<=3; i++)
    {
        temp_scenario = g->scenario[i];
        sorted_scenario = temp_scenario->ranked;
        switch(sorted_scenario->que_rank)
        {
            case 18 : t_rank = 5; break;
            case 17 : t_rank = 5; break;
            case 16 : t_rank = 5; break;
            case 15 : t_rank = 5; break;
            case 14 : t_rank = 4; break;
            case 13 : t_rank = 3; break;
            case 12 : t_rank = 2; break;
            case 11 : t_rank = 1; break;
            default : t_rank = 0;
        }
        if (rank < t_rank)
            rank = t_rank;
    }

    if (rank == 0)
        rank += -3;
    o_rank += rank;

    /* Ontario */

    rank = 0;
    for (i=0; i<=3; i++)
    {
        temp_scenario = g->scenario[i];
        sorted_scenario = temp_scenario->ranked;
        switch(sorted_scenario->ont_rank)
        {
            case 18 : t_rank = 5; break;
            case 17 : t_rank = 5; break;
            case 16 : t_rank = 5; break;
            case 15 : t_rank = 5; break;
            case 14 : t_rank = 4; break;
            case 13 : t_rank = 3; break;
            case 12 : t_rank = 2; break;
            case 11 : t_rank = 1; break;
            default : t_rank = 0;
        }
        if (rank < t_rank)
            rank = t_rank;
    }
}

```

```

if (rank == 0)
    rank += -3;
o_rank += rank;

/* British Columbia */

rank = 0;
for (i=0;i<=3;i++)
{ temp_scenario = g->scenario[i];
  sorted_scenario = temp_scenario->ranked;
  switch(sorted_scenario->bc_rank)
  { case 18 : t_rank = 5; break;
    case 17 : t_rank = 5; break;
    case 16 : t_rank = 5; break;
    case 15 : t_rank = 5; break;
    case 14 : t_rank = 4; break;
    case 13 : t_rank = 3; break;
    case 12 : t_rank = 2; break;
    case 11 : t_rank = 1; break;
    default : t_rank = 0;
  }
  if (rank < t_rank)
      rank = t_rank;
}

if (rank == 0)
    rank += -3;
o_rank += rank;
if (o_rank < 0)
    o_rank = 0;
return o_rank; /* Return the total ranking value for this group's
               high criteria */
}

int check_low (struct group_type *g)
{ struct scenario_type *temp_scenario;
  struct prov_sort *sorted_scenario;
  int rank, i, o_rank, t_rank;
  char get_usage[2];

  o_rank = 0;

  /* Nfld */

  /* Rank is being used as a flag to make sure that each province
     contains a low scenario. If any province does not, then o_rank
     will be demerited by 3.
  */

  rank = 0;

  for (i=0;i<=3;i++)
  { temp_scenario = g->scenario[i];
    sorted_scenario = temp_scenario->ranked;
    switch(sorted_scenario->nfld_rank)
    { case 1 : t_rank = 5; break;
      case 2 : t_rank = 5; break;
      case 3 : t_rank = 5; break;
      case 4 : t_rank = 5; break;
      case 5 : t_rank = 4; break;
      case 6 : t_rank = 3; break;
      case 7 : t_rank = 2; break;
      case 8 : t_rank = 1; break;
      default : t_rank = 0;
    }

    if (rank < t_rank)
        rank = t_rank;
  }

  if (rank == 0)
      rank = -3;

  o_rank += rank;

  /* Quebec */
  rank = 0;

  for (i=0;i<=3;i++)
  { temp_scenario = g->scenario[i];
    sorted_scenario = temp_scenario->ranked;
    switch(sorted_scenario->que_rank)
    { case 1 : t_rank = 5; break;
      case 2 : t_rank = 5; break;

```

3 of/de 3

PM-1 3½"x4" PHOTOGRAPHIC MICROCOPY TARGET
NBS 1010a ANSI/ISO #2 EQUIVALENT

PRECISIONSM RESOLUTION TARGETS

```

        case 3 : t_rank = 5; break;
        case 4 : t_rank = 5; break;
        case 5 : t_rank = 4; break;
        case 6 : t_rank = 3; break;
        case 7 : t_rank = 2; break;
        case 8 : t_rank = 1; break;
        default : t_rank = 0;
    }
    if (rank < t_rank)
        rank = t_rank;
}

if (rank == 0)
    rank = -3;
o_rank += rank;
rank = 0;

/* Ontario */

for (i=0;i<=3;i++)
{ temp_scenario = g->scenario[i];
  sorted_scenario = temp_scenario->ranked;
  switch(sorted_scenario->ont_rank)
  { case 1 : t_rank = 5; break;
    case 2 : t_rank = 5; break;
    case 3 : t_rank = 5; break;
    case 4 : t_rank = 5; break;
    case 5 : t_rank = 4; break;
    case 6 : t_rank = 3; break;
    case 7 : t_rank = 2; break;
    case 8 : t_rank = 1; break;
    default : t_rank = 0;
  }
  if (rank < t_rank)
      rank = t_rank;
}

if (rank == 0)
    rank = -3;
o_rank += rank;

/* British Columbia */

rank = 0;
for (i=0;i<=3;i++)
{ temp_scenario = g->scenario[i];
  sorted_scenario = temp_scenario->ranked;
  switch(sorted_scenario->bc_rank)
  { case 1 : t_rank = 5; break;
    case 2 : t_rank = 5; break;
    case 3 : t_rank = 5; break;
    case 4 : t_rank = 5; break;
    case 5 : t_rank = 4; break;
    case 6 : t_rank = 3; break;
    case 7 : t_rank = 2; break;
    case 8 : t_rank = 1; break;
    default : t_rank = 0;
  }
  if (rank < t_rank)
      rank = t_rank;
}

if (rank == 0)
    rank = -3;
o_rank += rank;
rank = 0;

if (o_rank < 0)
    o_rank = 0;

return o_rank; /* Return the total ranking value for this group's
               high criteria */
}

int check_medium (struct group_type *g)
{ struct scenario_type *temp_scenario;
  struct prov_sort *sorted_scenario;
  int rank, i, o_rank, t_rank;
  char get_pause[2];

  o_rank = 0;

