Appendix E: Socioeconomic Information

Contents

I. Introduction

A. Demographics, Socioeconomics, Economics, and Environmental Decision Making

The environment decisions of the Agency have always and inevitably been shaped and influenced by economic, social and demographic conditions and events, and by perceptions, assumptions and beliefs regarding the significance and relevance of such conditions and events. Correspondingly and characteristically, economic, social and demographic data and information has – with certain programmatic exceptions – only been brought into Agency decisions informally and implicitly: according to the case-by-case experiences and judgements of those Agency staff and stakeholders immediately involved in particular policies or programs.

To recognize these characteristic limitations of Agency decision making is not to suggest that over time Agency decisions have been incorrect or technically unsound. It is to argue however – in keeping with certain essential recognition of GOAL 21 – that by finding ways to more usefully and effectively bring demographic, socioeconomic and economic considerations into decision making, environmental policy decisions can potentially be: better focused and coordinated across media; more closely attuned to

stakeholders issues and concerns; and better able to proactively respond to systemic societal change. As a part of this overall effort this section of the EIR is intended to be a first step.

B. The Challenge of Selection. One of the fundamental challenges of incorporating economic data and information into the Environmental Information Report (EIR) – and especially of trying to provide an overview and summary of such data and information – is that of selecting those facts to be presented. Across Minnesota there is a vast, almost limitless accumulation of recorded and unrecorded environmental, demographic, socioeconomic and economic facts and correspondingly literally thousands of specific and more general stories of economic – environmental interactions

To select and present in summary form certain, particular economic, social, demographic and environmental facts is to inevitably leave out the overwhelming majority of facts that could be profitably considered and explored. It is also – if not to actually suggest or present some number of stories regarding such facts – to select certain places where, based on the facts, stories of interactions ought to be considered explored and uncovered. In this first iteration of the EIR we have focused on the following major areas:

- *Demographics,* particularly the demographics of rural decline and urban expansion and the aging of Minnesota's population;
- *Income,* including the distribution of income within as well as between Minnesota's communities;
- *Economic Productivity and Materials Flows,* emphasizing the material basis of the economy as inflows, outflows and hidden flows; and
- *Transportation, Population Density and Energy Use*, particularly the role of transportation in structuring Minnesota's communities and their corresponding energy use.

In selecting these areas of attention we have necessarily and inevitably left out far more than we have included. It is the intent of this first iteration of the Demographics, Socioeconomics and Economics section of the EIR however, that what we have included serve as something like a *baseline* for the areas considered – subject of course to updating, expansion and correction. Subsequent iterations of the EIR will have the opportunity to explore other demographic, socioeconomic and economic questions, facts and stories.

C. Appendices and Supplemental Materials. Following the main body of the report there are several appendices that provide data tables used to generate the charts and graphs in the main body of the report along with supplemental data tables and graphics. Finally there is preliminary typology of five characteristic Minnesota socioeconomic/cultural groups; a discussion of conceptual issues faced by the overall EIR in bringing together the particular and the general; and a preliminary discussion of the demographics and socioeconomics of rural Minnesota relative to the ISTS program and programmatic alternatives.

II. Demographics

A. Demographics: Population Growth, Relocation and Decline

From 1900 to 1960 Minnesota's population close to doubled from 1.75 million to 3.41 million, growing at an average rate of approximately 15% per decade. By 1970 – the approximate beginning of the MPCA and its programs – the population of the state was 3.80 million. From 1970 to 2000 the State's population grew at an average rate of approximately 9% per decade (weighted by a 90s rate of 12.45%) to a total of 4.91 million. The projected 2020 population of Minnesota is 5.24 million. At least as noteworthy as this overall growth in population are two other trends:

- the geographical redistribution of Minnesota's population from rural to urban/suburban: and
- the overall aging of Minnesota's population.

In thirty year increments, from 1900 to 2020 the rural - urban (i.e., urban/suburban) balance of Minnesota's population changed and is expected to change as follows:

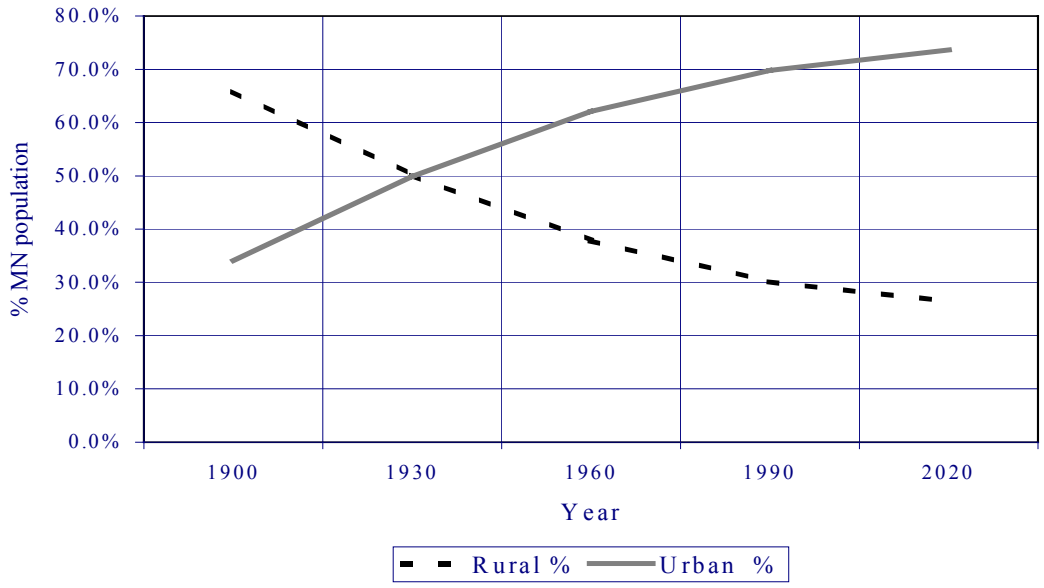

Figure D.1 The Urbanization of Minnesota's Population 1900-2020

The Demographics and Geography of Urban Expansion

Geographically the urban/suburban dominance of Minnesota's population has involved: the continuing rapid demographic and spatial expansion of the Twin Cities Metropolitan area; accompanied by the emergence as metropolitan centers of Rochester, Mankato, and St. Cloud, and by the development and expansion of population corridors extending from Rochester and Mankato north to the Twin Cities, and from the Twin Cities north to St. Cloud. In addition to St. Cloud and Rochester, those other regional centers designated as metropolitan areas by the US census: Duluth-Superior, Fargo-Moorhead, Grand Forks-East Grand Forks, have also continued to expand, if at a slower rate than the Twin Cities metropolitan area.

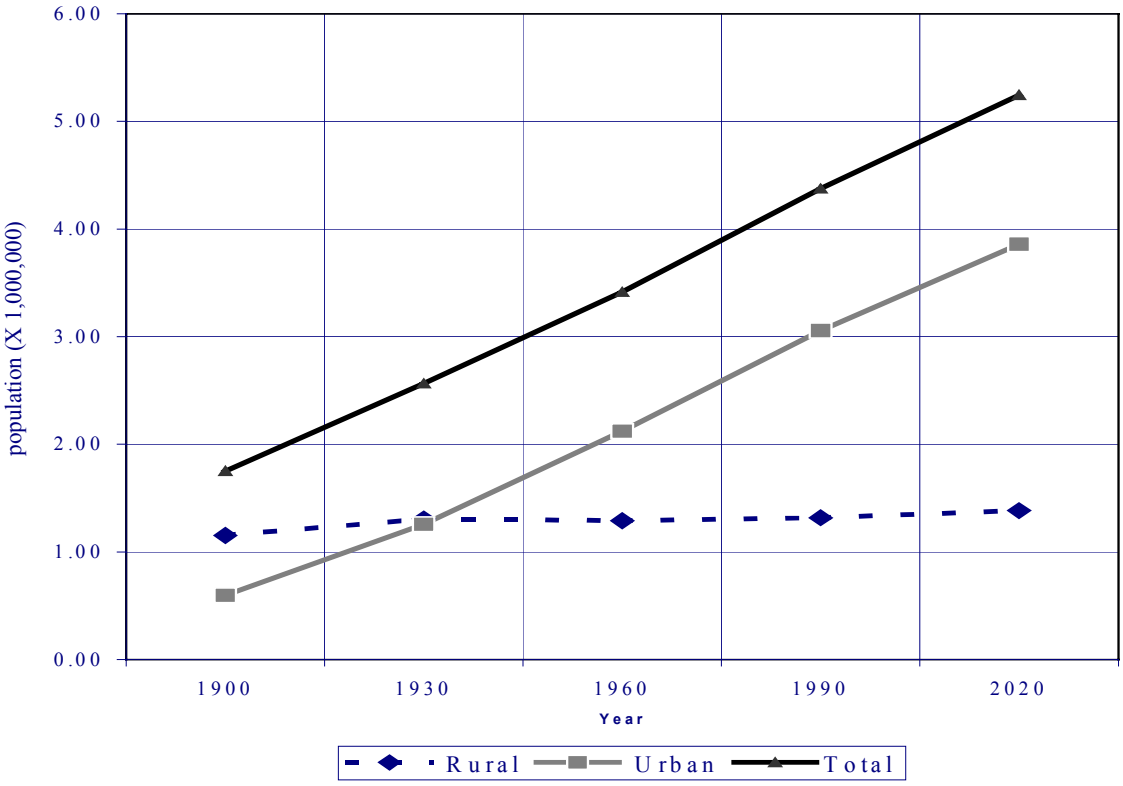

Figure D.2. The Rural/Urban Configuration of Population Expansion 1900-2020

The Demographics of Rural Decline

At a statewide level Minnesota's rural population has remained relatively constant from 1930 to 1990 and as projected to 2020. An exclusively statewide perspective however, masks significant even dramatic structural socioeconomic and cultural changes in the state's rural population. Consider that from 1980 to 2000 no less than forty of Minnesota's eighty-seven counties actually lost population, led by Traverse which declined at a rate of slightly more than 25%. In contrast, over the same time period Minnesota's two fastest growing counties – Sherburne and Scott of the Twin Cities metropolitan area – expanded at over 100%.

B. Demographics: The Aging of Minnesota's Population

Perhaps the most remarkable demographic change in Minnesota from 1900 through 2000 and as projected to 2025, is the dramatic re-distribution in the age profile of the State's population. The age profile of a population is the distribution of the overall population by age groupings. The population distributions in Figure D.3 represent the age distributions of the State's 1900, 1930, 1960, 2000 (i.e.,1998), and projected 2025 populations.

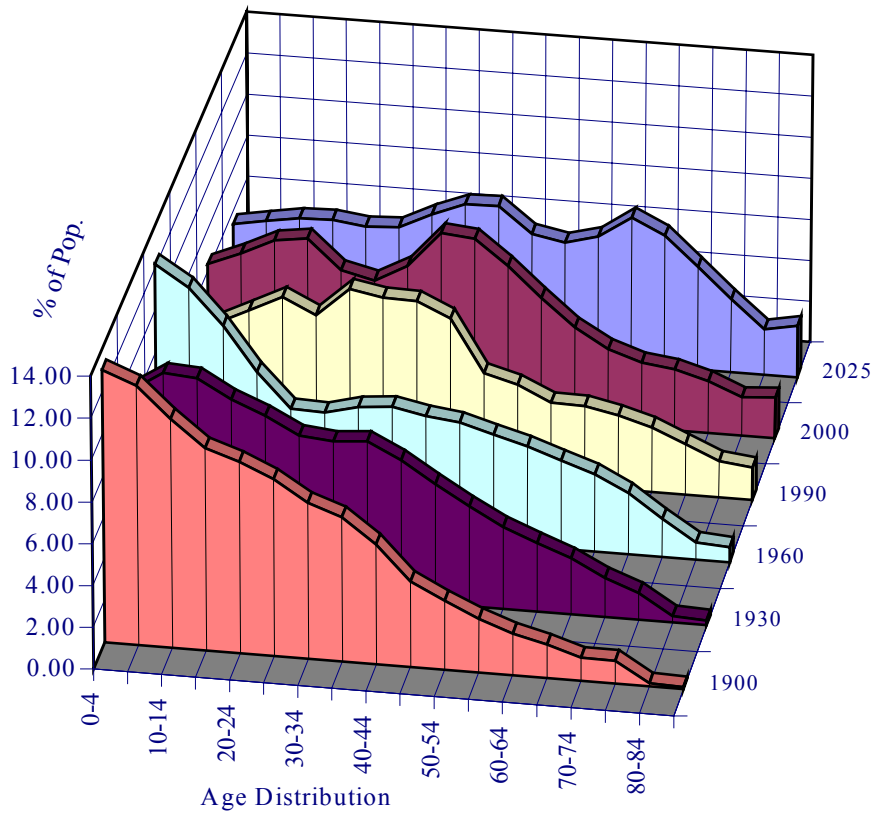

Figure D.3 The Age Distribution of Minnesota's Population

The shape of the age distribution for 1900, although somewhat exaggerated by the influx of young immigrants is generally analogous to the structure characteristic of pre-modern societies. In contrast, demographically the 2000 profile with its tiered configuration is characteristic if a *mature industrial society*. Finally the projected 2025 profile, where the lower age groupings are substantially reduced while the elderly population has become much more pronounced represents the aged population of a *post-industrial*. Overall the aging of Minnesota's population is generally recognized as one of the most significant demographic trends of the next several decades, but to fully appreciate the dramatic, even overwhelming effects of this change requires a structural consideration of changes in age distribution not only between but *within* Minnesota communities.

