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Community Materials Flow Analysis: A Case Study of Ann Arbor, Michigan

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COMMUNITY MATERIALS FLOW ANALYSIS:

A CASE STUDY OF ANN ARBOR, MICHIGAN

BY

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Abstract

Materials move through communities in the form of products and raw materials to satisfy human needs such as shelter and transportation. Though the flows of materials into and out of communities provide benefits, inefficient material flows result in social, environmental and economic costs. The efficiency of material flows can be improved by reducing the mass of materials used to meet the needs of communities as long as the reduced flows still provide the same services and the change does not introduce greater social, environmental and economic costs elsewhere.

This report presents estimates for the mass and economic value of flows of selected materials used to meet the need for food and water, shelter, communication, transportation, and clothing in Ann Arbor, Michigan in 1997. The methodology developed for this study is presented as a possible approach for materials flow analysis in other communities. The inflow and outflow estimates from this study are used to develop recommendations to reduce the mass of material flows. Analytical tools are also introduced to help community leaders prioritize the implementation of recommendations.

The inflow and outflow masses (in tons) estimated are 22 million and 21 million for Water, 128,000 and 15,000 for building materials (Shelter), 127,000 and 13,000 for food and beverages (Food), 19,000 and 19,000 for printed material (Communication), 18,000 and 16,000 for ground motor vehicles and their maintenance materials (Transportation), and 2,900 and 2,200 for clothing and footwear (Clothing). The economic value of inflows as measured by retail price (in millions) are $330 for food, $240 for clothing, $200 for transportation, $120 for shelter, $96 for communication, and $9.7 for water. These estimates include only selected materials that directly satisfy the human need for each category.

Ann Arbor has one of the nation's most progressive waste management programs, so the community should focus on strategies to reduce its inflow of materials. This can be accomplished by increasing the efficiency with which materials are used to meet functional needs in order to reduce consumption, or by redesigning or rethinking the way functional needs are met to develop alternative systems.

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Executive Summary

Human needs such as shelter and transportation are satisfied by the flow of materials through our communities. While materials may provide multiple benefits, there are social, environmental, and economic costs associated with the extraction, processing, manufacturing, use, and disposal of these materials that may be reduced by improving the efficiency of material use in our communities. In this study, the efficiency of material flows is based on the community's ability to maximize the services provided per unit of mass of materials. The efficiency of material flows can be improved by reducing the mass of materials used to meet the needs of communities as long as the reduced flows still provide the same services and the change does not introduce greater social, economic and environmental costs elsewhere.

This study has three goals:

- To increase the understanding of material flows moving through the City of Ann Arbor, Michigan;
- To develop a methodology by which community leaders may analyze material flows at a community level;
- To stimulate further research into the use of materials flow analysis (MFA).

This study uses MFA to quantify mass and economic value of selected materials moving into and out of Ann Arbor in 1997 in order to identify recommendations to improve the efficiency of material use in the community. Materials are grouped for analysis into categories based upon the human needs that they satisfy. The scope of this study is limited to the following categories: Food and Water, Shelter, Communication, Clothing, and Transportation. Within each category only materials that directly satisfy needs are included in mass estimates. Included materials are food and beverages (Food); water; ground motor vehicles and their maintenance materials (Transportation); clothing and footwear (Clothing); building materials (Shelter); and printed material, blank paper, envelopes, and mail (Communication). Other materials are excluded due to the scope of the study or because of limited availability of data. Data are gathered at the business, industry, city, county, state and national levels to create estimates for Ann Arbor.

Analyzing material flows at a community level has several benefits. Many material flows are handled at a community level. Examples include local business-to-customer relationships, handling of solid wastes, and transportation and utility infrastructures. Studying a community rather than a smaller unit such as a household offers the potential to identify approaches to increase material efficiency that balance the needs of a variety of stakeholders and utilize the integrated resources of the community. MFA at the community level can lead to recommendations that are more relevant to community organizations and to local government than a national level materials flow analysis. Proposals that are relevant to stakeholders increase the likelihood of successful implementation of recommendations because of the existence of decision-making, policy-making and enforcing bodies at the community level.

As a result of this study, a number of observations are made for the year 1997 in Ann Arbor .

- Water represents the largest flow in and out of Ann Arbor in terms of mass. The inflow of water is about 22 million tons, which is 70 times greater than material inflows for food, shelter, communication, transportation, and clothing combined. The outflow of water is about 21 million tons, which is 300 times greater than material outflows for the other categories combined.
- The inflow mass for Ann Arbor for all categories in this study, excluding water, is 290,000 tons, which is almost 5 times greater than the outflow mass of 63,000 tons. The difference between inflow and outflow mass is primarily caused by food and shelter having much larger inflow masses than outflow masses. The difference between inflows and outflows for food occurs because respiration gases are not included in this study and because water content of food is included in water outflows when it leaves the community. The disparity between inflows and outflows for shelter is due to a growth in stock in Ann Arbor.
- The mass of material flowing into Ann Arbor to provide shelter is 130,000 tons, which is more than 6 times the mass of individual inflows for transportation, communication, and clothing. Over 75% of the building permits issued in Ann Arbor are for residential renovation. Within residential renovation, reroofing is the most common activity, accounting for 36 percent of the permits for residential renovation and generating 1,400 tons of material outflows. Though new residential and nonresidential construction accounts for 7 percent of building permits issued, it is responsible for over 80 percent of the mass inflows of materials for shelter brought into Ann Arbor and over 50 percent of the estimated cost.
- The mass of material flowing into Ann Arbor associated with food and beverages (except tap water) is 130,000 tons, and the annual per capita spending in Ann Arbor for food and beverages is $3,000, which is the highest of all the categories examined. Of the edible food that enters Ann Arbor (not including beverages), 73 percent is ingested by humans, with the rest lost due to spoilage, discards from food preparation, and plate waste. This utilization efficiency is 66 percent if the inedible portion of food, including peels, pits, and bones, is included.
- Sales of clothing and footwear per capita in Ann Arbor are $2,200, which is approximately double national per capita spending.
- 1997 per capita transportation expenditures are $1,900. The station wagon body class of vehicles, defined by the Michigan Department of State to include Sport Utility Vehicles, is the largest contributor to the growth of vehicle stocks in Ann Arbor, while two-door cars account for the largest decline in stocks.
- Expenditures per pound in Ann Arbor are the lowest for water, at 44 cents per ton and the highest for clothing, at $41.60 per pound. Expenditures per pound for the other categories are $0.40 for Shelter, $1.30 for Food, $2.90 for Communication, and $5.70 for Transportation.
- This study focuses only on paper-based communication media, such as books and mail. The inflows and outflows estimated for material flows associated with

communication that are included in this study are approximately equal, at about 19,000 tons. 16,000 tons of material leave the community as MSW, and another 3,300 tons leave as mail processed by the United States Postal Service. Calculations assume that the net accumulation of stocks of paper-based communication media in the community annually is low. Within the limited data set included in this study for communication, the material flows are likely higher than the national average based on median income and educational attainment in the community, two factors positively correlated with paper consumption. However, according to local data, the community of Ann Arbor recovers more paper-based communication media per capita than national recovery per capita.

Estimates described in this study represent only a fraction of the total flows of materials used to satisfy the human needs of Ann Arbor residents. The scope of this study focuses on “direct materials” that explicitly satisfy the human need for its category. Other “indirect materials” that help provide support and infrastructure for the direct materials to satisfy the need are not included in the scope of this study. However, the masses of a few indirect materials with large flows are estimated to provide additional context for certain categories. For example, it is estimated that almost 1 pound of primary packaging is used to provide 5 pounds of food. The study’s scope also excludes a significant amount of material that never enters the community, even though its use elsewhere ultimately serves the community’s needs. For example, an automobile used in Ann Arbor requires the use of a wide variety of materials during manufacturing that do not become part of the automobile, ranging from manufacturing facilities and equipment to scrap metal wastes. The magnitude of the total upstream raw material inputs for the City of Ann Arbor is estimated to be 3,100,000 tons.

Based on estimates of mass and economic value associated with material flows, suggestions are directed to community stakeholders. Suggestions are not evaluated for their total net impact on the community; they are proposed because they may reduce the mass of material flows specifically examined in this study, while ensuring that the flows still meet basic functional needs. The outcomes of proposals based only on mass and economic value may be socially impractical without incorporating measures that account for other concerns of community stakeholders. One concern may be that reducing the mass of a single material category could lead to an increase in the mass of a different material category and its associated social, environmental, and economical costs. Another concern is that solutions primarily focused on mass neglect considerations of other material characteristics such as toxicity or the energy used in the production and transportation of the material.

A focus on meeting basic human functional needs does not account for other aspects of the functional need such as convenience or personal enjoyment of the experience satisfying the need. For example, a suggestion that people build or buy smaller houses does not take into account the benefits of the larger home. People may desire larger homes to accommodate guests, to provide space for additional activities such as hobbies or work, to demonstrate social status, or simply for the enjoyment of the space.

Recommendations that focus on the earliest stages in the life cycle of materials have the potential to achieve the greatest impacts on material flows. Reducing use of materials avoids the upstream impacts associated with raw material extraction, manufacturing, use, and disposal of a product. For example, reducing the overall demand for paper products by switching from single-sided to double-sided printing and copying results in a decrease in the inflow mass of paper. The mass of paper outflows is also reduced due to the reduced mass of paper used within the community. This action could have a more significant impact than merely improving the recycling rate of paper products, which reduces neither the total community inflow nor the outflow mass. With that in mind, a framework is developed to categorize recommendations into one of six themes: Rethink, Redesign, Reduce, Reuse, Remanufacture, and Recycle. The six themes are presented in the order in which they are prioritized in this study - from largest potential impact on mass flow reduction to smallest impact. This study focuses on consumption rather than production, so the theme of remanufacturing is not developed in this study.

Ann Arbor has been recognized by the United States Environmental Protection Agency as a record-setter in reducing their solid waste stream. However, in terms of the inflow of materials, Ann Arbor residents exceed national per capita spending on many goods such as clothing. To increase the efficiency of material flows in the community, the city should focus beyond waste management to other stages of the materials life cycle. Informing people about ways of reducing material inflows through their purchase decisions and use of goods may be helpful. For example, providing a better match between household size and house size takes greater advantage of the resources needed for construction. Decreasing food losses in the home reduces expenditures on food and the need for waste management. Choosing vehicles whose size is appropriate for a household's vehicle occupancy and hauling needs ensures that the appropriate level of transportation service is provided per unit mass.

Examples of recommendations focusing on other themes include:

- Rethink - The adoption of electronic books by libraries would enable them to provide an larger supply of books and print media to the community with a minimum of paper resources.
- Redesign - Buildings and landscaping could be designed to reuse water for purposes that do not require drinking quality water such as flushing toilets.
- Reuse - More widespread deconstruction of buildings rather than demolition would enable the reuse of more building materials.
- Recycle - Initiating a local program for recycling asphalt shingles could capture a significant portion of construction debris generated during alteration of buildings.

Development of a matrix, which examines each of the material categories from different perspectives, helps to address the limitations of a methodology that only uses mass and economic value to reduce the mass of material flows. Using this matrix assists in identifying important material flows and prioritizing recommendations. Some qualitative factors examined in this study include existing efforts in the community focused on material flows, the potential for each recommendation to make an impact relative to others in reducing material flows, and barriers to and enablers of success in the implementation of the recommendation.

The methodology presented and the recommendations made in this study are a starting point for community leaders to better understand and to improve the efficiency of material flows. It is hoped that researchers in the future will refine the methodology presented to improve the quality of estimates of material flows through communities and tailor it to address specific issues of concern in the community. A better understanding of material flows may help to steer communities away from activities that degrade the environment and our quality of life and towards new approaches that enhance ecological, social, and economic well being.

Chapter 1: Introduction

Materials move through communities in the form of products and raw materials that are used to satisfy the needs of our communities. There are three main goals for this study. First, material flows moving through the "model" community of Ann Arbor, Michigan are examined in order to develop local solutions for increasing the efficiency of these flows. Second, methods from this study can be used to create a general approach for analyzing material flows that may be applied to other communities in the United States. Lastly, it is hoped that this work will stimulate further interest and research into the area of materials flow analysis and its application to issues surrounding sustainable communities.

This study looks at material flows in Ann Arbor in the context of the human needs they satisfy. This study examines five needs, which are food and water, shelter, clothing, communication, and transportation. For each of these, flows of materials into and out of the community are quantified in terms of mass and economic value for the year 1997.

Understanding material flows can help to identify ways of improving their efficiency, while providing the same service and reducing the social, economic and environmental costs associated with the use of materials. For the purposes of this study, the efficiency of material flows is based on the community's ability to maximize the services provided per unit of mass of the product. Inefficient material flows represent a reduction of potential benefits to our communities. This also results in increased social, environmental and economic cost to both the community and individuals within it.

This study does not focus on a specific issue of current concern to Ann Arbor but instead provides a baseline of understanding regarding community material flows and recommendations to improve the efficiency of those flows. Using the methods described in this report, other researchers and community leaders may be better able to prioritize areas of focus and to recognize opportunities for improving the efficiency with which material flows are used to meet their community's needs. They can then target their research to address specific issues and solutions for their community.

Chapter 2: Background

The growing populations and economies of the world's neighborhoods, cities, and countries have led to a growing demand for goods and services. Meeting the needs of these communities for food and water, shelter, clothing, communication, and transportation has required increasing quantities of materials. In a study completed in 1998, Matos and Wagner estimate that the quantity of materials consumed in the U.S. annually, excluding food and fuel, grew from 2.1 metric tons per capita in 1900 to 10.7 metric tons per capita in 1995, a five-fold increase. Over the same period, the world's consumption of the same materials is reported to have risen from 5.7 billion tons to 9.5 billion tons.[1] It is expected that, if this trend continues, by 2022 the world's population will consume four times the resources it consumed in 1996.

Materials provide many benefits for our communities. Materials are used to meet basic human needs, such as food and shelter, and they are important to maintaining and improving the standard of living of our communities. Yet are these materials being used efficiently? Are needs being met with the least materials? One measure of resource or material efficiency refers to the amount of output that a process provides per unit of input[2]. Opportunities exist to increase the efficiency of material flows. For example, the material efficiency of vehicles could be increased by producing automobiles that use fewer material resources during their manufacture and use, or by extending the useful life of those automobiles. However, defining the output of vehicles as the service of providing mobility and access to distant resources leads to other opportunities for increasing material efficiency. For example, using public transportation or locating stores and employers close to residential homes may provide the services of mobility and

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[1] Matos, Grecia and Lorie Wagner. "Consumption of Materials in the United States, 1900-1995." Annual Reviews of Energy and the Environment. v. 23, 1998: 107-122. <http://greenwood.cr.usgs.gov/pub/min-info-pubs/ann-rev/ar-23-107/> 15 May 2000.

[2] Hawken, Paul, Amory Lovins, and L. Hunter Lovins. Natural Capitalism. New York: Little, Brown and Company, 1999. p. 12.

access using reduced quantities of material and decreasing dependence on the automobile.

Material flows also contribute to the economic well being of our communities through job creation that comes from the manufacture and transfer of goods and services. A significant reduction in material consumption would result in a crisis for our economies as they are traditionally structured. However, new sources of economic growth in industries such as information technology, electronic commerce, and biotechnology demonstrate that economic value can be created from the information content of goods in addition to their material content.

For those human needs that will continue to require physical goods, the concept of a service economy could provide manufacturers of durable goods with a way to view reducing the material flows associated with meeting human needs as an opportunity rather than a threat. In a service economy, consumers rent or lease goods instead of buying them. For example, an individual would pay a monthly fee for access to a washing machine in her home while the manufacturer would be responsible for the service and eventual replacement of the machine. Manufacturers in effect sell the services of their goods while maintaining ownership of the goods themselves, providing them with the incentive to increase profits by meeting the functional need in ways that require fewer material resources over the life of the product.[3]

Material Flows

Figure 2-1 is a diagram produced by the United States Geological Survey that offers a view of the total life cycle of materials as they flow through our economy.

[3] Ibid. p. 16.

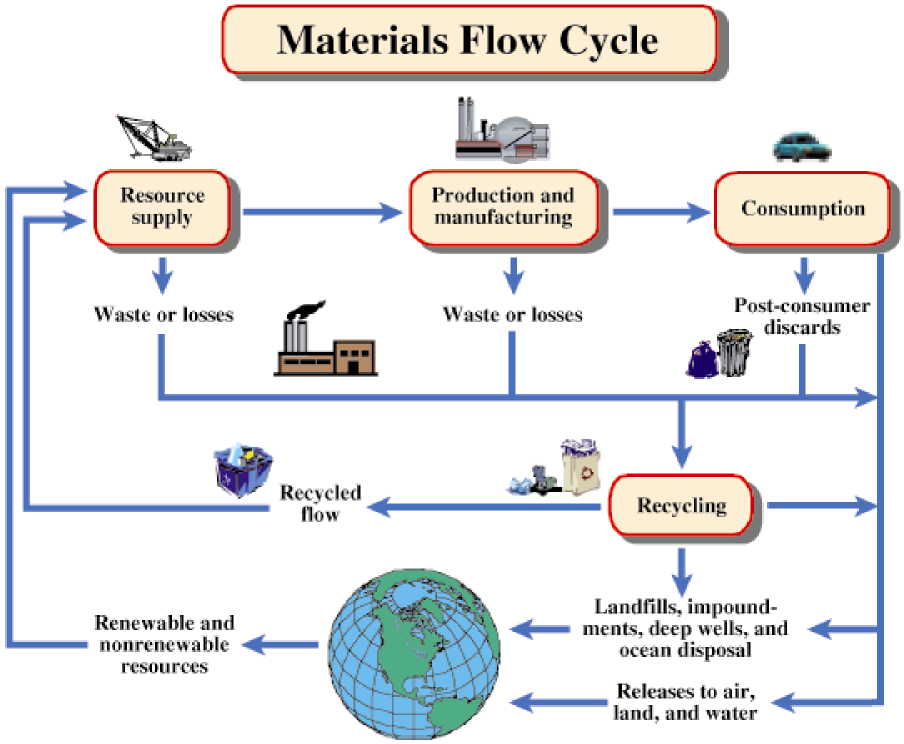

Figure 2-1 The Cycle of Material Flows

Source: Sznopek, John L., and William M. Brown. Materials Flow and Sustainability. USGS Fact Sheet FS-068-98. U.S. Geological Survey. June 1998.

The materials flow cycle starts with the extraction of renewable and nonrenewable resources from the earth. Materials extracted are processed for the purpose of production and manufacturing. The resulting products and materials are then distributed to our communities where they are consumed. The consumption of materials and products results in post-consumer discards. A small portion of this material is recycled, while the remaining portion ends up in landfills or other disposal sites. At each stage of the materials flow cycle, there are inefficiencies that result in waste or material losses.

Even though material reuse and recycling has been growing in many communities there still remains a significant quantity of material that flows through our communities from which the maximum benefit is not realized. The vast quantity of solid waste generated by our communities is only one example of the inefficiency of material use. In 1995 the U.S. consumed 2.5 billion tons of raw materials and generated 208 million tons of municipal solid waste. It is estimated that, for every 100 pounds of product produced in the U.S., 3200 pounds of waste are generated.[4] Food loss in the U.S. is a good example of unrealized potential to meet human needs. According to a study by Kantor, Lipton, Manchester and Oliveira estimating food losses in the U.S., 91 billion pounds, or 26 percent of the edible food available for human consumption in 1995, was lost as consumer or food service waste. These losses include foods forgotten and spoiled in refrigerators and uneaten portions of food that are thrown out. [5] At the same time that this loss was estimated in 1995, 10.3 percent of households in the U.S. households were classified as food insecure, meaning they did not have access to enough food to meet basic nutritional needs at all times[6].

The lack of efficiency in material flows results in the underutilization of available resources in meeting human needs, leading to economic, environmental and social costs. Often these outcomes are not separately economic, social or environmental in nature, but a combination of these. For example, pollution has not only an environmental impact, but also a social cost when people can not enjoy their communities' resources because of it.

Underutilized materials often represent wasted money. Businesses that purchase raw materials for processing are losing the value of their purchases when any of these materials do not end up in a finished product. Profits lost for unused materials are compounded by the cost of disposing of the resulting waste. Inefficiencies in the use of materials mean that consumers may pay more for materials that satisfy the same levels of service. When consumers choose a vehicle that is not the most fuel efficient, it is an economic cost to the consumer because more money is spent on fuel for each mile driven. At a community level, economic costs often manifest themselves in the budgets of municipal governments. Local governments and their taxpayers bear the burdens of

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[4] Shaner, Hollie. 1999 Washtenaw County Waste Knot Awards. Marriott Hotel. Ypsilanti, Michigan, April 22, 1999.

[5] Kantor, Linda Scott, et al. "Estimating and Addressing America's Food Losses." Food Review. Vol. 20, No. 1, Jan.-Apr. 1997.

[6] United States Department of Agriculture. Measuring Food Security in the United States: Household Food Security in the United States 1995-1998. Jul. 1999. <www.fns.usda.gov/oane/MENU/Published/FSP/FILES/foodsec98.pdf> 20 May 2000.

developing and maintaining the infrastructure to support the flow of materials. Examples include the infrastructure for roads and utilities and the handling of solid wastes.

These material inefficiencies sometimes occur when short-lived materials with a low initial cost are favored over more expensive alternatives that last longer. For example, the most commonly installed roofing shingles last 20 years. More expensive shingles with a 40 year life are available in the market. Homeowners more often purchase the less expensive shingles even though in the long-term, the longer lived shingles are less expensive because they do not need to be replaced as often.

There are many environmental burdens associated with the consumption of materials. The exhaustion of resources is one of these environmental costs. Nonrenewable resources such as metals, and petroleum-based materials are in limited supply; inefficient use of these materials may lead to permanent loss of these resources. Renewable resources such as water, forests, fish, and wildlife are capable of regeneration; however, if these resources are consumed faster than they can regenerate, supplies can be exhausted. Poor management of resources can lead to degraded ecosystems, habitat destruction, and loss of biodiversity. At the same time, the generation of waste at any stage in the materials flow cycle results in the contamination of air, land and water.

The social costs of our patterns of material consumption can be significant. Suburban sprawl is a result of inefficient use of land for housing. As communities spread out, commuters spend more time sitting in traffic, and travel time increases. Sprawl results in the loss of green spaces in our communities, and it affects the quality of services provided to our communities. Instead of spending resources to improve existing roads, utilities, schools, hospitals and fire departments, resources must be allocated to build additional facilities to reach the outlying communities. Materials disposed before the end of their useful life represent a loss of materials that could help address social needs. For example, communities often throw away usable clothing because of fashion trends despite the fact that some citizens are in need of clothing.

While there are costs associated with the consumption of materials, there are also benefits. Individuals consume material goods because the perceived benefits exceed the costs. Larger vehicles, such as sport utility vehicles (SUVs), allow the flexibility of transporting one person or six people in one vehicle; they also allow for transporting more cargo than a smaller vehicle could, and provide a perception of greater security and prestige. Buying new clothes to keep up with latest fashions may be a form of expression for people. How people dress can impact society's acceptance of them, and therefore can affect their self-esteem. Though food meets a basic human need in providing sustenance, preparing food can be an enjoyable pastime and eating food is often a social experience for people. The perceived benefits and costs associated with material consumption will vary from individual to individual. Recognizing the benefits as well as the costs of materials may help in the development of approaches to materials management that promote a society in which the use of materials is sustainable, and that contribute to a quality of life that is perceived positively by its inhabitants.

Approaches to Estimating Material Flows

One approach to estimating material flows is Materials Flow Analysis (MFA). The method has three key steps described by Schwarzenbach, Scholz, et. al. First, the system and materials to be studied are defined. The system could be a nation, city, or factory, and the materials might include goods (food, vehicles), raw materials (water, concrete, metals), or elements (phosphorous, nitrogen). The second step is data acquisition and quantification of stocks and flows. Stocks are the quantity of materials present in the system at a given point in time, and flows are the quantity of materials moving into and out of the system over a period of time. The last step is the analysis and interpretation of the results.[7]

The concept of material flows analysis is based on the principle of conservation of mass from physics. Conservation laws maintain that during a physical process, mass and energy cannot be destroyed; at the end of the process, all mass can still be accounted for. A simple example is the cutting of a piece of wood. The individual wood pieces that

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[7] Schwarzenbach, R. C. et al. "A Regional Perspective on Contaminated Site Remediation - Fate of Materials and Pollutants." Environmental Science & Technology, 33:14 (1999): 2305-2310.

result from the process of cutting account for most of the mass of the original wood block. A smaller portion of the mass may end up on the floor or in the air in the form of dust particles. A complete mass balance should include those small particles as well. Material flow analysis uses the law of conservation of mass to understand the relationship between stocks and flows. The change in stocks of a particular material over a period of time must equal the inflow of that material into the system minus any outflows.

Examples of past MFA work are described below, categorized by the type of system chosen for analysis. These examples help provide context for the selection of system and materials for this study.

Global

A system boundary at the global level is easy to define but hard to analyze. Data exist in the monetary value of materials, but rarely in their mass. Global studies are usually high-level analyses of the amount of selected materials produced or consumed. Nriagu analyzed worldwide emissions of trace metals from natural sources.[8] Natural fluxes were compared with anthropogenic emissions. Baccini and Brunner focused on specific elements, such as iron, chlorine, and cadmium, in order to determine how materials moved through a region, how those materials were physically transformed by processing, and where the materials ended up.[9] Global studies tend to use models and general projections rather than variables established through actual measurement.

National

According to Fischer-Kowalski, national level boundaries have been the most helpful in advancing the development of material flows methodology and in generating empirical research. Data availability is an issue for material flow studies conducted at any level. Relevant data are more often collected at the national level than at smaller or larger scales. National level flows also link well with more traditional approaches of measuring national environmental performance, such as emissions, wastes, and economic data.

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[8] Nriagu, Jerome O. "A Global Assessment of Natural Sources of Atmospheric Trace Metals." Nature. 1989: 338: 47-49.

[9] Baccini, Peter, and Paul H. Brunner. Metabolism of the Anthroposphere. Berlin: Springer-Verlag, 1991: 38-42.

Germany and Japan are the only countries that have incorporated overall materials flow statistics on a regular basis into their standard public statistics, with Austria, Netherlands, and Sweden on the verge of doing so.[10] The U.S. conducted a fairly comprehensive overview of material metabolism in 1990, concentrating on three broad categories of commodity inputs in the economy - food, fuel, and materials, with materials defined as everything not used for the first two purposes.[11] The U.S. EPA publishes annual updates of the "Characterization of Municipal Solid Waste," providing data on generation, recovery, and disposal of municipal solid waste. Understanding national material flows provides benchmarks for domestic performance, and could allow for international comparisons. National level studies are important for resource planning in order to ensure and maintain adequate supplies of resources to meet the demands and expected growth of resource consumption. At the national level, macroscale trends can be identified, supporting important decisions related to materials policies at the national level. However it is not appropriate to study environmental variables only at the national level; local monitoring of materials is needed for improving material flows for a specific region or community. Studying material flows at the national level is limited by the fact that atmospheric and water systems do not respect national boundaries, and many material flows cannot be confined to territorial parameters. Another difficulty lies in choosing a common currency to compare quantities of materials – volume, energy content, toxicity, or weight. The objectives of the analysis determine which unit of measure to use to account for materials.

Regional

Fewer studies have been conducted at the regional level. Regions studied have ranged in size from the Rhine Basin, extending over five European countries, down to a single city. In 1965, Wolman first described the metabolic requirements of a city, focusing on three metabolic problems faced by city administrators: provision of an adequate water supply,

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[10] Fischer-Kowalski, Marina. "Society's Metabolism: On the Development of Concepts and Methodology of Material Flow Analysis – A Review of the Literature." ConAccount Conference on Material Flow Accounting. University of Leiden, Vienna: Institut fur Interdisziplinare Forschung und Fortbildung der Universitaten Innucbruc, Klagenfurt und Wein, 1997.

[11] Rogich, Donald, et al. "Materials Use, Economic Growth, and the Environment." Capital Metals and Materials Forum 1992. Division of Mineral Commodities, U.S. Bureau of Mines.

effective disposal of sewage, and the control of air pollution.[12] In 1978, Newcombe, Kalma, and Aston characterized the metabolism of Hong Kong, analyzing the flow of energy, nutrients, and water through the city and the resulting waste water, air pollution, and land and solid wastes. Their analysis of an urban city was one of the first studies to describe an actual settlement, rather than a theoretical city. [13] In 1991, for the fictional region METALAND, Baccini and Brunner modeled four activities, which they considered essential to all human communities: to nourish, to clean, to reside and work, and to transport and communicate. They grouped material flows into two categories, the "anthroposphere" and the environment. The anthroposphere includes material flows induced by human activities focused on supplying households with energy, consumer goods, and information. The environment includes biogeochemical flows of materials naturally occurring in the air, earth, and water. [14] In 1998, Burstrom et al. analyzed the metabolism of two elements, nitrogen and phosphorus, in the City of Stockholm. Their goal was to identify sources, sinks, and accumulation of these elements and the related material flows that could be directly influenced by the local community. [15]

Residential and Commercial Entities

Material flow analyses have been conducted for the average household in various nations and for specific facilities such as manufacturing plants. In this case, data collection is often easier due to the smaller scale of these entities, and the estimates of stocks and flows can be more accurate. Material flow analyses at this level can suggest ways to improve material efficiency within the entity being studied, but they overlook material flow issues that occur at a larger community level. Economic sectors have also been studied with material flow analyses. For example, a 1994 study quantified total material inputs and outputs for the Austrian paper and pulp, electrical, and petroleum products

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[12] Wolman, Abel. 'The Metabolism of Cities." Scientific American. 1965. 213: 179-188.

[13] Newcombe, Ken, Jetse D. Kalma, and Alan Aston. "The Metabolism of a City: The Case of Hong Kong." Ambio. 1978. 7: 3-15.

[14] Baccini, op. cit. 10-23.

[15] Burström, Fredrik, Nils Brandt, and Björn Frostell. "Analyzing Material Flows to Improve Local Environmental Management: Nitrogen Metabolism of a Swedish Rural Municipality." Municipal Materials Accounting and Environmental Management. Ed. Fredrik Burström. Stockholm: Royal Institute of Technology, 1998.

industries.[16] Understanding flows at this smaller scale can help effect change at larger scales; efficiencies identified for a specific facility can lead to public policies for an entire industry.

Community Level Material Flows

A community level material flow analysis is a type of regional analysis. A community may be defined in many ways, such as an interacting population of individuals and organizations in a particular area, such as a single metropolitan area. A community can be compared to a living system, which consumes material and energy inputs, processes them, and eliminates wastes. The web of interactions among households, industry, commerce, and municipal institutions within a community may be likened to the metabolic processes within a living system. This study focuses on material flows at the community level. In this study, a community is defined as any physical geographical area, whether delineated by a city or county political border or some other type of boundary.

Although not a focus for this study, examining internal material flows within a community allows the mapping of flows among various economic sectors in the community. For example, flows of paper may be traced from a local distributor to a printer of newspaper, and then on to a local distribution center for newspapers that circulates the finished product within the community and also exports outside of the community. This method allows the identification of key stakeholders in the community that have the greatest opportunity for reducing flows or making them more efficient. This complex web within a community provides a basis for identifying and implementing holistic solutions to local resource issues.[17] This method provides an illustration of the metabolism of specific target materials rather than a general understanding of the total flow of materials through a community.

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[16] Fischer-Kowalski, Haberl, and Payer, "A Plethora of Paradigms: Outlining an Information System on Physical Exchanges Between the Economy and Nature." Industrial Metabolism: Restructuring for Sustainable Development. Eds. Robert U. Ayres and Udo E. Simonis. New York: United Nations University Press, 1994. 337-360.