  /* Mfld */

```

```

/* Rank is being used as a flag to make sure that each province
   contains a medium scenario. If any province does not, then o_rank
   will be demerited by 3.
*/

rank = 0;

for (i=0; i<=3; i++)
{ temp_scenario = g->scenario[i];
  sorted_scenario = temp_scenario->ranked;
  switch(sorted_scenario->ufld_rank)
  { case 5 : t_rank = 1; break;
    case 6 : t_rank = 2; break;
    case 7 : t_rank = 3; break;
    case 8 : t_rank = 5; break;
    case 9 : t_rank = 5; break;
    case 10 : t_rank = 5; break;
    case 11 : t_rank = 5; break;
    case 12 : t_rank = 3; break;
    case 13 : t_rank = 2; break;
    case 14 : t_rank = 1; break;
    default : t_rank = 0;
  }

  if (rank < t_rank)
    rank = t_rank;
}

if (rank == 0)
  rank = -3;

o_rank += rank;

/* Quebec */

rank = 0;

for (i=0; i<=3; i++)
{ temp_scenario = g->scenario[i];
  sorted_scenario = temp_scenario->ranked;
  switch(sorted_scenario->que_rank)
  { case 5 : t_rank = 1; break;
    case 6 : t_rank = 2; break;
    case 7 : t_rank = 3; break;
    case 8 : t_rank = 5; break;
    case 9 : t_rank = 5; break;
    case 10 : t_rank = 5; break;
    case 11 : t_rank = 5; break;
    case 12 : t_rank = 3; break;
    case 13 : t_rank = 2; break;
    case 14 : t_rank = 1; break;
    default : t_rank = 0;
  }

  if (rank < t_rank)
    rank = t_rank;
}

if (rank == 0)
  rank = -3;
o_rank += rank;

/* Ontario */

rank = 0;
for (i=0; i<=3; i++)
{ temp_scenario = g->scenario[i];
  sorted_scenario = temp_scenario->ranked;
  switch(sorted_scenario->ont_rank)
  { case 5 : t_rank = 1; break;
    case 6 : t_rank = 2; break;
    case 7 : t_rank = 3; break;
    case 8 : t_rank = 5; break;
    case 9 : t_rank = 5; break;
    case 10 : t_rank = 5; break;
    case 11 : t_rank = 5; break;
    case 12 : t_rank = 3; break;
    case 13 : t_rank = 2; break;
    case 14 : t_rank = 1; break;
    default : t_rank = 0;
  }

  if (rank < t_rank)
    rank = t_rank;
}

if (rank == 0)
  rank = -3;
o_rank += rank;

```

```

/* British Columbia */
rank = 0;
for (i=0;i<=3;i++)
{ temp_scenario = g->scenario[i];
  sorted_scenario = temp_scenario->ranked;
  switch(sorted_scenario->bc_rank)
  { case 5 : t_rank = 1; break;
    case 6 : t_rank = 2; break;
    case 7 : t_rank = 3; break;
    case 8 : t_rank = 5; break;
    case 9 : t_rank = 5; break;
    case 10 : t_rank = 5; break;
    case 11 : t_rank = 5; break;
    case 12 : t_rank = 3; break;
    case 13 : t_rank = 2; break;
    case 14 : t_rank = 1; break;
    default : t_rank = 0;
  }
  if (rank < t_rank)
    rank = t_rank;
}

if (rank == 0)
  rank = -3;
o_rank += rank;

rank = 0;
if (o_rank < 0)
  o_rank = 0;

return o_rank; /* Return the total ranking value for this group's
                high criteria */
}

/*****
*
* Module: ask_questions
*
* Purpose: This module asks all the questions that the user
* must supply the data for. This Data is stored in
* a single answers record.
*
*****/

void ask_questions(struct answer_type *answers)
{
  int economy_nfid,economy_que,economy_ont,economy_bc;
  int long_term_trend_nfid,long_term_trend_que,long_term_trend_ont;
  int long_term_trend_bc;
  char temp_string[2];
  char temp_char;

  /* Nfid */

  clrscr();
  printf("Rate Newfoundlands medium range Economic future: \n");
  printf(" 1) Much stronger growth      \n");
  printf(" 2) Some growth                  \n");
  printf(" 3) No significant growth        \n");
  printf(" 4) Expected small decline       \n");
  printf(" 5) Large decline                \n");
  gets(temp_string);
  economy_nfid = atoi(temp_string);

  clrscr();
  printf("Historical long term demographic trends for Newfoundland have been: \n");
  printf(" 1) Large Movement of persons to province      \n");
  printf(" 2) Some Movement of persons to province      \n");
  printf(" 3) Maintaining Population Level               \n");
  printf(" 4) Small, but steady flow of people out of the\n");
  printf("    province.                                  \n");
  printf(" 5) Large Flow of people out of the province   \n");
  gets(temp_string);
  long_term_trend_nfid = atoi(temp_string);

  answers->nfid_economy = economy_nfid;
  answers->nfid_demography_trend = long_term_trend_nfid;

  /* Quebec Questions */

  clrscr();
  printf("Rate Quebecs medium range Economic future: \n");
  printf(" 1) Much stronger growth expected\n");

```



```

printf(" 2) Some growth\n");
printf(" 3) No significant growth\n");
printf(" 4) Expected small decline\n");
printf(" 5) Large decline\n");
gets(temp_string);
economy_que = atoi(temp_string);

clrscr();
printf("Historical long term demographic trends for Quebec have been: \n");
printf(" 1) Large Movement of persons to province\n");
printf(" 2) Some Movement of persons to province\n");
printf(" 3) Maintaining Population Level\n");
printf(" 4) Small, but steady flow of people out of the\n");
printf(" province\n");
printf(" 5) Large Flow of people out of the province\n");
gets(temp_string);
long_term_trend_que = atoi(temp_string);

answers->que_economy = economy_que;
answers->que_demography_trend = long_term_trend_que;

/* Ontario */

clrscr();
printf("Rate Ontario's medium range Economic future: \n");
printf(" 1) Much stronger growth\n");
printf(" 2) Some growth\n");
printf(" 3) No significant growth\n");
printf(" 4) Expected small decline\n");
printf(" 5) Large decline\n");
gets(temp_string);
economy_ont = atoi(temp_string);

clrscr();
printf("Historical long term demographic trends for Ontario have been: \n");
printf(" 1) Large Movement of persons to province\n");
printf(" 2) Some Movement of persons to province\n");
printf(" 3) Maintaining Population Level\n");
printf(" 4) Small, but steady flow of people out of the\n");
printf(" province\n");
printf(" 5) Large Flow of people out of the province\n");
gets(temp_string);
long_term_trend_ont = atoi(temp_string);

answers->ont_economy = economy_ont;
answers->ont_demography_trend = long_term_trend_ont;