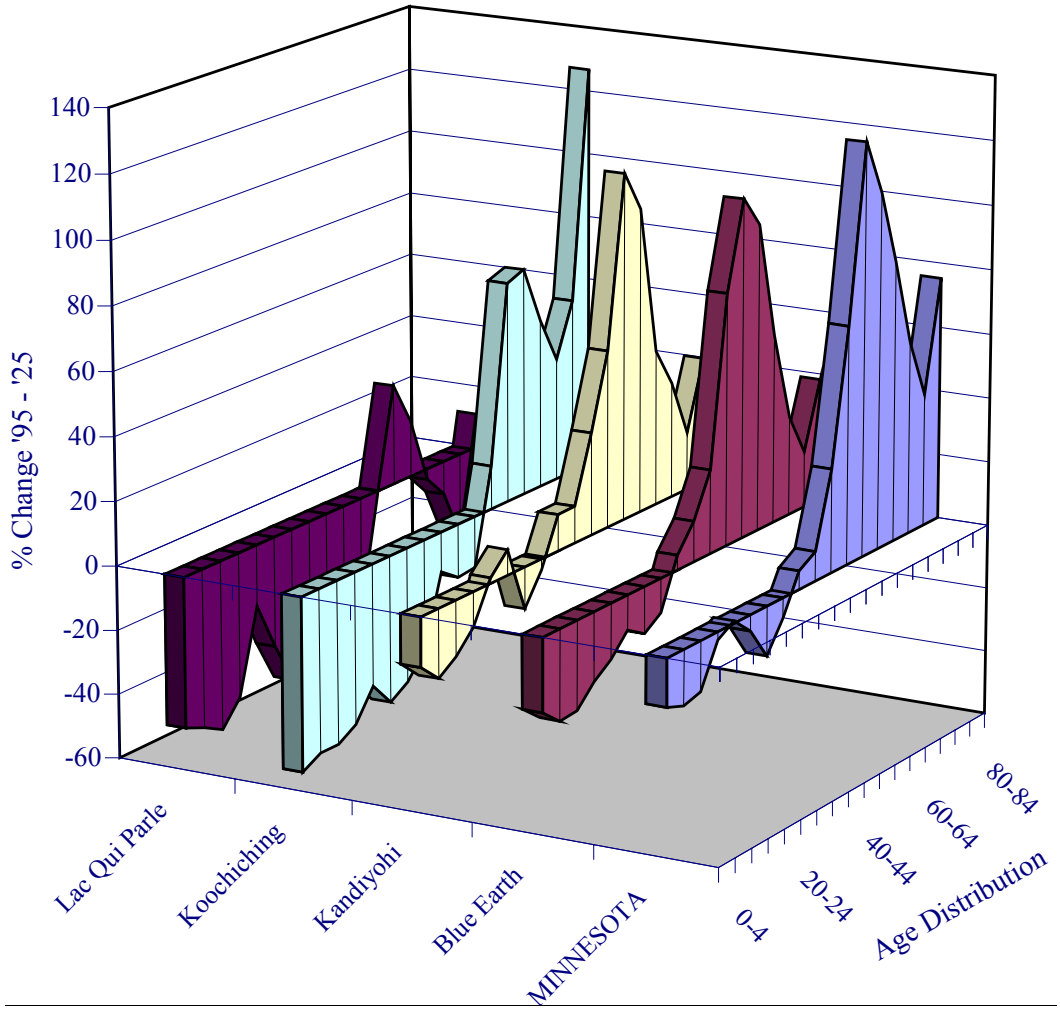

Figure D.4 Projected 1995-2025 Changes in Age Distribution of Four Rural Counties

Figure D.4 illustrates projected changes in age structure of five rural Minnesota counties for the period from 1995 to 2025. The corresponding projected changes in age structure of four urban/suburban Minnesota counties for the period from 1995 to 2025 is as follows:

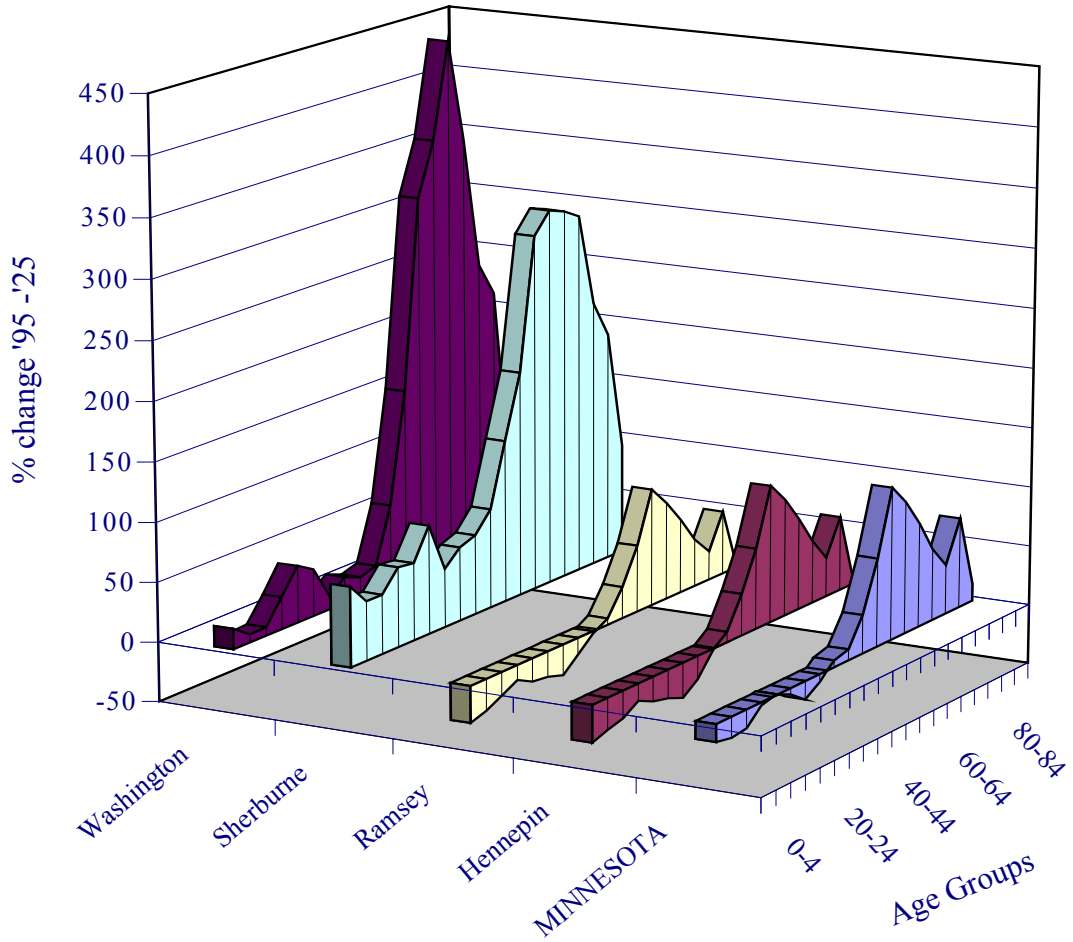

Figure D.5 Projected 1995-2025 Changes in Age Distribution of four Urban/Suburban Counties

The considerable difference in the positive scale of "% change '95 – '25" between Figures D.4 and D.5 (i.e., 140% to 450%) is driven primarily by Washington County and to a lesser extent Sherburne County. The dramatic increases in the elderly population is in part reflective of the small 1995 elderly population of these counties. Conversely, while the projected numbers of elderly in '95 and '25 are at least comparatively, not great the change in the character of these communities will nevertheless be pronounced.

Elderly Dependency and Rural Minnesota

For rural Minnesota, the *historically unprecedented* transformation to a population dominated demographically by the elderly has already been substantially accomplished.

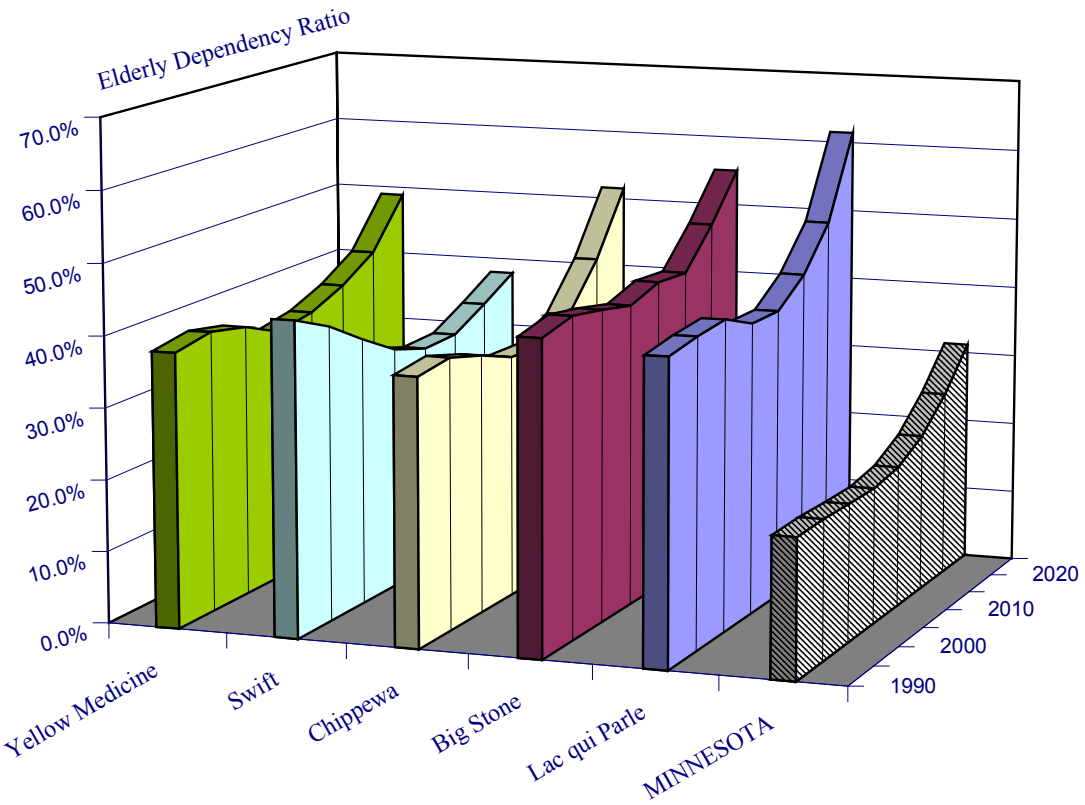

Figure D.6 Elderly Dependency Ratios of Upper MN River Counties: 1900-2025

As an example, consider the transformation of Lac Qui Parle County, as representative of the Upper Minnesota River Development District and of rural Minnesota generally. At the beginning of the 20th century the general age profile of Lac Qui Parle, as one of Minnesota's youngest communities, was as follows:

- 46.2% under 20;
- 49.9% from 20 to 64 inclusive;
- 3.8% 65 and older; and
- 6.4% elderly dependency ratio.

The *Elderly Dependency Ratio* is the number of individuals 65 and older as compared to the overall working age population (i.e., individuals from 15 to 64 years of age inclusive). It is in certain respects a measure of the ability of a community's government and community services to be self-supporting economically. That is, the lower the elderly dependency ratio the larger the working age population and corresponding economic activity available within the community to meet the needs of the elderly. With an elderly dependency ratio of 6.4% , Lac Qui Parle county of 1900 was a frontier community of recent immigrants

In contrast consider the elderly dependency ratio of Lac Qui Parle and the four other Upper Minnesota River counties[2] over the period from 1990 and as projected to 2025,

[2] These five counties are defined as the "Upper Minnesota River Economic Development District" by the Minnesota Department of Trade and Economic Development.

relative to the overall elderly dependency ration of Minnesota (Figure D.6). Note in particular that while the *change* in the elderly dependency ratio of the five counties over the period under consideration generally follows the 1990-2025 trend line throughout the State, the 1990 *starting point* of these Upper Minnesota River counties *already ranges from 38.3 to 43.8%* over twice that of the overall State (i.e., 19.3%).

Elderly Dependency and Urban Minnesota

Figure D.7 illustrates the 1990-2025 change in the elderly dependency ratio of four urban Minnesota counties and of the overall State. These counties exhibit greater variation in their 1990 elderly dependency ratios (9.6% to 18.4%) than the Upper Minnesota River counties, with the newly urbanizing suburban counties at close to one-half that of the state and the older, central city dominated counties approaching the overall state ratio. This variation however is clearly secondary to the striking contrast between these urban counties and Upper Minnesota River, where rural elderly dependency ratios are up to *four times* those of the identified urban counties.