[17] Community Metabolism. Indigo Development. <http://www.indigodev.com/Sustain.htm#metabolism> 20 May 2000.

Figure 2-2 illustrates many of the flows of materials through a community. The activities of production, including raw material extraction, material processing, parts manufacturing, and final goods manufacturing can occur both inside and outside of a community. Materials at each step of this chain, including raw materials, engineered products, and final products can enter the community as a purchase or leave the community as a sold export. Finished products support the services and functions required by a community to meet the needs of its residents. Following use, the waste products of finished goods generally leave the community as solid waste and are disposed in a landfill or recovered for recycling. Materials transported through a community without being consumed or transformed, such as freight transported on roads passing through a community, are generally excluded from a community level materials flow analysis.

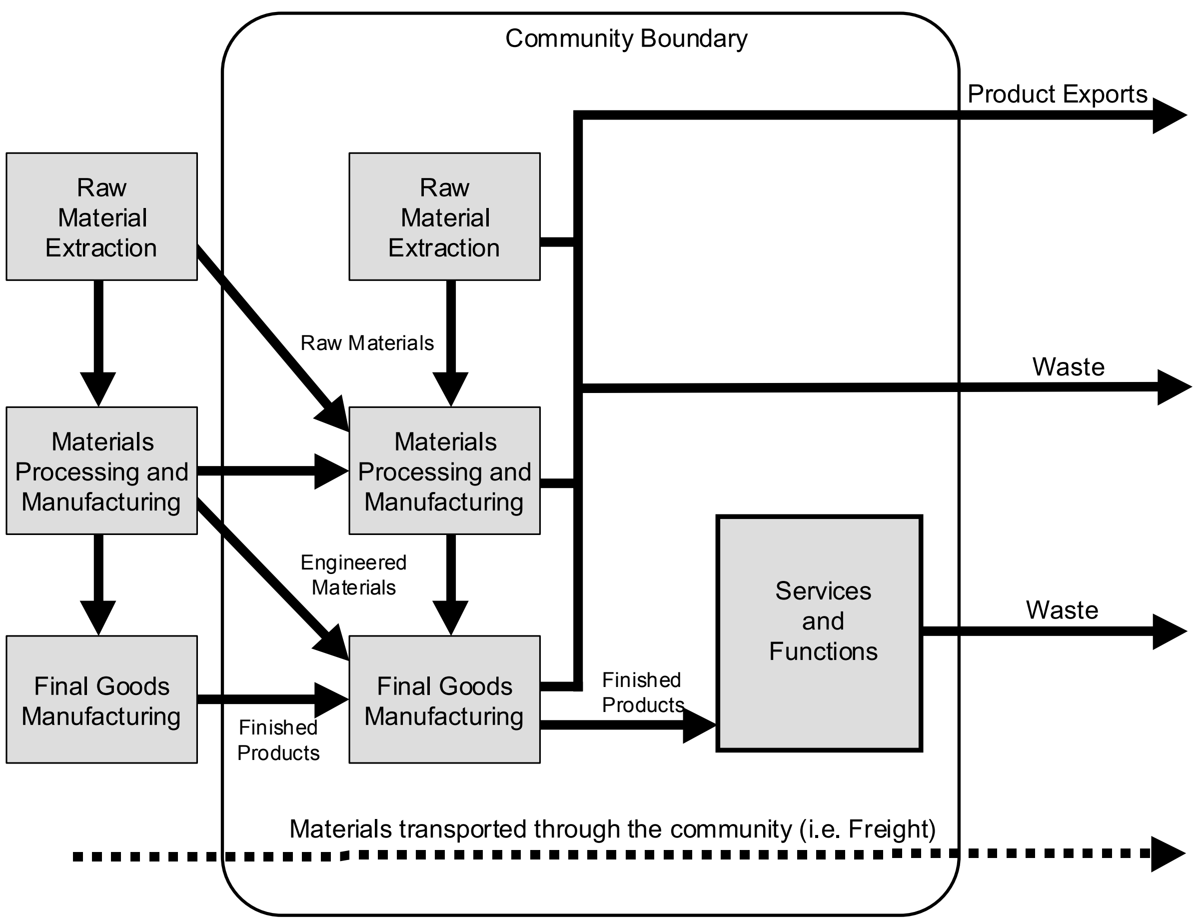

Figure 2-2 Model of Community Level Material Flows

Studying material flows at the community level has several advantages.

- Many material flows are handled at a community level. Examples include local business-to-customer relationships, handling of solid wastes, and transportation and utility infrastructures.
- Studying a community rather than a smaller unit such as a household offers the potential to identify integrated solutions to increase material efficiency that involve multiple stakeholders. Some issues such as sprawl or environmental issues can only be understood at a larger unit of analysis.
- The results of the study will be oriented towards community-level solutions, which offer a greater relevance to community organizations and especially to local government than a national level materials flow analysis. This increases the likelihood of the successful implementation of recommendation because of the existence of decision-making, policy-making and enforcing bodies at the community level
- Using a geographical spatial boundary provides a clear definition for the system.
- The area of study matches the organization of secondary data sources such as census data or local housing permits.

With the system defined at this level, the next step in the process of this study is the selection and definition of materials to be studied.

Chapter 3: Methodology

In undertaking a materials flow analysis, many factors must be considered prior to starting the study. The system boundary must be established, the types of materials and flows must be defined, and the units of measurement and estimation method determined. This chapter describes the process followed in this report as a methodology that others can use to perform a similar analysis for their community. First is a section describing the boundary established for the flows examined in this study, followed by a description of the process by which materials are selected for the study. That is followed by details of how the model community is chosen. The chapter concludes with an overview of the methods employed to estimate mass and economic value associated with the material flows.

Defining Material Flows

The first steps are to define material stocks and flows and to choose the units of measurement used to quantify them.

Stocks and Flows

As described in Chapter 2, material flows occur as part of the anthroposphere or the natural environment. The anthroposphere includes flows of materials that are transported, stored, and transformed in a human-created network of factories, vehicles, stores, households, and city infrastructure in order to satisfy human needs. The environment includes all biogeochemical flows of materials that occur outside of human control in air, water, and earth. While these two systems constantly interact, the most common interfaces between them, described in Chapter 2, are the extraction of resources from the natural environment for use in manufacturing and the eventual return of these materials from the anthroposphere back to the natural environment in the form of waste products.

An analysis of community material flows could include material flows associated with only the anthroposphere, with only the natural environment, or with both as did

Burstrom's 1998 analysis of nitrogen in Stockholm.[18] The purpose of this study is to investigate the efficiency of material flows controlled by a community's businesses, government agencies, institutions and individuals that are used to satisfy human needs in the community. To remain consistent with this focus, this study only considers the flow of materials related to the anthroposphere and not the natural environment.

The movement of materials can be described in terms of inflows, outflows, and stocks, which are each defined below. These conceptual definitions for inflows and outflows will be further developed later in the General Assumptions section.

- Inflow: The material transported **into** a community across its geographic boundary over a span of time.
- Outflow: The material transported **out of** a community across its geographic boundary over a span of time.
- Stocks: The material within the community's geographic boundary at a specific point in time.

For example, the difference between the stock of a material at the beginning and end of a year is the inflows that occur during the year minus the year's outflows.

Early attempts to quantify material stocks in the community showed that, for many material types, data are unavailable to complete sound estimates for stocks. Therefore, this study includes inflows and outflows but not stocks in its primary results.

Units of Measurement for Material Flows

Material flows must be measured over a period of time. A calendar year is chosen as the basic unit of time to avoid the impact of some temporary fluctuations, such as changes in seasonal demand. The year 1997 is the most recent year for which reports from a wide variety of sources are available during completion of this project in 1999-2000. This study therefore uses the calendar year 1997 as the time span over which the inflows and outflows are estimated.

[18] Burström. op. cit.

When determining how to measure material flows, one or more units of measurement must be established to quantify inflows and outflows. Each unit of measurement may apply for inflows, for outflows, or for both. Units of measurement considered for this study include mass, volume, and economic value. Economic value could represent the market price for a material as an inflow, the benefits derived from a material during its use, or the disposal costs and salvage revenues associated with the material as an outflow.

In selecting the units of measurement for the quantity of flows, three criteria are used.

- The quantity of flows for all material types can be estimated with the unit of measurement, and the data necessary to do so are available.
- The unit of measurement can be used as a meaningful comparison for the flows of different material types.
- The unit of measurement carries an intuitive meaning and is of interest to community stakeholders.

Following these criteria, mass and economic value (based on retail price) are adopted as the units of measurement for material inflows. Mass is the only measurement used for material outflows. The terms mass and weight are used interchangeably throughout this study.

Volume is rejected because it is not recorded for most materials as a matter of practice, so data are often unavailable. Also, the volume of a material can easily be changed by actions such as folding, packaging, stretching, and compressing, making this unit unreliable as a basis of comparison across materials.

Mass is chosen because it gives a clear sense of the scale on which the community utilizes the material. It provides a good basis for comparison because it remains constant regardless of the form of the material. Mass is also a convenient choice because most reports that attempt to characterize the scale of material flows do so using this unit of measurement. Mass is estimated for both inflows and outflows.

While mass is a useful tool to understand the scale of material flows, community stakeholders are more likely to be interested in the economic value to the community associated with those flows. Whereas an inflow to the community is the movement of material into the community, these inflows typically have an associated outflow or transfer of money out of the community. For example, a consumer who orders a shirt from a clothing catalog generates an inflow of material into the community in the form of the shirt and an outflow of financial resources for the retail price of the shirt. The dollar value of materials provides a basis for comparing the potential economic impact of material flows on a community. Although the economic value represents an economic outflow, it is called an "inflow economic value" because it is associated with an inflow of material for use in the community.

For most material types in this study, the estimate of economic value is based on the retail price paid by the end consumer for the material. The retail price is the minimum value of the material to the consumer. She wouldn't buy the material if its value to her was less than the price, and the value to her may be higher. The retail price includes the market value of the physical components of the material (raw material costs), but it also includes other costs such as the labor costs and overhead of the material's manufacturer. Across the various material categories considered, raw material costs will represent a varied percentage of the retail price. The retail price for various materials is widely available, aiding in the data collection process.

A disadvantage of using retail price as a measure of economic value is that it does not distinguish between the cost paid to suppliers outside the community and economic exchanges between community members. For example, available building cost data usually include both the cost of the construction materials paid to an outside supplier and the cost of labor paid to a local construction company.

The economic value of material outflows was not analyzed in this study due to the lack of available data for many material types and the mixture of costs and revenues in outflow value. One form of outflow value is the revenue that could be captured if the material were sold on the market for reuse or recycling. The other is the negative value in the form of the costs of transporting, sorting, and disposing of waste materials.

Mass Balance

Creating a mass balance can help ensure that all materials associated with a process or activity under study have been accounted for in the analysis. For a community, a mass balance requires an understanding of both stocks and flows. Creating a mass balance for a material would mean showing that the difference between the materials inflows and outflows over a period of time equals the change in stocks that occurs during the same period of time.

This relationship can be stated in equations as follows:

$$\text{Stock at beginning of period} + \text{Inflows} - \text{Outflows} = \text{Stock at end of period}$$

$$\text{Inflows} - \text{Outflows} = \text{Change in Stocks}$$

One use of the mass balance concept is to create an estimate for the change in stocks based on inflow and outflow estimates. The relationships expressed in the equations above always hold true for actual material flows. However, they will only be true for the inflow and outflow estimates included in this report where the inflows and outflows of all forms of a material are included in the estimates. Therefore, the estimates of inflows and outflows can be used to characterize the change in stocks for some but not all materials, and the reader is advised to use caution when interpreting the difference between an inflow and an outflow as a change in stocks.

Because this study does not include material flows associated with the natural environment, any transfer of material between the two systems means that not all inflows and outflows associated with the material will be included, and an estimate for the change in stock cannot be created. An example of this kind of transfer is food that enters a community via the anthroposphere as a packaged food product but then is transformed through food preparation and consumption. Some of the food material will remain in the anthroposphere in the form of landfilled food scraps or biosolids collected from wastewater. However, some of the food will move from the anthroposphere to the natural environment in the form of compost used in local gardens or exhaled carbon dioxide created through human metabolism.

This method can be used to estimate the change in stocks for some materials, but not the actual stock level present in the community at a single point in time. An extension of the results of this study could be to collect data on the total stock of materials in the community as a point of comparison with the inflow and outflow estimates.

Material Categories

With a defined system boundary for the types of flows to be included in the study, the next step is to define and select the materials themselves.

General Methodology

Multiple methods exist for defining and categorizing materials for a material flow analysis. Two main methods to consider are a basic material categorization scheme and a functional use categorization scheme.

A basic material categorization scheme analyzes materials at the level of specific chemicals or raw materials. Examples of the substances analyzed in past studies include:

- specific chemical pollutants such as nitrogen[19] and mercury[20];
- bulk materials such as water and gravel[21];
- raw materials of common products such as paper, metals, and plastics[22].

Material flows are quantified for these basic materials without regard to the products they are used in or the human needs they satisfy.

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[19] ibid.

[20] Maag, Jacob, Eric Hansen, and Carsten Lassen. "Mercury - A Substance Flow Analysis for Denmark." Regional and National Material Flow Accounting: From Paradigm to Practice of Sustainability, Proceeding of the ConAccount workshop. 21-23 Jan. Leiden, The Netherlands: Wuppertal Institute for Climate, Environment and Energy, 1997.

[21] Baccini, op. cit.

[22] Fehringer, Roland and Paul H. Brunner. "Flows of Plastics and their Possible Reuse in Austria." Regional and National Material Flow Accounting: From Paradigm to Practice of Sustainability, Proceeding of the ConAccount workshop. 21-23 Jan. 1997. Leiden, The Netherlands: Wuppertal Institute for Climate, Environment and Energy, 1997.

A functional use categorization scheme has two main characteristics:

- Materials are organized into “functional categories” based on human needs. These can be needs that must be met for physical survival such as food and shelter, or they may be needs that are fundamental to the functioning of individuals, groups, and communities such as transportation and communication. The criteria used to choose these functional categories will be discussed later.
- Within these categories are specific types of materials that satisfy these needs. A “material type” is a material at the level of aggregation that communities interact with them. In most cases this will be at the product level at which materials are bought, sold, or consumed. Examples of these material types could include clothing, automobiles, or building materials rather than more basic components such as cotton, steel, or glass. For example, community citizens and businesses purchase and use clothing but in most cases do not handle the raw materials, such as cotton, wool, leather, metal, and petroleum products as distinct materials. Therefore, a material type for clothing has been defined but not for the basic materials that go into it. Note that some basic materials, such as water, are handled as distinct materials by the community and can be defined as a material type.

Choosing a Functional Use Categorization Scheme

Each of these methods for categorizing materials for a material flow analysis has its own strengths and weaknesses depending on the purpose of the study. Ultimately, the two approaches can provide complementary sets of information for a community's material flows.

A functional use categorization scheme is appropriate for the following purposes that all depend upon understanding the flow of materials in the context of the human needs they satisfy:

- To identify recommendations that reduce a community's consumption of materials while still meeting its needs;
- To identify recommendations that substitute one type of material or product for another that meets the same human need with fewer total materials;

- To identify recommendations based on the reuse of products within the community for the same functional use and on the extension of a product's life span;
- To identify the key materials that fulfill human needs. Often these materials act as indicator materials, in that they are associated with the use of other materials. Focusing on the reduction of flows for the key material types will therefore have broader benefits. For example, reducing the inflow of cars may reduce other material flows associated with road infrastructure, gasoline, garages, oil filters, etc.

However, a functional use categorization scheme also has several disadvantages relative to a basic material categorization scheme for the following purposes:

- To characterize a community's total flows of a single basic material for all uses in the community;
- To identify recommendations, such as recycling, that seek to improve the management of a community's waste stream for basic materials regardless of the functional use of the original products containing the materials;
- To understand important material flows that are not clearly connected to the satisfaction of a human need;
- To understand the flows of raw materials and products exported for use outside the community associated with manufacturing activity in a community.

This project uses the functional use categorization scheme to fulfill its purpose of analyzing material flows used to meet the needs of a community and of suggesting solutions to improve the efficiency of these material flows. As will be discussed later, the material type of water is an exception in that it more closely follows a basic material categorization scheme.

Selection of Categories

A functional use categorization scheme organizes material categories based on human needs. These can be needs that must be met for physical survival, such as food and shelter, or they may be needs that are fundamental to the functioning of individuals, groups, and communities, such as transportation and communication.

An original set of functional categories defined in an unpublished report from the Center for Sustainable Systems was adopted for use in this report[23]. The five functional categories used in this report are described below:

- **Food and Water:** Food and water provide the nourishment humans need to support bodily functions, such as building and repairing body tissue and providing energy for muscles. These two functional categories have been combined because the water systems and infrastructure operated by the City of Ann Arbor are intermingled with the community's flows of food in several ways: by providing water for drinking and cooking and by handling food wastes and human wastes through the sewer and wastewater treatment systems. Therefore, the total flow of water is included in this category, even though water may be used for purposes other than for human sustenance such as cleaning, manufacturing, or watering lawns and gardens.
- **Shelter:** Shelter is needed to provide protection from inclement weather and societal dangers such as theft, and to allow for privacy. This need is primarily met through the use of residential and nonresidential buildings.
- **Clothing:** Clothing also provides protection from weather, as well as serving various cultural and social purposes.
- **Transportation:** Transportation supports the need for mobility - transporting people and objects across the physical landscape. Personal mobility and freight transport are both included in this category.
- **Communication:** Communication is the exchange of thoughts, messages, or information through a common system of symbols via print, sounds, or a combination of the three. This analysis focuses on print media such as books, newspapers, and personal and business correspondence.

Many alternative ways to define functional use categories are possible. One might combine clothing with shelter because both relate to the need for temperature regulation and protection from inclement weather. However, this study categorizes them as separate needs because they are only realistic substitutes in Ann Arbor in the limited sense of choosing between wearing extra layers of clothing indoors or maintaining a warmer room

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[23] Center for Sustainable Systems. Research database. University of Michigan. 23 Apr. 2000.

temperature. The original set of functional categories from which the list above was adopted included health and recreation as functional categories, but these are not included in this study due to the broad variety in and lack of available data for materials that satisfy these needs.

Baccini and Brunner developed a set of activities similar to functional uses that encompass all major processes and goods of the anthroposphere[24]. These four activities are listed below with notes on how they compare to the functional categories used in this study.

- **to nourish:** includes food and beverages that are a part of the Food and Water category in this study.
- **to clean:** includes water used for a variety of cleaning processes that is part of the Food and Water category, materials related to sewage treatment also included in the Food and Water category, and cleaning agents that do not have a clear place among the functional categories used in this report except as indirect materials.
- **to reside and work:** includes the buildings, furniture, and clothing that are part of the Shelter and Clothing categories. Also includes a variety of materials that would have been included in the Recreation category.
- **to transport and communicate:** includes vehicles, printed material, communication devices, and infrastructure that is a part of the Transportation and Communication categories.

A significant overall difference is that Baccini and Brunner's activities include manufacturing and other industrial processes that support these activities, while industrial activities are not included in this study.

Selection of Material Types

Material types can be classified as direct or indirect. A "direct material" is one that directly satisfies the human need for its functional category. An "indirect material" is one that does not directly satisfy the human need but helps provide support and infrastructure for the direct materials to satisfy the need. For example, automobiles would be a direct

[24] Baccini, op. cit. 78-79

material type for the transportation functional category, while roads are an indirect material type.

The following criteria are used to develop a set of material types for each functional category:

- Material types should be defined to cover the most significant direct materials for the functional category.
- Other direct and indirect material types can be added, though the value of analyzing additional material types should be balanced with the time and resources available for the study.
- Judgment is required to choose an appropriate level of aggregation for some materials. Material types should be defined at the level at which the community understands and interacts with the material.

This study only includes direct materials in the inflow and outflow estimates for each category. These main estimates are restricted to direct materials to provide a consistent approach across all categories and to create a targeted project scope achievable in the time available for this study. For example, the mobility category estimates focus only on vehicles, even though partial data on material flows associated with road construction are available. Rough estimates for a few indirect materials, such as road asphalt, are included in the discussion of various categories, but these estimates are presented separately and are not counted towards the total inflow and outflow for the category. The estimates for indirect material flows are presented separate from direct materials.

Note that the quantification of inflows and outflows for direct materials may represent only the tip of an iceberg if large quantities of indirect materials are required. This effect will vary between categories. For example, food may have a proportionally larger amount per unit mass of associated packaging and infrastructure for its distribution, sale, and storage relative to those required for building materials.

Energy is not a focus of this study because extensive past research has already been done on community flows of energy, and Marc Jensen, a research assistant with the Center for Sustainable Systems at the University of Michigan, is currently analyzing energy flows for Ann Arbor. The infrastructure for supplying energy is considered an indirect material for all of the functional categories. The materials that embody energy such as gasoline, natural gas, and coal are also considered indirect materials.

The specific functional categories and material types used in the analysis of inflows and outflows for Ann Arbor are shown in Table 3-1. Unless otherwise stated, decisions to exclude direct materials mentioned in the chart are based on the need to limit the number of material types included to meet the time constraints of the project. In some cases secondary data for the particular materials were unavailable.

Table 3-1 Functional Categories and Material Types Included and Excluded

Functional Category	Inflow Material Type	Included	Excluded
Food and Water	Food and Beverages	Fresh produce, packaged foods and beverages. Solid food wastes are represented as two additional material types: biosolids and landfilled food scraps	▪ Direct: compost ▪ Indirect: packaging, grocery stores, dishes, cooking utensils, and toilet paper ▪ Note: The transition of food to the natural environment through respiration and other biological processes is not included as an outflow.
	Water	Water used for all purposes in the community	▪ Indirect: water infrastructure, water treatment chemicals ▪ Note: Water flows associated with the natural hydrological cycle such as rainfall, evaporation, and the flow of the Huron River are not included.
Shelter	Building Materials	Buildings projects registered by permit, including new construction, renovation, demolition	▪ Direct: maintenance and repair related materials, floorings, furnishings, appliances ▪ Indirect: construction equipment
Clothing	Clothing and Footwear	Apparel, footwear, and accessories purchased new	▪ Direct: used clothing, disposable clothing, surgical and medical gloves ▪ Indirect: packaging, clothing stores, cleaning materials such as water, detergent, and dry cleaning chemicals
Transportation	Vehicles	Registered vehicles, including vehicles for residential, commercial, government use	▪ Direct: bicycles, trains, airplanes, boats ▪ Indirect: roads, transportation infrastructure, fuel
	Maintenance Materials	Materials used in the normal course of vehicle maintenance such as tires, engine oil, and spark plugs	▪ Indirect: packaging, auto parts stores
Communication	Paper	Separate material types are defined for United States Postal Service delivered mail, printed material such books, magazines, and newspapers, and blank office paper and envelopes	▪ Indirect: packaging, distribution systems ▪ Other communication materials not included: painting, photography, music CDs, cassette tapes, video cassettes, motion pictures, stereos, telephones, personal computers, televisions

Choice of Community

The next step in the process is the selection of the model community for the study. The following section describes the considerations leading to the selection of the City of Ann Arbor, Michigan.

Choosing a Real Community

Some previous studies have analyzed material flows based on a theoretical community model. For example, one study created a fictitious community named METALAND with an area of 2500 square kilometers and a population of one million people.[25]

This study uses a specific, real community for several reasons. The study is meant to illustrate methods communities could use to evaluate their own material flows, so the choice of a real community makes the research more relevant and tangible. Several researchers consulted have advised the project team to choose a specific community. Using real local data makes the results more concrete and compelling and illustrates methods that other communities might use to understand their own material flows. However, this approach includes characteristics that may be unique to a specific community, such as the presence of a university or major industry, while use of a fictitious community such as METALAND may be generalized to a broader range of communities.

Criteria

Early candidates for the community of study include the City of Ann Arbor, in which the project team lives and works, and Washtenaw County, which contains Ann Arbor. Virtually any other community in the United States could also have been chosen.

As described in Chapter 2, a community is defined as any physical geographical area, whether delineated by a city or county political border or some other type of boundary. The criteria developed for choosing a community may be helpful for another research team who wants to apply and further develop the project methods to a selected

[25] Baccini, op. cit. 77-78.

community. The criteria can be used to help determine the scale of analysis from among city, county, or regional levels.

The following characteristics describe a community appropriate for study and are used as criteria for choosing a community:

- The size of the community is small enough to make data collection feasible given the number of types of materials to be studied, yet large enough to provide a meaningful analysis of material flows as a coherent community.
- The community is in close proximity to the project team to facilitate data collection and relationship building with community groups.
- Relationships exist between community groups and the research team to facilitate the process of local data collection and access to community stakeholders.
- Local material flow data are available for the community.
- Project results will be relevant to other similar communities.

City of Ann Arbor

Only communities in the Ann Arbor area are considered in order to meet the criterion for close proximity to the project team. Washtenaw County is not chosen because its large size and its inclusion of a number of cities and townships would make data collection for a broad variety of materials very difficult to gather. While this larger level of community is not used for this study, in some cases data collected at the county level are used to better understand Ann Arbor when data at the city level were unavailable. Note that if agricultural production for local consumption had been the focus of the study, a county level analysis may be more appropriate, because production takes place throughout the county, but virtually none occurs within the City of Ann Arbor.

The City of Ann Arbor, Michigan, is chosen as the community of study to take advantage of the city's size, existing relationships with community stakeholders, and proximity to the project team.

- The School of Natural Resources and Environment at the University of Michigan is part of the City of Ann Arbor, and all research team members live and work in the area. This proximity has aided the collection of local data throughout the project analysis.

- While making this decision, the project team has met with local government officials, who received this project with great interest. Relationships had already been established between one of the project faculty advisors, Gregory Keoleian, and the Washtenaw County Department of Environment and Infrastructure Services, through his work on the Sustainable Washtenaw Initiative.
- Ann Arbor has a large and sophisticated municipal government that provides extensive local data on topics ranging from economic activity to housing permits to water utilities infrastructure. These data would be difficult to collect from the multiple municipal governments present in Washtenaw County.
- Many cities exist that are about the size of Ann Arbor and could apply the results of this research to themselves. On the other hand, Ann Arbor does have some unique features, such as its status as a college town and the large size of the University of Michigan. The strength of Ann Arbor's various environmental programs, such as waste reduction, is another unique feature of the city. This study therefore provides descriptions of programs already in place from which other communities could learn in addition to new recommendations to increase the efficiency of materials flows in Ann Arbor.

Appendix A includes detailed demographic, economic, waste management, and other information about the City of Ann Arbor.

Estimation Methods

Before beginning data collection, it is helpful to consider the general approach to be used in making estimates. This provides guidance in searching for data sources and using the data they provide in a consistent manner to develop estimates.

Data Collection

When collecting data to estimate material inflows and outflows for Ann Arbor, local data relevant for Ann Arbor are clearly the first choice for use when available. However, these data are often difficult to collect because they require the tracking of transportation and consumption activities of numerous individuals and organizations throughout the community. In order for data on the inflow and outflow of materials to be collected, there must be an organization with the motive and resources to do so that is also willing to share the data with others. Therefore, very limited material flow data are collected in most local communities, most often by local government agencies. Examples used in this study include local housing permit records, water consumption records, and vehicle registrations.

In order to quantify the material flows for Ann Arbor, available local data are supplemented with additional research. Both primary and secondary research strategies are considered for use. Primary research methods would include collecting original data, while secondary research relies on already completed reports and studies.

Primary research has the benefit of providing data specific to Ann Arbor. With this approach, the project team would contact individuals and organizations via phone or mail and attempt to gather a statistically significant sample to make conclusions about the total material flows for the community. Below are three examples of potential approaches to primary research:

- Survey residents about the quantity and expense of key materials they purchase.
- Survey shipping and trucking companies to gauge the movement of materials into and out of Ann Arbor.
- Interview businesses to gain information about the flows and stocks of specific materials in their stores and warehouses.

This data collection and analysis process would be extremely time and labor intensive. Also, it would be difficult to gather a statistically significant level of responses to give a comprehensive view of community material flows.

Most secondary sources provide information at a higher geographic level, such as for the U.S. Various data conversion techniques must be used to alter the data to reflect an estimate for Ann Arbor. This approach must be used cautiously, because the accuracy of the results depends both on the accuracy of the original study and the applicability of the data for Ann Arbor. However, this approach provides a much easier and faster way to generate results.

Secondary research is the approach chosen for this project for several reasons. Using secondary research would allow the project team to create estimates for multiple material categories in the limited time available. Also, others could apply these methods to their own communities without a large time commitment and without a sophisticated knowledge of survey methods and statistical analysis.

For a more detailed, focused analysis of a single material type, primary research methods may be more appropriate. Surveying individuals and organizations in a community could provide an understanding of material flows that more accurately reflects the unique characteristics of the community. It could also provide a better understanding of the flow of materials between sectors within the community.

General Assumptions and Omissions

Several general assumptions are made to estimate the value and mass of material inflows and outflows for Ann Arbor. Also, certain types of flows are excluded from the estimates for all categories as part of the general methodology. Additional assumptions and omissions associated with specific data conversion techniques are included later in this chapter.

- **No internal production**: This study does not include the local production of materials and assumes that all goods came from outside the community. This omission is made in order to focus the study on flows of material that all communities have in common. Production of materials varies widely among communities, but all communities have similar inflows and outflows related to satisfying human needs such as food and shelter.

- **Static population**: This study uses the Southeast Michigan Council of Governments' 1997 population estimate[26] and assumes that this population remained static throughout the year.
  - **No permanent resident immigration or emigration:** This study does not account for people moving into or out of the community with their material belongings but instead assumes that use and disposal of materials in the community causes all inflows and outflows of material.
  - **No seasonal change of population:** The full population of Ann Arbor, including students, is assumed to be present year round. This is a significant assumption, given that approximately one-third of this population is undergraduate and graduate students, many of whom leave the community in the spring and return in the fall.
  - **No Commuters:** Commuters may have a significant impact on material flow and other data. For example, those residing in the community are captured in Ann Arbor population estimates while those who commute into the city are not, even though the needs of both groups cause material flows in the community. This study assumes that the impact of commuters coming into the city during the day will balance the impact of resident commuters leaving the city, so neither needs to be included.
  - **No drive-through traffic:** The inflows and outflows associated with material transported by trucks, trains, and other vehicles through Ann Arbor without being loaded or unloaded are not included.
- **Fiscal year equivalent to calendar year**: In some cases, data are not available for the 1997 calendar year but instead for another twelve-month period such as a fiscal year. In these cases, data are used for any twelve-month period that overlapped with the 1997 calendar year as if it were the 1997 calendar year.
- **Consumption implies inflow**: In many cases, it is assumed that all consumption of materials is satisfied by an inflow of materials from outside the community and not from reducing existing stocks of that material from within the community. For

[26] Nutting, Jeffrey. Population and Households in Southeast Michigan 1995-1998. Southeast Michigan Council of Governments. Nov. 1998. <http://www.semcog.org/data/popocc/popocc98.pdf> 3 Jun. 2000.

example, it is assumed that the amount of consumer product materials brought home from retail stores implies an equal amount of material replaced in the store's inventory from outside the community.