/* British Columbia */

clrscr();
printf("Rate British Columbia's medium range Economic future: \n");
printf(" 1) Much stronger growth\n");
printf(" 2) Some growth\n");
printf(" 3) No significant growth\n");
printf(" 4) Expected small decline\n");
printf(" 5) Large decline\n");
gets(temp_string);
economy_bc = atoi(temp_string);

clrscr();
printf("Historical long term demographic trends for British Columbia have been: \n");
printf(" 1) Large Movement of persons to province\n");
printf(" 2) Some Movement of persons to province\n");
printf(" 3) Maintaining Population Level\n");
printf(" 4) Small, but steady flow of people out of the\n");
printf(" province\n");
printf(" 5) Large Flow of people out of the province\n");
gets(temp_string);
long_term_trend_bc = atoi(temp_string);

answers->bc_economy = economy_bc;
answers->bc_demography_trend = long_term_trend_bc;

/* Ask Question Regarding Internal Migration to Determine
   Which of the the Internal Migration Assumption (A, B or C)
   is the most likely.
*/

clrscr();
printf("Which Internal Migration Scenario Most closely approximates\n");
printf("recent demographic trends w thin Canada: \n");
printf(" Assumption A\n");
printf(" Assumption B\n");
printf(" Assumption C\n");

```

```

temp_char = '0';
printf("Your choice: \n");
while((temp_char != 'A') && (temp_char != 'B') && (temp_char != 'C') &&
      (temp_char != 'a') && (temp_char != 'b') && (temp_char != 'c'))
{
    temp_char = getc(stdin);
}

switch(temp_char)
{
    case 'A' : answers->recent_internal_trend = A;break;
    case 'a' : answers->recent_internal_trend = A;break;
    case 'B' : answers->recent_internal_trend = B;break;
    case 'b' : answers->recent_internal_trend = B;break;
    case 'C' : answers->recent_internal_trend = C;break;
    case 'c' : answers->recent_internal_trend = C;break;
}

gets(temp_string); /* Clear input mess created by last get */

/* Get Fertility Data */

read_fertility(answers);
}

/*****
*
* Module: check_range
*
* Purpose: This is the main module for evaluating the range criteria for
*          a given set of scenarios. This module checks the range for
*          each province. To accomplish this range evaluation, several
*          subfunctions are called.
*
*****/

int check_range (struct group_type *g, struct national_type *n,
                 struct scenario_type *pr, struct answer_type *answers)
{
    float nfld_upper_range,nfld_lower_range,nfld_overall_range;
    float que_upper_range,que_lower_range,que_overall_range;
    float ont_upper_range,ont_lower_range,ont_overall_range;
    float bc_upper_range,bc_lower_range,bc_overall_range;
    int nfld_range_rank,que_range_rank,ont_range_rank,bc_range_rank;
    int overall_range_rank;
    struct scenario_type *temp_scenario;
    struct prov_sort *temp_sorted;
    struct province_type *scenario1,*scenario2,*scenario3,*scenario4;
    char temp_str[6];

    overall_range_rank = 0;

    /* Nfld Range Check */

    temp_scenario = g->scenario[0];
    temp_sorted = temp_scenario->ranked;
    scenario1 = temp_sorted->pop_ptr;
    temp_scenario = g->scenario[1];
    temp_sorted = temp_scenario->ranked;
    scenario2 = temp_sorted->pop_ptr;
    temp_scenario = g->scenario[2];
    temp_sorted = temp_scenario->ranked;
    scenario3 = temp_sorted->pop_ptr;
    temp_scenario = g->scenario[3];
    temp_sorted = temp_scenario->ranked;
    scenario4 = temp_sorted->pop_ptr;
    nfld_upper_range = find_upper_range(scenario1->nfld_pop,
                                       scenario2->nfld_pop,
                                       scenario3->nfld_pop,
                                       scenario4->nfld_pop);
    nfld_lower_range = find_lower_range(scenario1->nfld_pop,
                                       scenario2->nfld_pop,
                                       scenario3->nfld_pop,
                                       scenario4->nfld_pop);
    nfld_overall_range = find_overall_range(scenario1->nfld_pop,
                                           scenario2->nfld_pop,
                                           scenario3->nfld_pop,
                                           scenario4->nfld_pop);

    nfld_range_rank = find_range_rank("small",nfld_upper_range,
                                       nfld_lower_range,nfld_overall_range,
                                       answers->nfld_demography_trend,
                                       answers->nfld_economy);

    /* This process is repeated for Ontario, Quebec and British
       Columbia. The only significant difference, besides the

```

utilisation of the corresponding population figures, is the call to find_range_rank. The first variable to be passed in the case of Ontario, Quebec and B.C. is "large".
*/

```
/* Quebec Range Check */

temp_scenario = g->scenario[0];
temp_sorted = temp_scenario->ranked;
scenario1 = temp_sorted->pop_ptr;
temp_scenario = g->scenario[1];
temp_sorted = temp_scenario->ranked;
scenario2 = temp_sorted->pop_ptr;
temp_scenario = g->scenario[2];
temp_sorted = temp_scenario->ranked;
scenario3 = temp_sorted->pop_ptr;
temp_scenario = g->scenario[3];
temp_sorted = temp_scenario->ranked;
scenario4 = temp_sorted->pop_ptr;
que_upper_range = find_upper_range(scenario1->que_pop,
                                   scenario2->que_pop,
                                   scenario3->que_pop,
                                   scenario4->que_pop);
que_lower_range = find_lower_range(scenario1->que_pop,
                                   scenario2->que_pop,
                                   scenario3->que_pop,
                                   scenario4->que_pop);
que_overall_range = find_overall_range(scenario1->que_pop,
                                       scenario2->que_pop,
                                       scenario3->que_pop,
                                       scenario4->que_pop);

que_range_rank = find_range_rank("large", que_upper_range,
                                 que_lower_range, que_overall_range,
                                 answers->que_demography_trend,
                                 answers->que_economy);
```