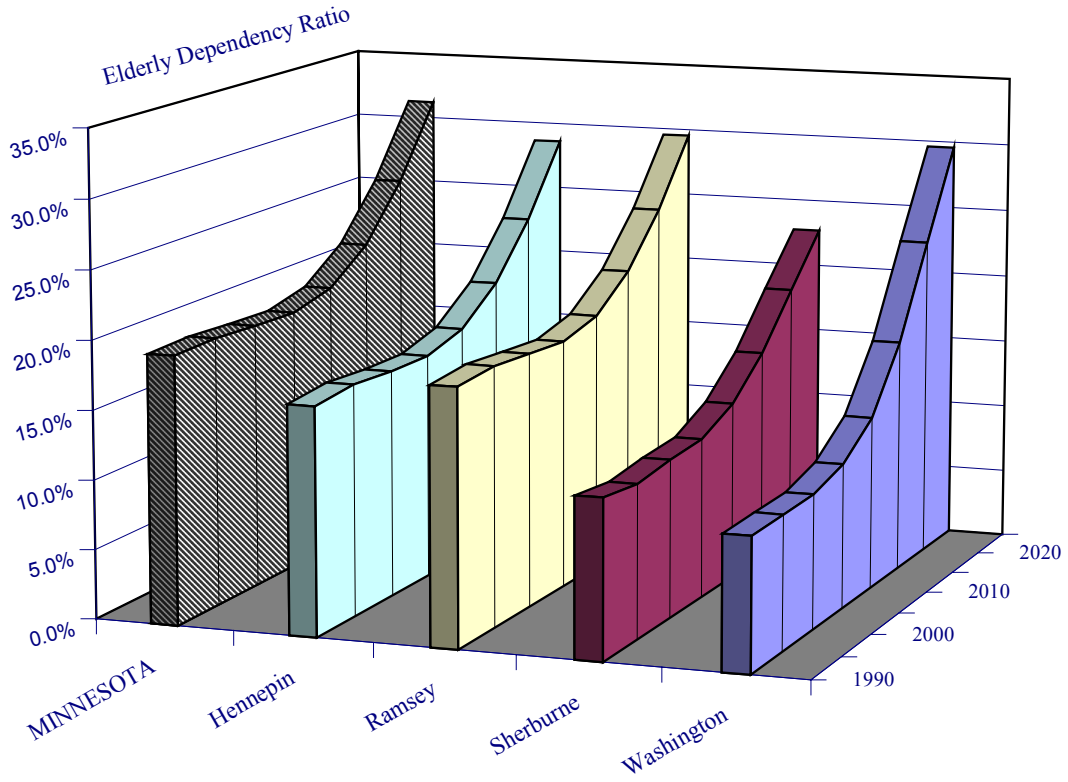

Figure D.7: Elderly Dependency Ratio for Minnesota and selected Minnesota counties.

III. Minnesota's Income, Income Distribution and Cost of Living

A. Income[3]

From 1970 to 2000 Minnesota's overall real[4] median household income (MHI) increased by 22.8% from $38,665 to 47,478., While characteristically at or above the national average, the trend of Minnesota's income from 1970 to 2000 paralleled the national economy, with income growth remaining relatively flat from the late seventies to the mid-eighties and then expanding continuously throughout the late eighties and nineties. Relative to per capita personal income Minnesota currently ranks among the top ten to fifteen states nationwide. Reflective of the structure of population and income nationally, Minnesota's economy and corresponding personal income is dominated by the state's metropolitan areas, as indicated below:

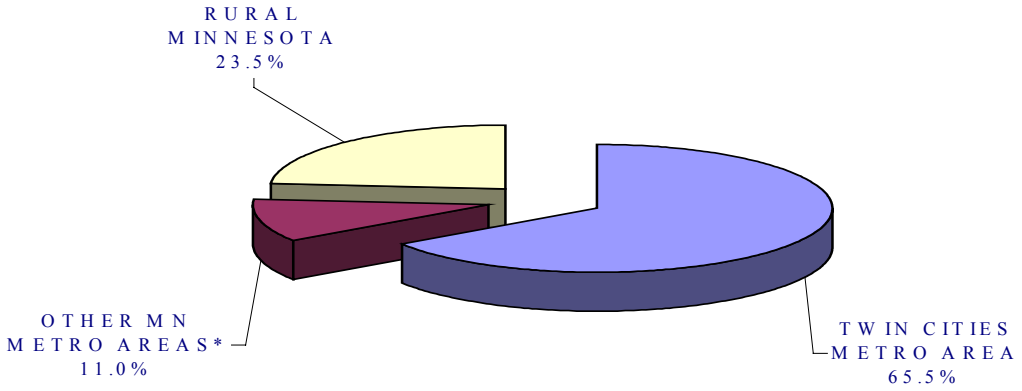

Figure D.8 Metropolitan – Rural Distribution of Household Income

* Duluth (Superior), Rochester, Moorhead (Fargo), St. Cloud, East Grand Forks (Grand Forks), Houston County (La Crosse)

B. Distribution of Income

While the metropolitan-rural geographical distribution of Minnesota's income is pronounced, uncovering the highly discontinuous and even dramatic character of the state's income distribution requires a structural consideration of *income levels* not only between but also *within* Minnesota communities. If we begin at a *generalized statewide* scale, the distribution of income according to *level of income* is, as illustrated in Figure D.9, *fairly continuous* with the exception of concentrations at the lowest and along a range of high incomes (i.e., from approximately $50,000 to $100,000).

[3] Because household income figures from the 2000 census are not scheduled to be available until the summer of 2002 the income information in this section is drawn primarily from 1990 census data. In those cases indicated the dollar amounts of such data have been converted to 2000 dollars.

[4] All dollar amounts are in 2000 dollars as adjusted by the Dept. of Commerce CPI.

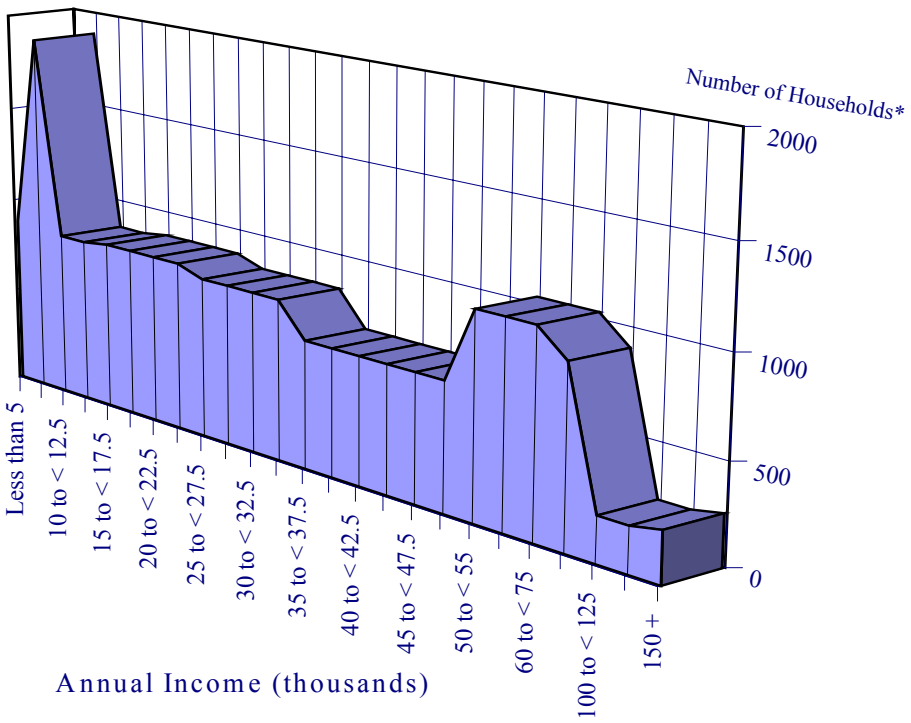

Figure D.9: Statewide distribution of household income by level of income Number of households has been normalized to 20,000.[5]

As we turn from a *generalized statewide* distribution however to consider the characteristic income structures of a number of Minnesota communities we encounter a much different story:

[5] For the comparison of income distribution between very different size communities the number of households on Figures D.9 through D.12 has been normalized, that is adjusted as if all of the communities considered have a total of 20.000 households.

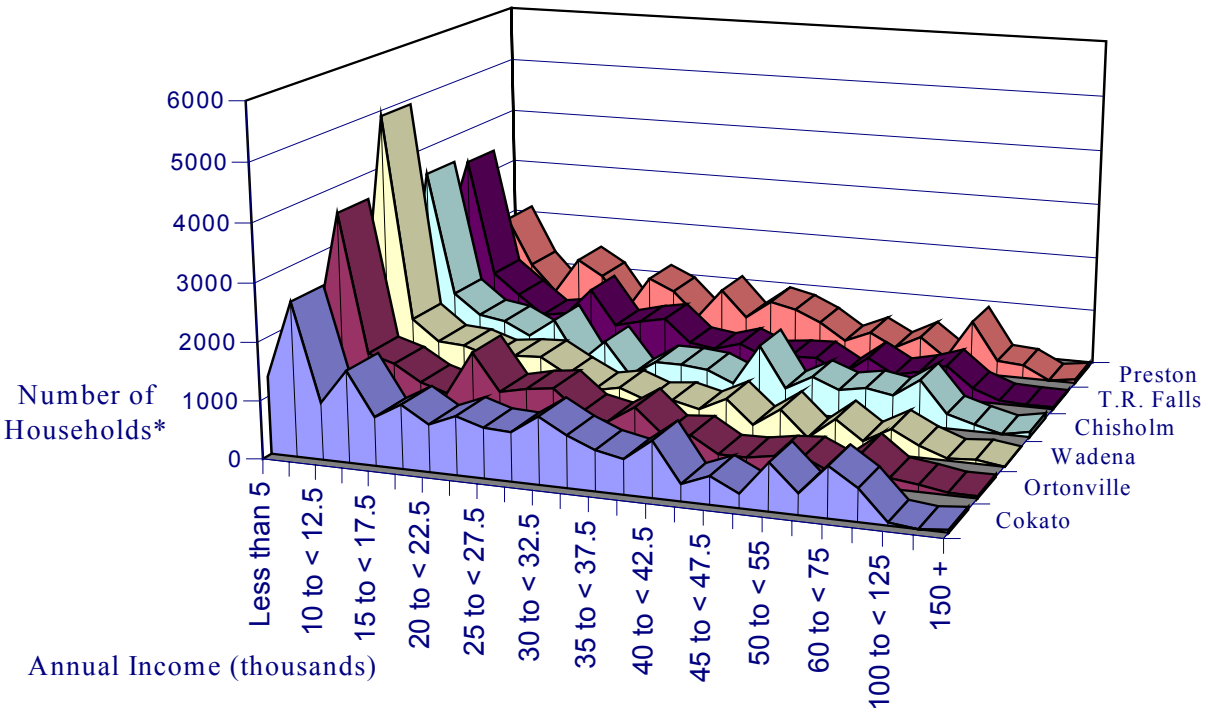

Figure D.10 Six Rural Cities: Distribution of household income by level of income Number of households has been normalized to 20,000.

These five cities are representative of the income structure of Minnesota's rural communities, and reveal the poverty levels characteristic of much of rural Minnesota. Of the five Cokato is an interesting example because given its location inside the western most boundary of Wright County it is technically categorized according to the US Census as a city of the Twin Cities metropolitan area. However the structure of its income is analogous to that of a rural community, and as such is something like a reversal or mirror opposite of the characteristic income structure of Twin Cities suburban communities as indicated below:

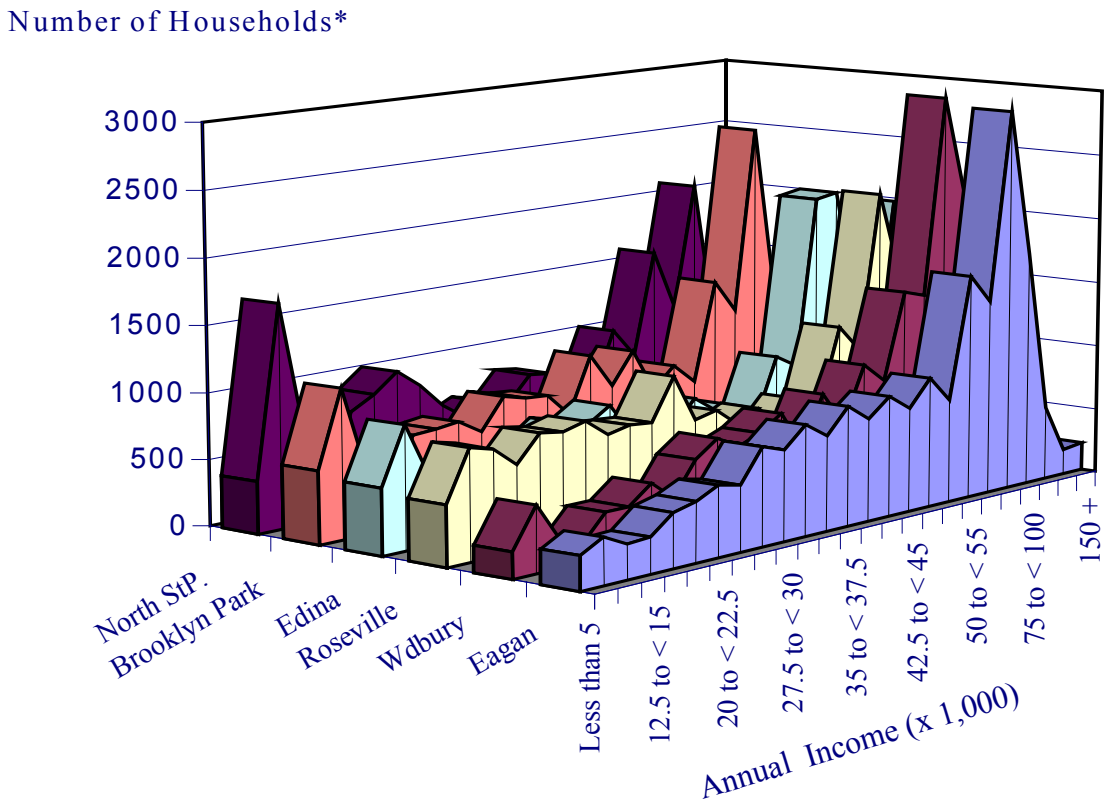

Figure D.11 Six Metropolitan Twin Cities Communities:Distribution of household income by level of income (Number of households has been normalized to 20,000).