- **Waste as outflow**: It is assumed that all waste is removed outside the community as an outflow, whether it is landfilled, incinerated, or recycled. One exception is food compost, which is assumed to remain in the community for use in local gardens. The University of Michigan hospital incinerates some of its medical wastes, creating a transfer of material from the anthroposphere to the natural environment in gaseous form. This gaseous mass is counted as an outflow, which is an exception to the decision to limit the study to only those inflows and outflows associated with the anthroposphere.
- **External landfill:** The landfill used by Ann Arbor lies outside of the city's boundary, so municipal solid waste is included as an outflow in our analysis. For communities where the landfill is within the geographic boundary, landfilling should be accounted for as a growing stock rather than as an outflow. In this case, the community should develop estimates for additions to the stock of wastes in the landfill that occur during the period of study.
- **No External Flows to MRF**: The City of Ann Arbor Materials Recovery Facility (MRF) processes multiple kinds of recyclable and waste materials. Garbage trucks drop off materials for temporary storage and compaction, which are later loaded onto semi-trailers to be taken to a landfill. Materials arrive from the City of Ann Arbor, the University of Michigan, and customers located outside of Ann Arbor, including the City of Ypsilanti, Ypsilanti Township, Eastern Michigan University, and numerous private haulers. Materials delivered to the MRF for separation and processing from locations outside of Ann Arbor are not included in estimates for the flow of materials through Ann Arbor.
- **No source or destination:** This study uses an established geographic boundary to set limits on the extent to which the path of materials used by the community would be traced. Sources of and the destination of materials that fall outside of the city boundary are not analyzed in this study. Though it is clear that the source and destination of materials moving in and out of the community are important in

understanding more completely the upstream and downstream impacts of the community's material use, it is not central to this study.

Figure 2-2 in the Background chapter provides an illustration of basic material flows into and out of a community. Figure 3-1 below shows which of these flows are excluded from this study based on the omission of internal production and of drive-through traffic. As shown in Figure 3-1, most of the flows included in this study can be described as an inflow of finished goods or as an outflow of the waste products for these materials after their use.

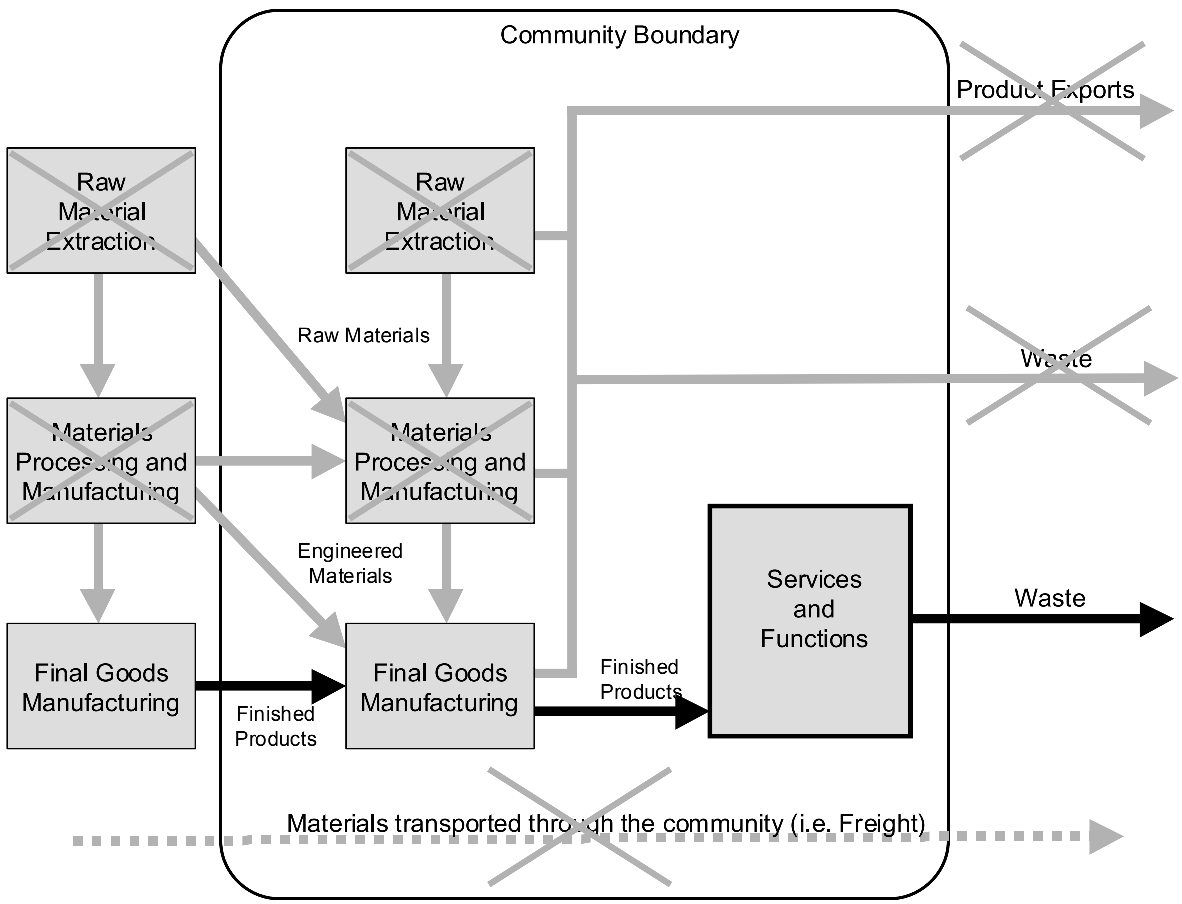

Figure 3-1 Omissions in the Model of Community Level Material Flows

Data Conversion Techniques

The desired estimates of material flows for this project have the following characteristics:

- They represent an inflow or outflow to the community;
- They represent total flows for Ann Arbor (not per capita);

- They include all flows that occurred in 1997;
- Their units are in mass (tons) or economic value (United States dollars).

Often, available data do not have all of the characteristics listed above. Various modeling techniques can be used to convert data from their original form to a closer match with the desired characteristics listed above. Use of particular conversion techniques may imply additional assumptions about the material flows.

The data conversion techniques used in this report are shown in Table 3-2. Multiple techniques may be needed for a single material type. Variations of these techniques exist, such as using Washtenaw County level data instead of national level data.

Table 3-2 Commonly Used Data Conversion Techniques

Initial Form of Data	Conversion Technique	Implied Assumption	Example
National per capita inflow or outflow	Multiply per capita flow by the population of Ann Arbor. (Per capita flow * Ann Arbor Population)	▪ On average, the inflow and outflow patterns of Ann Arbor residents are the same as national patterns, so per capita flows are the same for Ann Arbor as for the United States.	National per capita mass of consumed food multiplied by the population of Ann Arbor to get the inflow mass of food.
Total national inflow or outflow	Divide the national consumption by the total United States population and multiply by the population of Ann Arbor. (National consumption * Ann Arbor Population / US Population)	▪ The inflow or outflow can be understood on a per capita basis rather than some other unit of analysis such as number of households or number of buildings. ▪ On average, the inflow and outflow patterns of Ann Arbor residents are the same as national patterns so per capita flows are the same for Ann Arbor as for the United States.	National expenditures for clothing divided by the United States population and multiplied by Ann Arbor's population to get the inflow economic value for clothing.
Inflow or outflow data for separate activities associated with the material type	Sum the inflows or outflows associated with each category to estimate the total inflow or outflow of material for the material type.	▪ There is no overlap in the inflows and outflows associated with each category of activity. ▪ The activities included represent all inflows or outflows associated with the material type.	Estimate inflow or outflow building materials used for separate activities such as construction, demolition, and renovation. Sum the activity estimates to get a total inflow or outflow.
Inflow or outflow data are measured in an alternate unit such as quantity (not mass or economic value)	Multiply the alternate units by a conversion ratio. The conversion ratio represents the average mass or economic value for the alternate unit. (Flow * Conv Ratio)	▪ The conversion ratio used accurately reflects the average mass or economic value of the unit given.	Multiply the estimated number of new cars by an average mass per car to get an estimate of the total inflow mass.
The inflow is known, but not the outflow (or vice versa)	Assume that the outflow is equal to the inflow (or vice versa), accounting for any diversion of material into or out of the stock that occurs between inflow and outflow.	▪ There is no transfer of material from the anthroposphere to the natural environment. ▪ There is no change in the level of stocks or the change in stocks is reflected by the diversion rate.	Assume the inflow of newspaper is equal to 107% of the outflow, reflecting a 7% diversion rate. Multiply the outflow mass by 107% to get an estimate for the inflow.

Estimate Accuracy

Secondary research and data conversion techniques provide estimates for all categories in this study, but the preciseness of each estimate may vary. In a few instances, multiple approaches can be used to estimate inflow or outflow mass based on different data sources. These different estimates have differed by as much as a factor of two.

Three factors contribute to inaccurate estimates:

- The accuracy of the data collected through secondary research;
- The match between the material types used in this report with the material types used by the secondary research sources;
- The validity of the assumptions implied by the data conversion techniques used.
- The similarity of the consumption behavior of people in Ann Arbor to that of people in Washtenaw County, Michigan, and the United States as a whole in those cases where data from these larger areas are used on a per capita basis.

Data are collected from government reports, industry websites, interviews with local government officials, local permits, prior material flow research, and other sources. Reputable sources are sought for data collection, but this study does not include a careful analysis of the accuracy of each data source.

The data used should characterize the flow of materials as the material types are defined in this report. Several promising data sources are not used because they combine categories of materials that classified into separate functional categories. In some cases the definitions of the material types are modified slightly to reflect the available data.

Each data conversion technique performed for a material type, as described in Table 3-2, will erode the quality of the resulting estimate, because none of the implied assumptions above will be 100 percent accurate in reality. Ultimately, the implied assumptions will be neither completely true nor completely false, and the accuracy of the estimate will depend on how close the assumption is to being true.

In most cases there is no algorithm to determine how accurate the assumptions are. Common sense plays an important role in choosing data conversion techniques to create estimates. If it seems likely that a required assumption is not likely to be very accurate, then the researcher should avoid the particular estimation technique and attempt to find an alternative data source or data conversion technique.

Despite these warnings, the methods used in this report should provide estimates accurate to within an order of magnitude. In several cases supplemental data are available from a different data source using different methods that provide a new estimate that closely matches the one used in this report. For a few material types, accuracy may be as high as to be within one or two significant digits of the actual flow, though accuracy is difficult to evaluate.

Based on the methodology presented in this section, estimates for inflow mass, inflow value, and outflow mass have been calculated for Food and Water, Shelter, Clothing, Transportation, and Communication. The next chapter, Chapter 4, provides information on the application of this methodology specifically for each material, and the results of that process.

Recommendations to the Community

This study does not focus on a specific issue of current concern to Ann Arbor but instead provides a set of recommendations to improve the efficiency of material flows analyzed in this study. This study also provides analytical tools for identifying important flows and prioritizing recommendations. Using the methods described in this report, other researchers and community leaders may be better able to prioritize areas of focus and to target future research to develop specific solutions that meet their community's needs.

Development of Suggestions Within Material Categories

Recommendations developed as a result of this study are focused on reducing material flows while still meeting basic functional needs. This focus is based on the assumption that a reduction in the mass of material flows yields economic, social, and environmental benefits. This approach clearly has its limitations. Reducing the mass flow of a particular material may lead to an increase in the mass of a different material and its associated social, environmental, and economical costs. Solutions primarily focused on mass neglect considerations of other material characteristics such as toxicity and the energy used in the production and transportation of the material. Solutions put forth in this analysis are presented without due consideration of the potential increase in mass of other materials that may result from implementing a suggestion.

In addition, recommendations focus on meeting the basic human functional needs but do not take into account other aspects of the functional need, such as convenience or personal enjoyment of the experience satisfying the need. For example, a suggestion that people build or use smaller houses does not take into account the benefits to those people of the larger home. People may desire larger homes to accommodate guests, to provide space for additional activities such as hobbies or work, to demonstrate social status, or simply for the enjoyment of the space.

Focusing primarily on reducing material flows potentially leads to suggestions that are socially impractical. It should be understood that suggestions made in this study have not been evaluated for their total net impact and are proposed because of their ability to impact the material flows specifically examined in this study.

Development of Analytical Tools

A series of recommendations are developed within each material category, independent of all other categories. Two analytical tools are used to compare the findings from different material categories, and to compare the various recommendations. First, a framework to aid in organizing recommendations is developed based on work published by the Interagency Working Group on Industrial Ecology, Materials and Energy Flows[27]. Second, a matrix is used to compare individual material flows across categories to help prioritize where a community might focus its resources. A description of these tools follows.

[27] The Interagency Working Group on Industrial Ecology, Material and Energy Flows. “Materials”. Washington, D.C. Aug 1998. <http://www.oit.doe.gov/mining/materials/> 23 May 2000.

Framework to Categorize Types of Recommendations

Recommendations which focus farther up in the life cycle of materials have the potential to achieve greater impacts on material flows. Avoiding use of a material reduces the upstream impacts associated with raw material extraction, manufacturing, use, and disposal of the product. For example, reducing the overall demand for paper products results in a decrease in the inflow mass, which subsequently reduces the mass of outflows. This action could have a more significant impact than merely improving the recycling rate of these products, which reduces neither the inflow nor the outflow mass. With that in mind, a framework is developed to categorize recommendations into one of six themes. Each theme implicitly gives a sense of the potential impact that the recommendation could have in reducing material flows.

The themes chosen for the framework are defined below.

- Rethink: to alter current concepts regarding the means by which human needs are satisfied (e.g. email as an alternative to corresponding via traditional mail);
- Redesign: to change the physical form of existing goods used to meet human needs (e.g. a lightweight vehicle);
- Reduce: to lower the quantity of material consumed during the use phase of the material life-cycle (e.g. duplex printing);
- Reuse: to extend the use of a material or product through transfer of ownership. In this case no repair or restoration is required (e.g. donation of clothing to charitable organization);
- Remanufacture: to disassemble, clean, and repair and/or reassemble discarded goods to extend the useful life (e.g. rebuilt automobile parts);
- Recycle: to return used or already processed material to an industrial process resulting in new production (e.g. recycled plastic)

The six themes are presented in the order in which they are prioritized in this study - from largest potential impact to smallest impact. Though not a rigorous method of evaluation, this framework offers an aid in determining which solutions hold the potential for greater overall impact. As an example, focusing first on suggestions that call for "rethinking" concepts may be preferable to other suggestions because these suggestions potentially offer opportunities to reduce flows of materials beginning from extraction of raw materials all the way through use and disposal. In contrast, a solution focusing on "recycling" is less likely to impact the amount of material flowing into the community. These end-of-pipe-solutions focus more on waste management and less on achieving resource efficiency.

Matrix to Compare Research Findings Across Categories

Deciding where to focus limited community resources can be difficult. Development of a matrix which examines each of the material categories from different perspectives assists in identifying important material flows and prioritizing recommendations. The following comparisons and evaluations are summarized in the matrix for each material category.

Comparing Data Across Categories identifies significant findings from comparisons of the category to all of the others (e.g. Water has the largest inflow mass of all categories).

Existing Community Programs highlights existing efforts in the community that help to reduce material flows. If efforts are already focused in a specific area, either expansion of the effort is possible or the community may choose to focus in an area not yet targeted.

Types of Recommendations Resulting from this Study summarizes the categories, as described in the above categorization framework, for which recommendations are made.

Barriers to Success and **Enablers of Success** highlight characteristics of the community that may either decrease or improve the chance of successful implementation of the suggestions made in any particular category. For instance, Ann Arbor has a relatively unlimited, easily accessible supply of water, so reducing water consumption may not be an issue of major concern to the community as a whole.

Given this methodology that will be applied in this analysis, the next chapter provides details and results of the material flow analyses for the five material categories.

Chapter 4:

Material Flow Analyses for Ann Arbor, Michigan

Five studies were carried out, each focusing on the material flows associated with a different material category. Presented in this chapter are the details and results of these studies for the City of Ann Arbor, Michigan. The material categories presented in order are: Food and Water, Shelter, Clothing, Transportation and Communication.

Each section starts with a description of the category as it has been defined, followed by a discussion of associated material inflows and outflows. Also discussed are data sources used, assumptions made in carrying out the study, and the process used to estimate the mass and economic value associated with material flows. The analysis of results and a discussion of those results in the context of Ann Arbor lead to recommendations for reducing material flows or increasing the efficiency of those flows. Supplementary information for the material categories, including step by step calculations, are provided in Appendices B through F.

Chapter 4.1: Food and Water

Food and water provide the nourishment humans need to build and repair body tissue, to create energy for external movement and internal functioning of organs, and to cleanse the body of accumulated wastes. A tour of Ann Arbor's restaurants would reveal that food and water help satisfy social and artistic human needs as well. This chapter describes the material flows associated with this need for food and water, the process and results of estimating material inflows and outflows, and recommendations to improve the efficiency of these flows.

Category Description

This category includes all types of food and beverages ingested by humans, the wastes associated with discarded food, and wastes from human metabolism. Water used for nourishment is a small fraction of the total use of water by Ann Arbor. However, the water systems and infrastructure operated by the City of Ann Arbor are intermingled with the community's flows of food in several ways: by providing water for drinking and cooking, and by handling food wastes and human wastes through the sewer and wastewater treatment systems. Therefore, the total flow of water is included in this category, even though water may be used for purposes other than for nourishment, such as cleaning, manufacturing, or watering lawns and gardens.

Materials associated with the provision of food and water are shown in Table 4-1.

Table 4-1 Materials Associated with Food and Water

	Direct Materials	Indirect Materials
Food	• Food and beverages (e.g. fresh produce, packaged solid foods, packaged beverages) • Food scraps in MSW • Biosolids and scum • Compost* • Human tissue* • Respiration gases*	• Packaging* • Food infrastructure* (e.g. grocery stores, trucks, refrigerators) • Food preparation equipment* • Eating utensils* • Toilet paper*
Water	• River and well water • Treated wastewater • Rain water* • Evaporated water*	• Water infrastructure* • Water treatment chemicals*

* This report does not include separate inflow or outflow estimates for these materials. However, a rough estimate is included for some types of food packaging in the discussion of results.

Direct Materials

Direct material inflows include all food, beverages, and water brought into the community and their waste products. Each of these direct materials is described further below.

Food and Beverages

This inflow includes all food items brought into the community, whether purchased at a grocery store or farmer's market for use at home, eaten at a restaurant, or provided by an institution such as a hospital or school. Food items are counted as part of this inflow as they would appear in a retail store, whether fresh or in processed form. This flow is the food brought into the community and not the food actually ingested, so it includes inedible portions such as peels or bones and other portions of food eventually discarded during food preparation. All packaged beverages are included, such as milk, juice, and bottled water.

River and Well Water

Water moves into Ann Arbor through natural processes such as the flow of the Huron River and through precipitation that recharges the groundwater. The water inflow for this category includes all water taken from the natural environment for human use. The City of Ann Arbor collects 80% of its water from the Huron River and 20% from wells that tap two groundwater aquifers.

Food Scraps

This outflow includes all food scraps placed into the city's municipal solid waste (MSW) stream by food retailers, foodservice and restaurants, and households.

Biosolids and Scum

These outflows are biological solids collected during the treatment of sewage. Biosolids are solids that are settled out of the sewage through gravity. In one stage of the process, bacteria are added to digest suspended solids to make them easier to remove. Lime and ferric oxide are added before disposed to stabilize the activity of the bacteria in the biosolids. Thus biosolids are a mixture of solids removed from sewage, bacteria, and added chemicals. Scum comes from floating solids and oils that are skimmed off the top of the sewage. Scum is removed separately because it is mainly composed of fats and oils that degrade at a slower rate than the rest of the sewage.

Although they may include suspended solids from other sources, most of the content of biosolids and scum originates from food wastes disposed into the sewer system and human wastes. They are either added to MSW and sent to the landfill or applied as fertilizer to agricultural lands. As recently as fiscal year 1996/1997, biosolids were sometimes incinerated, with the ashes sent to the landfill. In fiscal year 1997/1998, this practice was discontinued due to environmental and cost concerns.

Treated Wastewater

The final product of the processing of sewage at the Ann Arbor Wastewater Treatment Plant is clean water that is released back into the Huron River.

Direct Materials Not Included in Estimates

Composted food is not included as an outflow because it stays within the community. Human tissue such as hair, skin, and organs and respiration gases such as carbon dioxide and water vapor are created by the human body using food and water, but they are not included in outflow estimates because they are not handled as a material by the community. The community does manage rain water through its storm water system, but storm water is not measured and is not used to meet human needs, so it is not included.

Similarly, an estimate of the amount of evaporated water lost from the water supply, sewage, and storm water systems is not included.

Indirect Materials

As previously discussed, no indirect materials are included in the final estimates for food and water, though a rough estimate for certain types of packaging for food and beverages is developed in the discussion of results. Other indirect materials for food include the trucks, stores, restaurants used to transport, house, and sell food and beverages, the kitchen equipment and utensils used during food preparation and ingestion, and any used toilet paper. Water infrastructure includes the treatment centers, pumping stations, and distribution mains and pipes. Water treatment chemicals are regularly used in the treatment centers to help clean water before drinking or before disposal into the Huron River.

Inflows and Outflows

Figure 4-1 shows the flows of all direct materials through Ann Arbor. Stocks of food and water in stores, households, and pipes and tanks in the various water systems are represented by rectangles. These stocks are likely to remain fairly stable over time. Over the course of a year, food and water can be considered a continuous flow through the community, with little held in stocks for great lengths of time. Processes that change the form of direct materials are shown as ovals in Figure 4-1.

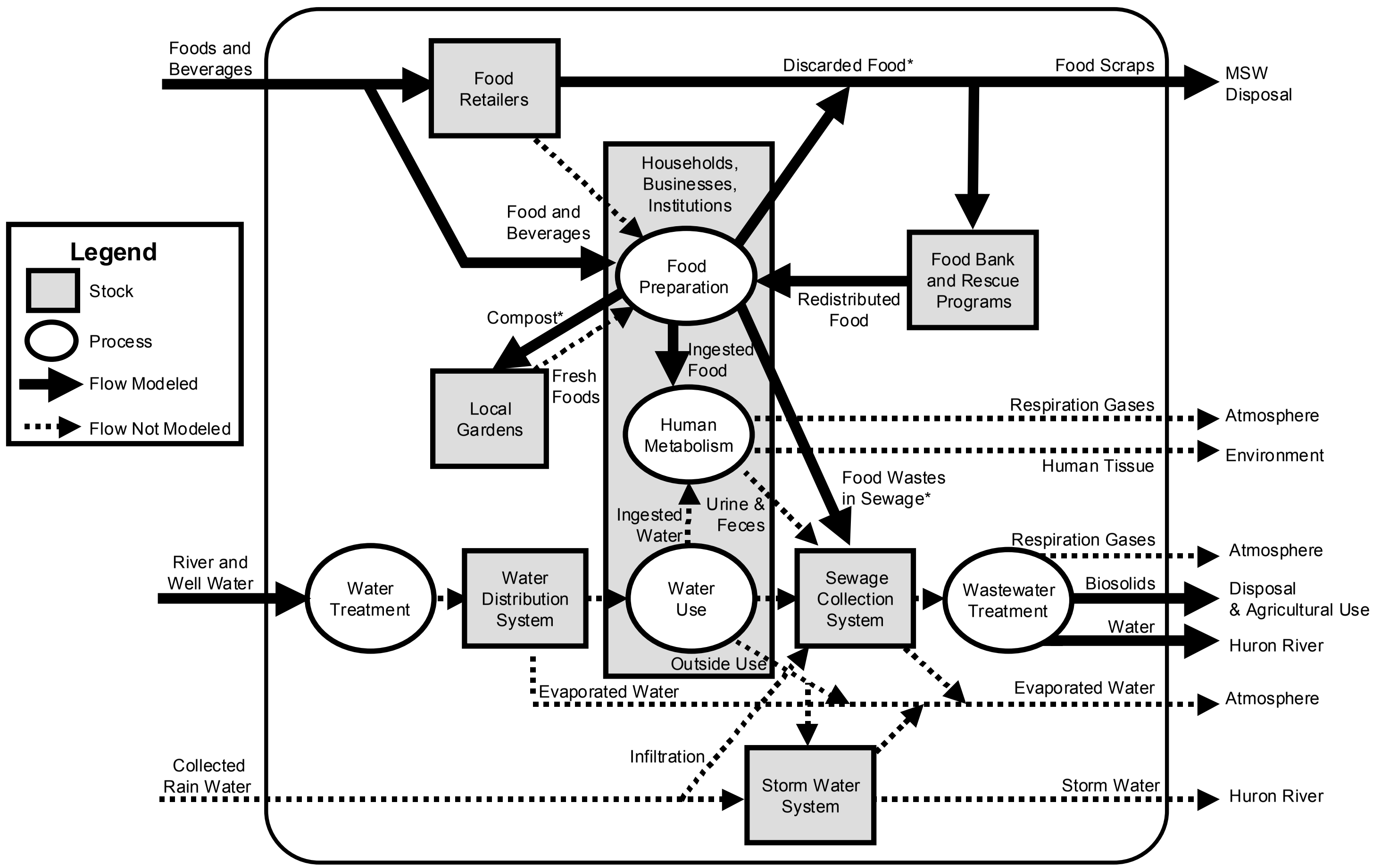

Figure 4-1 Food and Water Direct Material Flows Through Ann Arbor

* The total food losses in discarded food, compost, and sewage are estimated as a single aggregate number in Observation 6.

The direct materials listed in Table 4-1 flow through and are changed by the processes shown in Figure 4-1. Each of these processes is described further below.

Food Retail

Retail establishments include grocery stores, convenience stores, and the Ann Arbor farmers market. These establishments serve as a point of exchange where food brought in from outside the community is transferred to those who will prepare and ingest it. The retail channel is bypassed when foodservice organizations have food directly delivered to them from outside the community. Some food is disposed from retail channels, usually dairy products and fresh fruits and vegetables that are past their prime.

Consumer and Foodservice

This segment includes any household or organization that prepares food for ingestion, including restaurants, schools, hospitals, and business/commercial cafeterias. Food waste is the difference between the food purchased from retail establishments or brought in from outside the community and the food actually ingested. Food waste is created when perishable food that has not been used soon enough is disposed, when inedible portions are removed during food preparation, and when food is left on the plate after a meal. Food wastes are disposed into MSW, given to a food bank or rescue program, composted, or added to the sewer system through a disposal device or simply by being poured down the drain.

Food Bank and Rescue Programs

Food banks ask for donations of food from individuals and organizations. They maintain a stock of food and distribute it to local residents who cannot otherwise afford it. Food banks focus on packaged, non-perishable foods. Food rescue programs focus on perishable items such as dairy foods, baked goods, and fresh produce. They collect food that is still safe and edible but otherwise would have been disposed into MSW and redistribute it those who cannot afford it.

Local Gardens

Only eight acres of city land are zoned for agricultural use, so food production within the community is primarily in small household produce gardens. The city does not have a system in place to collect and compost food wastes, but it encourages individuals and organizations to compost their own food wastes. This compost is used to fertilize community soil, typically by being spread over an individual's yard or in their garden. The city does collect yard wastes for composting and sells the compost.

Human Metabolism

The human body ingests food and water and uses them for several purposes. A small portion is used to build human tissue ranging from hair to blood cells to muscle cells. This tissue functions as part of the body for a while and is eventually released into the environment by sloughing off dead skin cells or through release into the bowels. Food is also used to generate energy for the body's use. This food and water will be released as water vapor or carbon dioxide through respiration and sweat or will be excreted as urine or feces.

Water Treatment and Water Distribution Systems

The Ann Arbor Water Treatment Plant collects water from the Huron River and local wells and prepares it for human use. All water is treated to be clean enough to drink, regardless of its final use. Water is distributed for use via 420 miles of mains throughout the City of Ann Arbor, Ann Arbor Township, Scio Township, and a small number of residences in Pittsfield Township. The service area for the Ann Arbor water treatment and supply system extends beyond the community boundary of this study, so the inflow estimates for water only include that portion of the water used for the City of Ann Arbor.[28] Evaporation and leaks cause water losses from the water distribution system. These losses are not explicitly modeled in this study.

Water Use

Water is used for a wide variety of purposes, including drinking, cooking, bathing, flushing, clothes washing, and industrial use. Most water goes down a drain into the sewage collection system after being used. Water used outside to water lawns or wash a car may be diverted to groundwater, to the storm water system, or it may evaporate into the atmosphere.

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[28] Ann Arbor Water Utilities. <http://www.ci.ann-arbor.mi.us/framed/Utilities/WTP/index.htm> 20 Apr. 2000.

Sewage Collection System

This system collects wastewater and sewage from the City of Ann Arbor, Ann Arbor Township, Scio Township, and Pittsfield Township and transports it to the wastewater treatment plant via 327 miles of sewer pipes. Only outflows associated with sewage generated by the City of Ann Arbor are included in this study. Volumes arriving at the wastewater treatment plant increase during rainstorms, indicating that some rainwater does infiltrate into the sewage collection system. For example, many homes have drains around the footings of the house that lead to the sewage system.

Wastewater Treatment

The Ann Arbor Wastewater Treatment Plant cleans wastewater and sewage delivered by the sewage collection system and discharges the clean water into the Huron River. Material removed from the sewage includes filtered grit and dirt, biosolids, and scum. Bacteria are used to digest and remove biosolids, and, just as in human metabolism, some of the biosolids eaten by the bacteria is released into the atmosphere in the form of carbon dioxide gas. Note that outflows for biosolids, scum, and water are estimated based only on the City of Ann Arbor's share of the sewage being treated.[29]

Storm Water System

This system collects runoff rainwater and discharges it into the Huron River. Its service area is the City of Ann Arbor only.

Data Sources

The data sources used for the food and water estimates are described below and are also described in further detail in Appendix B.

USDA Report – Food Consumption

The United States Department of Agriculture (USDA) Report, *Food Consumption, Prices, and Expenditures, 1970-97* is the main data source used for food inflow data.[30] It

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[29] CACHE Corporation. Material & Energy Balances. Vers. 2.0. Computer software. Multimedia Education Laboratory. University of Michigan. Macintosh / Windows CD-ROM. This CD-ROM has a module that shows the layout of the Ann Arbor Wastewater Treatment plant and steps through its processes**.**

[30] Putnam, Judith Jones and Jane E. Allshouse. "Food Consumption, Prices, and Expenditures, 1970-97." United States Department of Agriculture. Statistical Bulletin No. 965. Food and Rural Economics

estimates food consumption based on the mass of basic food ingredients unaccounted for in food stocks, production, international trade, and non-food uses as shown in the below equation.

U.S. Food Consumption = Beginning Stocks + Production + Imports
- Ending Stocks - Farm and Industrial Use - Exports

The resulting mass estimate is a "primary weight," which is the mass of raw food ingredients. For each food type, the primary weights are converted to an estimated "retail weight" to represent the mass of finished food products on store shelves. These retail weights are used to create the inflow estimates for food because food enters the community as a finished product. The USDA recognizes the limitations of their retail weight data in their report:

> "Most available data are concentrated near the farm and primary processing levels. There are little or no data available for many further-processed products, such as bread, other bakery products, and soup. In short, relatively good data exist for many of the ingredients, but not for final products."

A helpful study to address this issue would be to estimate food consumption through a sampling of grocery stores and other food distribution channels. The study would group items as customers would identify them, not by their ingredients. For example, categories would include soup and pasta sauce, but not the vegetables, meat, and pasta used to make these food products. Such a study could be a useful mechanism to capture data on food packaging as well.

The USDA provides another report that estimates food intake by individuals.[31] While this a more accurate depiction of the mass of food in product form, it was not used for the

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Division, Economic Research Service, USDA. <http://www.econ.ag.gov/epubs/pdf/sb965/index.htm> 20 May 2000.

[31] Agricultural Research Food Service Group. Agricultural Research Service. Data Tables: Results from USDA's 1996 Continuing Survey of Food Intakes by Individuals and 1996 Diet and Health Knowledge Survey. U.S. Department of Agriculture, 1997. <http://www.barc.usda.gov/bhnrc/foodsurvey/home.htm> 18 May 2000.

inflow estimate because it does not include food inflows to the community that become wastes during storage and food preparation.