```
/* Ontario Check */

temp_scenario = g->scenario[0];
temp_sorted = temp_scenario->ranked;
scenario1 = temp_sorted->pop_ptr;
temp_scenario = g->scenario[1];
temp_sorted = temp_scenario->ranked;
scenario2 = temp_sorted->pop_ptr;
temp_scenario = g->scenario[2];
temp_sorted = temp_scenario->ranked;
scenario3 = temp_sorted->pop_ptr;
temp_scenario = g->scenario[3];
temp_sorted = temp_scenario->ranked;
scenario4 = temp_sorted->pop_ptr;
ont_upper_range = find_upper_range(scenario1->ont_pop,
                                   scenario2->ont_pop,
                                   scenario3->ont_pop,
                                   scenario4->ont_pop);
ont_lower_range = find_lower_range(scenario1->ont_pop,
                                   scenario2->ont_pop,
                                   scenario3->ont_pop,
                                   scenario4->ont_pop);
ont_overall_range = find_overall_range(scenario1->ont_pop,
                                       scenario2->ont_pop,
                                       scenario3->ont_pop,
                                       scenario4->ont_pop);

ont_range_rank = find_range_rank("large", ont_upper_range,
                                 ont_lower_range, ont_overall_range,
                                 answers->ont_demography_trend,
                                 answers->ont_economy);
```

```
/* British Columbia Check */

temp_scenario = g->scenario[0];
temp_sorted = temp_scenario->ranked;
scenario1 = temp_sorted->pop_ptr;
temp_scenario = g->scenario[1];
temp_sorted = temp_scenario->ranked;
scenario2 = temp_sorted->pop_ptr;
temp_scenario = g->scenario[2];
temp_sorted = temp_scenario->ranked;
scenario3 = temp_sorted->pop_ptr;
temp_scenario = g->scenario[3];
```

```

temp_sorted = temp_scenario->ranked;
scenario4 = temp_sorted->pop_ptr;
bc_upper_range = find_upper_range(scenario1->bc_pop,
                                   scenario2->bc_pop,
                                   scenario3->bc_pop,
                                   scenario4->bc_pop);
bc_lower_range = find_lower_range(scenario1->bc_pop,
                                   scenario2->bc_pop,
                                   scenario3->bc_pop,
                                   scenario4->bc_pop);
bc_overall_range = find_overall_range(scenario1->bc_pop,
                                       scenario2->bc_pop,
                                       scenario3->bc_pop,
                                       scenario4->bc_pop);

bc_range_rank = find_range_rank("large",bc_upper_range,
                                bc_lower_range,bc_overall_range,
                                answers->bc_demography_trend,
                                answers->bc_economy);

if (nfld_range_rank < 1 || ont_range_rank < 1 ||
    que_range_rank < 1 || bc_range_rank < 1)
{
    overall_range_rank = nfld_range_rank + ont_range_rank
                        + que_range_rank + bc_range_rank;
    overall_range_rank += -10;
    if (overall_range_rank < 0)
        overall_range_rank = 0;
}
else
    overall_range_rank = nfld_range_rank + ont_range_rank
                        + que_range_rank + bc_range_rank;

return overall_range_rank;
}

/*****
*
* Module: find_range_rank
*
* Purpose: The purpose of this routine is to evaluate the range, considering
*          the size of the province, the medium term economic outlook,
*          and the long term trends to date with regards to population.
*          The ratios used are based on the final interview with J.
*          Perreault in Fall of 1991.
*
*****/

#define IDEAL_MAX_RANGE .30
#define IDEAL_MIN_RANGE .15
#define FLAT_MAX_RANGE .10
#define FLAT_MIN_RANGE .05

int find_range_rank(string_type prov_size,float upper_range,float lower_range,
                   float total_range, float long_term, float recent_economy)
{
    int range_tally,ideal_range;
    float range_ratio;

    range_tally = 0;

    if (strcmp(prov_size,"small") == 0)
    /*****
    * Small Province Checks
    *****/
    {
        if (total_range < (IDEAL_MAX_RANGE - (IDEAL_MAX_RANGE / 3.0)))
            range_tally += -5;
        if (total_range < (IDEAL_MAX_RANGE - (IDEAL_MAX_RANGE / 2.0)))
            range_tally += -5; /* Very Low Ranges are Particularly bad for
                               Small Provinces */
    }
    /*****
    * All Sized Provinces
    *****/
    if (abs(long_term - recent_economy) > 2)
    /*****
    * significant uncertainty
    *****/
    {
        if (total_range < (IDEAL_MAX_RANGE - (IDEAL_MAX_RANGE / 4.0)))
            range_tally += -10;
    }
}

```

```

    else
        range_tally +=5;
    )
    else
        /*****
        * Greater Certainty in Economic/Demographic
        * Situation
        *****/
        if (total_range < (IDEAL_MAX_RANGE / 3.0 * 2.0))
            if (total_range > IDEAL_MIN_RANGE)
                range_tally += -5;
            else
                range_tally += -10;
        else
            range_tally += 5;

    if (lower_range)
        range_ratio = upper_range/lower_range;
    else
        printf("Error: Divide by Zero! lower Range = 0, function find_range_rank \n");
    /*****
    * Positive Economic/Demographic Trends
    *****/
    if ((long_term + recent_economy) <= 4)
        if (range_ratio <= .6)
            if (range_ratio >= .3636)
                range_tally += 5;
            else
                range_tally += -5;
        else
            range_tally += 5;
    else
        if ((long_term + recent_economy) >= 8)
            if (range_ratio > 1.6)
                if (range_ratio < 3.28)
                    range_tally += 5;
                else
                    range_tally += -5;
            else
                range_tally += -5;
        else
            if ((range_ratio > .85 && range_ratio <= 1.25))
                range_tally += 5;
            else
                if (range_ratio > .5 && range_ratio < 2)
                    range_tally += 2;
                else range_tally += -5;

    if (range_tally < 0)
        range_tally = 0;
    ideal_range = range_tally;