In contrast to rural and suburban communities Minneapolis, St. Paul, and Duluth, as established central cities of metropolitan areas, share their own characteristic income structures as indicated below:

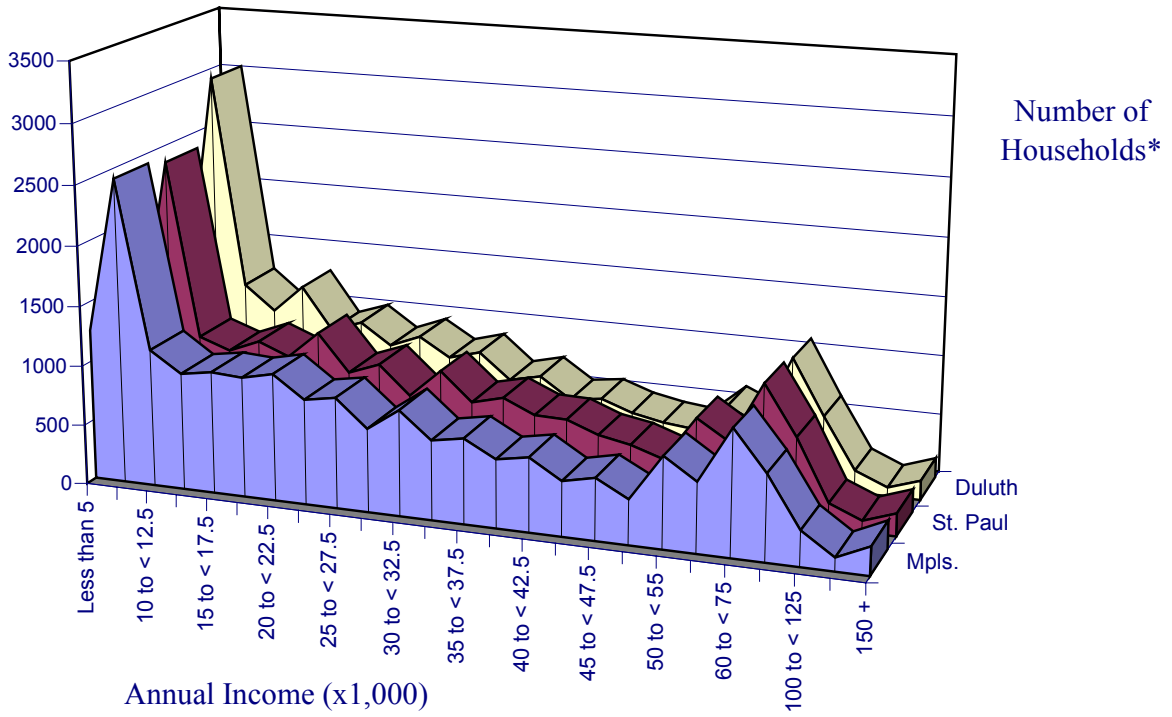

Figure D.12 Three Central Cities:Distribution of household income by level of income (Number of households has been normalized to 20,000).

B. Cost of Living

While the overall *disparity* of income between rural and particularly suburban Minnesota (i.e., Figure D.10 as compared to Figure D.11) would seem to be more pronounced than is generally assumed is the case; the corresponding and generally held assumption that a *lower cost of living* in rural areas substantially off-sets this disparity requires some consideration.

United States Bureau of Labor Statistics studies provide a picture of the *distribution of expenditures* in an average household budget in the Twin Cities Metropolitan Area, as illustrated in Figure D.13:

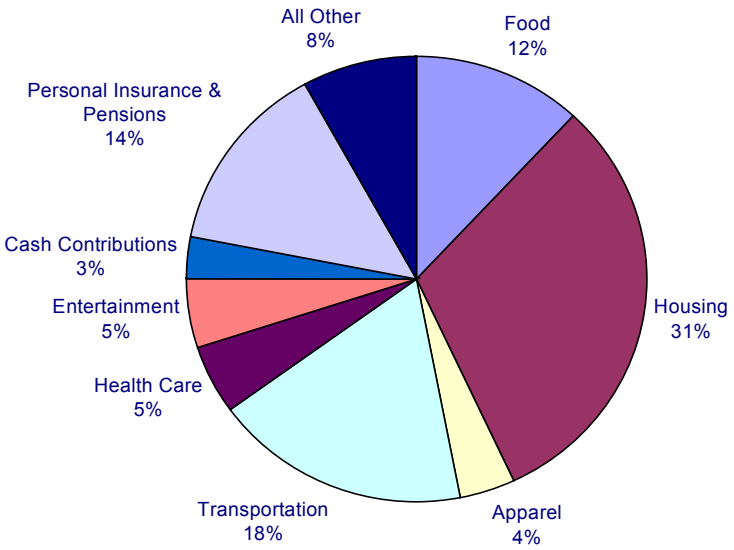

Figure D.13 Twin Cities Metropolitan Area:Distribution of Household Expenditures

Housing costs account for the largest part of the household budget. Housing costs cover more than house payments. They include the costs of: rents, property taxes, utilities, household appliances and furnishings, insurance, and maintenance. After housing costs come transportation and a mixed category called "health, recreation and other" costs. (Note: the transportation category includes an element of public transit costs.)[i]

Households outside of the Twin Cities metropolitan area have a different budget picture than Twin Cities metropolitan households. A Minnesota legislative auditor's report (1989) found that housing costs outside of the Twin Cities Metro Area averaged 40% lower than costs within the metropolitan area. This difference in housing costs is the primary factor in reducing the overall cost of living by 11% outside of – as compared to within – the Twin Cities metropolitan area. However regional differences in other areas of household costs tend to offset each other (e.g., Twin Cities metro area costs for physical goods and utilities are lower, costs of services are higher) such that apart from housing the prices of goods and services in rural Minnesota are not necessarily lower than in the Twin Cities metropolitan area. Accordingly the average difference of an 11% lower rural cost of living as driven by lower housing costs, does not make up for an average 29.3% difference in income, and as the remarkably skewed household income distributions in Figures D.10 and D.11 indicate, in this case averages are not particularly representative of the actual situations of households.

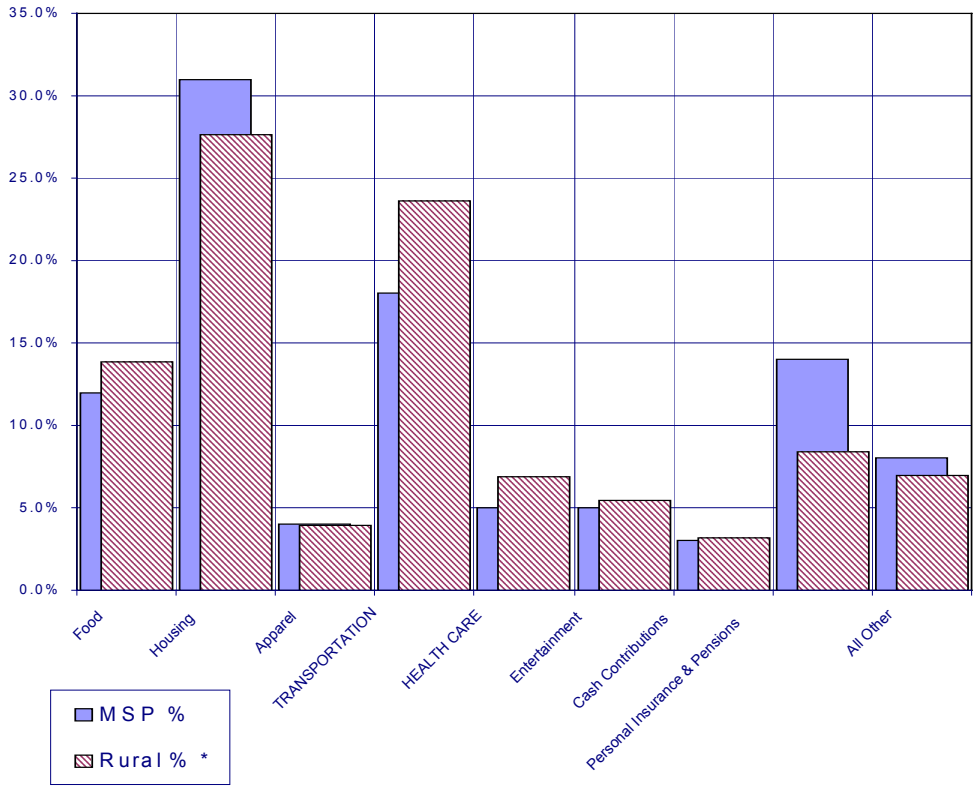

Figure D.14 Twin Cities Metropolitan Area and Rural Minnesota: Distribution of Household Expenditures

Finally, as indicated in Figure D.14, rural Minnesotan's expend a higher percentage of their overall household budgets on transportation and health care: costs that tend to be not only inflationary and even potentially volatile relative to household expenditures generally but where rural opportunities for economizing and substitution are limited by access and dispersion.

IV. Economic Productivity and Materials Flows

A. Economic Productivity

Minnesota's gross state product increased by 61.2% from 1986 to 1999 achieving a 1999 total of $167.11 trillion dollars (i.e., in constant 1997 dollars). As Figure D.15 indicates Minnesota's economic growth over the last two decades has generally exceeded that of the nation as a whole:

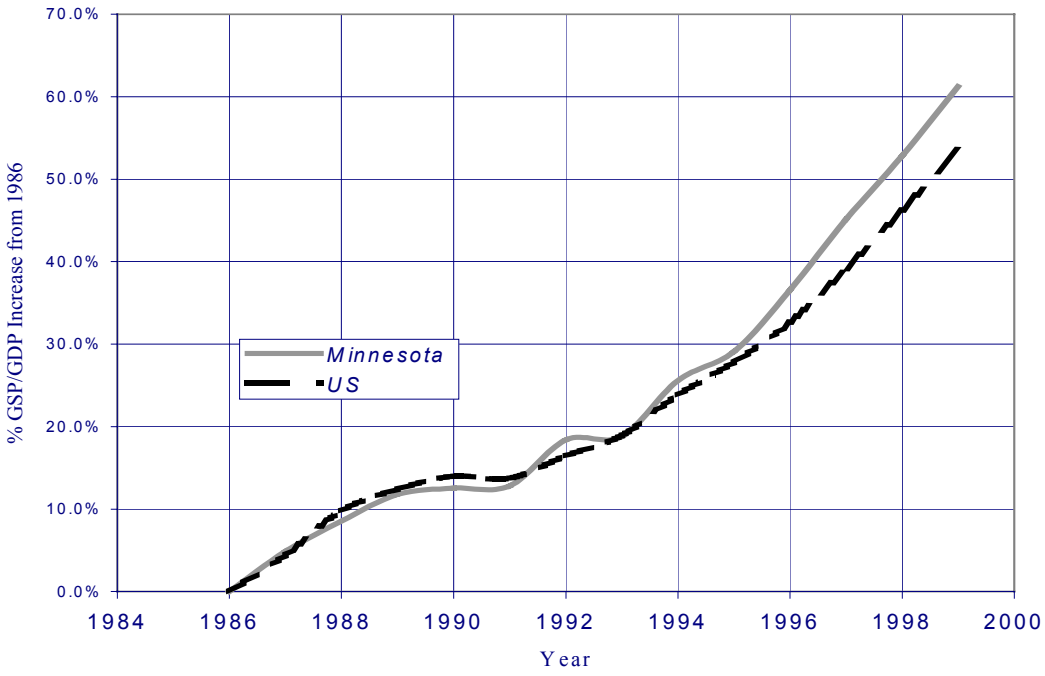

Figure D.15 Gross State Product as Compared to the US Gross Domestic Product
(in constant 1997 dollars)

As the source of Minnesota's income, perhaps the most significant and fortuitous characteristic of Minnesota's economy is its diversity. While certain regions of the state, for example the iron range, are dependent upon particular economic sectors, overall the diversity of Minnesota's economy closely matches that of the national economy. The makeup of Minnesota's economy by major industrial sector, represented below, varies by at most 1.5% per sector from the analogous distribution of the national economy

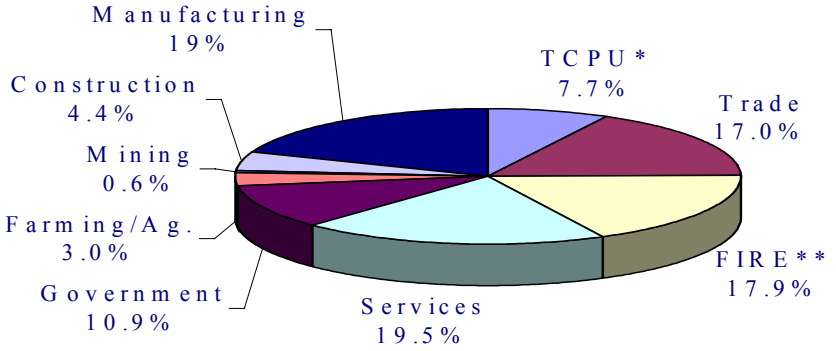

Figure D.16 Gross State Product by Industrial Sector
* TCPU – Transportation, Communications, Public Utilities; **FIRE – Finance, insurance, real estate (1996).

This diversity is in part the result of the established role of the Twin Cities as a regional center providing transportation, distribution, energy, communications, financial, legal,

etc., services to a extensive geographical area, extending from western Wisconsin to Montana and from Iowa into Canada. Minnesota's diversity is also the result of the continuing strength of historically established industries and firms, as represented by, for example: Dayton-Hudson's, Supervalu, 3M, Northwest Airlines, General Mills, The St. Paul Companies, etc., and comparatively more recent expanding ventures in computing and in particular medical technologies and services. Parenthetically, while the diversity of Minnesota's economy closely matches the national economy, considered nationally the scale of the state's economy is relatively small, with the gross state product (GSP) comprising 1.86% of the overall U.S. gross domestic product (GDP).