USDA Report – Food Expenditures

Food expenditures data are taken from another USDA report, *Food Expenditure Indicators*. The expenditures data are based on the price paid for the food by the last customer, whether an individual buying food at a grocery store or a hospital buying food from a food supply company. The USDA estimated expenditures based on sales data from companies that sell food.[32]

Food Scraps in MSW

The estimate for food scraps in MSW is based on a Franklin Associates report that characterizes MSW in the United States, though adjustments (detailed in Appendix B) are made based upon Ann Arbor's active composting and food rescue programs.[33]

Local Water

Data for water inflows and outflows, biosolids, and scum were gathered from various departments of the City of Ann Arbor and are specific to Ann Arbor water systems. Much of the local data is organized by fiscal year rather than calendar year. In most cases, estimates are based on the fiscal year July 1, 1997 to July 1, 1998.

Assumptions

The methods used to estimate the mass and economic value of material flows related to food and water rely on several assumptions described in detail in Appendix B. A few of the more important assumptions are listed below in Table 4-2.

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[32] Food Expenditure Indicators. United States Department of Agriculture. <www.econ.ag.gov/briefing/foodmark/expend/expend.htm> 19 April 2000.

[33] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update. United States Environmental Protection Agency, July 1999. <http://www.epa.gov/epaoswer/non-hw/muncpl/mswrpt98/98charac.pdf> 16 Mar. 2000.

Table 4-2 Major Assumptions for Food and Water Estimates

Assumptions
1. There are no daily or seasonal changes in Ann Arbor's population. 2. The community of Ann Arbor is identical to the United States on a per capita basis for the following items: • mass of each type of food consumed • financial resources spent on food • food wastes generated (before composting and food rescue programs) 3. The community of Ann Arbor is identical to the larger service area of its water systems on a per capita basis for the following items: • volume of water used • volume of sewage generated • fees paid for water used

Each of these assumptions is discussed further below:

Assumption 1: There are no daily or seasonal changes in Ann Arbor's population.
The estimates for food inflows are based on the year-round consumption of food by Ann Arbor residents. Thus it is assumed that all meals are eaten in the community even though residents who commute to work and travel outside Ann Arbor will eat a significant number of meals outside the community. Similarly, meals eaten within Ann Arbor by people who are not residents (such as commuters) are not included in the inflow estimates. It is not known to what degree these factors balance each other or make inflow estimates too high or too low.

The food inflow estimates also do not include the impact of seasonal changes in food consumption caused by the presence of a large student body. About one-third of the population of Ann Arbor is undergraduate and graduate students, many of whom leave the community during the summer. Actual food consumption may therefore be lower than is estimated in this report.

Assumption 2: The community of Ann Arbor is identical to the United States on a per capita basis for the following items: mass of each type of food consumed, financial resources spent on food, and food wastes generated (before composting and food rescue programs).

Estimates for food consumption, food expenditures, and food scraps in MSW are available for the United States. This assumption enables these data to be used to create estimates for Ann Arbor. Multiple factors described later in the discussion of results (Observation 8) make differences between Ann Arbor's food consumption per capita and the national average difficult to estimate.

Assumption 3: The community of Ann Arbor is identical to the larger service area of its water systems on a per capita basis for the following items: volume of water used, volume of sewage generated, and fees paid for water use.

The Ann Arbor Water Treatment plant supplies water for the City of Ann Arbor, Ann Arbor Township, Scio Township, and a few households in Pittsfield Township. This assumption enables data for the total volume of water used and the total water fees to be scaled down to Ann Arbor on a per capita basis. Similarly, the Ann Arbor Wastewater Treatment plant has the same service area except that it serves all of Pittsfield Township. This assumption enables data for the total volume of treated wastewater and biosolids to be scaled down to Ann Arbor on a per capita basis. This assumption is reasonable as long as there are no major industries who are major users of water (agriculture, manufacturing, etc.) and who are disproportionately represented in either the City of Ann Arbor or in the townships. Large differences in the indoor use of water between the City of Ann Arbor and the townships are unlikely, but outdoor use can vary widely between communities, which could make this assumption less accurate. It is not known whether actual Ann Arbor use of water would be higher or lower than the quantities estimated using this assumption.

Summary of Estimation Process

The estimates for the inflows and outflows for food and water are created using the steps described below. A step-by-step description of the estimation process can be found in Appendix B.

Food Inflow Mass

The mass is estimated by finding the per capita retail weight for each type of food and beverage from the USDA *Food Consumption, Prices, and Expenditures, 1970-97* report. These retail weights are multiplied by the population of Ann Arbor to get an estimate for the city and then summed for a total inflow estimate. In most cases the retail weight is readily available, but additional calculation steps are needed to estimate the retail weight for some food types.

Food Inflow Value

The economic value of food inflows is estimated based on food expenditures. Total U.S. food expenditures are divided by the U.S. population to get a per capita estimate and then multiplied by the population of Ann Arbor.

Food Scraps

Food scraps are estimated by taking a national food waste generation estimate and adjusting it to Ann Arbor's population size on a per capita basis. Estimates for the mass of composted food and the food reclaimed by the Food Gatherers food rescue program are subtracted from the food waste estimate because both of these activities keep food in the community and reduce the wastes entering MSW as food scraps.

Water and Biosolids

The estimates for the mass and economic value of water inflows, the mass of water outflows, and the mass of biosolids and scum are all based on the same method. The total amount reported for the water system's service area is adjusted to Ann Arbor's population size on a per capita basis to reflect Ann Arbor's portion of the total.

Results and Analysis

The final estimates for the mass and economic value of material inflows and outflows related to food and water are shown in Table 4-3.

Table 4-3 Food and Water Inflow and Outflow Estimates

Material Type	Inflow Value (in millions)	Inflow Mass (in tons)	Outflow Mass (in tons)
Food and Beverages	$330	130,000	13,000*
Water	$9.7**	22,000,000	21,000,000
Total (rounded)	**$340**	**22,000,000**	**21,000,000**

*Outflow mass is made up of 7,900 tons of food scraps in MSW and 4,700 tons of biosolids and scum. Note that much of the water content of food and beverages will leave the community as part of the water outflow.
** This value only includes charges for water supply. Ann Arbor's share of sewerage charges (which are billed based on water use) is an additional $9,400,000.

In Figure 4-2, the width of the arrows is proportional to the mass of the inflow and outflow of each material type. The flow of water is so large, however, that it has been shown on a different scale than the food flows. Dotted arrows indicate material flows not modeled.

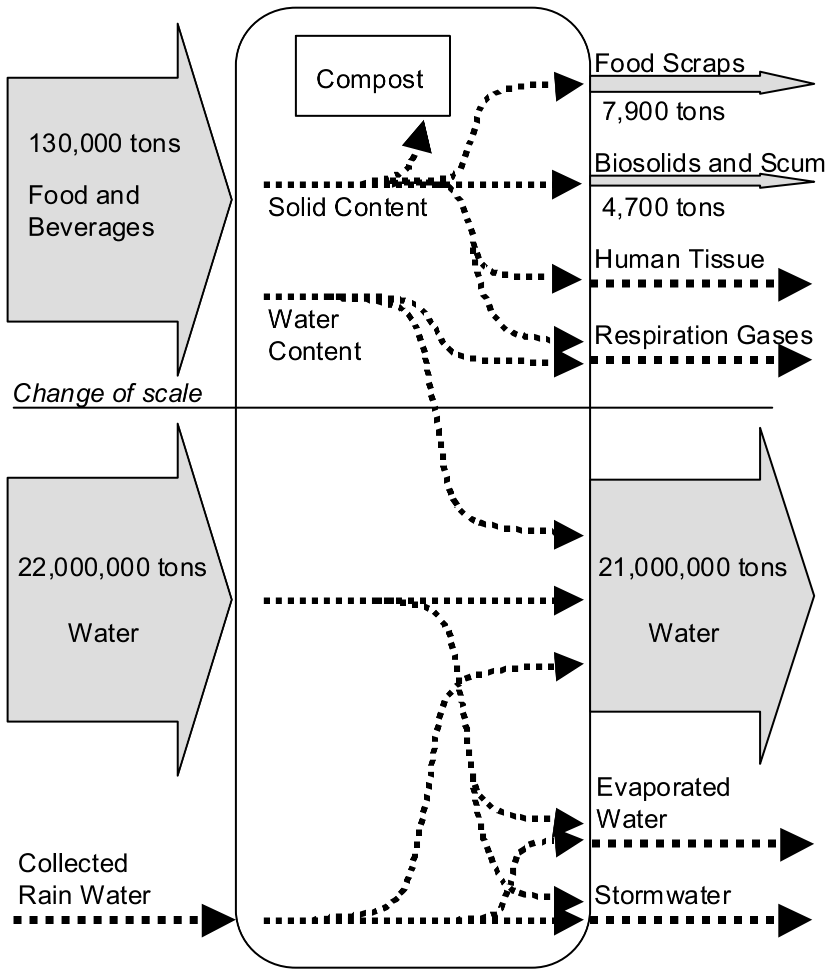

Figure 4-2 Food and Water Mass Flow Diagram

Dotted lines outside the community boundary represent direct material flows not modeled. Dotted lines inside the boundary show connections between the inflow and outflow materials.

Analyzing the details behind these estimates results in several observations, stated in Table 4-4 below. The data upon which these observations are based can be found in Appendix B.

Table 4-4 Observations of Food and Water Estimates

Observations
1. Water is the most important food ingredient.
2. The large difference between food inflows and outflows occurs because most food leaves the community as a gas or liquid, not as food scraps in MSW or biosolids.
3. Water inflows are larger than outflows due to the net effect of exchanges of water between the water supply and sewage systems and other water systems and are not related to a growth in the stock of water.
4. Water inflows and outflows are massive and inexpensive.
5. Food Stores and Restaurants Dominate Food Sales.

Observation 1: Water is the most important food ingredient.

Table 4-5 shows the estimated mass of inflows for various food types. The USDA categorizes milk as a dairy food, not as a beverage. The dry weight of coffee beans and tea leaves are included as a food. Coffee and tea are not included as beverages (with the exception of canned iced tea). The assumption is that coffee and tea are made within the community using tap water.

Table 4-5 1997 Food and Beverages Inflow Mass for Ann Arbor Based on National Retail Weight

Foods	Mass (tons)	% of total	Beverages	Mass (tons)	% of total
Dairy Products	16,000	12.5%	Carbonated soft drinks	24,000	18.8%
Meat, poultry, and fish	12,000	9.3%	Alcohol	11,000	8.9%
Flour and cereal products	11,000	8.5%	Fruit juices and drinks	7,900	6.2%
Vegetables - Fresh	9,300	7.3%	Bottled water	5,900	4.6%
Caloric Sweeteners	8,300	6.5%	Canned iced tea	360	0.3%
Fruits - Fresh	6,800	5.4%	Vegetable Juices	140	0.1%
Vegetables - Processed	6,600	5.2%	**Total Beverage Mass**	**49,000**	**39%**
Fats and oils	3,700	2.9%			
Eggs	1,700	1.3%			
Fruits - Processed	1,300	1.0%			
Coffee, tea, and cocoa	640	0.5%			
Treenuts and peanuts	460	0.4%			
Spices	160	0.1%			
Total Food Mass	**77,000**	**61%**			

Numbers may not sum due to rounding.
Based on: Putnam, Judith Jones and Jane E. Allshouse. "Food Consumption, Prices, and Expenditures, 1970-97." United States Department of Agriculture. Statistical Bulletin No. 965. Food and Rural Economics Division, Economic Research Service, USDA. <http://www.econ.ag.gov/epubs/pdf/sb965/index.htm> 20 May 2000.

Tap water used for drinking and cooking is included in the inflow estimate for water and is excluded from the inflow estimate for food and beverages. Despite this exclusion, water is the largest ingredient or component in the inflow of fresh and packaged food and beverages. Beverages are primarily water, and they represent 39% of the mass of food and beverages (48% if liquid milk is included as a beverage). Other food items contain significant amounts of water, especially fruits and vegetables, which make up a large portion of the remaining solid food. Some packaged foods such as soup, canned fruits, and canned vegetables contain large amounts of water which are unaccounted for in the food and beverage estimates.

Carbonated soft drinks represent the single largest inflow of mass into the community of any type of food. This estimate is based on the assumption that carbonated soft drinks enter the community as a complete product in cans and bottles and not in the form of syrup to be mixed with tap water, so the inflow mass of carbonated soft drinks may be overstated. Also, there may be some double counting between the caloric sweeteners reported as food and their use in carbonated soft drinks.

Observation 2: The large difference between food inflows and outflows occurs because most food leaves the community as a gas or liquid, not as food scraps in MSW or biosolids.

An immediate question that arises upon examination of the food flows is why the inflow mass is so much larger than the mass of food scraps and biosolids. Reasons for this difference are listed below.

- As discussed earlier, the water content of the food and beverages inflow is large. The water content of food and beverages inflows leaves the community in one of three ways: it is transpired into the atmosphere by the human body as water vapor, it evaporates into the atmosphere while traveling through the sewage collection system, or it becomes part of the water outflow and is returned to the Huron River.
- Food undergoes a fundamental transformation as it moves through the community due to human metabolism. Most of the dry weight of food that is ingested leaves the body as carbon in exhaled carbon dioxide. These respiration gases enter the atmosphere and are not counted among the food outflows.
- Some food wastes are diverted from MSW by Food Gatherers.

- Composted food is not included among the outflows.

Observation 3: Water inflows are larger than outflows due to the net effect of exchanges of water between the water supply and sewage systems and other water systems and are not related to a growth in the stock of water.

The inflow of water is about two million tons greater than the outflow of water as estimated in this report. This difference is caused by the exchange of water between the water supply and sewage systems modeled in this study, other water systems in Ann Arbor, and water flows in the anthroposphere. These exchanges both add to and subtract from the flows of water between the time it enters the Water Treatment Plant as an inflow and the leaves the Wastewater Treatment Plant as an outflow. The sum of these exchanges is a net loss of two million tons of water to other systems.

Additions to the flows of water include the water content of food and beverages disposed in the sewage system and the infiltration of rain water that enters the sewage system rather than the storm water system. Water losses occur due to water evaporation throughout Ann Arbor's water system, diversion into the storm water system and additional evaporation during outdoor use, water ingested by humans, animals, and plants that is released in gaseous form as water vapor, and water that is exported in locally produced goods such as beverages.

Any changes in the stock of water play a small role in the difference between the inflow and outflow mass of water. The mass of the flow of water into and out of Ann Arbor each year is much larger than the mass of stored water. For example, the average mass of water flowing through Ann Arbor's water distribution system in a single day is approximately equal to the maximum mass of water that could be stored in the distribution system's reservoirs and tanks.

Observation 4: Water inflows and outflows are massive and inexpensive.

As will be discussed in Chapter 5, water is by far the largest flow on a mass basis of any material included in this study. The mass of water flows is so much larger than flows associated with food (the water inflow mass is almost 200 times as large as the food inflow mass) that the food flows can be considered to have an insignificant contribution to the total for this category when rounded off to the nearest million tons. In contrast, the economic value for the inflow food is about 34 times larger than that of water.

The ease of access to a relatively clean local water supply and the city's efficient distribution system make it possible to move large quantities of water for little cost. The City of Ann Arbor pays approximately $2,600 per ton of food and beverages but only 44 cents per ton of water (87 cents per ton if sewage fees are included).

Observation 5: Food stores and restaurants dominate food sales.

Figure 4-3 shows greater detail for the estimate of Ann Arbor's food and beverage expenditures based on data from the USDA.[34] The figure does not include expenditures for alcohol, but all other types of food and beverages are included.

Expenditures for food to eat at home account for slightly over half of total food expenditures. However, the proportion of expenditures for each channel shown in the figure is based on national averages, and Ann Arbor may have a different pattern or degree of spending. For example, the proportion of food purchased from schools and colleges is likely to be larger for Ann Arbor due to the presence of the University of Michigan.

Despite this concern, food stores and "eating and drinking places" clearly account for the majority of expenditures (about 75%). Ann Arbor residents are estimated to spend $130 million at food stores and $92 million at restaurants and bars for food and beverages, not including alcohol.

[34] Food Expenditure Indicators. op. cit.

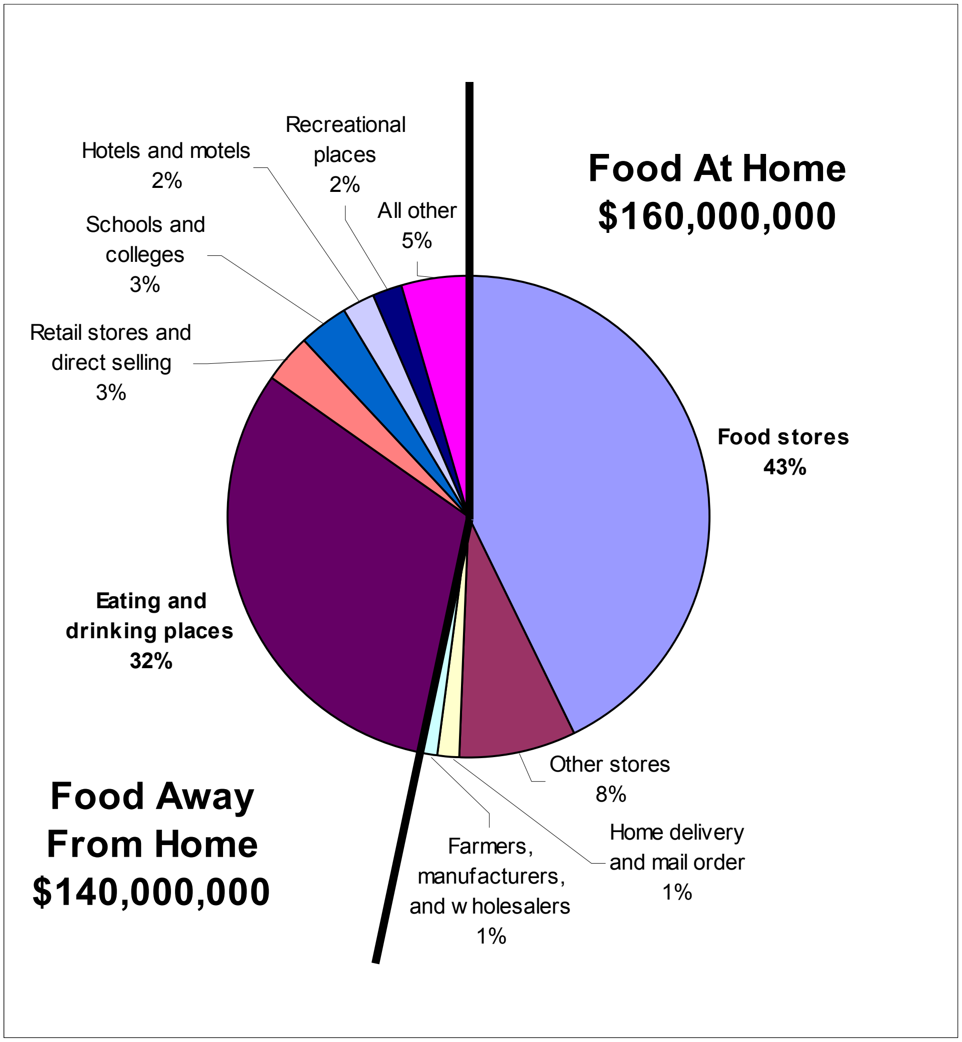

Figure 4-3 Ann Arbor 1997 Food Expenditures Based on National Data

Based on: Food Expenditure Indicators. United States Department of Agriculture. <www.econ.ag.gov/briefing/foodmark/expend/expend.htm> 19 April 2000.

Additional Discussion

Placing these results into a broader context of information about food and water results in the discussion points listed in Table 4-6

Table 4-6 Additional Food and Water Observations

Observations
6. About one third of all food inflows are lost as waste.
7. Food rescue programs can simultaneously reduce food wastes and efficiently reduce the community's required inflow of food.
8. Multiple factors make differences between Ann Arbor's food consumption and national consumption trends difficult to estimate
9. Almost one pound of food packaging is used to provide five pounds of food.
10. A significant amount of water is used by the University of Michigan, but most water is used by residents in toilets, washing machines, showers, and faucets.
11. Ann Arbor's toughest water issues are related to water quality, not water quantity.

Observation 6: About one third of all food inflows are lost as waste.

Not all food brought into the community serves its intended function of nourishment. Figure 4-1 was provided earlier to show the flows of food and water throughout the community at a high level. Figure 4-4 below shows additional detail for a subset of these flows related to food ingestion and losses, including the following:

- Inflow: Food is delivered to either a retail establishment such as a grocery store or to household consumers and foodservice providers such as restaurants and institutions. Retail establishments provide distribution and storage services, while consumers and foodservice providers perform the food preparation and act as the site of ingestion.
- Edible Loss: This flow contains food that is or was suitable for human consumption and yet is not ingested. Significant losses of food occur as milk spoils in a grocery store or household refrigerator, as edible produce is discarded during food preparation, and as part of a meal is left on a plate uneaten. Note that edible losses include food that has spoiled before it is discarded and food that is still in good condition when discarded. Separate flows are shown for retail losses and consumer and foodservice losses.
- Inedible Loss: This flow contains food parts that are discarded because they are inedible, such as bones, pits, and peels. These losses occur at retail establishments, but because they primarily occur during food preparation, they have been drawn as a waste flow from consumers and foodservice providers.
- Ingested: This flow contains food that is ingested by humans.

- Recovered: This flow contains food that would have otherwise been wasted had it not been for the Food Gatherers food rescue program. Food Gatherers distributes food to non-profit foodservice providers, as indicated by the dotted arrow, and food losses will occur once again when the recovered food is prepared for ingestion. However, for this analysis it is assumed that all recovered food is eaten as represented by the solid line.
- Food Wastes: This flow contains all edible and inedible losses that are not rescued by Food Gatherers. These food wastes have several possible fates, depending on whether they are discarded into a composting system, in the trash as food scraps in MSW, or down the drain to the sewage system.

Figure 4-4 also shows the estimated mass of food associated with each flow described above. Note that these estimates do not include beverages but do include all foods except for coffee, tea, cocoa, and spices. The methods were used to estimate each flow are described below. Appendix B contains additional detail about the data sources and methods used for data estimates for this observation.

- Inflow: The inflow estimates from Table 4-5 are adjusted to remove beverages, coffee, tea, cocoa, and spices.
- Losses: A 1997 article estimated the percent of edible food lost by retailers, consumers, and foodservice.[35] Data from the article are used first to estimate the portion of the 1997 inflow estimate that is edible for each food type. Next, food loss percentages for each major food type (1%-2% for retail and 15%-32% for consumer and foodservice) were applied to the edible food estimates. Summing the loss estimates for each food type creates the total estimates shown in Figure 4-4.
- Recovered: This estimate was provided by Food Gatherers.[36]
- Food Wastes: This estimate is calculated by subtracting the tons of food recovered from the total amount of edible and inedible losses.

[35] Kantor, Linda Scott, op. cit.
[36] Food Gatherers. Personal interview. 8 May 2000.

- Ingested: The first number shown is the inflow mass of food minus all losses. The second number includes the food recovered by Food Gatherers under the assumption that all recovered food is eaten. This estimate of 50,400 tons is validated by comparing it to the USDA estimate that 1.2 kg of the same food types is ingested daily by United States residents.[37] This is equivalent to an ingestion of 52,000 tons for Ann Arbor residents over a one year period.

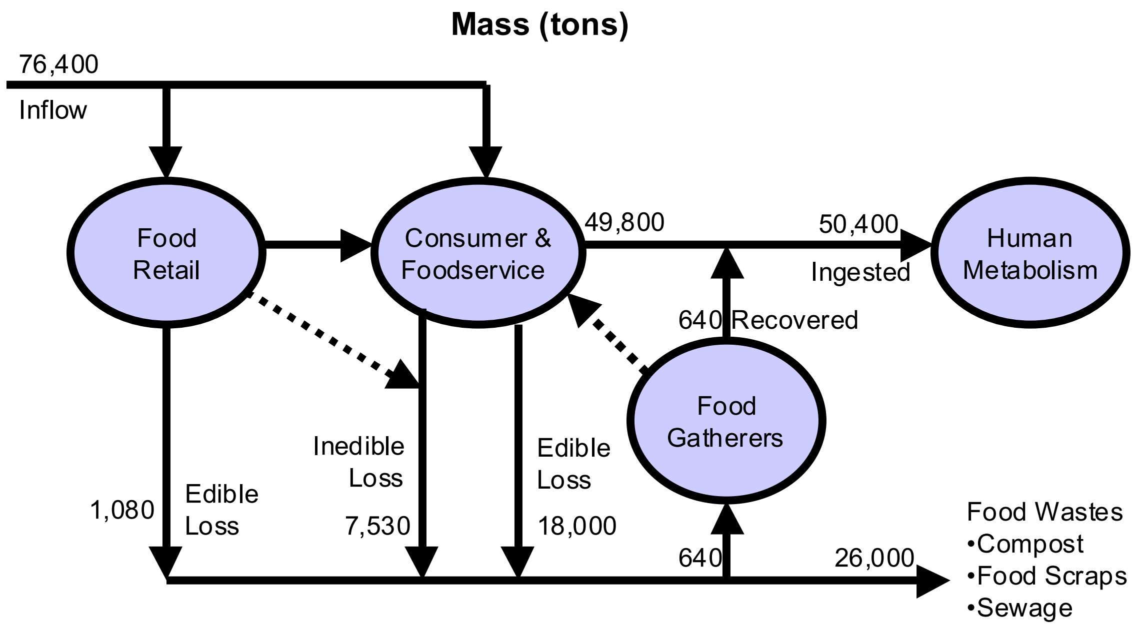

Figure 4-4 1997 Ann Arbor Food Inflow, Losses, Recovery, and Ingestion
Dotted lines represent flows not modeled.

Based on this analysis, Table 4-7 shows the efficiency with which food was used in Ann Arbor in 1997. The food losses are shown as a financial loss by assuming that all food types have the same value per ton. About two-thirds of all food entering Ann Arbor were used to provide nourishment, while one-third became food wastes. The losses associated with inedible food are unavoidable, so it is important to note that the efficiency of food utilization rises to three-fourth when only edible food is considered. In either case, the

[37]Agricultural Research Food Service Group. op. cit.

financial implications are significant, with losses measuring in the tens of millions of dollars.

Table 4-7 1997 Ann Arbor Food Mass and Economic Value Utilization Efficiency and Financial Losses

	Food Utilization Efficiency	Financial Loss of Inefficiency
Total food inflow	66%	$67,000,000
Total edible food inflow	73%	$53,000,000

Observation 7: Food rescue programs can simultaneously reduce food wastes and efficiently reduce the community's required inflow of food.

Another observation from Figure 4-4 is that efficiency improvements that occur further "downstream" closer to human ingestion can create larger savings "upstream" in the amount of food required as an inflow to the community. If it takes three tons of food as an inflow to the community to provide two tons of ingested food, then reducing the amount of ingested food required by two tons will in turn reduce the amount required as a community inflow by three tons.

With this observation, the value of food rescue programs becomes more clear. Not only do they reduce the amount of food wastes that must be managed, but they also reduce the need for food purchases associated with food drives and other food donations to feed community residents who cannot afford to feed themselves.

In Ann Arbor, Food Gatherers prevented 640 tons of food from becoming wastes in 1997. If it is assumed that all of this recovered food was ingested, then the need for an inflow of food to the community was reduced by 960 tons (640 tons divided by 66% efficiency utilization). A realistic estimate for this reduction including the effect of food losses from recovered food would be between 640 and 960 tons.

Most of the food rescued and distributed by Food Gatherers is perishables, such as dairy products and produce. This focus on perishables matches the food losses that occur in the community. Figure 4-5 shows how the 19,000 tons of edible food losses in Ann Arbor are distributed among different types of food. Fluid milk and fresh produce account for almost half of the losses.

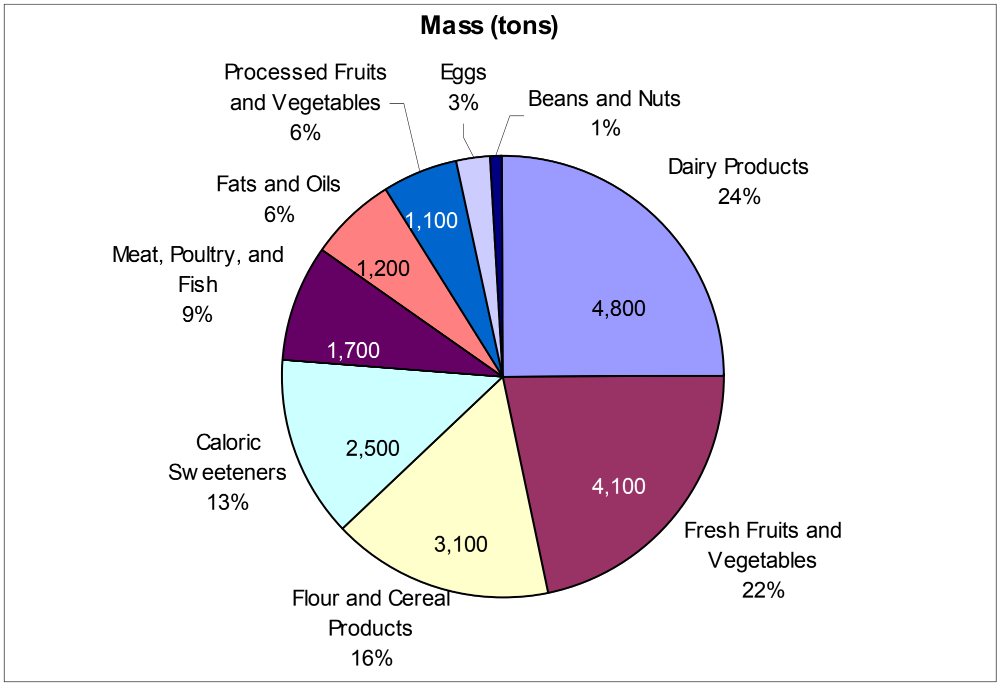

Figure 4-5 Mass of Edible Food Losses by Food Type in Ann Arbor in 1997 Based on National Data

Observation 8: Multiple factors make differences between Ann Arbor's food consumption and national consumption trends difficult to estimate.

Food mass and value estimates are based on national data adjusted for Ann Arbor on a per capita basis. This technique ignores any unique characteristics of Ann Arbor that may lead to larger or smaller material flows. However, whether any particular estimate is too high or too low is difficult to determine because arguments can be made for either direction.

For example, students are included in the population estimate for Ann Arbor alongside year-round residents, but many students leave each summer. This seasonal change in population reduces local inflows and outflows for food, a reduction that is not reflected in estimates for the mass and value of food inflows and food scraps in MSW computed using per capita data.

The high levels of disposable income among Ann Arbor residents may lead them to spend more per capita for food than the national average. A recent *Food Review* article studied regional variations in food expenditures and had the following conclusions about food spending patterns of high-income Americans.[38]

- In developed nations, the total quantity of food ingested is unlikely to increase with a raise in income.
- Expenditures will rise with income due to increased purchases of more expensive fresh foods, more processed food, more meals eaten out, and more refrigerated and frozen products.
- Often the increased expenditures are for improvements in the taste, nutrition, quality, or convenience of foods. These improvements require additional processing and labor but usually not additional quantities of farm commodities.

In summary, the mass estimate for the inflow may be accurate in the aggregate (if not for individual types of food), but the estimate for the economic value of food inflows may be an underestimate due to Ann Arbor's high average incomes.

However, the authors of the article make another point counter to this conclusion. They note that the Midwest region of the United States (of which Ann Arbor is a part) is the most frugal when it comes to food expenditures, and that this regional phenomena cannot be fully explained by regional average income levels.