/* Check "Flat Range" */

range_tally = 0;

if (strcmp prov_size, "small") == 0)
    /*****
    * Small Province Checks
    *****/
    {
        if (total_range < (FLAT_MAX_RANGE - (FLAT_MAX_RANGE / 3.0)))
            range_tally += -5;
        if (total_range < (FLAT_MAX_RANGE - (FLAT_MAX_RANGE / 2.0)))
            range_tally += -5; /* Very Low Ranges are Particularly bad for
                               Small Provinces */
    }
    /*****
    * All Sized Provinces
    *****/
    if (abs(long_term - recent_economy) > 2)
        /*****
        * significant uncertainty
        *****/
        if (total_range < (FLAT_MAX_RANGE - (FLAT_MAX_RANGE / 4.0)))
            range_tally += -10;
        else
            range_tally +=5;
    )
    else
        /*****
        * Greater Certainty in Economic/Demographic
        * Situation
        *****/
        if (total_range < (FLAT_MAX_RANGE / 3.0 * 2.0))
            if (total_range > FLAT_MIN_RANGE)

```

```

        range_tally += -5;
    else
        range_tally += -10;
    else
        range_tally += 5;
if (lower_range)
    range_ratio = upper_range/lower_range;
else
    printf("Error: Divide by Zero! lower Range = 0, function find_range_rank \n");
/*****
* Positive Economic/Demographic Trends
*****/
if ((long_term + recent_economy) <= 4)
    if (range_ratio <= .6)
        if (range_ratio >= .3636)
            range_tally += 5;
        else
            range_tally += -5;
    else
        range_tally += 5;
else
    if ((long_term + recent_economy) >= 8)
        if (range_ratio > 1.6)
            if (range_ratio < 3.28)
                range_tally += 5;
            else
                range_tally += -5;
        else
            range_tally += -5;
    else
        if ((range_ratio > .85 && range_ratio <= 1.25))
            range_tally += 5;
        else
            if (range_ratio > .5 && range_ratio < 2)
                range_tally += 2;
            else range_tally += -5;

if (range_tally < 0)
    range_tally = 0;
if (range_tally > ideal_range)
    return range_tally;
else
    return ideal_range;
}

```

```

/*****
*
* Modules: find_upper_range
*          find_lower_range
*          find_overall_range
*
* Purpose: These Modules are pretty basic routines that calculate the
*          appropriate range ratios. For purposes of taking the ratio,
*          the midpoint of the range shall be used as the denominator.
*****/

```

```

float find_overall_range(long pop1, long pop2, long pop3, long pop4)
{ long high, low, median, range, medium;
  float range_ratio, real_range, real_median;
  char temp_str[2];

  high = pop1;
  low = pop1;
  if (pop2 > high)
      high = pop2;
  if (pop2 < low)
      low = pop2;
  if (pop3 > high)
      high = pop3;
  if (pop3 < low)
      low = pop3;
  if (pop4 > high)
      high = pop4;
  if (pop4 < low)
      low = pop4;

  range = high - low;
  median = low + (range / 2);
  range = high - low;
  real_median = median;
  real_range = range;
}

```

```

    if (median)
        range_ratio = real_range / real_median;
    else
        printf("Error! Division by Zero!\n");
    return range_ratio;
}

float find_upper_range(long pop1, long pop2, long pop3, long pop4)
{
    long high, low, median, range, medium, temp1, temp2;
    float range_ratio, real_range, real_median;
    char temp_str[2];

    high = pop1;
    low = pop1;
    if (pop2 > high)
        high = pop2;
    if (pop2 < low)
        low = pop2;
    if (pop3 > high)
        high = pop3;
    if (pop3 < low)
        low = pop3;
    if (pop4 > high)
        high = pop4;
    if (pop4 < low)
        low = pop4;

    range = high - low;
    median = low + (range / 2);
    temp1 = abs(pop1 - median);
    medium = pop1;
    temp2 = (abs(pop2 - median));
    if (temp2 < temp1)
    {
        temp1 = temp2;
        medium = pop2;
    }

    temp2 = (abs(pop3 - median));
    if (temp2 < temp1)
    {
        temp1 = temp2;
        medium = pop3;
    }

    temp2 = (abs(pop4 - median));
    if (temp2 < temp1)
    {
        temp1 = temp2;
        medium = pop4;
    }

    range = high - medium;
    real_median = median;
    real_range = range;
    if (median)
        range_ratio = real_range / real_median;
    else
        printf("Error! Division by Zero!\n");
    return range_ratio;
}

float find_lower_range(long pop1, long pop2, long pop3, long pop4)
{
    long high, low, median, range, medium, temp1, temp2;
    float range_ratio, real_range, real_median;
    char temp_str[2];

    high = pop1;
    low = pop1;
    if (pop2 > high)
        high = pop2;
    if (pop2 < low)
        low = pop2;
    if (pop3 > high)
        high = pop3;
    if (pop3 < low)
        low = pop3;
    if (pop4 > high)
        high = pop4;
    if (pop4 < low)
        low = pop4;

```

```

range = high - low;
median = low + (range / 2);

temp1 = abs(pop1 - median);
medium = pop1;
temp2 = (abs(pop2 - median));
if (temp2 < temp1)
{
    temp1 = temp2;
    medium = pop2;
}

temp2 = (abs(pop3 - median));
if (temp2 < temp1)
{
    temp1 = temp2;
    medium = pop3;
}
temp2 = (abs(pop4 - median));
if (temp2 < temp1)
{
    temp1 = temp2;
    medium = pop4;
}

range = medium - low;

real_median = median;
real_range = range;

if (median)
    range_ratio = real_range / real_median;
else
    printf("Error: Division by Zero!\n");

return range_ratio;
}

/*****
 *
 * Function: check_short
 *
 * Purpose: To ensure check to see if the most likely scenario
 *          is one of the scenarios in the group.
 *          Returns a 1 if most likely is present, 0 otherwise
 *
 *****/

int check_short(struct group_type *g, struct national_type *n, struct scenario_type *ps, struct answer_type
*answers)
{
    int found, i, internal, fertility, external;
    char pause_string[2];
    struct scenario_type *t_temp;
    struct national_type *medium;
    char internal_string[7];

    /* Find the medium scenario */
    found = 0;
    while (n && !found)
    {
        if (strcmp("Medium", n->scenario_type) == 0)
        {
            medium = n;
            found = 1;
        }
        else
            n = n->next;
    }
    if (!found) {
        printf("Error in finding the Medium Scenario! Results may be invalid!\n");
        cts(pause_string);
        return 0;
    }