B. Materials Flows Analysis[6]

Conventional economic accounts are not designed to identify or make explicit environmental modifications or uses of natural resources with potential environmental impact. For example, measures such as the GDP or GSP do not include the *movement, processing* and *disposal* of large quantities of materials that have no apparent or actual economic value and may have negative value. Concepts such as full-cost accounting attempt to deal with such shortcomings, but characteristically falter because of conceptual and data limitations resulting in an inability among natural resource and environmental economists to arrive at anything approaching consensus regarding the pricing of such *externalities* (i.e., *external* to market processes and metrics).[7]

Materials flow analysis provides an alternative or supplementary approach for addressing the movement, processing and disposal of materials that occurs as a result of economic activity. Materials flow analysis is based on a set of *physical* accounts that parallel such monetary accounts as the GDP and GSP. Relative to natural and environmental resource activities providing the necessary *materials inputs* for economic activity the summary measure of materials flow analysis is the Total Materials Requirement (TMR) of an industrial economy. Relative to *material outputs* to society and the environment, that is products and services as well as waste flows, the summary measure of materials flow analysis is Total Domestic Output (TDO).

Given the comparatively recent emergence and development of materials flow analysis data is at this point only available at the national level according to national accounts. Consequently, in order to provide a proximate description of materials flows relative to Minnesota's economy we are, for the purposes of our discussion, we are scaling national flow data so as to correspond to the State's proportionate scale of the national economy as GSP / GDP. While there are likely to be significant variations between the relative TMR and TDO of Minnesota's economy as compared to the national economy the fact

[6] The majority of this section is based on the results of a collaborative multi-national effort which in the United States was lead and facilitated by the World Resource Institute (WRI). The two primary documents of that effort, published by WRI are: *Resource Flows: The Material Basis of Industrial Economies*. (1997) WRI. Washington D.C., and *The Weight of Nations: Material Outflows from Industrial Economies.* (2000) WRI, Washington D.C.

[7] For an introduction of the market based approach to the environment according to *externalities* see section: *3. Resource Management*, of *FIVE PARADIGMS RELATING THE ENVIRONMENT AND THE ECONOMY: A BACKGROUND PAPER*. April 1997. Water Quality Division; Minnesota Pollution Control Agency. Copies available from James R. Anderson.

that Minnesota's economy varies by at most 1.5% per sector from the analogous distribution of the national economy by major industrial sector suggests at least a reasonable level of congruency between the state and national economies relative to materials flows particularly for the Twin Cities metropolitan area. Keeping in mind that relative to certain flows such as iron ore mining state flows would be much higher, and for others such as coal mining, much lower.

For example, over 99% of US coal production is from domestic sources and at a 1994 TMR of 6,800 million metric tons (936 production + 5,864 hidden flows (including overburden removal)) while *coal represents no less than 31% of the TMR of the entire US economy* all of the coal used in Minnesota comes from out of state. Conversely, 80% of the iron ore mined in the United States comes from the Mesabi Range (1994) and accordingly Minnesota's environment is directly subject to an iron ore TMR which in 1994 consisted of 384 million metric tons (150.4 production + 233.6 hidden flows). Or consider, relative to domestic agriculture, Minnesota provides approximately 3.7% of total national production and accordingly is subject to a (1994) TMR of approximately 30.7 million metric tons (21.8 production + 8.9 hidden flows). Parenthetically, as of 1994, 55% of the nation's direct inputs of iron into production were provided by scrap, a percentage that has fluctuated without evidencing a trend over the period 1975-94, dropping to 45% during '81 – '82 and peaking at 62% in 1990.

C. Direct Inputs, Total Materials Requirements and Hidden Flows

The total materials required to provide those *inputs* necessary for economic production consists of two parts: 1) Flows of resources that as inputs are brought *directly* into the production of goods and services, and, 2) Flows of resources that are not production inputs but that come about through the processes of acquiring such inputs. The later are aptly described in materials flows analysis as *hidden flows*: hidden not because invisible – the slag and overburden from mining or the sediment loads in rivers from agricultural runoff are materially formidable – but because they are not accounted for according to conventional economic measures. Figure D.17 illustrates the annual Total Materials Requirements (TMR) of Minnesota's economy in million metric tons:

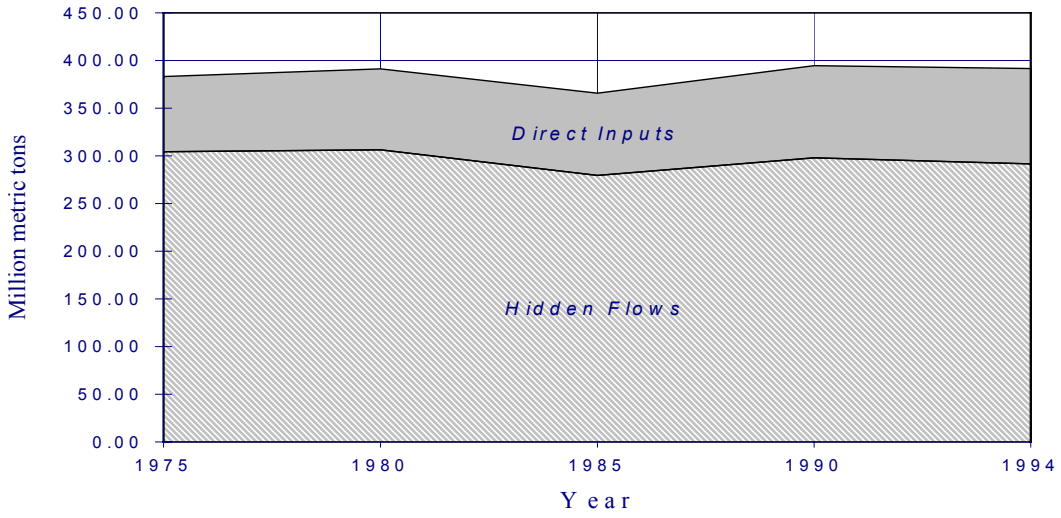

Figure D.17 Annual TMR of Minnesota's Economy

During the period from 1975 to 1994 the TMR of Minnesota's economy increased by a comparatively modest 2.2%, (i.e., 383.25 to 391.63 million metric tons) suggesting that the total materials requirement of *inputs* to the economy has changed little over the period 1975-94. The reduction indicated for 1985 is probably an expression of a general down turn in economic activity. Direct inputs (DI) increased as a percentage of TMR from 20.6% to 25.5%, representing a more efficient delivery of material inputs to the economy. Correspondingly from 1975-94 the hidden flows of Minnesota's economy declined by 4.1%.

D. Domestic Processed Output, Total Domestic Output and Hidden Flows

The total domestic *output* (TDO) from Minnesota's economy consists of Domestic Processed Output (DPO) and Hidden Flows. DPO consists of the quantity of materials of all of the goods and services *produced*, *consumed and disposed of* annually by Minnesota's economy. That part of domestic processed output that consists of infrastructure, structures, and durable goods (e.g., cars, washing machines, railroad cars, etc.) is earmarked by materials flows analysis as *net additions to stock*. Throughout the economy, *oxygen* is the *primary material addition* as inputs are processed and consumed and accordingly become DPO. For example, the various oxides that are released to the environment as a result of motor vehicle use, the burning of coal to produce electricity and other activities involving the combustion of fossil fuels proportionally increase the DPO over the DI (e.g., 22 metric tons per capita of CO_2 (1996)). Conversely recycled materials flows in the economy (e.g., metals, paper, glass) are *subtracted* from DPO. Finally, it is important to note relative to materials flow analysis that the Hidden Flows included in TMR and TDO are the same. According to systems terminology, for the purposes of physical accounting and the generally accounting principle of balancing accounts, hidden flows represent a simultaneous input and output. Correspondingly hidden flows (e.g., soil erosion from agricultural production, mining overburden) characteristically cannot be rigorously allocated exclusively to inputs or outputs. Figure D.18 illustrates the annual Total Domestic Output (TDO) of Minnesota's economy in million metric tons:

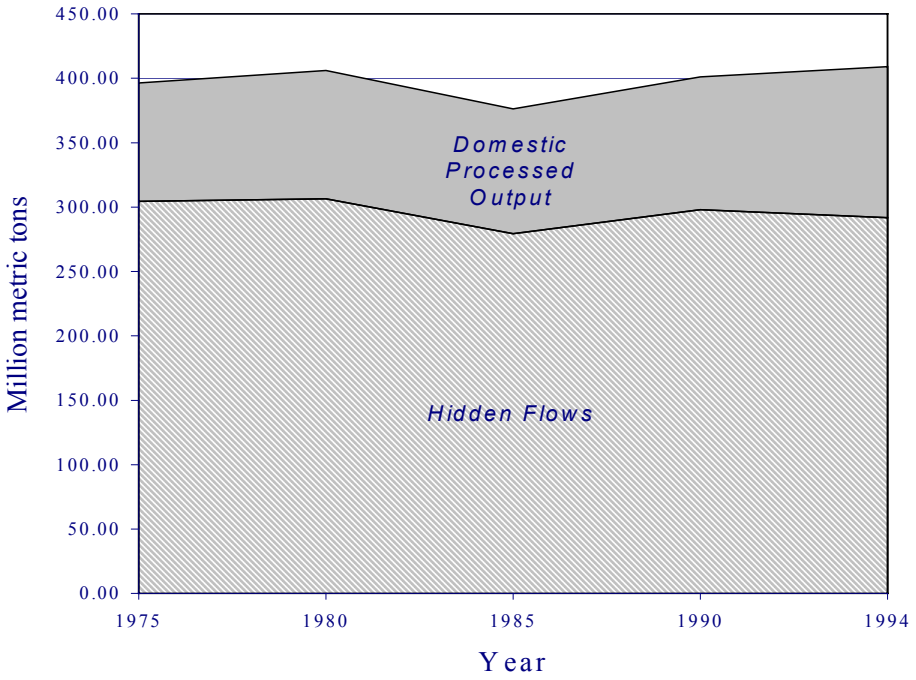

Figure D.18 Annual TDO of Minnesota's Economy

During the period from 1975 to 1994 the TDO of Minnesota's economy increased by 3.2%, (i.e., 396.39 to 409.06 million metric tons). As with TMR, the reduction indicated for 1985 is probably an expression of a general down turn in economic activity. During the same period DPO as a percentage of TDO increased by 5.5% from 23.2% to 28.7%, representing at least in part an increase in *recycling*. As with TMR there is a corresponding 1975-94 decline in hidden flows of 4.1%.

E. Materials Flow Indicators

Figure D.19 provides a series of materials flow indicators for Minnesota's economy. Please note that the units on the *y*-axis vary according to indicator as described in the legend.