Observation 9: Almost one pound of primary food packaging is used to provide five pounds of food.

Packaging used to store and transport food and beverages is an important indirect material for the food and water category. Two types of packaging are primary and secondary. Primary packaging includes all packaging for a product as it sits on a retail

[38] Jekanowski and Binkley. "Food Spending Varies Across the United States." FoodReview. 23:1, Jan.-Apr. 2000.

shelf or at a consumer's home. Secondary packaging, such as corrugated boxes, shrink wrap, and wood pallets, is used to store products and transport them to retail establishments.

Figure 4-6 shows the estimated amount of food and beverage primary packaging wastes for Ann Arbor in 1997. These data are based on the EPA's estimate for national municipal solid waste generation[39] adjusted to Ann Arbor's population size. Figure 4-6 includes only packaging that can be directly related to food and beverages. Some packaging types included such as folding cartons may be used for other purposes besides food. Packaging such as "bags and sacks" that are used for food but also commonly used for other purposes is not included. Estimates for all types of packaging and containers in MSW can be found in Appendix B.

Secondary packaging is also not included in this estimate because materials such as corrugated boxes are also commonly used for other goods besides food. As can be seen in Appendix B, the mass associated with materials commonly used as secondary packaging is significant.

[39] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update. op. cit.

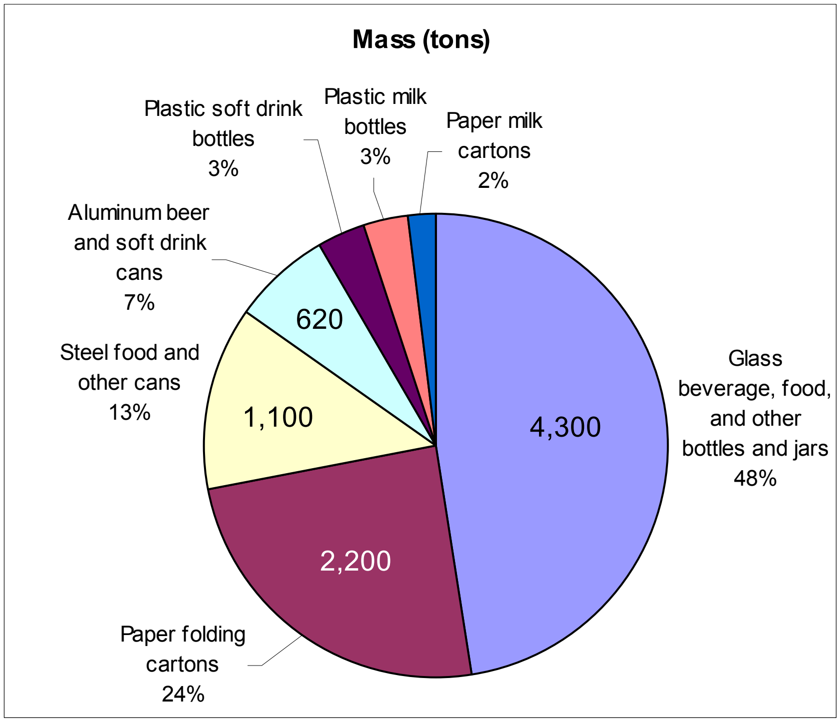

Figure 4-6 Estimated Food Primary Packaging Wastes Generated in Ann Arbor during 1997 Based on National Data

Source: Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update. United States Environmental Protection Agency, July 1999. <http://www.epa.gov/epaoswer/non-hw/muncpl/mswrpt98/98charac.pdf> 16 Mar. 2000.

The total mass of food packaging estimated for Ann Arbor is 22,000 tons and can be considered an estimate for both the inflow and outflow of primary packaging for food in 1997. This mass of packaging is 18% of the total mass of food and beverages. This mass for packaging can be considered an estimate for both the inflow and outflow of For every five pounds of food and beverage brought into the community, almost a pound of primary packaging is used to transport and store it. Almost half of the mass of primary packaging is associated with glass jars and bottles due to the heavy weight of these containers relative to other packaging materials such as paper and plastic.

The estimate for Ann Arbor packaging is based upon data for total municipal solid wastes and does not distinguish between recycled versus landfilled wastes. Considerable attention has been paid to food packaging wastes as recyclable materials. Ann Arbor provides curbside recycling services for every type of packaging included in Figure 4-6.

The State of Michigan requires that a 10 cent surcharge be collected for beer and carbonated soft drink bottles and cans, and that grocery stores pay back 10 cents when these bottles are returned to the store. This legislation has provided a strong incentive for the collection of these containers for recycling.

Although not a focus for this report, Ann Arbor should look beyond recycling to consider additional programs that encourage consumers to find ways to meet the need for transporting and storing food that use less food packaging, such as buying food in bulk.

Observation 10: A significant amount of water is used by the University of Michigan, but most water is used by residents in toilets, washing machines, showers, and faucets.

Table 4-8 shows the ten organizations who used the most water in 1997. Some of these water users are in the City of Ann Arbor, and others, such as Pittsfield Township, lie in the broader service area of the Ann Arbor Water Treatment Plant.

Table 4-8 Top Water Users for the Ann Arbor Water Treatment Plant

Organization Name	1997 Mass Used (tons)	1997 Amount of Billings (for water supply and sewerage)
University of Michigan	1,946,815	$1,735,662
Pittsfield Township	388,290	$244,927
Arrowwood	119,203	$122,545
Pheasant Run	118,844	$120,355
Colonial Square	95,461	$98,211
Ann Arbor Public Schools	69,239	$73,092
Washtenaw Community College	76,341	$68,475
Parke-Davis	57,150	$58,794
Botanical Gardens	51,138	$47,819
Concordia College	4,304	$4,813

Source: Stauder, Barch & Associates, Inc. Prospectus for City of Ann Arbor Sewage Disposal System and Water Supply System Revenue and Revenue Refunding Bonds. City of Ann Arbor. 17 Dec. 1998.

The University of Michigan alone accounts for 9% of the use of water treated by the plant. With the exception of Parke-Davis, a pharmaceutical manufacturer, all other major water users are educational institutions or residential developments such as a neighborhood or a large apartment house.

Based upon an estimate of 80 gallons of water used per person per day for residential uses,[40] the total mass of water used by residents in Ann Arbor was over thirteen million tons, or 59% of Ann Arbor's total use. Figure 4-7 shows this use of water broken out by specific uses based upon the water use patterns in a typical home.

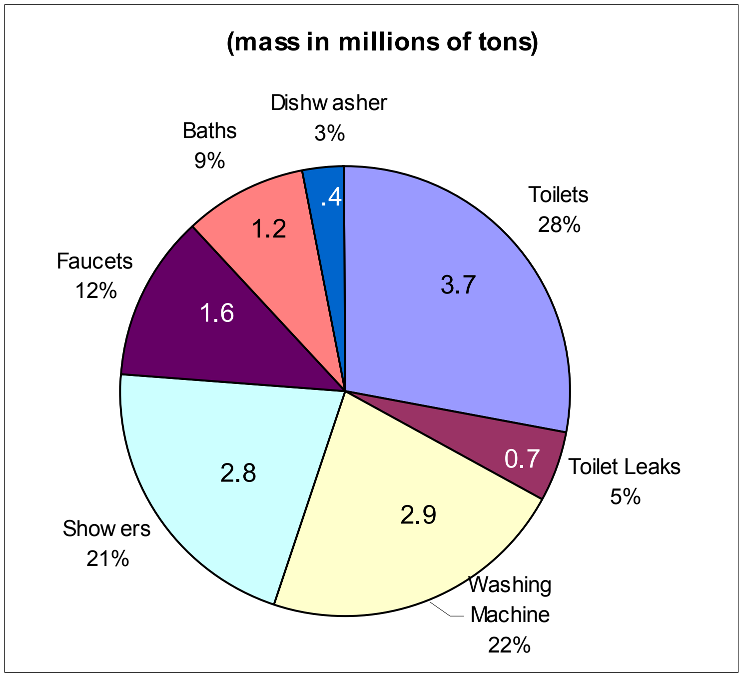

Figure 4-7 Mass of Total Ann Arbor Residential Water Use in 1997 Based on National Data

Woodwell, John C, et al. "Water Efficiency for Your Home: Third Edition." Rocky Mountain Institute. 1995. <http://www.rmi.org/images/other/W-WaterEff4Home.pdf> 20 May 2000.

Toilets, washing machines, and showers together account for over three-fourths of residential water use. Note that the smallest of these residential uses shown, the dishwasher, uses a quantity of water several times larger than the entire inflow of food and beverages.

[40] Woodwell, John C, et al. "Water Efficiency for Your Home: Third Edition." Rocky Mountain Institute. 1995. <http://www.rmi.org/images/other/W-WaterEff4Home.pdf> 20 May 2000.

Observation 11: Ann Arbor's toughest water issues are related to water quality, not water quantity.

Many cities around the country face daunting water shortages, but Ann Arbor is fortunately not one of them. Ann Arbor is the only city in Washtenaw County that does not take its water from local groundwater (except for Ypsilanti, which gets its water from Lake Erie). Though Ann Arbor takes some water from wells, most of its water is taken from the Huron River and returns it with small losses associated with evaporation and other causes. Michigan has enough year round precipitation that drawing too much water from the river is not a significant concern.

The most significant issue facing Ann Arbor related to water is emissions of phosphorous into the Huron River that are contributing to algal blooms in a downstream impoundment used for recreation. Many non-point sources exist, but the Ann Arbor Wastewater Treatment Plant is the most significant point source of phosphorous contributing to the problem. The Ann Arbor Wastewater Treatment Plant has been working in good faith with groups such as the Huron River Watershed Council to find ways to reduce its emissions.[41]

Other issues of concern to the Huron River Watershed Council include protecting the water quality of groundwater used for drinking by those not served by the Ann Arbor Water Treatment Plant and limiting the pollutants washed into the river during a storm.

Material Flow Recommendations

Table 4-9 contains suggestions for ways to improve the efficiency of material flows related to food and water. The table also indicates whether the suggestion is already in place in Ann Arbor or if there a recommendation for Ann Arbor for further action.

[41] Huron River Watershed Council. Personal interview. 18 May 2000.

Table 4-9 Material Flow Recommendations for Food and Water

Idea/Suggestion	Ann Arbor	Recommendation
Food rescue program	Food Gatherers	Explore expansion opportunities
Community supported agriculture	Farmers market, grocery stores, Community Farm of Ann Arbor, Project Grow	Explore expansion opportunities
Food loss reduction	Restaurant education	Consumer education, expand restaurant education
Composting	Home composting, University of Michigan, Del Rio Restaurant	Expand to restaurants, education, recognition
Water conservation and reuse	Residential user education	Many options, target residential and University of Michigan

Food Rescue Program

Food Gatherers is a food rescue program that operates throughout Washtenaw County. They collect food that would otherwise go to waste from restaurants, grocery stores, and other sources and distribute it to a wide variety of organizations that provide meals to the hungry. While the total amount of food rescued is only about 2% of all food wastes in Ann Arbor, the impact on the efficiency of food is important in its social impact. The recipients of food donations are those who may not otherwise be able to eat, so the functional benefit per unit of mass of food can be thought of as much higher than that of food consumed by other residents in Ann Arbor. Refer to discussion Observation 6 above for further discussion of the benefits of programs such as Food Gatherers.

Community Supported Agriculture

The production of food and other goods does not fall within the scope of this project. However, the production of food is important to discuss as a form of local production in which virtually any community can participate on a large or small scale. Supporting local food production can help provide a community with fresh produce that is often higher in quality because it did not need to be trucked long distances. It also supports local farmers and their livelihood.

Ann Arbor has several programs and businesses related to local food production.

- Farmers Market: This market operates year-round in the heart of Ann Arbor and provides residents with an opportunity to purchase produce and other items from local farmers and artisans. The Farmers Market only allows sellers who live in Washtenaw County to participate to ensure that local businesses are supported.

- Grocery Stores: Several Ann Arbor grocery stores prefer to buy produce from local farmers when possible. The largest is Whole Foods, which purchases as many as 75% of its varieties of produce from local farmer during harvest season.[42]
- Community Farm of Ann Arbor: city residents can purchase a share of this farm located close to the City of Ann Arbor. Share owners receive farm proceeds in the form of deliveries of produce. A significant advantage for the farmer is that the share owners share in the risks of a bad year of low production.
- Project Grow: city residents can reserve a small plot of land in designated areas of several Ann Arbor parks to grow produce.

Food Loss Reduction

Reducing food losses has multiple positive benefits. These benefits include reducing food scraps in landfills, reducing packaging use, and reducing community expenditures on food. Of the food-related recommendations included in this chapter, food loss reduction has the greatest potential to improve the efficiency of food material flows. Food loss reduction is valuable because it focuses on lowering the inflow of food rather than on managing food wastes.

Food rescue programs collect donations from organizations ranging from grocery stores to dormitories. A food loss reduction program can reach households and smaller food providers missed by food rescue programs and may help to avoid losses, such as plate waste, that cannot be collected by food rescue programs. Changes in food consumption patterns and food technologies, such as improved packaging to extend food shelf life, can also have a large impact on food losses beyond any food loss education program.

Washtenaw County Department of Environment provides brochures for restaurants that discuss tips for reducing food losses associated with food preparation or spoilage. Ann Arbor may consider expanding this education program with more active engagement with

[42] Whole Foods, Ann Arbor. Personal interview. 1 Jun 2000.

restaurants to address food loss reduction and composting. Education programs should also be directed to household consumers to help them avoid food losses. Helping consumers to understand manufacturers' expiration codes and "use-by" and "sell-by" dates, to distinguish between spoiled and safe food, and to use appropriate portion sizes can all help reduce unnecessary discard of food items.

Composting

Washtenaw County and Ann Arbor municipal governments educate and encourage residents to compost home food scraps by providing composting information and workshops. Though residential yard wastes are collected by the City of Ann Arbor to be composted, food scraps are not collected. The compost created from yard wastes is made available for sale to Ann Arbor residents.

The City of Ann Arbor began a program with the University of Michigan in which food scraps are collected from kitchens in University dining halls for composting along with the City's residential yard wastes. The three participating dining hall kitchens collected 31 tons of food waste during the 1997-98 school year.[43]

The Del Rio, an Ann Arbor restaurant, sends 40 gallons of vegetable peelings each week to Community Farm of Ann Arbor (described above) to be composted.[44] The Del Rio is an exception. Most restaurants do not bother to compost their food wastes, and most would find it difficult if they tried because they produce too much food wastes each day to compost in a backyard lot.

The Cornell Waste Management Institute Food Scrap Composting Project addressed this issue in Ithaca, New York. The project leaders held workshops and sent videos to educate restaurants and institutions about composting. They were unable to build interest

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[43] University of Michigan Recycling Food Composting Program. University of Michigan Plant Operations. <http://www.recycle.umich.edu/grounds/recycle/food_composting.html> 2 Jun. 2000.

[44] 1999 Waste Knot Award Winners: Restaurants. Washtenaw County Department of Environment and Infrastructure Services. <http://www.co.washtenaw.mi.us/depts/eis/wk99.html#Restaurants> 2 Jun. 2000.

among local retail grocers but were successful in recruiting restaurants. They managed a central composting facility and coordinated pickup from various local restaurants..[45]

A similar program in Ann Arbor may create several benefits. Restaurants are an important segment to target because they are responsible for a large portion of edible food losses (see Figure 4-4) and food expenditures (see Figure 4-3). Food wastes would be turned into a useful product, compost, instead of adding to the landfill. As restaurant staff became better educated about their own food wastes, they would become more likely to adopt practices to avoid creating these wastes in the first place. This reduction in waste creation would be even more valuable than the composting because it would reduce the amount of food inflow required to meet the community's need for food. An award program for local restaurants could be used to create a public awareness in the program which in turn could lead to additional household composting and avoidance of creating waste.

Water Conservation

Although water use for Ann Arbor is not a pressing issue, the community should still investigate opportunities to meet its needs with less water. Water conservation will help minimize water treatment costs and may help prevent the need to invest in additional water treatment and distribution equipment as Ann Arbor continues to grow and develop.

A detailed description of every water conservation technique is beyond the scope of this report, but they include efficient toilets and showerheads, landscaping designs that require less water, industrial reuse of water, rainwater and grey water recovery, and community engagement. Recovery and reuse of water before it enters the sewage system is helpful because activities that do not require water pure enough to drink, such as cleaning, predominate the use of water.

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[45] Cornell Waste Management Institute Food Scrap Composting Project. Cornell University. <http://www.cfe.cornell.edu/wmi/Compost/CaseStudies.html> 15 May 2000.

Ann Arbor should target its water conservation programs towards residential users, who use the majority of the city's water, and the University of Michigan, which is the single largest user of water.

Chapter 4.2: Shelter

Shelter provides protection from the weather, danger, and allows for privacy.[46] Shelter is available for both residential use, including single family dwellings and apartment buildings, as well as for nonresidential purposes such as office buildings, retail stores, commercial uses, and schools. Activities associated with providing shelter include construction of new buildings, maintenance and repair, renovation of existing structures, and demolition.

Category Description

This analysis looks at the sum of materials required for construction and renovation of residential and nonresidential buildings and the waste materials generated by construction, renovation, and demolition. Certain materials have been excluded from the analysis, including some materials that directly meet the need for shelter, and indirect materials that provide a supporting role. Table 4-10 lists materials related to the provision of shelter. Materials not included in this analysis are marked with an asterisk.

Table 4-10 Materials Associated with Shelter

Direct Materials	Indirect Materials
▪ Residential buildings ▪ Commercial buildings ▪ Retail stores ▪ Schools ▪ Office buildings ▪ Renovation - bathroom, windows, roofing ▪ Appliances* ▪ Flooring* - carpet, tile ▪ Furnishings*	▪ Maintenance & repair* ▪ Energy for heating, cooling, lighting* ▪ Retail stores selling building materials* ▪ Packaging* ▪ Transportation*

* This report does not include separate inflow or outflow estimates for these materials.

Direct Materials

The focus of this study is on structures that provide shelter including both residential and nonresidential buildings. Mass and economic value data for these buildings are available

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[46] "Shelter." Dictionary.com. WordNet® 1.6, © 1997 Princeton University. <http://www.dictionary.com/cgi-bin/dict.pl?term=shelter> 28 May 2000.

from the City of Ann Arbor Building Department. Appliances, flooring, and furnishings are excluded due to a lack of local data on the rate of addition and alteration of these products.

Indirect Materials

Maintenance and repair, packaging, and transportation are not included in this analysis because they are indirect materials. While they support the need for shelter, these materials alone do not provide shelter. Additionally, energy consumption by buildings, while a significant flow, is outside of the scope of this analysis.

Inflows and Outflows

The flows examined in this analysis are the materials associated with new construction, renovation, and demolition. Figure 4-8 provides an illustration of the flow of these materials through the City of Ann Arbor.

Based on available Census and waste composition data, the U.S. Environmental Protection Agency (EPA) developed six categories for building-related activities: new residential construction, new nonresidential construction, residential renovation, nonresidential renovation, residential demolition, and nonresidential demolition.[47] In order to maintain consistency with existing data, these categories have been used in this analysis. The City of Ann Arbor Building Department uses different terminology than the EPA to describe the same activities. These terms, which are used interchangeably in this report, are listed in Table 4-11.

Table 4-11 Clarification of Building-Related Terminology

EPA Terminology	Ann Arbor Building Dept. Terminology
Nonresidential	Commercial/Institutional
Renovation	Alteration/Addition

Waste generated during construction, renovation, and demolition is termed construction and demolition (C&D) debris.

[47] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, U.S. Office of Solid Waste and Emergency Response. Environmental Protection Agency, June 1998.

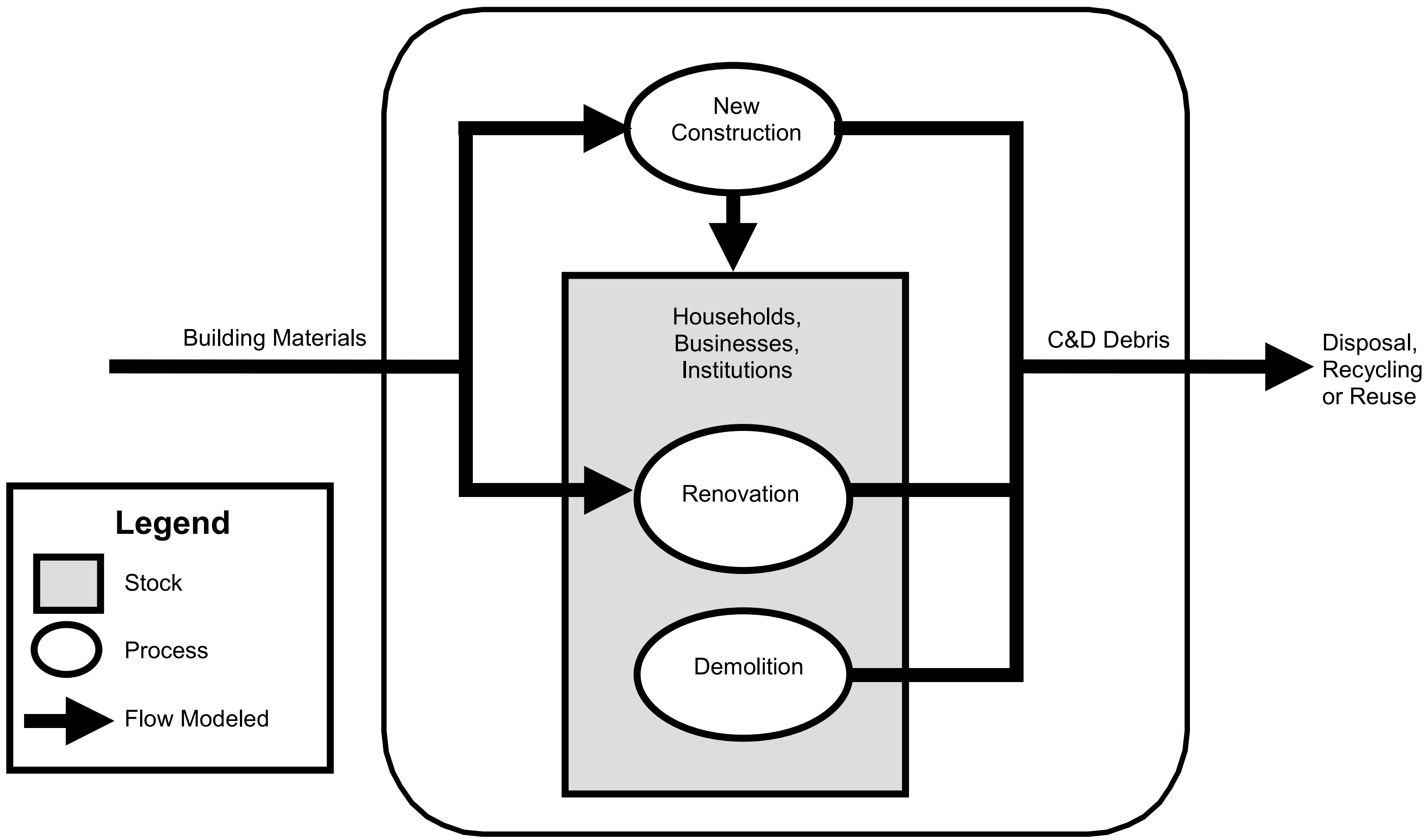

Figure 4-8 Shelter Direct Material Flows Through Ann Arbor

New construction

New construction adds to the stock of existing residential and nonresidential structures. Residential construction includes single family dwellings, two-family dwellings, apartment buildings, and townhouses. New nonresidential construction includes commercial buildings, offices, churches, retail buildings, assisted living facilities, and schools. Materials needed to construct the foundation and building shell are included in this analysis, but furnishings, appliances, machinery, and packaging materials are excluded. Some data sources may include these materials, and it is not possible to isolate these materials from the sum of other building materials. Building materials entering Ann Arbor are not based on delivery or sales of building materials by retailers located in Ann Arbor, but are based on the mass of materials required to supply the construction activities occurring in 1997. Debris generated during construction leaves the community and is either recovered for recycling or landfilled.

Renovation

Residential renovation includes activities that add to the stock (e.g. additions, new decks), alter or repair the stock (e.g. bathroom, basement), and replace existing stock (e.g. cabinets). A very small percentage of construction materials used for alteration projects are purchased or acquired through donation from either the Recycle Ann Arbor Re-Use Center, second-hand stores, or salvaged from other renovation projects. As described in Appendix C, certain residential renovations were eliminated from the analysis because of low total estimated cost, few permits issued, or the activity involved materials that would be difficult to characterize. The activities excluded are installation, repair, or replacement of the following: entry / door, fence, insulation, shed / barn, and sign / awning. Nonresidential renovation includes interior and exterior alterations of existing buildings. As mentioned in Table 4-10 furnishings, flooring, and general maintenance and repair are not included in the analysis.

Demolition

Building permits were issued for demolition of entire residential and nonresidential structures, as well as for demolition of garages and building interiors. This analysis did not identify masses of specific materials, such as wood, concrete, metal, and drywall generated in demolition, but instead looked at the total mass of debris generated.

Construction and Demolition (C&D) Debris

C&D debris is collected by three main groups in the City of Ann Arbor: private waste haulers, the City of Ann Arbor Solid Waste Department, and Recycle Ann Arbor. C&D debris is transported out of Ann Arbor and specific materials are either recovered for recycling or landfilled. A limited amount of C&D materials are recovered by Recycle Ann Arbor and reuse centers before leaving the city.

Data Sources

Three main data sources provide the basis for estimating the material flows required for meeting the shelter needs in Ann Arbor. These include the City of Ann Arbor Building Permits[48], EPA Characterization of Building-Related Construction and Demolition Debris in the United States[49], and interviews with Ann Arbor-area building contractors and waste haulers[50]. Additional details regarding data sources are provided in Appendix C.

City of Ann Arbor Building Permits

Construction activities occurring within the City of Ann Arbor are characterized based on building permits issued by the City of Ann Arbor Building Department in 1997. Building-related construction (e.g. carpet replacement, painting, minor repairs) that did not require a permit is not included in this analysis. Economic value is determined by

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[48] City of Ann Arbor Building Department. Building Permit. Ann Arbor: City of Ann Arbor Building Department, 1997.

[49] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit.

[50] Astro Building Products. Personal interview. 28 Mar. 2000.
Friedman, Larry. City of Ann Arbor, Community Development Department. Personal interview. 3 Aug. 1999.
Hunter, Therman. Calvert's Roll-Off Containers, Inc. Personal interview. 16 May 2000.
JC Beal Construction. Personal interview. 18 May 2000.
Laroe, Paul. Laroe Residential Remodeling. Personal interview. 16 May 2000.
Sloan, Maureen. Washtenaw County Home Builders Association. Personal interview. 10 Aug. 1999.
The Renewal Company. Personal interview. 15 May 2000.
York, Pat. Stanson Wrecking. Personal interview. 16 May 2000.

analyzing the Estimated Cost reported on each building permit. Estimated cost includes value of building materials, labor, and waste disposal.

Building permits from 1997 are sorted by type of construction activity. These categories are presented in Table 4-12.

Table 4-12 Categorization of Ann Arbor Building Permits

New Construction	Renovation		Demolition
Single Family Dwelling	Basement	Bathroom	Residential - Single & Multifamily
Two-Family Dwelling	Cabinets	Nonresidential Renovation	Garage / Storage Building
Apartment Dwelling	Deck	Entry / Door	Nonresidential
Townhouse	Fence	Foundation	Interior Demolition
Commercial / Institution	Garage / Carport	Insulation	Miscellaneous / Unknown
	Kitchen	Porch / Patio	
	Residential Addition	Residential Interior Alteration	
	Roofing	Shed / Barn	
	Siding	Sign / Awning	
	Windows		

Except for nonresidential renovation, all renovation activities are placed into the category of residential renovation. A limitation of the categorization method shown in Table 4-12 is that, while most of the renovations are residential projects, some nonresidential projects are included, e.g. roofing and foundations for nonresidential buildings. This miscategorization leads to inaccuracy in comparisons between residential and nonresidential renovations. In addition, when making comparisons using the Ann Arbor Building Department Annual Reports, containing a yearly summary of issued building permits, nearly two-thirds of the permits are classified as 'Miscellaneous', rather than 'Alteration/Addition Residential' or 'Alteration/Addition Nonresidential'.

This analysis could have been more detailed if information on each project was available, e.g. total square footage per project, type of materials used (e.g. siding: vinyl, aluminum, wood; new commercial buildings: wood, steel, concrete frame). Building permits provide an excellent start for data collection on building-related material flows; however, the creation of a computerized system for tracking and collecting information would allow for a much more detailed analysis. According to a Building Department staff member, the Department is investigating a computerized system. Square footage of building projects could be quickly totaled, miscategorization could be eliminated, and an overall better characterization of the building-related activity could be generated.

EPA Characterization of Building-Related Construction and Demolition Debris in the United States

Generation of C&D debris is not tracked by the City of Ann Arbor because very little C&D debris is collected by the Ann Arbor Solid Waste Department. Therefore, C&D debris is estimated from data collected by the EPA on the generation of C&D debris. In 1998, the EPA took a new approach to characterizing the quantity and composition of building-related C&D debris[51]. This study was a first attempt to characterize C&D debris by using national Census Bureau data on construction industry activities with point source waste assessment data. Data are provided on waste generated from new construction, renovation, and demolition of both residential and nonresidential structures. Considerable uncertainty exists in the data because studies are based on very small sample sizes, and a standardized methodology and reporting format for waste assessment data have not been established. However, variation is inherent because construction practices vary depending on the builder, type of project, and materials used. The EPA report is a first step towards a better characterization of C&D debris.

Materials brought onsite for construction and the waste generated are not broken out by individual material due to the variability in data from waste assessments. Waste assessments are conducted by many organizations across the country, and each collected data and categorized materials using a different method. A consistent list of materials is not found for C&D debris, but the most commonly tracked materials are listed in Table 4-13.

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[51] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit.

Table 4-13 Composition of Waste Generated by Construction and Demolition Projects

	New Residential Construction	New Nonresidential Construction	Residential Renovation	Nonresidential Renovation	Residential Demolition	Nonresidential Demolition
Wood	X	X	X	X	X	X
Drywall	X	X	X	X	X	X
Concrete	X	X	X		X	X
Metals	X	X	X	X	X	X
Roofing	X	X	X	X	X	X
Brick	X	X	X	X	X	X
Cardboard	X	X	X	X		X
Asphalt	X	X				X
Plastics	X	X	X	X		

Calculation of waste generation rates, where applicable, are altered to reflect the size of projects occurring in Ann Arbor. Ann Arbor activities are often not available in the same units as the EPA waste generation data, e.g., square footage is not given for projects, but waste generation data are given in pounds per square foot. Waste assessment data are available for a limited number of building categories, so data are extrapolated for categories in which there were no data.

Ann Arbor Building Contractors and Waste Haulers

Residential and nonresidential building contractors and waste haulers have supplied information on size of average construction projects, trends associated with the construction industry in Ann Arbor, volume of materials generated, and types of materials commonly recovered. Quantitative data are not available for Ann Arbor C&D debris generation, but qualitative information has been provided.

Assumptions

A number of assumptions have been made in estimating materials flows. Some of these assumptions are worth discussing as they may have significant implications for the accuracy of estimates made in this analysis. Table 4-14 lists major assumptions; details on all assumptions are provided in Appendix C.

Table 4-14 Major Assumptions for Shelter Estimates

Assumptions
1. Ann Arbor construction and demolition debris generation rates are equivalent to rates in other parts of the United States.
2. Mass of inflow materials required for new multifamily and nonresidential construction can be estimated by summing debris generated from demolition and total scrap generated during new construction of a similar sized building.
3. Estimated cost and mass of material required for renovation are assumed to be proportional to the size of the project (square feet).
4. For activities that entail replacement of stock (e.g. windows), it is assumed that outflows equal inflows.
5. No materials are brought into the community for demolition, because this activity results in removal of stock.