    /* Convert internal to format for comparison */

    switch(answers->recent_internal_trend)
    {
        case A : strcpy(internal_string, "A"); break;
        case B : strcpy(internal_string, "B"); break;
        case C : strcpy(internal_string, "C"); break;
    }

    found = 0; /* Use found now as a boolean check for the most likely checks */

    /* Check each scenario in the group */

```



```

for (i=0;i<=3;i++)
{
    internal = external = fertility = 0;
    /* Check Internal Migration */
    s_temp = g->scenario[i];

    if (strcmp(s_temp->internal_migration,internal_string) == 0)
        internal = 1;

    /* check external migration */

    if (strcmp(s_temp->external_migration,medium->external_migration) == 0)
        external = 1;

    /* Check fertility */

    /* Answers has the most likely National fertility level
       as determined in the National Segment and stored in
       fertility.txt See read_fertility() for where it is
       "read in".
    */

#ifdef SHORT_TRACE
    printf("s: %s a: %s \n",s_temp->fertility,answers->fertility);
    gets(pause_string);
#endif

    if (strcmp(s_temp->fertility,answers->fertility) == 0)
    {
        fertility = 1;
    }

#ifdef SHORT_TRACE
    printf("i: %d e: %d f: %d \n",internal,external,fertility);
#endif

    if ((internal == 1) && (external == 1) && (fertility == 1))
        found = 1; /* This is a "most likely" scenario */
}

#ifdef SHORT_TRACE
    printf("Found: %d \n",found);
    gets(pause_string);
#endif

return found;
}

/*****
 *
 * Function: check_assumptions
 *
 * Purpose: Check to see if all the different components are
 *          represented in the scenario group. Returns 1 if
 *          this is the case, a 0 otherwise.
 *****/

int check_assumptions(struct group_type *g, struct national_type *n, struct scenario_type *ps)
{
    char fertility_types [MAX_FERTILITY] [7];
    char internal_types [MAX_INTERNAL] [7];
    char external_types [MAX_EXTERNAL] [7];
    int fertility_count,internal_count, external_count,i,j;
    struct scenario_type *temp_s;
    char pause_string[2];

    fertility_count = 1;
    internal_count = 1;
    external_count = 1;

    /* Check fertility */

    temp_s = g->scenario[0];
    for (i = 0; i < MAX_FERTILITY; i++)
    {
        strcpy(fertility_types[i],temp_s->fertility);
    }

    for (i=1;i<=3;i++)
    {
        temp_s = g->scenario[i];
        for (j=0;j<=fertility_count;j++)
        {

```

```

        if (strcmp(fertility_types[j],temp_s->fertility) == 0)
            j = fertility_count;
        else
        {
            if (fertility_count == j)
            {
                if (j < MAX_FERTILITY)
                {
                    strcpy(fertility_types[j],temp_s->fertility);
                    fertility_count++;
                }
                j=fertility_count; /* get out of loop */
            }
        }
    }
}

/* Check INTERNAL */
temp_s = g->scenario[0];
for (i = 0; i < MAX_INTERNAL; i++)
{
    strcpy(internal_types[i],temp_s->internal_migration);
}

for (i=1;i<=3;i++)
{
    temp_s = g->scenario[i];
    for (j=0;j<=internal_count;j++)
    {
        if (strcmp(internal_types[j],temp_s->internal_migration) == 0)
            j = internal_count;
        else
        {
            if (internal_count == j)
            {
                if (j < MAX_INTERNAL)
                {
                    strcpy(internal_types[j],temp_s->internal_migration);
                    internal_count++;
                }
                j=internal_count; /* get out of loop */
            }
        }
    }
}

/* Check EXTERNAL */
temp_s = g->scenario[0];
for (i = 0; i < MAX_EXTERNAL; i++)
{
    strcpy(external_types[i],temp_s->external_migration);
}

for (i=1;i<=3;i++)
{
    temp_s = g->scenario[i];
    for (j=0;j<=external_count;j++)
    {
        if (strcmp(external_types[j],temp_s->external_migration) == 0)
            j = external_count;
        else
        {
            if (external_count == j)
            {
                if (j < MAX_EXTERNAL)
                {
                    strcpy(external_types[j],temp_s->external_migration);
                    external_count++;
                }
                j=external_count; /* get out of loop */
            }
        }
    }
}

if (external_count == MAX_EXTERNAL &&
    internal_count == MAX_INTERNAL &&
    fertility_count == MAX_FERTILITY)
{
    /* All Assumptions are present */
    return 1;
}
else
{
    /* Not all assumptions are present */
    return 0;
}
}

```

```

/*****

```

```

*
* Function: read_fertility
*
* Purpose: The purpose of this routine is to read the file
*          fertility.txt and to store the results in the
*          answers array. fertility.txt contains the most
*          likely fertility assumption as determined in the
*          national question KiPlus segment
*
*...../
void read_fertility(struct answer_type *a)
{
    FILE *fp;
    char inline[81];
    char *ptr_index,*start;
    int choice_read,pos,ptr_pos;
    char pause_char[2];

    /* Open fertility File */
    if ((fp = fopen("fertility.txt","r")) == NULL) {
        printf("Error in reading: fertility.txt\n");
        gets(pause_char);
    } else {
        /* Read one line into buffer */
        fgets(inline,80,fp);

        choice_read = 0;

        ptr_index = inline;

        ptr_pos = 0;

        /* Read in fertility */
        pos = 0;
        start = inline;
        do
        {
            pos++;
            ptr_pos++;
            ptr_index++;
        }
        while ((pos <= 6) && (*ptr_index != NULL));
        strcpy(a->fertility,start,(pos-1));
        a->fertility[pos-1] = '\0';
    }
}

*
* Function: screen_short
*
* Purpose: This function ensures that there is a short term scenario
*          amongst the national scenarios selected. If there is not
*          such a scenario, it adds the short term scenario to the
*          national list. The maximum number of scenarios is then
*          adjusted upwards to compensate for the added scenarios.
*
*...../

int screen_short(struct national_type *n, struct answer_type *answers, struct scenario_data *SCENARIOS)
{
    int found;
    char pause_string[2];
    struct national_type *n_temp;
    struct national_type *medium;