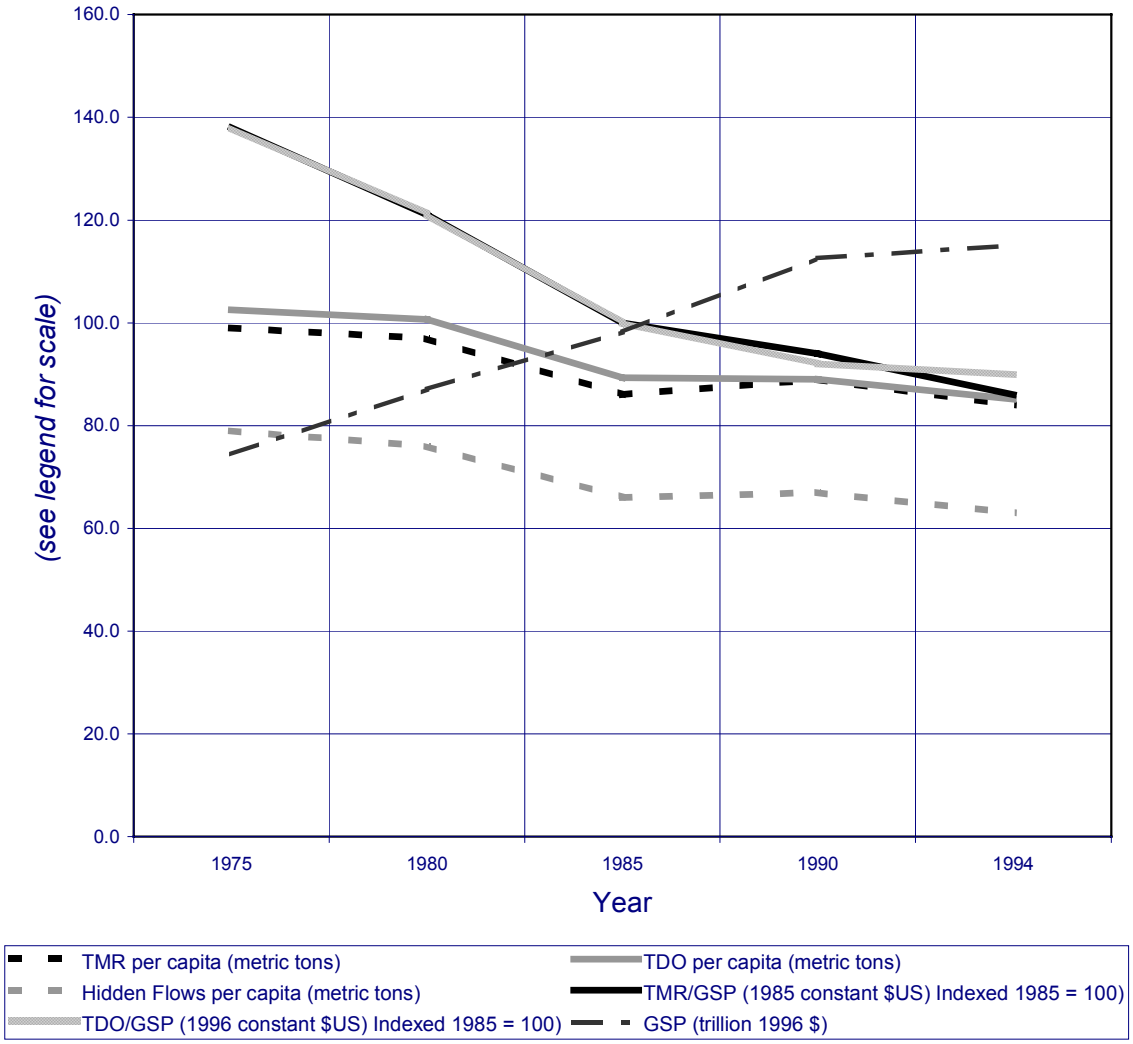

Figure D.19 Material Flow Indicators

- *Total Materials Requirement (TMR) per capita*: This parameter indicates in metric tons, what on average, is the annual per capita TMR necessary to achieve Minnesota's gross state product (GSP). The decline from 99 metric tons / person to 84 metric tons / person during the period from 1975-94 is a positive development relative to the environment. However relative to the State's total TMR, these per capital gains are at least in part offset by increases in population.
- *Hidden Flows per capita*. The 1975-94 decline in annual hidden flows per capita from 79 to 63 metric tons per person represents a substantial reduction of the hidden flows accompanying the processes whereby inputs are brought into economic production. This reduction is at least in part attributable to erosion control programs and set aside programs such as the federal Conservation Reserve Program (CRP) and the State's Reinvest in Minnesota (RIM).
- *Total Domestic Output (TDO) per Gross State Product (GSP) and Total Materials Requirement (TMR) per Gross State Product (GSP)*. The trajectories of this parameters, which are virtually the same, represent some combination of: a)

increased recycling and greater efficiency in the extraction/acquisition and delivery of materials to production processes (e.g., DI as a % of TMR increased by 5% over 1975-94), b) the *de-materialization* of the economy (i.e., designing and manufacturing products that require lesser amounts of materials and substituting lighter materials), and, c) *services* as opposed to *goods* as representing an increasingly significant percentage of the GSP.

- *Total Domestic Output (TDO) per capita*: This parameter indicates in metric tons, what on average, is the annual per capita TDO of Minnesota's gross state product (GSP). The decline from 102.5 metric tons / person to 85.2 metric tons / person during the period from 1975-94 is a positive development relative to the environment. However as with the corresponding decline in per capita TMR, these per capital gains are at least in part offset by increases in population.

Rates of Materials Flow and Sustainability

Relative to the question of pressure upon the environment, natural resources and ecological systems, the comparatively modest increases in a comparative lack of change is something of a positive indicator. However it is essential to recognize, according to the general question of sustainability and related questions of the carrying capacities of ecological systems, that even a significantly declining annual TMR would not necessarily mean that the economy is sustainable relative to the environment. For *the annual TMR is essentially an annual rate of extraction* and the extractions themselves are in many cases partially if not entirely *cumulative*. If we are depleting natural capital, and continue to do so without addressing replacement a decline in the rate of depletion will only be palliative. For example, if the current economic TMR of lumber is such that we are over-harvesting by 15%, a 5% or even a 7% reduction of the TMR will postpone but not resolve the sustainability issue. In and of itself materials flow data and information does not provide information regarding the renewal and depletion – the ongoing budgets in which we are running a deficit or a surplus – of the various forms of natural capital. The acquisition of such natural capital information however, if used in conjunction with materials flow data offers the possibility of benchmarking environmental sustainability for specific materials and industrial sector activities.

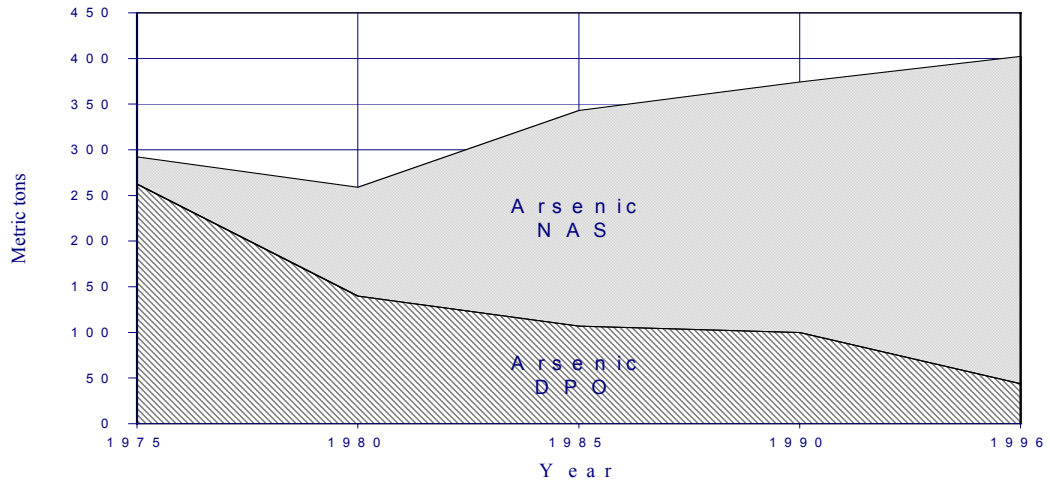

Figure D.20 Arsenic
NAS- Net Additions to Stock; DPO Domestic Product Output

F. Arsenic: A Materials Flow of Specific Environmental Concern
Clearly within the aggregation of materials flows that comprise the TDO of the economy all materials are not alike in their potential and actual effects on the environment. So for example, all else being equal, the domestic output to the environment of certain metals or organic compounds have are likely to have a decidedly more pronounced adverse effect on the environment and/or environmental health than substances such as sand or gravel. We will consider one such material: arsenic.

The output of arsenic to the environment depicted in Figure D.20 reveals that over the period 1975-96 the outflow of arsenic to Minnesota's environment (not including hidden flows) has increased by slightly more than 100 metric tons: from 292 to 402 metric tons. Relative to materials flow analysis arsenic is particularly interesting because over the period in question the type of product as well as the characteristic form of the output has shifted dramatically. In 1975, approximately 75%, or 219 tons of the 292 metric tons of arsenic in products released to Minnesota's environment was attributable to agricultural chemicals. By 1996 the arsenic released in agricultural chemicals was reduced to less than 20 metric tons. Relative to arsenic – and if consistent with 1975 one's focus continues to be on agricultural chemicals as close to 75% of the arsenic released to the environment – this is clearly a significant even dramatic environmental improvement. One might even be tempted to say that relative at least to products involved in the release of arsenic, the environmental problem of arsenic has been essential resolved. Conversely, if we move beyond agricultural chemicals and consider the *overall* materials release of arsenic to the environment we find the dramatic 38% in the release of arsenic (i.e., 292 to 402 metric tons) noted above. The new product that is the source of environmental release to the environment is of course treated lumber. Finally we would note that the delivery of arsenic has changed from the direct release and dispersal of arsenic as agricultural chemicals to arsenic as net additions to stock, where the following will become outputs to the environment in the course of there useful life and disposal.

V. Energy Use, Transportation, and Population Density

A. Energy Consumption in Historical Context
The environmental challenges facing 21st century Minnesota are the result of the state's dramatic transformation over the past one hundred and sixty years. A transformation characterized by extraordinary changes in population and even more extraordinary changes in the consumption of energy and transportation.

During the 1840s, on the verge of European expansion, the total population of Minnesota was approximately 21,000. Two-thirds of Minnesota's total population were Sioux, Chippewa, and other indigenous peoples, the remainder where Europeans. Energy sources were limited to foodstuffs from crops, hunting and gathering and firewood. Energy was expended through manual labor or by domesticated animals. The only noteworthy mechanical applications of energy were steamboat travel and shipping on the Mississippi and St. Croix Rivers, and sawmills on the St. Croix and at St. Anthony Falls

on the Mississippi (1848). The total annual energy consumption of Minnesota's population was approximately 0.25 trillion BTU (British Thermal Unit) per year.

By the close of the 20th century the sources supplying over 90% of Minnesota's energy were petroleum (41.0%), natural gas (21.5 %), coal (20.9%) and nuclear electric power (8.8%). The total population of the state as recorded by the 2000 census was 4,919,479. The total annual energy consumed by Minnesota's population in 2000 was 1,733.47 trillion BTU. Between 1840 and 2000 the total annual level of energy consumed in Minnesota increased approximately *seven-thousand fold* (Figure D.21)

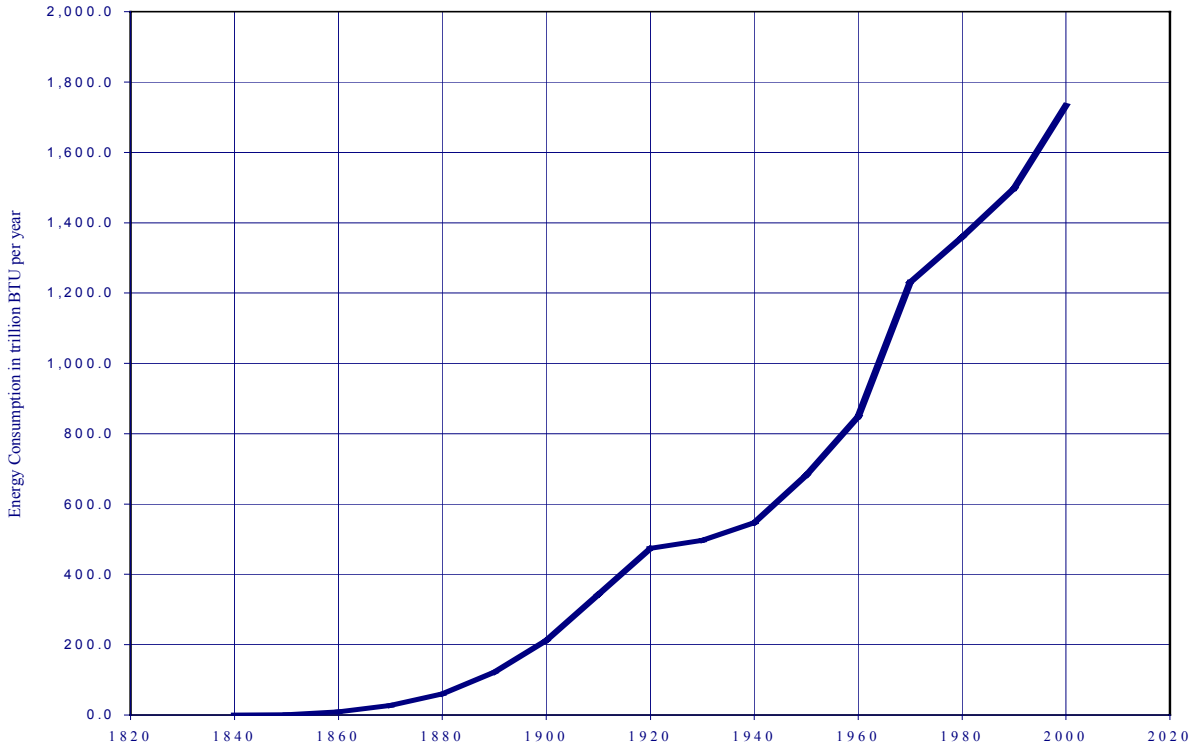

Figure D.21. Expansion of Overall Energy Consumption in Minnesota 1840-2000

When considered relative to the use of energy by *individuals* this extraordinary transformation represents a combination of a rapid expansion of population together with a twenty-five-fold increase in per capita energy use (Figure D.22).