Assumption 1: Ann Arbor construction and demolition debris generation rates are equivalent to rates in other parts of the United States.

Data on waste generation rates for Ann Arbor-specific projects are not available; therefore, EPA data collected from projects in other parts of the country are used as a substitute. This allows for use of data that are specific to the type of building project (e.g. specific data for new single-family dwellings and new nonresidential buildings, as compared to generic new construction data). Construction practices are known to vary widely, and it is not known if Ann Arbor builders generate more or less waste per project; however, this assumption implies that construction practices are consistent regardless of the builder or contractor.

Assumption 2: Mass of inflow materials required for new multifamily and nonresidential construction can be estimated by summing debris generated from demolition and total scrap generated during new construction of a similar sized building.

The mass of materials required for new construction is generally not available. For multifamily and nonresidential construction, demolition mass is used as a substitute for the mass of the completed structure because it is assumed that the mass of a building following construction is approximately equal to the material removed when the building is demolished. The rate at which waste is generated (i.e. pounds per square foot) is added to the demolition mass to account for the scrap that is generated during new construction.

Assumption 3: Estimated cost and mass of material required for renovation are assumed to be proportional to the size of the project (square feet).

Waste generation data are frequently given in terms of square feet of construction. Data on the size of all of the renovation projects are not available, so size is estimated based on the average cost per square foot of the projects with known size. This allows for calculation of the total square footage altered but implies that there is not variation in the cost per square foot. It is unclear what effect this assumption has on the estimation of renovation project size.

Assumption 4: For activities that entail replacement of stock (e.g. windows), it is assumed that outflows equal inflows.

Data are not available on the total mass of materials generated in projects like reroofing and window replacement. Mass data for the specific building material are multiplied by the amount of material replaced in order to estimate inflow (e.g. 4.7 lbs./window x 15 windows). Assuming that outflow equals inflow allows for an estimate of the outflow due to replacement. It is likely that this assumption results in an underestimation of the total inflow and outflow mass because some renovation projects involve not only material replacement but improvement. Improvements may include installation of additional windows, use of heavier replacement materials such as better insulating windows.

Assumption 5: No materials are brought into the community for demolition, because this activity results in removal of stock.

Demolition removes existing structures and does not add any material to the existing stock. Therefore, no materials need to be brought into the community for demolition.

Summary of Estimation Process

The following is a summary of the process used to estimate the flow of materials associated with shelter. A more detailed description of the estimation process is provided in Appendix C.

The flows of building materials through the City of Ann Arbor are estimated by determining the types of building-related activities occurring within Ann Arbor, and calculating the material inflows and outflows associated with each of these activities.

Data on building activities are based on building permits issued by the City of Ann Arbor Building Department in 1997. Waste generation data are obtained from studies conducted in other parts of the country.

New Construction

To estimate the inflow of materials required for new construction, the mass of materials generated per square foot by demolition is added to the mass of debris generated per square foot for new construction projects. As described in Assumption 2, this value represents the inflow of materials required per square foot for new construction. This inflow value is multiplied by the estimated square footage for each type of new building and by the number of building permits issued by the City of Ann Arbor for each type of new construction. Outflow mass is estimated by multiplying the waste generation rate per square foot by the estimated square footage for each type of new building and the number of building permits issued by the City of Ann Arbor. Estimated cost of new construction includes the cost of materials, labor, and waste disposal. Purchase of the lot is not included.

Renovation

The inflow of materials required for renovation is estimated by one or more of the following methods:

- Multiply mass of materials required (i.e. lbs./window, four 8'x19'x8" concrete walls), by the number installed (i.e. windows, foundations built).
- Sum estimated addition to stock (lbs./sq. ft.) and waste generation rate (lbs./sq. ft.). Multiply result by average square feet per project and by the number of permits issued for each type of project.
- When project entails replacement of stock (e.g. windows), outflow equals inflow.

Waste generated during renovation is estimated by one or more of the following methods:

- Multiply average square feet per project by the number of permits issued and the waste generation rate per square foot (lbs./sq. ft.7).
- Multiply number of permits issued by the waste generation rate per project (tons/project).

Estimated cost of renovation should include labor costs, even if the construction is performed by the homeowner and no actual labor costs are incurred. However, many homeowners only include cost of materials when estimating the cost on the building permit application. Estimated cost includes cost of waste disposal for contractor-built projects; however, homeowner do-it-yourself projects mostly likely do not include waste disposal since some C&D materials are collected with regular trash collection.

Many permits are issued for multiple construction activities (e.g. alteration of bathroom and replacement windows). In separating the activities listed on the permit, estimated cost is allocated to the first activity listed. Therefore estimated costs for each activity may be larger or smaller than actual cost depending on whether the activity is listed first or later on the permit.

Demolition

Demolition includes removal of entire residential and nonresidential structures, as well as garages and building interiors. It is assumed that there are no inflows of materials for demolition activities. Size and mass of the existing structures are estimated for each type of building structure demolished, and multiplied by number of permits issued. Estimated cost for demolition consists solely of labor and waste disposal costs, and, unlike every other building activity, does not include material costs.

Results and Analysis

Table 4-15 summarizes the calculations estimating the inflow value, inflow mass, and outflow mass of materials associated with shelter. Additional detail can be found in Appendix C.

Table 4-15 Shelter Inflow and Outflow Estimates

Activity	Inflow Value (million)	Inflow Mass (tons)	Outflow Mass (tons)
New Residential Construction	$ 33.6	65,000	1,500
New Nonresidential Construction	$ 27.0	41,000	1,000
Residential Renovation	$ 21.4	15,000	2,600
Nonresidential Renovation	$ 27.6	5,800	2,900
Demolition	$0.77	-	7,300
Total	**$ 115**	**128,000**	**15,000**

Figure 4-9 illustrates the flow of building-related materials into and out of Ann Arbor. The width of the arrows are proportional to the mass of the materials.

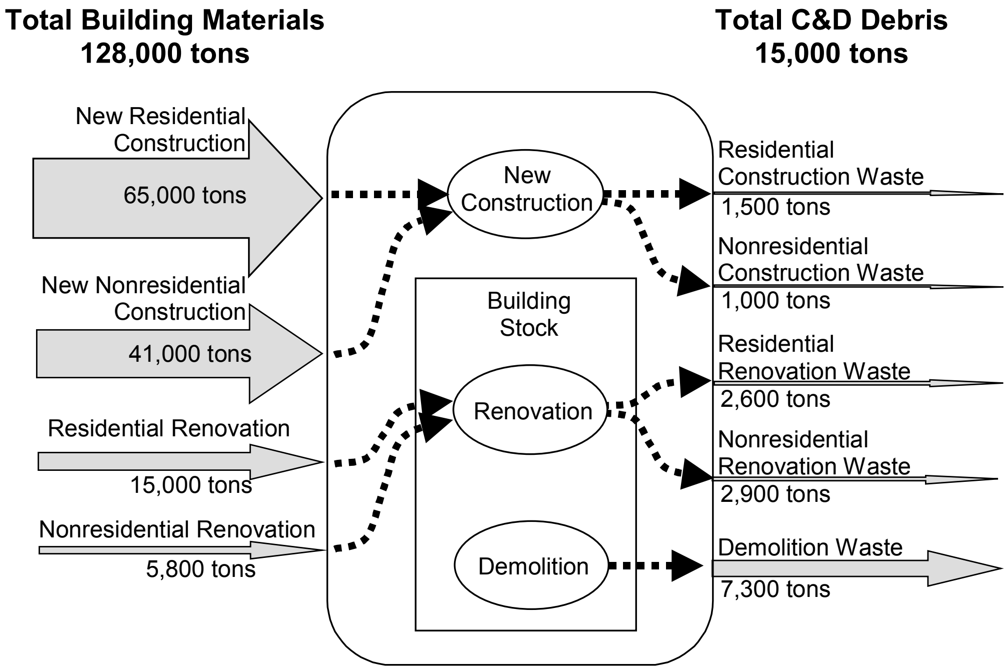


Figure 4-9 Shelter Mass Flow Diagram

Dotted lines show connections between the inflow and outflow materials.

Table 4-16 lists four observations that can be made from the detailed estimates of inflows and outflows. Following the table is additional detail and analysis of each observation. More detail on the data from which these observations have been made can be found in Appendix C.

Table 4-16 Observations of Shelter Estimates

Observations
1. The stock of residential and nonresidential buildings in Ann Arbor increased considerably in 1997. 2. Residential renovation accounts for a significant percentage of the building permits issued in Ann Arbor in 1997. 3. New construction is responsible for a significant percentage of the inflow mass and half of the estimated cost. 4. Nonresidential construction and renovation have an order of magnitude greater cost per permit than residential construction and renovation 5. The building sector that generates the largest total outflow mass is demolition. 6. Within residential renovation, roofing is the most common activity and generates the largest outflow of materials.

Each of these observations is described in further detail below.

Observation 1: The stock of residential and nonresidential buildings in Ann Arbor increased considerably in 1997.

The difference between inflow and outflow indicates that material is remaining in the community and adding to the existing stock of buildings. Inflows consist of new building materials, while outflows can be a combination of scrapped new building materials and materials removed from existing stock.

Table 4-17 Change in Stock of Shelter

Activity	Change in Stock (inflow – outflow)	% of Total Change	Comments
New Residential Construction	64,000 tons	57%	Outflow consists of construction debris
New Nonresidential Construction	40,000 tons	36%	Outflow consists of construction debris
Residential Renovation	13,000 tons	11%	Outflow consists of construction debris and/or existing stock
Nonresidential Renovation	3,000 tons	3%	Outflow consists of construction debris and/or existing stock
Demolition	(7,000) tons	-7%	Value is negative because activity only entails removal of existing stock
TOTAL	**112,000 tons**	**100 %**	

Note: values may not sum due to rounding.

Residential construction is adding the most mass to the building stock, followed by nonresidential construction and residential renovation. While demolition accounts for nearly half of the total mass of outflows, the inflow of materials is so much larger that removal of stock by demolition is outpaced by additions to the stock.

Observation 2: Residential renovation accounts for a significant percentage of the building permits issued in Ann Arbor in 1997.

As shown in Figure 4-10, residential renovation accounted for over 75 percent of the building permits issued in Ann Arbor in 1997, nonresidential renovation accounted for 7 percent, new construction represented 7 percent, and demolition 2 percent of the building permits issued.

In 1997, the City of Ann Arbor was estimated to have 43,381 occupied housing units.[52] With nearly 2,400 permits issued for residential renovation in Ann Arbor in 1997, approximately 5 percent of the occupied residential housing units in Ann Arbor were altered in 1997.

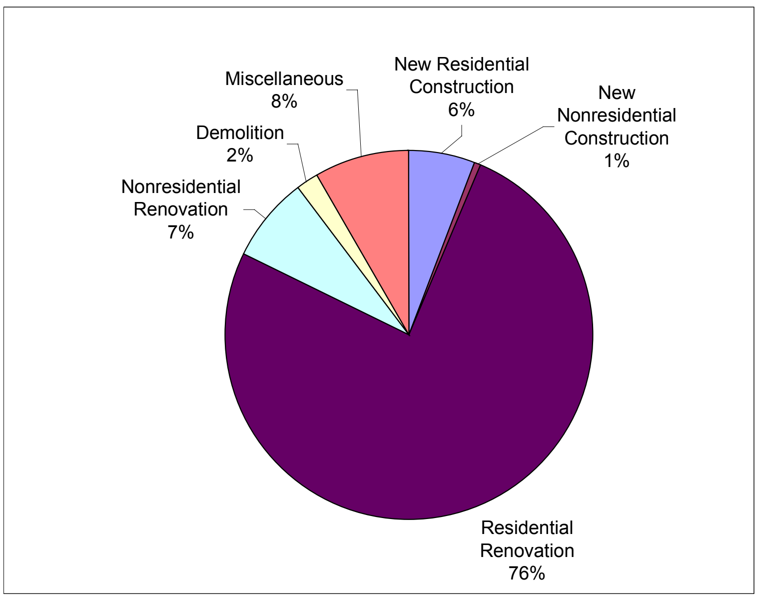


Figure 4-10 Breakdown of Number of Building Permits Issued, Ann Arbor, MI, 1997

However, as shown in Table 4-15, the total cost of residential renovation is lower than new construction and nonresidential renovation, and results in smaller inflows of materials than new construction. With residential renovation projects ranging from fence repair to reroofing to two-story additions, estimated costs range from $100 to over $200,000, with most of the projects falling on the lower end of the cost range. Costs per project are much lower than any other type of building project, and these less expensive projects also use fewer materials. Based on this information, number of permits does not appear to be correlated with cost or mass.

Observation 3: New construction is responsible for a significant percentage of the inflow mass and half of the estimated cost.

Analyzing building activities by inflow mass and estimated cost, rather than number of permits issued, presents a different picture. Figure 4-11 shows the relative percentages of the material inflows and total estimated costs for each building category. As shown in Figure 4-11, new construction is responsible for over 80 percent of the mass of materials brought into Ann Arbor, and over 50 percent of the estimated cost. With the addition of 200 new residential and nonresidential buildings in 1997, it is not surprising that new construction dominates inflow mass.

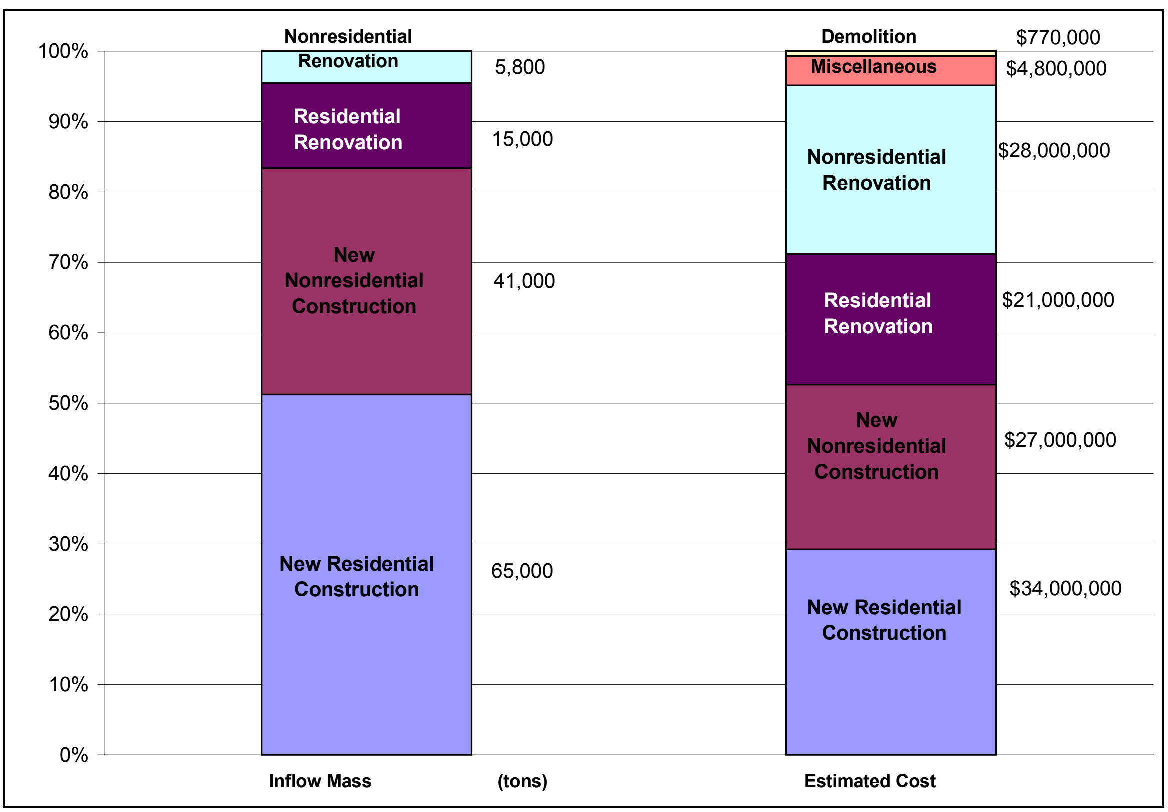


Figure 4-11 Breakdown of Inflow Mass and Estimated Cost

[52] Nutting, op. cit.

While residential renovations are observed to be the most frequent activity, it appears that these renovations are less material intensive, i.e. they require less mass per project.

Observation 4: Nonresidential construction and renovation have an order of magnitude larger cost per permit than residential construction and renovation.

The magnitude of nonresidential new construction and renovation are more clearly seen when looking at the average cost per permit issued for each type of building activity as illustrated in Figure 4-12. Nonresidential construction is over seven times more expensive than residential construction, and nonresidential renovation is over ten times more expensive than residential renovation. Cost data are obtained directly from Ann Arbor building permits and thus reflect the most accurate information available for Ann Arbor. Residential renovation values are probably slightly underestimated because homeowners typically do not include their personal labor costs when calculating estimated cost for the building permit.

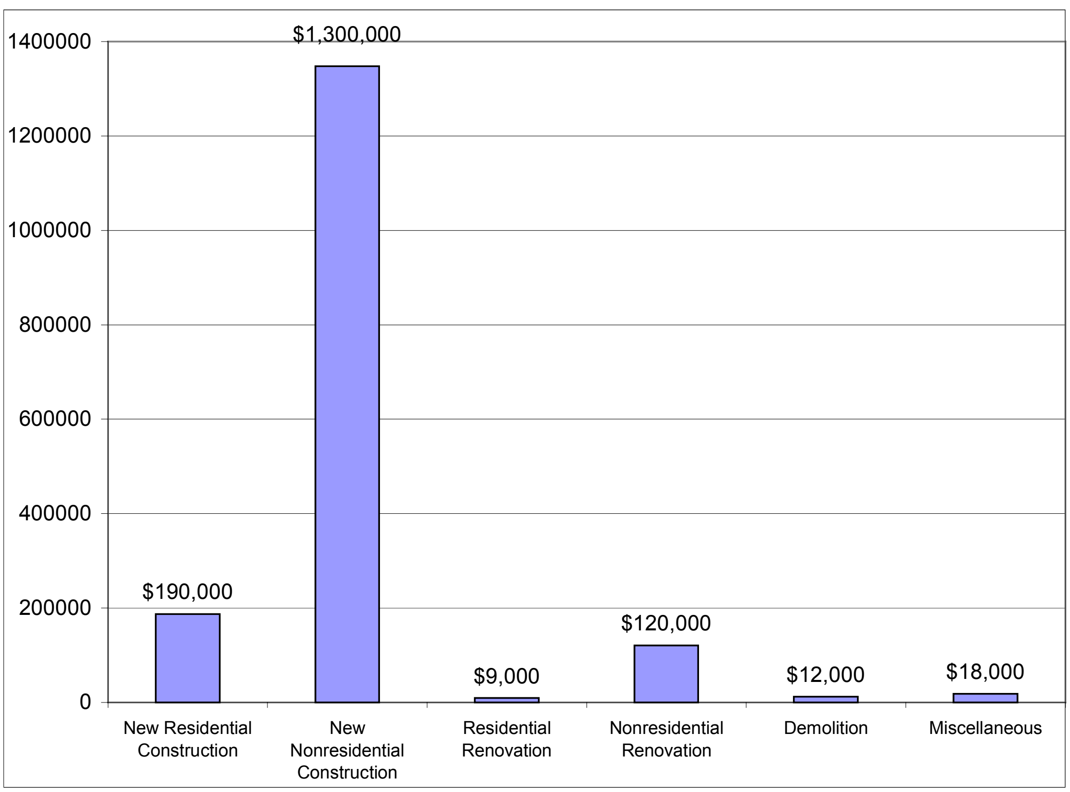


Figure 4-12 Estimated Cost per Building Permit

Observation 5: The building sector that generates the largest total outflow mass is demolition.

Figure 4-13 illustrates the outflow mass generated by each type of building category. Demolition results in the largest flow of materials, while accounting for only two percent of the building permits (Figure 4-10). Renovation generates the next most significant mass, with new construction contributing the least to total outflow mass. This result is not unexpected. A third of the demolition permits were for the removal of either an entire residential or nonresidential structure, or a garage or storage building. Generation of tremendous amounts of debris is inherent in the demolition process, while new construction and renovation aim to minimize waste.

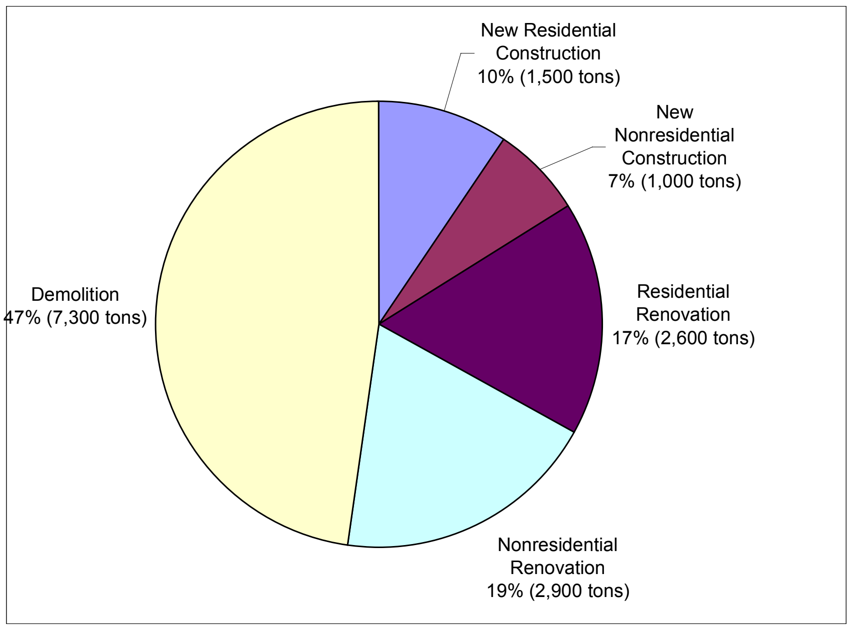


Figure 4-13 Characterization of Outflow Mass in Ann Arbor (Percent of Total)

There is a large uncertainty in the calculation of demolition debris. Size of residential buildings is estimated based on personal communication with Home Builders Association of Washtenaw County;[53] however, data on average size of nonresidential buildings demolished in Ann Arbor are not available. Individual building permit applications for the nonresidential demolitions are unavailable, so dimensions were estimated to be

[53] Sloan, op. cit.

13,299 sq. ft. per building.[54] If this assumption is inaccurate, the total mass of outflows could be altered significantly.

Observation 6: Within residential renovation, roofing is the most common activity and generates the largest outflow of materials.

In order to calculate material flows associated with residential renovation, the category was broken down into specific activities. The most common residential renovation occurring in Ann Arbor in 1997 was reroofing, with 751 permits issued. This value probably overestimates the true number of residential roofing projects. A few nonresidential projects are included in the number of roofing permits issued because it is not possible to separate residential from nonresidential roofing projects.

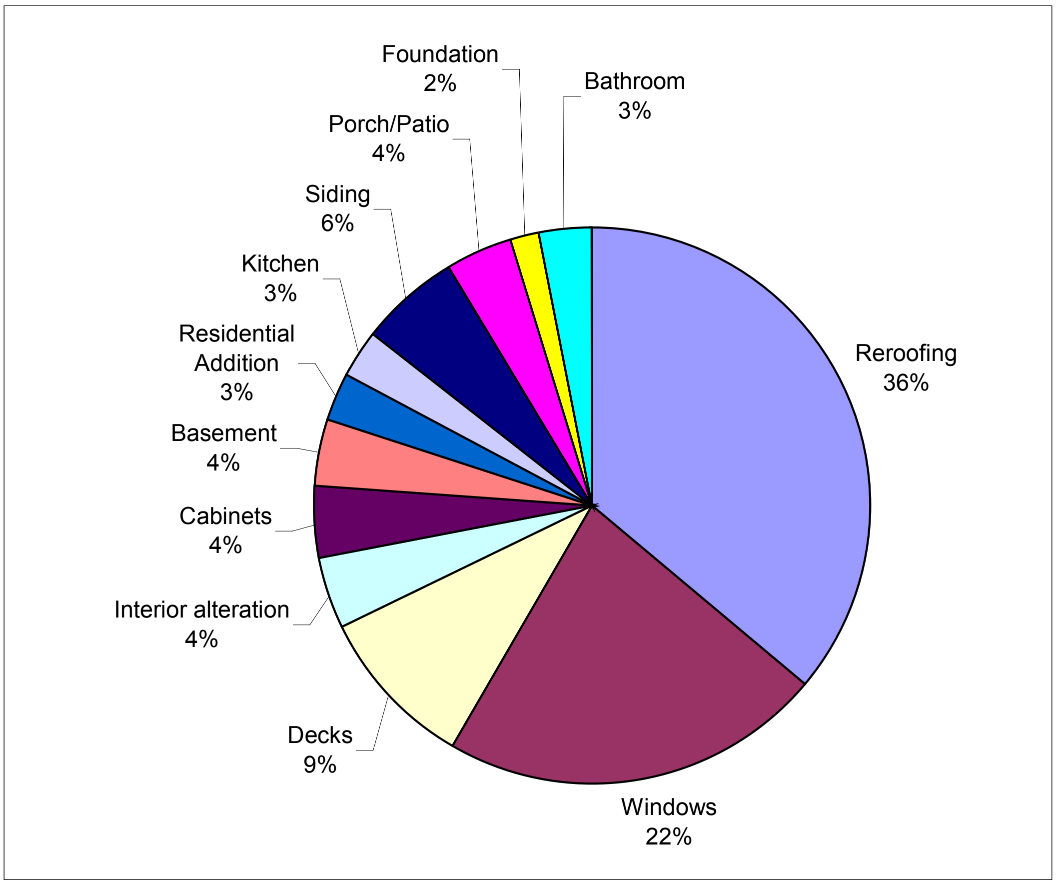
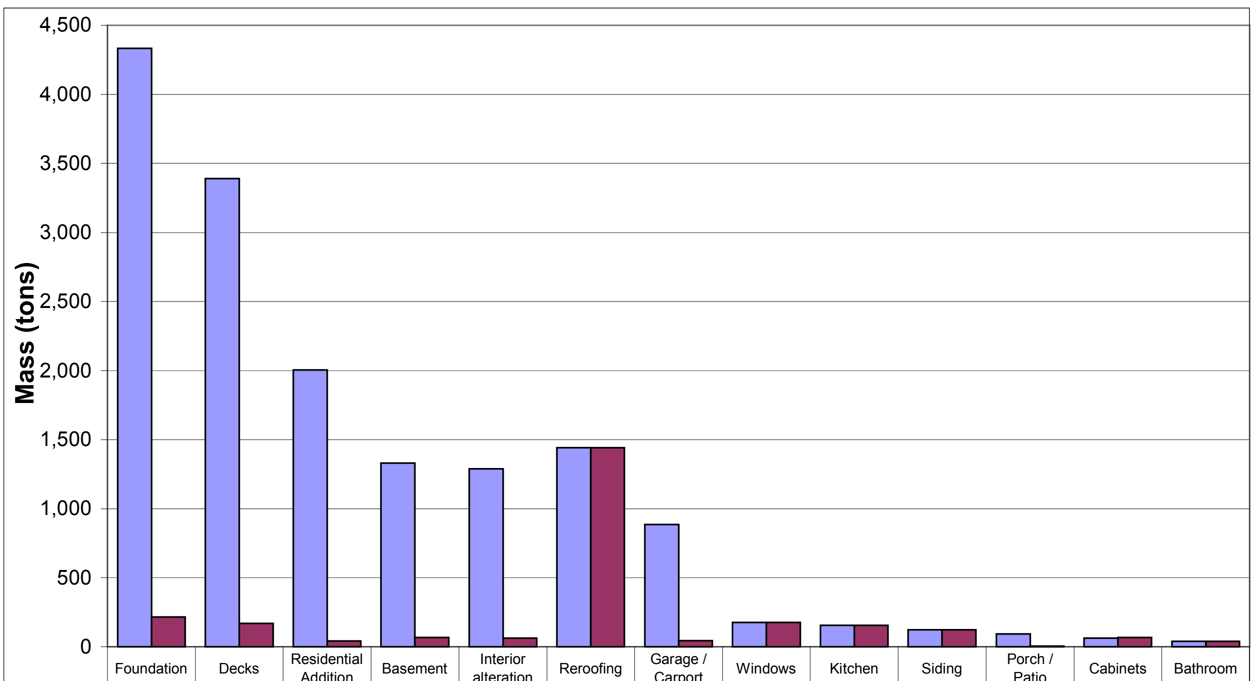


Figure 4-14 Frequency of Residential Renovation Activities

[54] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010. op. cit.

The inflow and outflow mass estimates are presented in Figure 4-15. The largest inflows are associated with foundations, decks, additions, and roofing. A factor contributing to the large flows associated with foundations and additions is their use of concrete, a very dense building material. As previously noted, some of the mass associated with foundations and roofing are due to nonresidential projects, and are not separated from total. A residential roof size is chosen for the analysis, assuming complete reroofing, although some roofing projects entailed partial reroofing or minor repair. Asphalt shingles are the most common type of shingles used for residential roofing.



	Foundation	Decks	Residential Addition	Basement	Interior alteration	Reroofing	Garage / Carport	Windows	Kitchen	Siding	Porch / Patio	Cabinets	Bathroom
Inflow	4,332	3,390	2,004	1,332	1,290	1,442	886	177	155	125	94	65	40
Outflow	217	169	43	67	65	1,442	44	177	155	125	5	67	40

Figure 4-15 Characterization of Residential Renovation

Additional Discussion

To put the results into context, the inflow and outflow estimates have been compared with other data. Two additional data sources are used: the City of Ann Arbor Building Department Annual Reports from 1989 to 1999 and the EPA Characterization of

Building-Related Construction and Demolition Debris in the United States. Table 4-18 lists observations resulting from these comparisons.

Table 4-18 Additional Shelter Observations

Observations
7. Cost of nonresidential construction and renovation has significantly increased in the last several years.
8. The number of people per household in Ann Arbor is decreasing.
9. The ratio of C&D debris generated by individual building sectors in Ann Arbor is similar to the ratio found nationally.

Each of these observations is described in further detail below.

Observation 7: Cost of nonresidential construction and renovation has significantly increased in the last several years.

Nonresidential renovation has generated a significant amount of activity in the community over the last 10 years. As shown in Figure 4-16, the number of permits issued for nonresidential alteration has remained fairly constant between 1989 and 1999. However, the total estimated cost showed a large increase beginning in 1997, when it jumped to $30 million, and continuing to $56 million in 1999.[55] Building contractors in the City of Ann Arbor have indicated that, in the last few years, material costs for nonresidential renovation projects are rising because materials are becoming harder to get, requiring longer lead times, ranging from 10 to 14 weeks. In order to accommodate project deadlines, contractors are paying more for quicker delivery of materials.[56]

[55] Note: These figures have not been adjusted for inflation.

[56] JC Beal Construction. op. cit.