    /* Find the medium Scenario */
    found = 0;
    while (n && !found)
    {
        if (strcmp("Medium",n->scenario_type) == 0)
        {
            medium = n;
            found = 1;
        }
        else
            n = n->next;
    }
    if (!found) {
        printf("Error in finding the Medium Scenario! Results may be invalid!\n");
        gets(pause_string);
        return 0;
    }

    found = 0; /* Use found now as a boolean check for the most likely checks */

```

```

/* Check each scenario in the group */
#ifdef SCREEN_TRACE
printf("Fertility : %s \n",answers->fertility);
gets(pause_string);
#endif

if { ( (strcmp("high",answers->fertility) == 0) && (strcmp("high",medium->external_migration) != 0) )
    || ( (strcmp("low",answers->fertility) == 0) && (strcmp("low",medium->external_migration) != 0) ) )
{
/* Skip to end of national database */

while (n->next && n)
    n = n->next;

/* Add a new national scenario */

n_temp = n;
n++;
n_temp->next = n;
strcpy(n->fertility,answers->fertility);
strcpy(n->scenario_type,"likely");
strcpy(n->external_migration,medium->external_migration);
strcpy(n->scenario_name,"likely");

n->next = NULL;

/* Add a new national scenario */

found = 1;
SCENARIOS->MAX_SCENARIOS = 4;
}
else
{
    SCENARIOS->MAX_SCENARIOS = 3;
    found = 1;
}
}

#ifdef SCREEN_TRACE
printf("Screen Trace\n");
printf("# Nat. Scenarios : %d \n",SCENARIOS->MAX_SCENARIOS);
gets(pause_string);
#endif