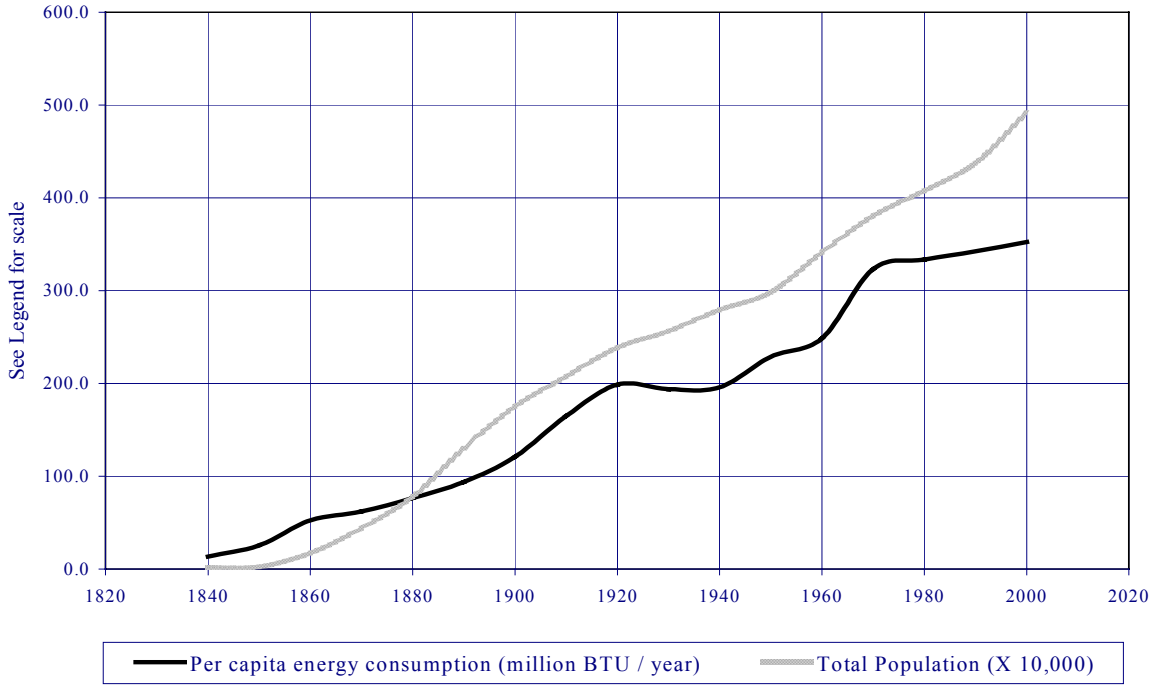

Figure D.22. Per capita energy consumption and Population in Minnesota 1840-2000

B. Energy and the Transformation of Society and Nature

In both its intended and unintended consequences, a change of this magnitude in the energy consumption patterns of a society over what is historical a comparatively short period of time is inevitably overwhelming even drastic in its impacts and its transformations of society the natural landscape and ecological systems:

The *intended* consequences of this transformation include:

- extracting, processing and manufacturing materials into finished products and consuming and disposing of materials (including reuse and recycling);
- extensive and intensive modifications of the land, of land use patterns and of the intensity of land use;
- the creation of infrastructure – the ongoing transformation of natural landscape into built and/or managed environment;
- the increasingly frequent movement of people, goods and materials in increased volumes and capacities and at increasing speeds;
- interior climate control;
- outdoor and indoor lighting;
- availability and use of outdoor and indoor appliances (e.g., lawn mowers, computers, washers, etc.); and
- energy intensive recreational activities.

In addition to the extensive and dramatic environmental effects of the *intended* uses of energy, the *unintended* results of energy production and consumption are also acute and extensive, and include:

- the release of high levels of energy directly to the environment due to inefficiency/entropy, resulting in the disruption and/or elimination of ecological activities and processes;
- the release to the environment of materials with high levels of embodied energy (e.g., fertilizers, pesticides; discarded industrial products, materials and chemicals, etc.);
- the release to the environment of the by-products of energy production and consumption (e.g., CO_2, SO_2, fly-ash, mercury, nuclear waste, etc.);
- routine as well as large scale releases of energy source materials (i.e., gasoline, natural gas, etc.) to the environment through handling and mishandling;
- the disruption and elimination of ecologies through the mining of materials (i.e., iron ore) and energy (i.e. coal);
- the disruption and elimination of landscapes and corresponding ecologies through intensive modifications of the land, of land use patterns and in the intensity of land use;
- the introduction of exotics as a result of the transportation of materials between regional, national and international ecological systems;
- noise pollution; and
- light pollution.

While energy is consumed and dissipated in all of these intended and unintended uses there are also clearly *cumulative effects and consequences* beyond the ongoing consumption of energy – particularly those involving changes in the land and in the built environment, and in the biological and physical accumulation of pollutants. Accordingly it is worth noting that the difference between 1840 and 2000 relative to energy consumption is not just a matter of overall *daily* and *annual* consumption – as vast as that difference may be – it is also the ongoing and cumulative effects of such dramatic differences in energy consumption. For example, over the fifty year time period *preceding* 1840 the cumulative total energy consumed in Minnesota was approximately 12.5 trillion BTUs, its accumulated effects were minimal, and the rate of energy consumption remained relatively constant. In contrast, during the *fifty years preceding 2000,* increasing annually at 3.1%, the total energy consumed was approximately 62,660 trillion BTUs.

C. The Transformation of Urban Industrial Society and Stages in Transportation and Transportation Infrastructure

The extraordinary expansion of energy consumption during the one hundred fifty years from 1850 to 2000 represents but one, albeit a major, indicator of innumerable, revolutionary transformations in the structure and fabric of Minnesota society and in the lives of individual Minnesotans. Remarkable transformations involving urbanization, industrialization, material wealth, communications, computerization, socioeconomic well being, diversity of life styles, etc.

While these extraordinary transformations can be useful examined and considered from any number of vantage points, for the purposes of our immediate discussion we will

organize and examine the 1840-2000 transformation of Minnesota with reference to stages in the development of transportation and transportation infrastructure.

1840 – 1950 Steamboats, Ox Carts, Railways and Streetcars

European involvement in Minnesota originated during the 1700's with the fur trade, which continued to dominate the economy and export trade of the region into the first several decades of the 19th century. In the 1820s and 1830s steamboat travel connected the region to St. Louis and other established downstream destinations, and river towns began to develop on the Mississippi (Winona, Lake City, Red Wing, Hastings, St. Paul etc.) and on the St. Croix (Stillwater and Prescott, WI). The 1850 territorial census indicates the initial development of European settlement as concentrations in and surrounding these Mississippi and St. Croix river towns, particularly in St. Paul and Stillwater and surrounding Ramsey (i.e., 1850 pop. 2,227) and Washington (i.e., 1850 pop. 1,056) counties. The territorial census also indicates one other settlement of comparable size to St. Paul and Stillwater: the Pembina fur trading center on the Red River (1850 pop. 1,134) at what is now the boarder between Kittson County, Pembina, North Dakota and Canada. Pembina was an ethnically diverse community of European fur traders, native Americans and their descendants and the northern terminus of the Red River Ox Cart Trail. The trail, was initiated in the 1840s to connect the fur trade to the Mississippi followed the Red to its confluence with the Minnesota and the Minnesota to St. Paul and the steamboats. The ox cart trail, representing along with steamboat landings an early development of transportation infrastructure, peaked during the 1850s and then gave way to expanded steamboat traffic and the railroads.

In 1850 European settlement and economic activity in Minnesota was focused on the export of raw materials, principally furs and lumber rather than agricultural production. Sawmills were in operation on the St. Croix and the first sawmill at St. Anthony Falls opened in 1848. In contrast the total number of farms statewide as recorded by the 1850 census was 157, accounting for approximately 5,000 acres of improved and 24,000 acres of unimproved land. The development of steamboat service however – expanding up the Minnesota River during the 1850s – provided the initial infrastructure for immigration and as the tide of European settlement that surged across the Midwest reached Minnesota the dramatic extraordinary expansion of agriculture began. By 1860 there were more than *one hundred times* as many farms in Minnesota (i.e.,17,999) as in 1850 and the total of farmland had expanded from 18,000 to 2,711,968 acres. By the turn of the century the number of farms had again increased, this time by more than an order of magnitude to 154,659 spread over 26 million acres. The primary crop was wheat, and by 1900, with the extraordinary development of the milling industry centered at St. Anthony Falls, Minneapolis had become the largest flour-milling district in the world.

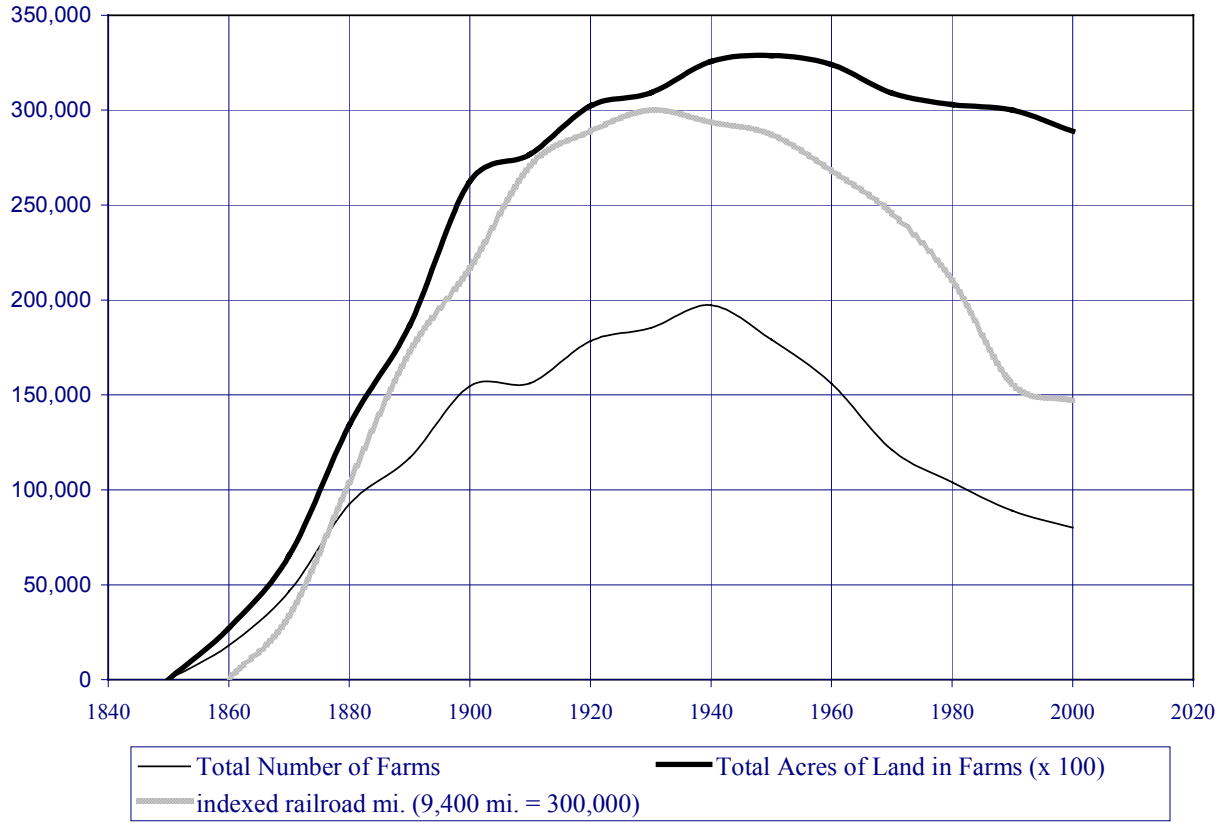

Figure D.23 The Expansion of Farms and Railroads 1840-2000

Corresponding to this rapid expansion of agriculture was the development of first statewide transportation system: the railroads. Beginning in 1962 with a railroad connection between St. Paul and Minneapolis, by the late 1920s track mileage had reached over nine thousand miles. Throughout the 19th and into the first decades of the 20th century, rural Minnesota reflected a bringing together of the railroads and the characteristic economic and transportation patterns of an agriculture of comparatively small scale family farms and limited in mechanization and the use of fossil fuel. The demographic, social, cultural and physical infrastructure characterizing rural Minnesota was a extensive patchwork of small towns accessible by wagon from the surrounding farms. These small town communities were in turn connected step-by-step in local and regional hierarchies to larger railroad communities and finally to the burgeoning Twin Cities.

Figure D.24 depicts the dramatic expansion of population of what is today the eleven county Twin Cities metropolitan area.

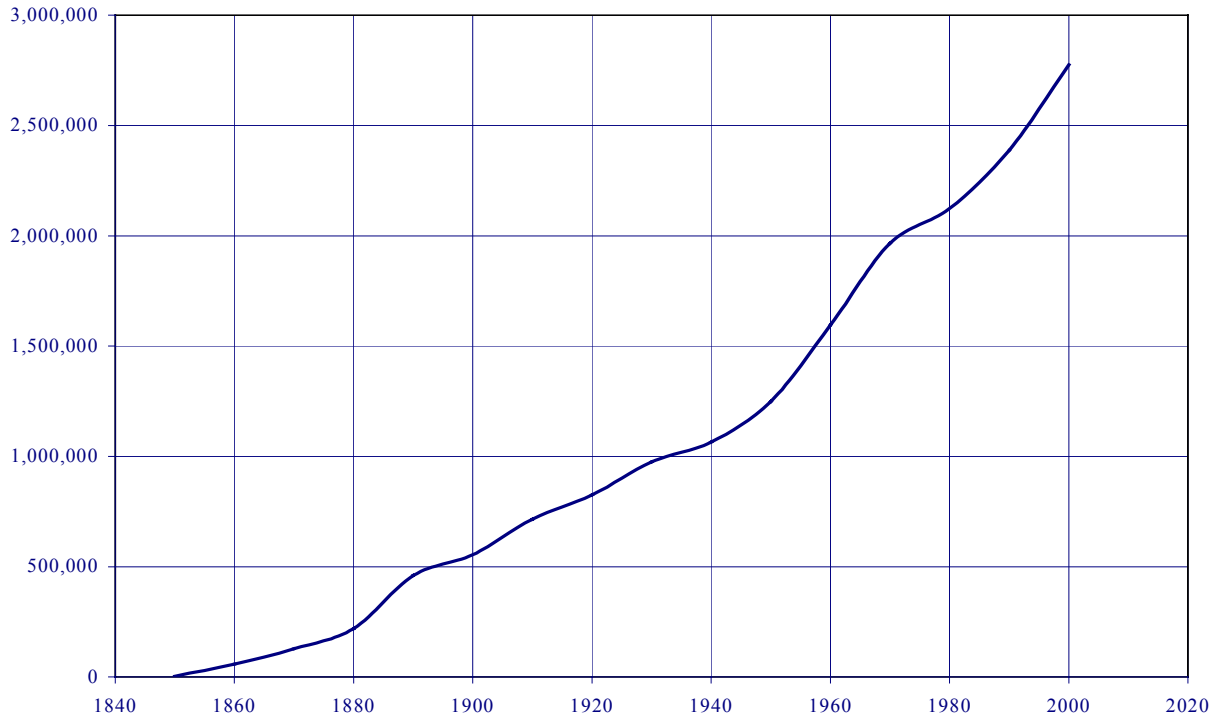

Figure D.24. The Expanding Population of the MSP 11 County Metropolitan Area

While this generalized information is useful for certain purposes it conceals the transformation of the urban and suburban Twin Cities according to population density and as stages in the development of transportation and transportation infrastructure. Figure D.25 depicts various aspects of the population density of the Twin Cities:

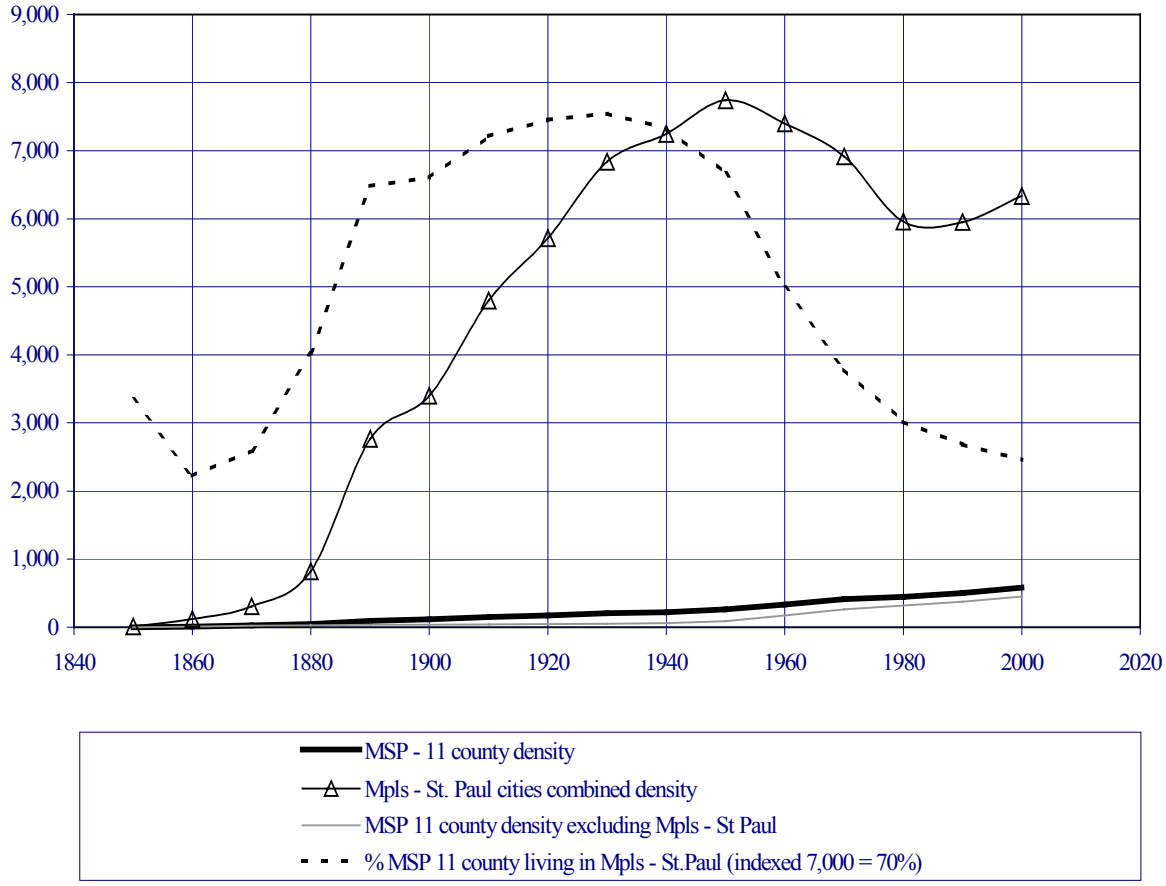

Figure D.25 Population Densities of the Twin Cities and of the MSP 11 County Metro Area

St. Paul and Minneapolis began as *walking* cities. The extension and density of walking cities is determined and bounded by the distance an individual can reasonably travel by foot from residence to employment to market, etc., extending no more than a mile or two from the center. The density of population and physical structures within a walking city is high, as pressures to expand *vertically* as well as *horizontally* are limited by human physiology and technology. Following a characteristic, nationwide pattern two developments in the second half of the 19th century transformed the *horizontal* and *vertical* limits of the walking city: the advent of urban street railroad transportation systems and the emergence and construction of steel frame buildings (i.e., skyscrapers) and elevators.

The first horse drawn street railroads where introduced in Minneapolis and St. Paul during the 1870s. By 1893 there was a combined two hundred ten miles of track in the Twin Cities and the system was almost completely electrified. By the late 1920s when the system reached its peak as far as mileage, there was a combination of four hundred thirteen (413) miles of track within the Twin Cities proper with additional lines running to Minnetonka (43 miles), Stillwater (33 miles) and fourteen miles of "local suburban" tracks in Columbia Heights, Robbinsdale, St. Louis Park and South St. Paul. With the

expansion of the Twin Cities street railway system the walking city gave way to the "streetcar city." The horizontal Relative to land use the horizontal density of the streetcar city remained comparable to that of the walking city. However, the *vertical* density of the late 19th and 20th century city was also transformed by steel frame buildings (i.e., skyscrapers) and elevators. The first identified "skyscraper" was constructed in Chicago in 1885 to what – by today's standards – was a modest height of nine stories. In Minnesota the first phase of skyscraper development ended with the construction of the 32 story Foshay Tower in Minneapolis in 1929, the next phase would not begin until the 1970s. While the Foshay and the 1st National Bank Building in St. Paul (41 stories, (1931)) symbolized skyscraper development in the Twin Cities until the second phase of construction beginning with the IDS building in Minneapolis in 1971, the dramatic transformation of Twin Cities urban *vertical* space was accomplished primarily by more modest structures of less than ten stories – for example, the ____ story Pioneer Press Building (1989) and the six story Federal Courts Building (1902) in St. Paul.

Shaped by streetcar transportation and vertical expansion, the combined density of the cities of Minneapolis and St. Paul continued to increase throughout the first half of the 20th century to a 1950 peak of 7,742 pop./ sq. mile. (i.e., Mpls: 9,697 and St. Paul: 5,965). A density that, if one excludes such major metropolises as New York, Philadelphia and Chicago, is not dissimilar to other Midwestern and Eastern cities. During the second half of the 20th century however transportation, population density and energy use would be dramatically transformed by the automobile.

1950 –2000 Automobile Suburbs, the Decline of Rural Small Towns and Family Farms
With the introduction of the assembly line and mass production the automobile moved from being a curiosity to a reasonable form of transportation during the period from 1900 – 1930. By the end of the Twenties however only approximately one in ten households owned automobiles. All else being equal, the expansion of automobile use and ownership may very well have taken off during the 1930s and into the 1940s. Instead, the Depression and World War II severely stunted the growth in automobile production and availability. During the post WWII era however, three factors came together to initiate the transformations that have reshaped metropolitan as well as rural America during the second half of the 20th century:

- the conversion of the country's enormous war production capacity to consumer goods, especially automobiles, and to dramatic increases in the mechanization and the use of increasing levels of inputs (i.e., fertilizers, pesticides, fossil fuels) in agriculture;
- the GI Bill which made it possible for lower middle class and working class families to own homes, purchase automobiles and commute; and
- the Federal Highway Act of 1956 which committed the federal government to construction of the interstate highway system and encouraged and received corresponding commitments to highway development by the states and cities.

The following three figures depict the magnitude and the remarkable dynamics of Minnesota's automobile use throughout the 20th century.

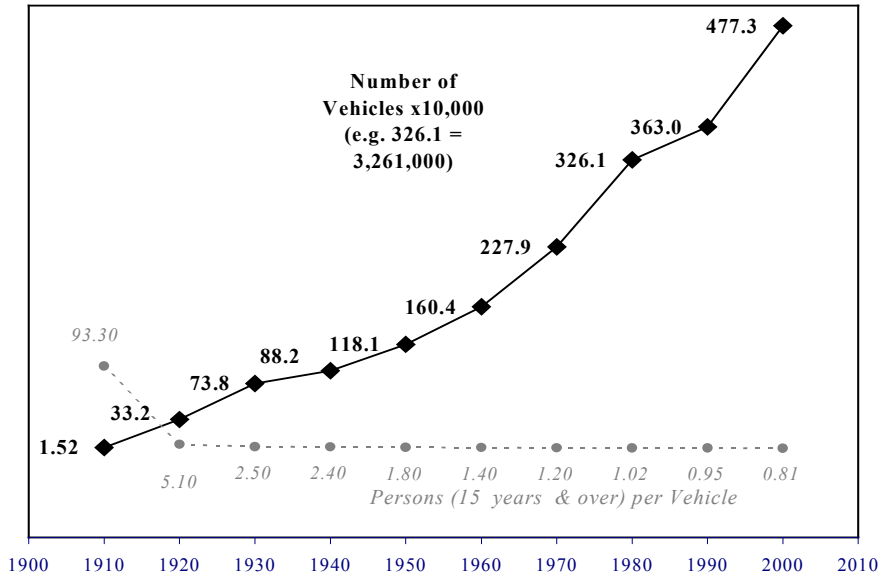

Figure D.26 Number of Vehicles and Vehicles Per Capita 1900-2000

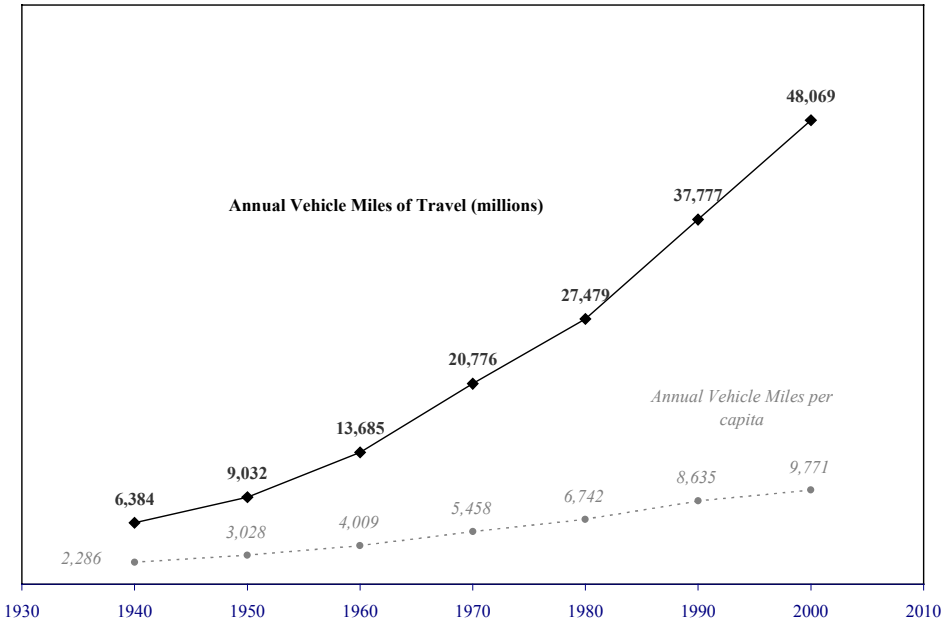

Figure D.27 Annual Vehicle Miles Traveled andPer Capita 1900-2000

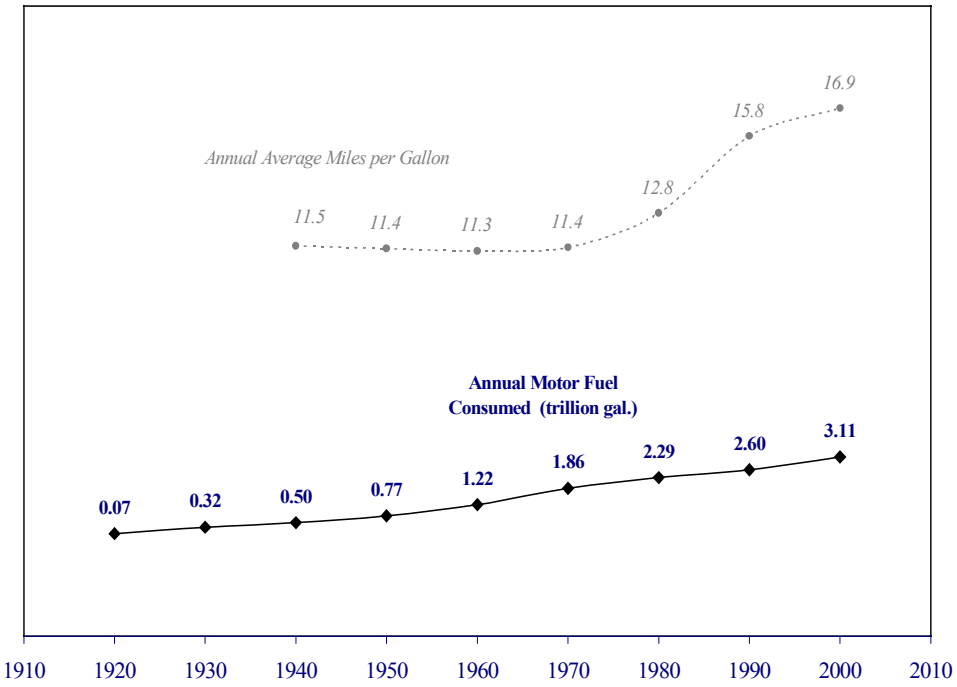

Figure D.28 Annual Motor Fuel Consumed and Vehicle MPG 1900-2000