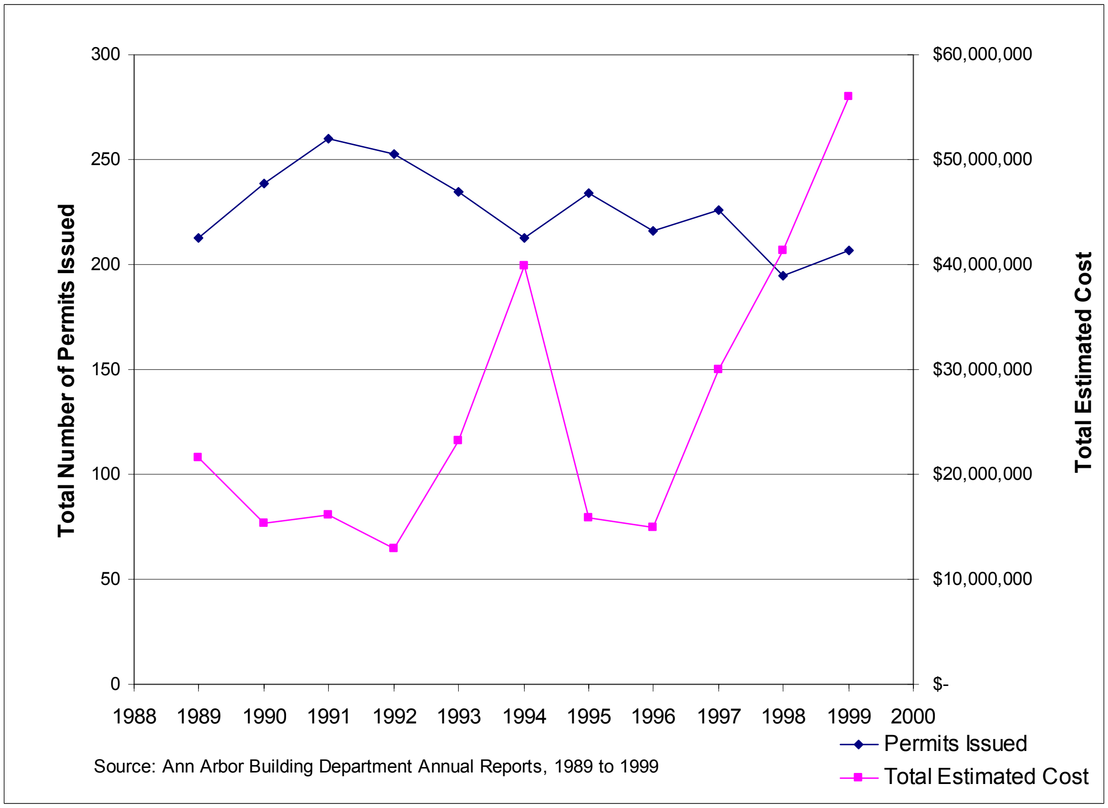


Figure 4-16 Trends in Nonresidential Renovation

The number of permits issued for new nonresidential buildings has varied widely over the last 10 years, peaking at 100 in 1989, to a low of 5 in both 1992 and 1993 (Figure 4-17). New nonresidential construction has undergone a similar increase in total estimated cost that is observed with nonresidential renovation. In 1997, the number of permits dropped, while the total cost continued to rise. Data on trends in size of new nonresidential construction in Ann Arbor are not available; based on the cost trends, it appears that new nonresidential buildings are either increasing in size or are facing higher labor and material costs. The increasing cost can be seen as both a benefit and a loss to a community. For local builders and contractors, higher costs for new buildings may result in higher employment and revenues. Increased spending on new construction indicates a healthy local economic climate, with more jobs and services for local residents.

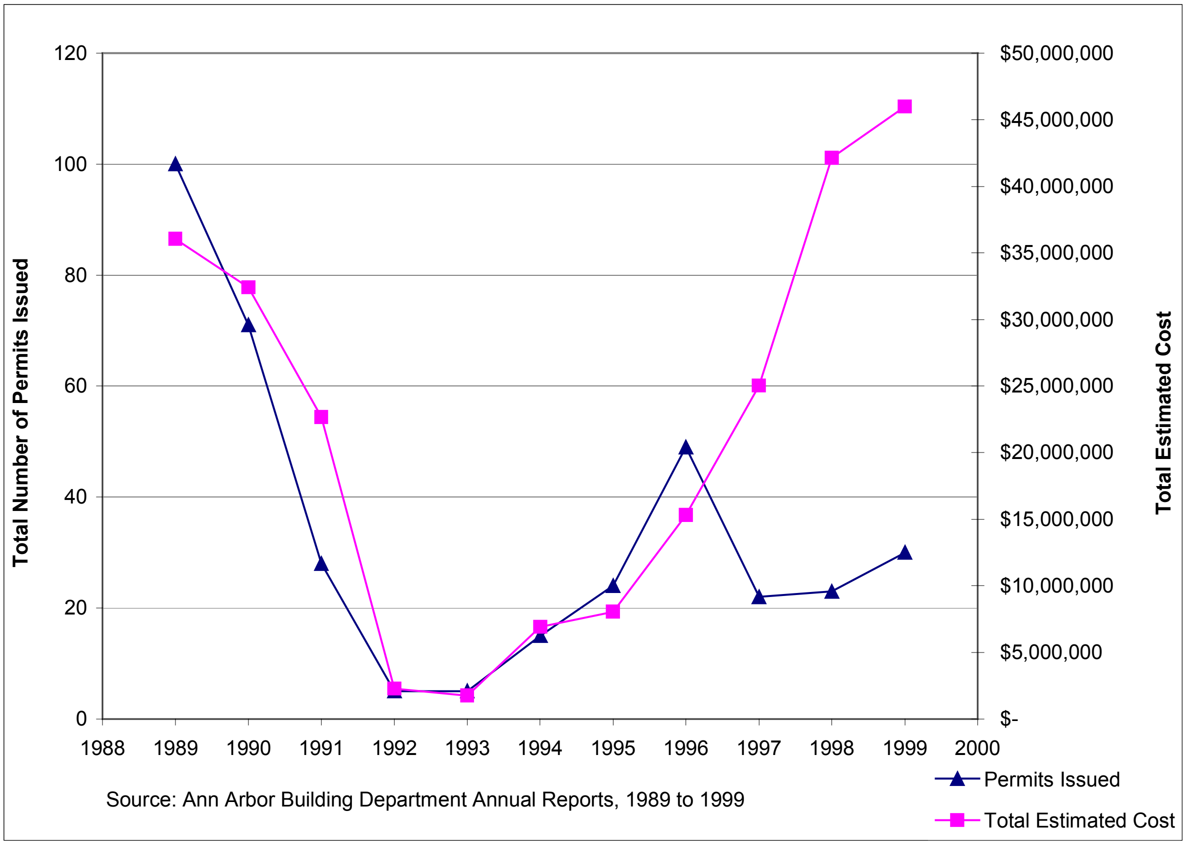


Figure 4-17 Trends in New Nonresidential Construction

Observation 8: The number of people per household in Ann Arbor is decreasing.

In 1990, the U.S. Census Bureau reported 44,010 total housing units within the City of Ann Arbor, of which 41,657 were occupied.[57] The Southeast Michigan Council of Governments (SEMCOG) estimates that the population of Ann Arbor has remained steady since the 1990 census[58]. The addition of 531 individual residential units (located in 180 residential buildings, i.e. single-family dwellings consist of one unit, apartment buildings contain numerous units) in 1997, and only four residential demolitions, suggests that there has been either a decrease in household size or an increase in the number of unoccupied housing units. Data from SEMCOG suggest that household size

[57] United States Bureau of the Census. 1990 Census of Population and Housing: Ann Arbor City Population and Housing. Michigan Information Center. <http://www.state.mi.us/webapp/dmb/mic/census/stf1a3a_1990.asp?cmd=data&lev=place&id=1421&cat=pop> 7 Feb. 2000.

in Southeast Michigan has been decreasing since 1950, dropping from 2.66 persons per household in 1990 to 2.56 in 1998. They estimate that the number of households in Ann Arbor has increased from 41,657 in 1990, to 43,381 in 1997[59]. Based on this information, it appears that Ann Arbor is no exception in the trend of decreasing household size. The impact of this trend is that more residential units are needed to house the same number of people, thereby consuming more resources and land.

Observation 9: The ratio of C&D debris generated by individual building sectors in Ann Arbor is similar to the ratio found nationally.

Figure 4-18 provides a breakdown, in percent of total outflow mass, of the building sectors that generate C&D debris, comparing the estimates calculated in this analysis for Ann Arbor and the estimates given by the EPA for the United States. Both estimates used C&D debris generation data from the EPA study, "Characterization of Building-Related Construction & Demolition Debris in the United States."[60] However, calculations for the outflow mass generated in Ann Arbor included the actual number of building permits issued for each project type and used project sizes that reflect Ann Arbor data on building sizes. As shown in Figure 4-18, comparing the generation of C&D debris in Ann Arbor to national estimates, the ratio of C&D debris generated by individual building sectors in Ann Arbor is similar to the ratio found nationally. Demolition dominates generation of C&D debris both nationally and in Ann Arbor. The similarity in these estimates provides validation for the estimation method used for outflow mass in Ann Arbor.

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[58] Nutting, op. cit.

[59] Nutting, op. cit.

[60] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010. op. cit.

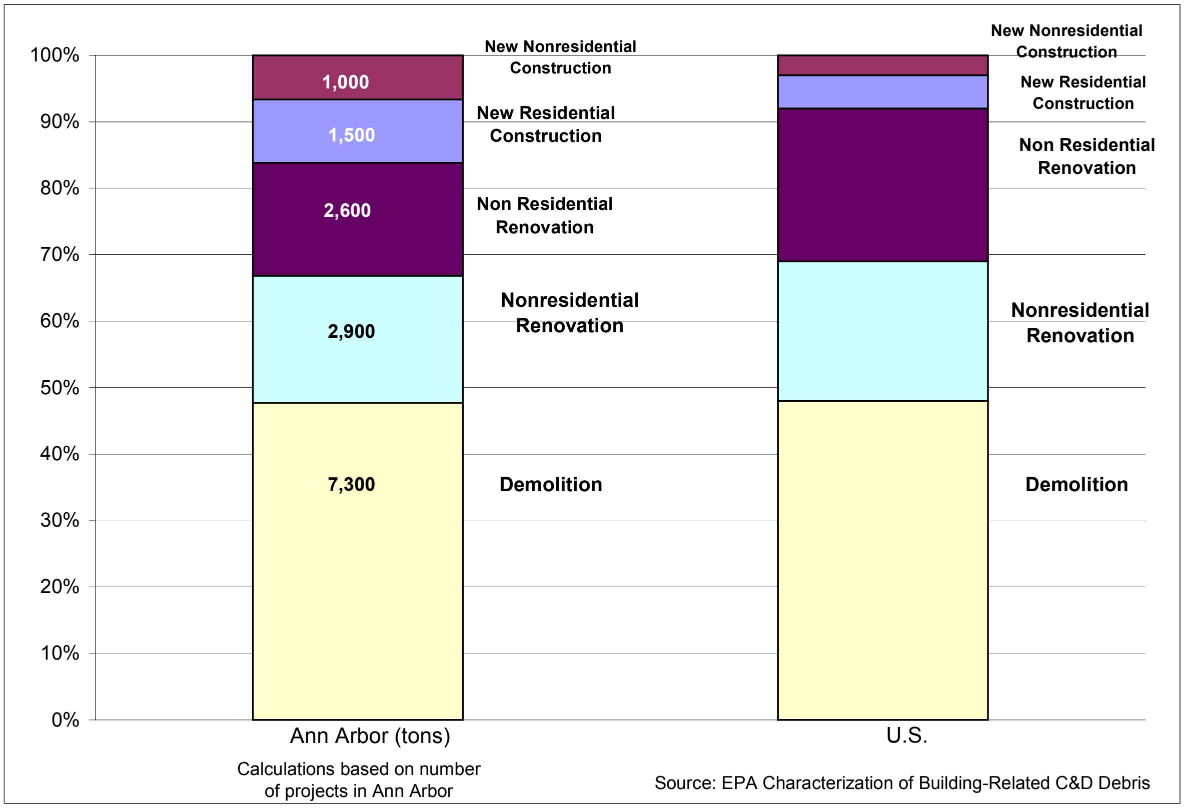

Figure 4-18 Characterization of C&D debris generation, Ann Arbor vs. U.S.

Material Flow Recommendations

The impact of the flow of materials associated with building-related activities can be diminished by reducing the total flow of materials, redirecting flows in order to capture the economic and resource value, or by lengthening the life or residence time of the material. Through better building design and strategic recovery of materials, flows associated with shelter, and the impacts that follow those flows, can be minimized. Table 4-19 lists potential solutions to improving the flow of materials through a community.

Table 4-19 Material Flow Recommendations for Shelter

Action	Current Program	Recommendation
Identify retailer for reused building materials	Recycle Ann Arbor ReUse Center	Explore expansion opportunities
Smarter design of buildings	▪ En-House (Environmental House) Green Building Demonstration at Ann Arbor ReUse Center ▪ Green Building discussion group	Educate contractors, builders, and home buyers on: ▪ Smaller is Better ▪ Materials that Fit ▪ Extend the Life
Promote deconstruction as an alternative to demolition	Builders required to consider as part of permit process	Community education on benefits of deconstruction
Identify further opportunities for recycling C&D debris		Identify markets for additional materials: ▪ Asphalt shingles ▪ Gypsum (wallboard)

Each of these suggestions is described in further detail below.

***Recycle Ann Arbor ReUse Center*[61]**

The ReUse Center, open since 1996, accepts and sells used building materials, household goods, appliances and furniture. The facility, occupying 20,000 square feet including a 10,000 square-foot warehouse, has a total processing capacity of 100 cubic yards per day and an estimated yearly processing volume of 26,000 cubic yards. In September of 1999, Recycle Ann Arbor opened the En-House (Environmental House) Green Building Demonstration. The En-House is a full-scale model house built inside the ReUse Center from recycled-content, natural, renewable, energy-efficient and non-toxic building materials. Inside the En-House is an education center.

While only donations are accepted by the ReUse Center, contractors and builders benefit by avoiding disposal costs associated with C&D debris. The ReUse center has proactively worked with local builders and remodelers to inform them of the materials that can be donated.

[61] About Recycle Ann Arbor. Recycle Ann Arbor. <http://comnet.org/recycleannarbor/raainfo.html> 2 May 2000.

Smaller is Better

Nationally, total square footage per house is increasing and household size is decreasing, resulting in fewer people housed per house. Providing a better match between household size and house size takes better advantage of the resources needed for construction. Smaller houses don't necessarily result in less comfort. The use of interior space can be optimized through careful design, thereby minimizing overall building size and the resources used in constructing and operating it. Additionally, careful design can yield additional benefits by minimizing energy consumption through the use of passive solar design, and efficient heating, ventilating, and air-conditioning systems, lighting, and electrical technologies.

The current trend in residential construction is "big is better," while, at the same time, number of individuals per household is decreasing. These large houses consume more materials during construction, will consume more materials during use (e.g. more roofing materials required during replacement), and provide shelter for fewer people. Another increasingly common practice is the demolition of an existing house and construction of a "bigfoot" house. These houses are typically twice as large as the previously existing house, and are viewed by many nearby residents as conflicting with the character of the neighborhood. Communities in the Detroit area are reacting to bigfoot houses by passing legislation limiting the footprint of homes to 25-35 percent of the lot area, and restricting the height of homes to 35 feet.[62] Ann Arbor must be aware of this trend. Communication to builders and potential home buyers on the benefits of careful design is needed.

Materials that Fit

Much of the waste generated during construction can be eliminated by using materials that are the correct size for the structure, or by designing the structure to accommodate the sizes of commonly used building materials. For example, framing lumber is one of the largest material purchases and is the largest component of the waste stream for

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[62] Detroit Free Press. "Planners Tie House Footage to Lot Size." Detroit Free Press Online. 14 Apr. 2000. Detroit Free Press. 20 Apr. 2000. <http://www.freep.com/news/locoak/nfoot14_20000414.htm>.

residential construction.[63] Designing a structure with 11 foot walls and wood studs generates considerable wood debris when wood studs come in 10 or 12 foot lengths. Alternatively, metal studs can be ordered to the specific size needed. Doors, windows, and stairs can be placed to coincide with modular studs, thereby reducing the number of framing members required to frame a wall or floor[64]. Gypsum wallboard typically comes in sheets 4' x 8' or 4' x 12'. Doors and windows are not placed at intervals that correspond to the width of wallboard, resulting in a lot of scrap material due to cutting the wallboard to fit. As an alternative, plaster is adaptable to the available size and results in less waste.

Extend the Life

Choosing durable and long-lived materials reduces the frequency of replacement and therefore reduces the energy and resource impacts of producing the materials. There is a perception that the increased cost for longer lived materials will not be recovered by the homeowner. Because most people stay in a house only 8 years, the difference in replacement cost for 20 and 40 year shingles will not be seen. Some builders in Ann Arbor are working on educating their customers on the long-term financial savings associated with choosing durable, long-lived materials.[65]

Buildings can be designed to be adaptable to other uses, so when one user has outgrown its use, it can be easily transformed for another use. Choosing materials and components that can be reused or recycled is another strategy for extending the life of materials.

Deconstruction

Deconstruction is a new label to describe the process of selective dismantling or removal of materials from buildings prior to or instead of demolition. Deconstruction is an alternative that offers both economic and environmental benefits as a means to convert unvalued demolition waste into valuable resources for which markets exist. As seen in Figure 4-13, demolition is responsible for nearly half of the C&D debris generated in

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[63] National Association of Home Builders Research Center, Inc. Residential Construction Waste Management: A Builder's Field Guide. <http://www.nahbrc.com/builders/green/wastepub.htm> 5 May 2000.

[64] National Association of Home Builders Research Center, Inc. Residential Construction Waste Management: A Builder's Field Guide. op. cit.

[65] Laroe, op. cit.

Ann Arbor. Based on research by the NAHB, the benefits of deconstruction include: lower building removal costs, reduced impact to soil and vegetation at the site, and less dust and noise, and conserved landfill space by diverting up to 90 percent of a building into reuse or recycling. Buildings which are good candidates for deconstruction exhibit one or more of the following characteristics: wood-framed with heavy timbers and beams or with unique woods, constructed with high-value specialty materials like hardwood flooring, unique doors, high quality brick, and a minimum of rotted and decayed materials.[66]

Deconstruction is often not seen as a feasible alternative because it takes a lot more time to dismantle a structure than to demolish it, resulting in higher expenses for labor and equipment. These costs may be recovered by selling salvaged materials. However, builders may also be hesitant to spend their time identifying markets for recovered materials, when C&D landfill tipping costs are so low. Case studies conducted by the National Association of Home Builders (NAHB), the EPA, and others are being published to promote the cost effectiveness of deconstruction. Specifically, in a case study of a 9,180 square foot wood construction building, the NAHB determined that demolition would have cost $16,800, while deconstruction had a net cost of $9,349 ($53,000 in expenses for labor, equipment, and administration; $43,660 income from salvage value of material).[67] As landfill tipping fees rise, deconstruction and use of mixed construction waste become more appealing.

In investigating recovery of materials from a demolition site, it becomes apparent that many buildings were not designed to facilitate dismantling. Design for disassembly is one solution to that problem. Buildings should be designed with components that can be easily taken apart for reuse or recycling.

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[66] National Association of Home Builders Research Center, Inc. "Materials Salvaged Through Deconstruction. Case Study: Riverdale Village Apartments." Deconstruction: Building Disassembly and Material Salvage. 1998. <http://www.nahbrc.org/builders/green/Decon_br.pdf> 5 May 2000.

[67] National Association of Home Builders Research Center, Inc. "Materials Salvaged Through Deconstruction. Case Study: Riverdale Village Apartments." op. cit.

In Ann Arbor, in order to obtain a building permit for demolition, the City of Ann Arbor Building Department requires applicants to fill out an "Affidavit of Investigation into House Relocation and Reclamation of Usable Materials." The Building Department provides a list of organizations interested in homes that will be moved, a directory of pre-demolition salvage contractors, locations where salvaged building materials are accepted, and a directory of house raisers.

Recovery of C&D Debris for Recycling or Reuse

A great deal of research has focused on management of the outflow of materials. Recovery of materials for reuse or recycling is an important management tool to reduce the mass of materials disposed. Characteristics of the debris that make recycling easier include: separation of target material from other materials, little contamination, and availability of a large volume.

The percent of C&D debris recovered for reuse or recycling by building contractors and waste haulers in Ann Arbor ranges from 10 to 50 percent.[68] The materials most commonly recovered are lumber, metals, concrete, and cardboard. Nearly all of the sorting is conducted offsite by the waste hauler and not by the contractor at the construction site. Due to the high current cost of separating C&D debris and the low cost of disposal, most of the C&D debris is sent to landfill. Another reason cited for low C&D recovery is the lack of interest on the part of contractors to participate and to ensure that materials are well sorted onsite.

Two particular materials are generated in large volumes and have available recycling technology.

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[68] Hunter, op. cit.
JC Beal Construction, op. cit.
Laroe, op. cit.
York, op. cit.
The Renewal Company, op. cit.

Asphalt shingles

Twenty four percent of the building permits in Ann Arbor in 1997 were issued for roofing projects. Residential dwellings made up the majority of roofing jobs, with asphalt shingles being the most common type of shingle used. Asphalt shingles have a tremendous recycling potential because they are plentiful in C&D debris, they are frequently generated separately from other C&D debris, recycling technology exists, and they have proven to perform well as an additive to pavement. There is interest within Ann Arbor for asphalt shingle recycling from building contractors. The existing Drop-Off Center could function as the collection site.

Roofing is also a prime target for increased durability. According to Environmental Building News, roofs commonly exhibit the lowest durability of any major building component except carpeting, requiring frequent replacement.[69] Alternative roofing materials under investigation include plastic panels.

Gypsum Products (Drywall)

Drywall is a material commonly found in C&D debris, generated by new construction, renovation, and demolition. Strategies that can be used to reduce the impact of gypsum board are 1) improving resource efficiency by using wallboard with recycled content, 2) disposing of scraps as a soil amendment onsite or for agricultural uses, or by storing scraps in empty wall framing cavities,[70] and 3) recycling gypsum for use in manufacturing new gypsum board.

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[69] Malin, Nadiv. "Roofing Materials: A Look at the Options for Pitched Roofs." Environmental Building News. Volume 4, No. 4. Jul./Aug. 1995.

[70] National Association of Home Builders Research Center, Inc. Residential Construction Waste Management: A Builder's Field Guide. op. cit.

Chapter 4.3: Clothing

Along with shelter, humans need to cover their bodies for protection from the elements. Clothing has evolved from providing basic function to serving cultural and social purposes, signaling gender, employment, wealth, and other personal characteristics.

Category Description

In order to identify and estimate the material flows associated with clothing, this analysis focuses on personal consumption of clothing, footwear, and clothing accessories by Ann Arbor residents and sales of these materials by Ann Arbor stores. Table 4-20 lists materials related to clothing. Materials not included in this analysis are marked with an asterisk.

Table 4-20 Materials Associated with Clothing and Footwear

Direct Materials	Indirect Materials
▪ New clothing and footwear ▪ Clothing accessories ▪ Used clothing ▪ Uniforms* ▪ Clothing purchased through mail order*	▪ Cleaning & repair* ▪ Clothes hangers, dressers, suitcases* ▪ Packaging* ▪ Retail stores* ▪ Transportation* ▪ Delivery of mail order *

* This report does not include separate inflow or outflow estimates for these materials.

Direct Materials

Direct materials satisfy the need for clothing. The focus of this study is on clothing, footwear, and clothing accessories sold in Ann Arbor. Uniforms and clothing purchased through mail order are not included.

Indirect Materials

Cleaning and repair, packaging, and transportation are not included in this analysis because they are indirect materials. While they support the need for clothing, these materials alone do not provide clothing.

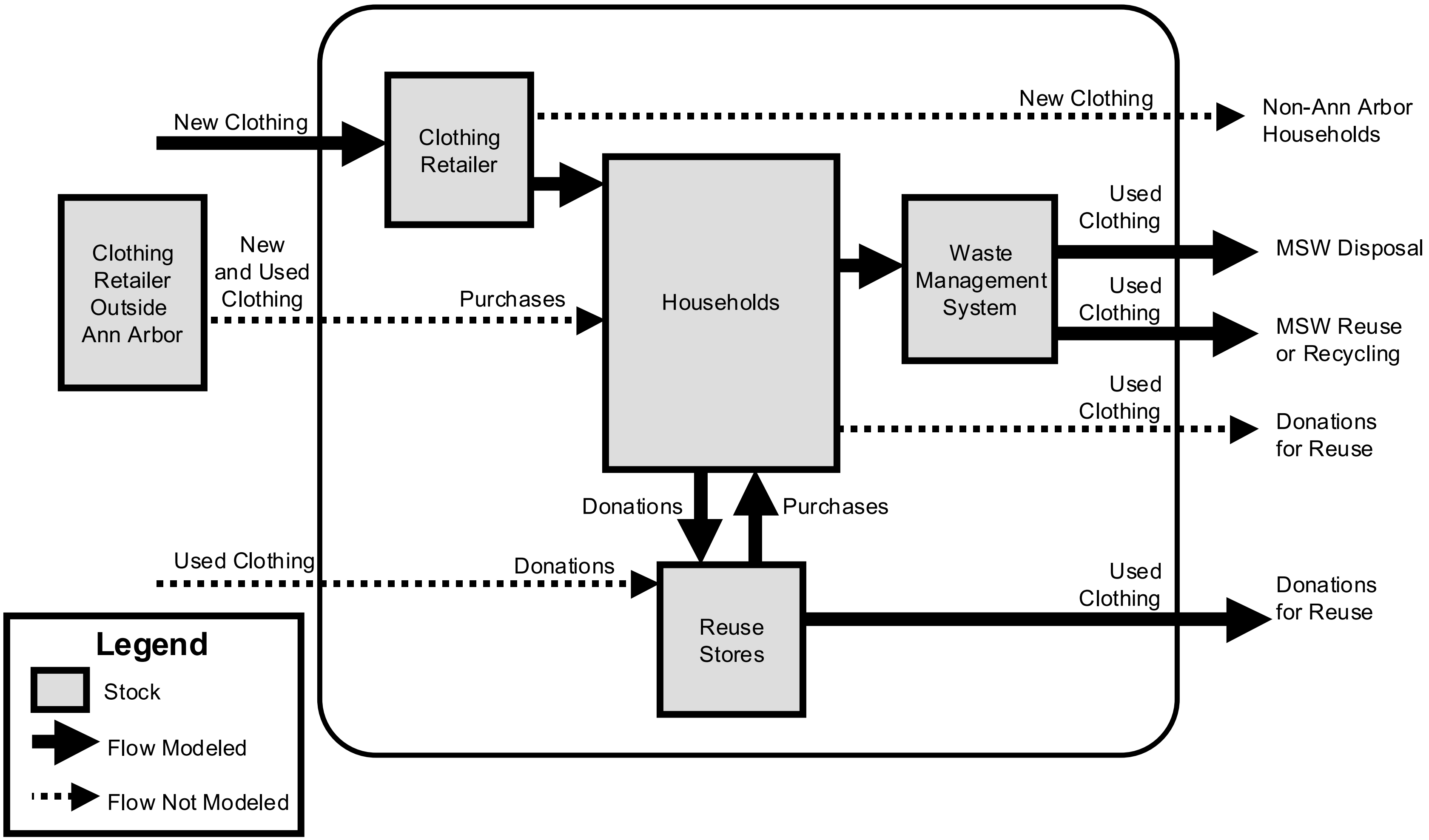

Figure 4-19 Clothing Direct Material Flows through Ann Arbor

Inflows and Outflows

Figure 4-19 illustrates the flow of materials through the City of Ann Arbor as analyzed in this study. The focus of this study is on the flow of clothing and footwear purchased at Ann Arbor retailers and reuse stores and the subsequent disposal of this clothing. Dashed lines represent flows that are not analyzed in this study.

New clothing

New clothing enters Ann Arbor in one of two ways: 1) to be sold in local retail stores or 2) as purchases made outside of Ann Arbor by Ann Arbor residents (e.g. including mail order). Clothing is sold by Ann Arbor retail stores to nonresidents; this export of clothing is not included in the analysis. All clothing sold by Ann Arbor stores is included in the analysis.

Used clothing

The inflow of used clothing from outside of Ann Arbor, either directly entering the stock or given to reuse stores located in Ann Arbor, is not included in this analysis. Used clothing sold by consignment stores or at garage / yard sales is also not included. This analysis focuses on used clothing donated to and purchased from the three Ann Arbor thrift stores: St. Vincent DePaul Society, Ann Arbor PTO Thrift Shop, and the Kiwanis Club. Clothing donations to these stores exceed what can be sold; therefore, unsold merchandise is given to charitable organizations that are primarily located outside of Ann Arbor, including the Salvation Army and area churches. It is assumed that used clothing is sold only to Ann Arbor residents and therefore stays within the community.

Outflows

Clothing leaves the community in one of five ways. The first and last methods are not modeled in this analysis.

1. Non-Ann Arbor residents purchase clothing at Ann Arbor retailers.
2. Clothing is disposed in the municipal solid waste by Ann Arbor residents.
3. Clothing is collected by the City of Ann Arbor Solid Waste Department as part of its curbside recycling program. Recovered clothing is donated to Goodwill or sold to a textile recycling company, both of which are located outside of Ann Arbor.

4. Surplus used clothing from local thrift stores is donated to organizations located outside of Ann Arbor.
5. Ann Arbor residents directly donate their clothing to organizations located outside of Ann Arbor.

Data Sources

Four main data sources provide the basis for estimating the material flows required for meeting the clothing needs in Ann Arbor. These sources include Economic Census for Retail Trade[71], Current Industrial Reports[72], Ann Arbor Used Clothing Stores[73], and the EPA Characterization of Municipal Solid Waste in the U.S[74]. Additional details regarding data sources are provided in Appendix D.

1997 Economic Census for Retail Trade

Statistics on sales and number of establishments are available at a national level and at the Ann Arbor level. Sales are calculated from data on clothing & clothing accessories stores, general merchandise stores, and used merchandise stores. Using sales data as the basis for inflow value violates the system boundary for inflows described above. This source accounts for retail sales occurring within Ann Arbor, regardless of the residence location of the purchaser. However, if it is assumed that the purchases made in Ann Arbor by non-Ann Arbor residents is approximately equal to the non-Ann Arbor purchases made by Ann Arbor residents, then use of this data source is acceptable.

US Bureau of Census, Current Industrial Reports

The U.S. Bureau of the Census publishes Current Industrial Reports for various manufacturing sectors, including apparel and footwear. Data on quantity of U.S. apparent consumption[75] and data on average weights for each type of product[76] are used

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[71] United States Bureau of the Census. United States 1997 Economic Census, Retail Trade – Geographic Area Series. U.S. Department of Commerce, Mar. 2000. <http://www.census.gov/prod/ec97/97r44-us.pdf > 20 May 2000.

[72] United States Bureau of the Census. Current Industrial Reports - Products by Subject U.S. Department of Commerce < http://www.census.gov/cir/www/alpha.html> 29 August 1999.

[73] Personal interviews

[74] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update. op. cit.

[75] Apparent consumption represents new domestic supply and is derived from subtracting exports from the sum of manufacturers' shipments plus imports.

to calculate mass of inflows. The quantity of clothing and footwear actually sold in the U.S. is unknown.

Ann Arbor Used Clothing Stores

Ann Arbor used clothing stores have been contacted to obtain data on mass flows of used clothing, included clothing donated to the stores, clothing purchased at the stores, and mass of surplus clothing that the stores donate to non-Ann Arbor organizations. Most stores report number of bags of clothing donated or sold, so mass of clothing is estimated based on an estimated mass per bag.

Characterization of Municipal Solid Waste

The EPA Characterization of Municipal Solid Waste calculates generation of clothing and footwear in municipal solid waste. However, the EPA does not count reused clothing as being recovered out of the MSW stream. The EPA assumes that reused clothing enters the MSW stream in the same year that it is reused, so reuse only delays disposal.

Assumptions

A number of assumptions have been made in estimating the flow of clothing through Ann Arbor. Major assumptions are presented in Table 4-21. More detailed assumptions can be found in Appendix D.