return found;
}

```

APPENDIX 6: PSSA SAMPLE SESSION

Screen 1:

Expertech Xi Plus
Knowledgebase: none

Please select item and proceed

- Consult an application
- Build application
- Run tutorial
- Exit system

F1 help || space bar move down || backspace move up || Rtn select & proceed ||

Screen 2:

Expertech Xi Plus
Knowledgebase: none

Consult mode	Applications
Load knowledgebase	Select one of..
Examine conclusions	Xi Plus tutorial
Continue	Advanced Xi Plus tutorial
What if	• PSSA
Reset data	
Load/save data	
Exit system	
Command	

Esc cancel || Rtn select & proceed ||

Screen 3:

Expertech Xi Plus Knowledgebase: none	
Consult mode Load knowledgebase Examine conclusions Continue What if Reset data Load/save data Exit system	Application knowledgebases Select one of.. • National Questions National Selection Module
Command	

Esc cancel || Rtn select & proceed ||

Screen 4:

Application: P66A Knowledgebase: National Questions	
Consult mode Load knowledgebase Volunteer data • Start query Examine conclusions Continue What if Reset data Load/save data Exit system	<- Load a new knowledgebase <- Give answers before being asked <- Start a consultation <- Look at any conclusions (and explanations) <- Resume the current consultation <- Change answers and see the current answers <- Clear the answers (ready for the next consultation) <- Load or save answers and conclusions <- Quit
Command	Use 'Start query' to set the system running. Remember to do 'Reset data' between sessions. Press F1 for further help.

Esc cancel || Rtn select & proceed || Any other key command ||

Screen 5:

Application: PSSA
 Knowledgebase: National Questions

Consult mode Load knowledgebase Volunteer data • Start query Examine conclusions Continue What if Reset data Load/save data Exit system	Start query Select one of.. • ask questions
Command _____	

Esc cancel || Rtn select & proceed ||

Screen 6:

Application: PSSA
 Knowledgebase: National Questions

What trends are suggested by recent government white papers?

Select one of..

- very favorable to increase
- somewhat favorable to increase
- opposed to increase

Esc cancel || Rtn select & proceed || F3 why ||

Screen 7:

Application: PSSA
Knowledgebase: National Questions

What trends have been observed in federal immigration quotas in recent years?

Select one of..

- high increases
- some increases
- no increases
- decreases

Esc cancel || Rtn select & proceed || F3 why ||

Screen 8:

Application: PSSA
Knowledgebase: National Questions

What do recent economic and political events suggest about immigration quotas?

Select one of..

- very favorable to increase
- somewhat favorable to increase
- against increase
- favorable to decrease

Esc cancel || Rtn select & proceed || F3 why ||

Screen 9:

Application: PSSA
Knowledgebase: National Questions

What have been the trends in recent years with the acceptance of refugees?

Select one of..

- large increases
- some increases
- no increases
- decreases

Esc cancel | Rtn select & proceed | F3 why |

Screen 10:

Application: PSSA
Knowledgebase: National Questions

What do recent world events suggest about future worldwide refugee numbers?

Select one of..

- strongly favorable for increase
- somewhat favorable for increase
- unfavorable for increase
- favorable for decrease

Esc cancel | Rtn select & proceed | F3 why |

Screen 11:

Application: PSSA
Knowledgebase: National Questions

What has been the trend in admitting immigrants in other countries?

Select one of..

- large increases
- slight increases
- no increases or decreases
- decreases

Esc cancel || Rtn select & proceed || F3 why ||

Screen 12:

Application: PSSA
Knowledgebase: National Questions

How has immigration in the past year compared with the set federal quota?

Select one of..

- actual immigration much higher
- actual immigration somewhat higher
- actual immigration about the same
- actual immigration somewhat lower

Esc cancel || Rtn select & proceed || F3 why ||

Screen 13:

Application: PSSA
Knowledgebase: National Questions

How is the Canadian fertility rate expected to behave in the near future?

Select one of..

- expect short term fertility increase
- expect fertility at status quo
- expect short term fertility decline

Esc cancel || Rtn select & proceed || F3 why ||

Screen 14:

Application: PSSA
Knowledgebase: National Questions

How would you rate recent fertility trends in other western countries?

Select one of..

- recent increases
- remain at status quo
- recent decreases

Esc cancel || Rtn select & proceed || F3 why ||

Screen 15:

Application: PSSA
 Knowledgebase: National Selection Module

Consult mode
 Load knowledgebase
 Volunteer data
 Start query
 Examine conclusions
 Continue
 What if
 Reset data
 Load/save data
 Exit system

<- Load a new knowledgebase
 <- Give answers before being asked
 <- Start a consultation
 <- Look at any conclusions (and explanations)
 <- Resume the current consultation
 <- Change answers and see the current answers
 <- Clear the answers (ready for the next consultation)
 <- Load or save answers and conclusions
 <- Quit

Command

Use 'Start query' to set the system running.
 Remember to do 'Reset data' between sessions.
 Press F1 for further help.

Esc cancel || Rtn select & proceed || Any other key command ||

Screen 16

Application: PSSA
 Knowledgebase: National Selection Module

Consult mode
 Load knowledgebase
 Volunteer data
 Start query
 Examine conclusions
 Continue
 What if
 Reset data
 Load/save data
 Exit system

Start query
 Select one of..
 national selection

Command

Esc cancel || Rtn select & proceed ||

Screen 17:

Application: PSSA
Provincial Segment Questions

How you rate the expected economic situation for Newfoundland in the medium term future?

Select one of..

- Significant growth expected
- Some growth expected
- No growth expected
- Small decline expected
- Significant decline expected

Screen 18:

Application: PSSA
Provincial Segment Questions

What has been the overall long term demographic migration trend for Newfoundland?

Select one of..

- Large Movement of persons to the province
- Small Movement of persons to the province
- Balanced migration to and from province
- Small, but steady movement of persons out of the province
- Large movement of persons out of the province

Screen 19:

Application: PSSA
Provincial Segment Questions

How you rate the expected economic situation for Quebec in the medium term future?

Select one of..

- Significant growth expected
- Some growth expected
- No growth expected
- Small decline expected
- Significant decline expected

Screen 20:

Application: PSSA
Provincial Segment Questions

What has been the overall long term demographic migration trend for Quebec?

Select one of..

- Large Movement of persons to the province
- Small Movement of persons to the province
- Balanced migration to and from province
- Small, but steady movement of persons out of the province
- Large movement of persons out of the province

Screen 21:

Application: PSSA
Provincial Segment Questions

How you rate the expected economic situation for Ontario in the medium term future?

Select one of..

- Significant growth expected
- Some growth expected
- No growth expected
- Small decline expected
- Significant decline expected

Screen 22:

Application: PSSA
Provincial Segment Questions

What has been the overall long term demographic migration trend for Ontario?

Select one of..

- Large Movement of persons to the province
- Small Movement of persons to the province
- Balanced migration to and from province
- Small, but steady movement of persons out of the province
- Large movement of persons out of the province

Screen 23:

Application: PSSA
Provincial Segment Questions

How you rate the expected economic situation for British Columbia in the medium term future?

Select one of..

- Significant growth expected
- Some growth expected
- No growth expected
- Small decline expected
- Significant decline expected

Screen 24:

Application: PSSA
Provincial Segment Questions

What has been the overall long term demographic migration trend for British Columbia?

Select one of..

- Large Movement of persons to the province
- Small Movement of persons to the province
- Balanced migration to and from province
- Small, but steady movement of persons out of the province
- Large movement of persons out of the province

Screen 25:

Application: PSSA
Provincial Segment Questions

Which internal migration assumption best approximates recent Canadian demographic trends?

Select one of...

- Assumption A (Migration focused on Ontario, small gains in BC)
- Assumption B (Close to long term trends, medium for west, best fit Atlantic)
- Assumption C (Large flow to British Columbia and Alberta, least favourable for Ontario)

Screen 26:

Application: PSSA
Provincial Segment Questions

--- Selected Scenario Group ---

This Scenario is a Flat group.

Group No:	99
Scenario 1	E2.1A
Scenario 2	L1.7B
Scenario 3	L1.7C
Scenario 4	L1.2C

Scoring Values:

High Scenario Score	:	20
Medium Scenario Score	:	9
Low Scenario Score	:	20
Range Score	:	37
Total Score	:	86

APPENDIX 7: DATA REQUIREMENTS FOR NATIONAL SEGMENT

Task	Data Required	Data Source
Selection of High Scenario	Characteristics of National Scenarios	File
Selection of Low Scenario	Characteristics of National Scenarios	File
Determination of Fertility and Immigration levels best matching recent trends	Expected short term fertility rate changes	User Supplied
	Fertility Trends in Other Countries	User Supplied
	Recent Federal Immigration Quotas	User Supplied
	Recent Government Reports on Immigration	User Supplied
	Recent Economic or Political Events affecting immigration	User Supplied
	World Refugee Situation	User Supplied
	Refugee acceptance trends in Canada	User Supplied
	Comparison of former expected levels with actual immigration numbers	User Supplied
	Immigration Trends in other nations	User Supplied
Selection of Scenario which most closely represents recent trends	Fertility and Immigration Assumptions best matching short term trends	Model determined variables

Selection of Medium Scenario	Fertility and Immigration Assumptions best matching short term trends	Model determined variable
	Characteristics of scenario best representing recent trends	Model determined variable
	High scenario	Model determined variable
	Low scenario	Model Determined Variable

APPENDIX 8: DATA REQUIREMENTS FOR PROVINCIAL SEGMENT

Task	Data Required	Data Sources
Generation of provincial level scenarios	National Level Scenarios Interprovincial migration assumptions	File created through solution of National Segment Inherent in the model. Could be user supplied for greater flexibility.
Ranking of Scenarios by population for each province	Populations associated with each scenario broken down for each province	File
Creation of Scenario Groups	Provincial level scenarios	Variables created by the model
Determining Overall Strength of Each scenario group	Strength of each scenario group for each province	Variables created by the model
Determining strength of each scenario for each province	High Scenario Evaluation Data Medium Scenario Evaluation Data Low Scenario Evaluation Data Scenario Range Evaluation	Variable determined by model Variable determined by model Variable determined by model Variable determined by model
High Scenario Evaluation for each province	Population ranking evaluation	Variable created by model
Low Scenario Evaluation for each province	Population ranking evaluation	Variable created by model
Medium Scenario Evaluation for each province	Population ranking evaluations	Variable created by model

Task	Data Required	Data Sources
Range Evaluation for each province	Short term economic picture for that province	User provided
	Long term interprovincial migration trend	User provided
	Size of province	Internal model variables
Inclusion of scenario which best represents recent trends	Fertility assumption closest to recent trends	Variable determined in National segment
	International Migration assumption closest to recent trends	Variable Determined in National segment
	Interprovincial migration assumption closest to recent trends	User provided
Determination which group achieves best fit	Overall strength of each scenario group	Variables generated by model

END

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FIN