[76] Franklin Associates. Working paper: Methodology for Characterization of Municipal Solid Waste in the United States: Table G-04 Unit Weight Conversion Factors for Apparel.

Table 4-21 Major Assumptions for Clothing Estimates

Assumptions
1. Purchases made in Ann Arbor by non-Ann Arbor residents are equal to the non-Ann Arbor purchases made by Ann Arbor residents.
2. No used clothing enters Ann Arbor as a donation or purchase at non-Ann Arbor used clothing stores.
3. All of the used clothing purchases made in Ann Arbor are at three thrift stores and none of these purchases leave Ann Arbor.
4. Ann Arbor thrift stores donate surplus clothing to organizations located outside of Ann Arbor.
5. The mass of clothing and footwear consumed per capita is the same for Ann Arbor and the United States.
6. Per capita mass of clothing and footwear in the MSW stream is the same for Ann Arbor and the United States.

Assumption 1: Purchases made in Ann Arbor by non-Ann Arbor residents are equal to the non-Ann Arbor purchases made by Ann Arbor residents.

Data are published on retail sales by Ann Arbor stores; however, Ann Arbor residents do not purchase all of their clothing from local stores, and local stores do not sell all of their goods to Ann Arbor residents. It is assumed that the purchases made in Ann Arbor by non-Ann Arbor residents are equivalent to the non-Ann Arbor purchases made by Ann Arbor residents. Non-Ann Arbor purchases made by residents include mail order because mail order purchase is not included in Ann Arbor retail sales data.

Assumption 2: No used clothing enters Ann Arbor as a donation or purchase at non-Ann Arbor used clothing stores.

Data on donation of used clothing to Ann Arbor thrift stores from non-Ann Arbor residents are not available. Purchases of used clothing from non-Ann Arbor thrift stores are not included.

Assumption 3: All of the used clothing purchases made in Ann Arbor are at three thrift stores and none of these purchases leave Ann Arbor.

Data on mass of clothing flowing through consignment stores and garage/yard sales are not available, so only mass of clothing through the three major Ann Arbor thrift stores is analyzed. It is assumed that clothing purchased at Ann Arbor thrift stores remains within Ann Arbor.

Assumption 4: Ann Arbor thrift stores donate surplus clothing to organizations located outside of Ann Arbor.

Surplus donations to the three major Ann Arbor thrift stores are donated or sold to other charitable organizations which are assumed to be located outside of Ann Arbor.

Assumption 5: The mass of clothing and footwear consumed per capita is the same for Ann Arbor and the United States.

Mass of new clothing purchases is estimated based on quantity of clothing and footwear available for consumption in the U.S. according to the Current Industrial Reports. The total mass of clothing and footwear consumed per capita is assumed to be the same for Ann Arbor and the United States.

Assumption 6: Per capita mass of clothing and footwear in the MSW stream is the same for Ann Arbor and the United States.

Ann Arbor's generation rate for clothing and footwear waste is assumed to be equal to the national generation rate.

Summary of Estimation Process

The following is a summary of the process used to estimate the flow of materials associated with clothing. A more detailed description of the estimation process is provided in Appendix D.

No data source reports a complete picture of sales, consumption, and reuse/resale of clothing in either economic or mass values. Percent of Ann Arbor retail sales attributable to Ann Arbor residents cannot be determined. National Income and Product Accounts[77] on personal consumption of clothing and footwear may not be reflective of the buying power of Ann Arbor residents. In order to take into consideration the many different ways of accounting for clothing flows, several estimates have been made using different data sources. These individual estimations have been analyzed for gaps and limitations in

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[77] Bureau of Economic Analysis. National Income and Product Accounts Tables. U.S. Department of Commerce, Aug. 1998. .<http://www.bea.doc.gov/bea/articles/national/nipa/1998/0898nipa.pdf> 16 May 2000.

order to create the most accurate estimate for the inflows and outflows occurring in Ann Arbor.

Inflow mass

Inflow mass is estimated from Department of Commerce data on U.S. apparel and footwear production, import, and export[78]. Masses of individual types of apparel and footwear are multiplied by quantity (units) available for consumption in the United States. Total mass is summed, converted to national per capita consumption, and multiplied by the population of Ann Arbor.

Inflow economic value

Inflow economic value is calculated using multiple data sources. Two of the most applicable sources include:

- 1997 Economic Census, Retail Trade, supplies data on both national[79] and Ann Arbor[80] sales data from clothing and clothing accessories stores, general merchandise stores, and used merchandise stores. Disadvantages of using sales data include omission of purchases from mail order and non-Ann Arbor stores, and inclusion of purchases made by non-Ann Arbor residents.
- National Income and Product Accounts Tables, provides personal consumption expenditures for clothing and shoes.[81] Total national spending is converted to a per capita value and multiplied by the population of Ann Arbor in order to estimate the total amount spent on clothing and footwear by Ann Arbor residents.

Outflow mass

The total mass of clothing retired from use has four fates as modeled by this analysis. Clothing donated to reuse stores is resold and remains within Ann Arbor, reuse stores donate surplus clothing to other organizations located outside of Ann Arbor, clothing is recovered by the Ann Arbor Solid Waste Department, and clothing is disposed in MSW.

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[78] United States Bureau of the Census. Current Industrial Reports - Products by Subject op. cit.

[79] United States Bureau of the Census. United States 1997 Economic Census, Retail Trade – Geographic Area Series. op. cit.

[80] United States Bureau of the Census. Michigan 1997 Economic Census, Retail Trade - Geographic Area Series. U.S. Department of Commerce, Mar. 2000. <http://www.census.gov/prod/ec97/97r44-mi.pdf> 20 May 2000.

The total mass of clothing generated and all three fates, other than disposal, are estimated from national or local data sources. Disposal is estimated by subtracting the masses of the three other fates from the total mass of clothing.

Total mass of clothing and footwear retired from use is calculated from national estimates of the percentage of clothing and footwear generated in U.S. municipal solid waste[82]. This value is converted to a per capita basis and multiplied by the population of Ann Arbor. The mass of clothing sold by reuse stores in Ann Arbor and their donations of surplus clothing to other organizations located outside of Ann Arbor are estimated from personal communication with the reuse stores. The Ann Arbor Solid Waste Department tracks the mass of clothing that they recover for recycling.[83]

Results and Analysis

Table 4-22 summarizes the calculations estimating the inflow value, inflow mass, and outflow mass of clothing and footwear. Additional detail can be found in Appendix D.

Table 4-22 Clothing Inflow and Outflow Estimates

Clothing & Footwear	Inflow Value (million)	Inflow Mass (tons)	Outflow Mass (tons)
TOTAL	$241	2,900	2,200

Figure 4-20 illustrates the flow of clothing into and out of Ann Arbor. The width of the arrows are proportional to the mass of materials. The dotted inflow and outflow arrows are not modeled.

[81] Bureau of Economic Analysis. National Income and Product Accounts Tables. op. cit.
[82] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update. op. cit.
[83] City of Ann Arbor Department of Solid Waste. Annual Report 1997/1998. Ann Arbor: City of Ann Arbor Department of Solid Waste, 1998.

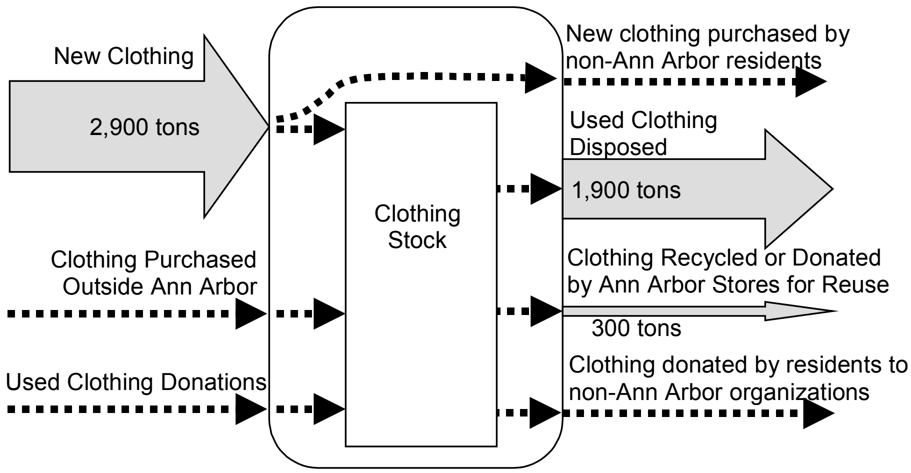

Figure 4-20 Clothing Mass Flow Diagram

Dotted lines outside the community boundary represent direct material flows not modeled. Dotted lines inside the boundary show connections between the inflow and outflow materials.

Table 4-23 lists five observations that can be made from the detailed estimates of inflows and outflows. More detail on the data from which these observations have been made can be found in Appendix D.

Table 4-23 Observations of Clothing Estimates

Observations
1. Sales of clothing by Ann Arbor stores greatly exceeds national per capita spending on clothing and footwear.
2. Clothing and Clothing Accessories Stores accounted for the majority of clothing sales, while used clothing represented a small fraction of total clothing sales.
3. Change in stock of clothing is uncertain.
4. A majority of the clothing leaving Ann Arbor is disposed in the Municipal Solid Waste stream. Of the mass of clothing recovered for reuse or recycling, surplus clothing donated to non-Ann Arbor organizations is larger than textiles recovered by the Ann Arbor Solid Waste Management system.
5. U.S. per capita generation of clothing and footwear in the Municipal Solid Waste stream greatly exceeds estimates of Ann Arbor generation of clothing and footwear.

Each of these observations is described in further detail below.

Observation 1: Sales of clothing by Ann Arbor stores greatly exceeds national per capita spending on clothing and footwear.

Table 4-24 shows four methods of estimating clothing sales in Ann Arbor. Data on clothing sales obtained from national level sources, U.S. 1997 Economic Census, American Apparel Manufacturers Association, and U.S. Department of Commerce, range from $68 million to $170 million for the City of Ann Arbor. Data on actual sales of clothing by Ann Arbor stores, as published by the 1997 Economic Census, show a much higher economic value.

Table 4-24 Comparison of Estimates of Clothing Inflow Value in Ann Arbor

Data Source	Inflow Value (scaled to Ann Arbor)	Comments
1997 Economic Census, Retail Trade ▪ National sales of new and used clothing	$170,000,000	▪ Ann Arbor is home to a large mall, so sales may be higher than national average ▪ Buying power of Ann Arbor residents is higher than the national average[84] ▪ Does not include mail order
1997 Economic Census, Retail Trade ▪ Sales of new and used clothing by Ann Arbor stores	$240,000,000	▪ Sales from Merchandise Stores estimated from Washtenaw County stores ▪ Does not include mail order ▪ Includes purchases by non-Ann Arbor residents ▪ Does not include purchases made outside of Ann Arbor by residents
American Apparel Manufacturers Association ▪ National New Apparel Sales	$68,000,000	▪ Sales numbers tend to be underestimated as compared to other estimation processes such as Consumer Expenditure Surveys[85] ▪ Includes mail order
U.S. Department of Commerce. National Income and Product Accounts Tables ▪ National Per capita spending on clothing and shoes	$110,000,000	▪ Buying power of Ann Arbor residents is higher than the national average[86]

Ann Arbor is home to over 150 clothing and clothing accessories stores including Briarwood shopping center. Ann Arbor retail stores service a large geographic area, with shoppers traveling from Toledo, Ohio to Lansing, MI. Ann Arbor stores also service a large tourist population, with visitors drawn by the automotive industry, the Ann Arbor Art Fairs, and the University of Michigan, including football weekends.

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[84] Strich, Marc. Briarwood Manager. Personal interview. 8 May 2000.

[85] Simon, Peter. NPD Group, Inc. Personal interview. 1 May 2000.

[86] Strich, op. cit.

The higher values observed in Ann Arbor could be due to two reasons. First, the sales attributable to non-Ann Arbor residents could not be determined, therefore, sales by Ann Arbor stores may be inflated due to these purchases. Second, according to Marc Strich, manager of Briarwood Mall, Ann Arbor residents spend less of their disposable income on nonconsumables, e.g. clothing, compared to the national average, while spending more on travel and recreation. However, Ann Arbor residents have much more disposable income than the national average, resulting in "healthy" spending patterns.[87] As an example, Jacobson's, a specialty department store located at Briarwood Mall, ranks in the top 5 Jacobson's stores by sales nationwide (out of 24 total stores)[88].

Observation 2: Clothing and Clothing Accessories Stores accounted for the majority of clothing sales, while used clothing represented a small fraction of total clothing sales.

Figure 4-21 shows the sales of clothing and footwear based on the 1997 Economic Census, Retail Trade for Ann Arbor. Clothing and clothing accessories stores account for over two-thirds of total sales of clothing and footwear in Ann Arbor. General merchandise stores account for almost a third of total sales, and used merchandise stores represent only 1 percent of total sales. The minor role of used merchandise stores is expected considering the small number of stores present in Ann Arbor and the low price of their merchandise.

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[87] Ibid.

[88] Clark, Betsy. Jacobson's Store Manager, Briarwood Mall. Personal interview. 8 May 2000.

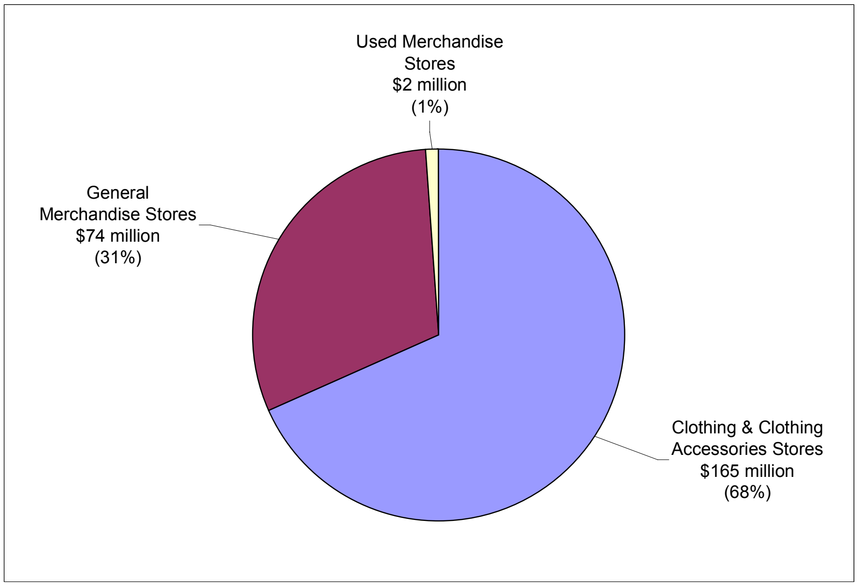

Figure 4-21 Sales of Clothing and Footwear in Ann Arbor, MI, by Retail Sector (Based on 1997 Economic Census data, Ann Arbor, MI)

Observation 3: Change in stock of clothing is uncertain.

The difference between inflows and outflows indicates an accumulation of approximately 13 lbs. per capita. However, due to the similar magnitude of the inflow and outflow mass, estimating the change in stock is highly uncertain.

The Southeast Michigan Council of Governments estimates that the population of Ann Arbor has remained steady since the 1990 census,[89] so a potential increase in the stock would not be due to an increase in the population. An addition to the stock is not unexpected considering the booming economy and the above average median income for Ann Arbor residents. The transition to business-casual work environments has also stimulated clothing sales.[90]

Observation 4: A majority of the clothing leaving Ann Arbor is disposed in the Municipal Solid Waste stream. Of the mass of clothing recovered for reuse or

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[89] Nutting, op. cit.

[90] Miller, Paul. "Apparel: Trends Analysis." Catalog Age. Section: Market Sector Closeup, Consumer. Intertec Publishing Corporation. Mar 2000.

recycling, surplus clothing donated to non-Ann Arbor organizations is larger than textiles recovered by the Ann Arbor Solid Waste Management system.

Table 4-25 shows how the masses of clothing outflows are obtained. The total mass of clothing retired from use in Ann Arbor is calculated based on EPA generation estimates. The total mass of used clothing resold within Ann Arbor, 80 tons, is subtracted from this value to determine the total outflow mass. Clothing leaves the community via three routes: surplus clothing from reuse stores donated to non-Ann Arbor organizations, clothing recovered for recycling by the Ann Arbor Solid Waste Department, and clothing disposed in MSW.

Table 4-25 Calculation of Mass of Clothing Outflows

<table>
<tr><th>Total Mass of Clothing Retired from Use</th><th>Fate</th><th>Mass</th><th>Destination</th></tr>
<tr><td rowspan="4">2,300 tons</td><td>Used Clothing Resold within Ann Arbor</td><td>80 tons</td><td>Reuse in Ann Arbor</td></tr>
<tr><td>Surplus Clothing Donated for Reuse/Recycling</td><td>230 tons</td><td rowspan="3">Outflow

(total =
2,200 tons)</td></tr>
<tr><td>Recovered for Recycling</td><td>68 tons</td></tr>
<tr><td>Disposed in MSW</td><td>1,900 tons</td></tr>
</table>

*may not sum due to rounding

This mass of clothing diverted from disposal is much lower than expected, based on research conducted by the Council for Textile Recycling. It estimates that about 25 percent of textile waste in the United States is diverted from the waste stream for reuse or recycling, either for domestic use or to be exported.[91] The low diversion rate in Ann Arbor may be due to the use of national generation data for the mass of clothing disposed, rather than data from the Ann Arbor Solid Waste Department. Ann Arbor data are not used because the estimate for generation is five times lower than estimates using EPA data, 450 tons vs. 2,300 tons.

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[91] Information: Don't Overlook Textiles. Council for Textile Recycling. <http://www.textilerecycle.org> 10 March 2000.

Observation 5: U.S. per capita generation of clothing and footwear in the Municipal Solid Waste stream greatly exceeds estimates of Ann Arbor generation of clothing and footwear.

Table 4-26 provides a summary of three methods for estimating mass of clothing and footwear in the municipal solid waste stream. The EPA's Characterization of MSW estimates the generation of clothing and footwear in the MSW from the mass of clothing manufactured and imported to the U.S., as determined by the U.S. Department of Commerce's Current Industrial Reports (CIR). The EPA estimates that clothing has a three year residence time within the community, therefore the mass of clothing in the MSW stream in 1997 is determined from the mass of clothing produced in 1994.

Table 4-26 Comparison of Generation, Recovery, and Disposal of Clothing and Footwear in MSW Stream

Data Source	Outflow Mass			Comments
	Generated	Recovered	Disposed	
EPA Characterization of MSW	2,300 tons	300 tons	2,000 tons	▪ Reuse is included in disposal[92], even though nearly all used clothing is exported abroad[93].
1994 Current Industrial Reports Apparent consumption of apparel and footwear[94]	2,700 tons			▪ Data and method used by Franklin Associates for calculating 1997 generation. ▪ Assumes all clothing and footwear produced/imported in 1994 has 3 year residence time, and then is disposed in 1997.
Ann Arbor Solid Waste Department	450 tons	68 tons	390 tons	▪ Does not include donations to reuse stores. ▪ Textiles include linens and other non-apparel items.

In an effort to replicate the method by which the EPA calculates the generation of clothing in MSW, the 1994 CIR data are analyzed and an estimate made for the mass of

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[92] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update. op. cit. The EPA assumes that reused textiles re-enter the waste stream the same year that they are first discarded, and so considers re-use as a diversion rather than recovery.

[93] Information: Don't Overlook Textiles. op. cit.

clothing generated in the MSW in 1997, assuming all clothing is disposed. The resulting estimates, 2,300 tons based on EPA data, and 2,700 tons based on 1994 CIR data, vary by only 400 tons. The discrepancy in the values may have resulted from gaps in the 1994 CIR data due to their withholding of the quantity of specific types of clothing to avoid disclosing proprietary information.

The estimate for generation using Ann Arbor Solid Waste Department data is much lower than either the EPA or CIR estimate. The Solid Waste Department value does not reflect the mass of clothing diverted prior to entering the waste stream through donations by Ann Arbor residents to reuse stores and charities in the area. The EPA assumes that used clothing will eventually be disposed, so it does not include reuse as a diversion.

According to estimates from Ann Arbor reuse stores, over 300 tons of clothing are donated to the three Ann Arbor thrift stores per year. If the mass of this diversion is added to the 450 tons of clothing generated in Ann Arbor's MSW stream, according to the Solid Waste Department data, the total is less than 800 tons, which is still only one third of the EPA estimate of 2,300 tons of clothing generated in MSW.

Additional Discussion

Not all indirect materials and select direct materials are included in the analysis. However to put the results into context, additional data on these excluded materials are presented below. Table 4-27 lists observations resulting from the additional data.

Table 4-27 Additional Clothing Observations

Observations
6. Mail order sales are a small but increasing percentage of total apparel sales.
7. Water use for cleaning is significant.

[94] Franklin, Marge. Franklin Associates. Personal interview. 18 May 2000. Estimates for generation of clothing and footwear in 1997 are based on 1994 Current Industrial Reports, because 3 year lag from year produced/imported is assumed. Therefore 1994 data is used to predict generation for 1997.

Observation 6: Mail order sales are a small but increasing percentage of total apparel sales.

Mail order sales are not included in the estimate of economic inflows because these sales can not be identified in the data source used to obtain Ann Arbor retail sales data. With the growing presence of e-commerce, mail order sales, including catalog and internet, have risen. Catalog sales alone have been rising at a 7.5 percent annual rate, compared to 5.2 percent for all U.S. consumer sales.[95] According to the American Apparel Manufacturers Association, an estimated $169 billion was spent on apparel in 1997, with direct mail sales accounting for 6 percent.[96] Online sales accounted for 0.6% of apparel sales.[97]

The environmental impacts of mail order are important in that transportation requires a large infrastructure and consumes large amounts of fuel. Method of delivery is important; standard delivery uses less energy than express air delivery. Distance traveled in delivering packages and frequency of returns is another factor in total transportation energy. Mail order displaces the need for individual consumers to travel and purchase clothing. It is not clear which transportation has a greater impact - delivery or purchasing. Packaging is also a concern with mail order sales. Some mail order retailers are reusing packaging materials. With attention to the method in which clothing is packaged and shipped, the impacts of moving clothing from manufacturer to consumer can be minimized.

Observation 7: The mass of water used for cleaning is over 10 times larger than mass of the inflows of clothing.

Water is a significant indirect material associated with clothing. Residential water use is estimated to be 80 gallons per person per day, with washing machines accounting for 22

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[95] Woodyard, Chris. “Wisconsin Cataloger Plows Through Storm. Lands' End Moves 40% of Business in 3-month Period.” USA Today. 15 Dec. 1997: Final Edition. Section: Money, 10B.

[96] American Apparel Manufacturers Association. AAMA Marketing Committee. Apparel Market Monitor Annual 1998. Arlington: AAMA, 1998.

[97] Kuntz, Jackie. “Age and Income Play Key Roles in Online Sales.” DNR. 27 March 2000, 30: 37. <http://web.lexis-nexis.com/universe> 26 May 2000.

percent of the water use.[98] This translates into washing machines consuming 17.6 gallons per person per day. Applying this figure to the population of Ann Arbor for a year results in water usage totaling 41,392 tons for cleaning clothing in the existing stock. This is 14 times greater than the estimated mass of clothing inflows in 1997. Water usage can be significantly reduced by replacing conventional, vertical axis washing machines with new "horizontal-axis" machines. This replacement can reduce water use by 30-60 percent. Maintenance materials such as water have a significant impact and should not be overlooked when looking for solutions related to improving the flows of clothing.

Material Flow Recommendations

The impact of the flow of clothing and footwear can be diminished by purchasing fewer clothes, redirecting flows in order to capture the economic and resource value, or lengthening the life or residence time of the material. Recommendations for improving the flow of clothing through a community focus on capturing the economic value by diverting clothing from landfills and are presented below.

In identifying solutions, it is important to understand why clothing is disposed. Clothing is discarded because it is worn out, damaged, outgrown, or out of fashion. The last reason may be the most important factor in altering clothing flows, because it seems to be the largest driver of new clothing purchases. Potential solutions are limited by the ability and desirability of altering purchasing patterns by changing human behaviors and attitudes. Table 4-28 summarizes potential recommendations for altering flows of clothing.

Table 4-28 Material Flow Recommendations for Clothing and Footwear

Action	Current Program	Recommendation
Household Recycling	Textile recycling	Further promotion of recycling program
Textile Recycling Business		Explore new business opportunity
Reuse	Sales by Ann Arbor stores	Promote reuse

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98 Woodwell, op. cit.

Household Recycling

Ann Arbor is one of only a few communities that collect textiles as part of curbside recycling. Eighteen communities were featured in the EPA report "Cutting the Waste Stream in Half: Community Record-Setters Show How."[99] Only 7 of the 18, including Ann Arbor, collected textiles at either curbside or drop-off locations.

According to Eric Stubin, of Trans-America Trading Co., a textile recycling company in New York, Ann Arbor's textile collection rate is much lower than expected for city with over 100,000 residents. He estimates that a city with a population of 100,000 could collect over 250 tons per year, in contrast to the 68 tons actually collected in Ann Arbor in 1997. This disparity may be explained by the mass of clothing donated directly to reuse stores or charities, rather than disposed in the MSW stream.

A key to the success of any recycling program is the generation of large volumes of well sorted material. The University of Michigan recognizes that large volumes of waste are generated when students move out of the Residence Halls in the spring. In order to facilitate capture of materials for reuse and recycling, the University publishes a Student Move-Out Guide[100] and puts collection bins in the Residence Hall lobbies for clothing, food and toiletries, household items, mixed containers, mixed paper, and shoes. This technique of targeting collection when large volumes are present in the waste stream appears effective for salvaging reusable or recyclable materials. One strategy that the City of Ann Arbor could use to stimulate clothing donations is to organize a once- or twice-yearly "Closet Clean-Out." Promotion on this collection could generate a large stream of well-sorted clothing.

Better promotion of textile recycling in Ann Arbor could generate additional revenue by reducing the total mass of clothing disposed in MSW and instead recovering it for recycling. The Trans-Americas Municipal Recycling Program pays a $100 minimum-

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[99] United States Environmental Protection Agency. Cutting the Waste Stream in Half: Community Record-Setters Show How. EPA-530-R-99-013. Washington, D.C.: U.S. EPA. 1999.

[100] Student Move-Out Guide. University of Michigan Plant Operations. <http://www.recycle.umich.edu/grounds/recycle/student_move-out.html> 2 Jun. 2000.

per-ton floor price for textiles,[101] thus guaranteeing a revenue stream even if the market price of textiles falls. According to Mr. Stubin, textiles are becoming a valuable recyclable commodity. However, with the booming economy, clothing donations have increased, resulting in a glut of used clothing, and dropping commodity prices.

Textile Recycling Business

Ann Arbor residents donate a significant amount of clothing to reuse stores and charitable organizations. While only a portion of these flows is studied in this analysis, donations to the three main clothing reuse stores in Ann Arbor are estimated to be over 300 tons. Factoring in these other methods of donation, the Ann Arbor community may want to investigate the feasibility of attracting a textile recycling business to locate nearby, servicing the larger southeast Michigan region.

The textile recycling industry is one of the largest exporters in the United States. Pre-consumer textile waste, generated during clothing or textile manufacturing, is recycled into new raw materials for the automotive, furniture, mattress, home furnishings, paper, and other industries. Approximately 75 percent of the pre-consumer textile waste is diverted from landfills and recycled. Post-consumer textile waste is composed of discarded clothing and household textiles. Recovered clothing can be exported as secondhand clothing, turned into rags or wipers for cleaning, or shredded for use as fibers. Approximately 20 percent of post-consumer textiles becomes wiping and polishing cloths, and 26 percent is converted into fiber that is used in products similar to those manufactured from pre-consumer textiles waste.[102] Almost half of the post-consumer textile waste that is recovered is recycled as secondhand clothing, which is typically sold to third-world nations.

Every ton of textiles recycled creates two man days of semi-skilled labor[103]. For a community needing to create jobs, textile recycling can fill that niche. However, Ann

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[101] Ridgley, Heidi. "More Municipalities Incorporating Textiles into Recycling Programs." Recycling Times. 13 Apr. 1998. <http://www.tranclo.com/hp35.asp#4> 2 Jun. 2000.
[102] Information: Don't Overlook Textiles. op. cit.
[103] Trans-America Trading Co. <http://www.tranclo.com> 2 Jun. 2000.

Arbor may not have enough employees to fill semi-skilled labor jobs. The Materials Recovery Facility sorts recyclables from Ann Arbor and the surrounding area, and hires semi-skilled workers. According to Bryan Weinert, Ann Arbor Solid Waste Department Manager, the city has had a difficult time finding reliable, competent workers.

Textile recycling firms support local communities by purchasing a large percentage of their clothing from charitable organizations. This economic investment supports these organizations and their goals, increasing their resource base.

With Ann Arbor's proximity to the automotive industry, textile recycling could supply automotive suppliers with materials for seat and carpet padding. For example, the new Ford Focus uses shredded cotton from old denim jeans for its underhood sound-deadening components[104].

Clothing Reuse

Reuse is an important strategy for reducing the inflow and outflow of clothing and decreasing the velocity at which clothing moves through the community. Reuse increases the life span of clothing and provides inexpensive clothing for people who do not have the economic resources to purchase new clothing. Keeping clothes in use reduces the financial expenditures by individuals, and discarding fewer clothes reduces the financial costs to the city for waste disposal.

[104] 1998 Environmental Report Ford Motor Company. <http://www.ford.com/content/report.pdf> 10 May 2000.

Chapter 4.4: Transportation

Communities have always needed to transport people and objects across the physical landscape; what has changed over time is the means to this end. This chapter describes the material flows associated with this need for mobility, the process and results of estimating material inflows and outflows, and recommendations to improve the efficiency of these flows.

Category Description

Transportation can be grouped into two types of needs: personal mobility and freight and other transport.

- Personal mobility addresses the need for residents to travel easily throughout and beyond the community. Purposes for personal travel include commuting between home and work or school, shopping, visiting friends and relatives, traveling to a place of recreation or entertainment, performing a job such as a police patrol, and other personal business.
- Freight and other transport addresses the need to move objects between locations. The most common form of freight and other transport is the movement of raw materials and finished goods between manufacturing facilities, warehouses, and retail stores. Specialized vehicles used to transport other types of materials include refuse trucks for garbage and recyclable materials, mixer trucks for cement, wreckers for automobiles, delivery trucks for mail, and tank trucks for gasoline.

Freight and other transport vehicles can be thought of as indirect materials for other functional categories, such as a dump truck used to support the construction of shelter. Freight and other transport vehicles have been included alongside personal mobility vehicles for three reasons:

1. The distinction between the two groups of vehicles is not always clear. For example, vans and pickup trucks are commonly used for both purposes.

2. The two needs complement each other and are often part of the same system. For example, a truck that delivers a mail order product to a residence may serve an analogous purpose as a car used to drive to a retail store. In both cases the need is to connect the consumer with the product and to transport the product to the residence.
3. Finally, all vehicles share the same need for fuel, the same road infrastructure, and the same data source of vehicle registrations.

This discussion of the links between personal mobility and freight and other transport provides an important observation. In some cases, improving access to information, goods, and services can reduce or transform the need for transportation. For example, if a grocery store is built in a residential neighborhood, then groceries are being transported closer to the residents' homes and their need for personal mobility to go grocery shopping is reduced. Thus in some cases the ultimate need being addressed is one of access, which can be met partially or in full through a change in neighborhood layout or in information technology rather than through personal mobility using automobiles.

Materials used to provide transportation services are shown in Table 4-29.

Table 4-29 Materials Associated with Transportation

Direct Materials	Indirect Materials
▪ Ground motor vehicles (e.g. cars, pickup trucks, motorcycles, vans, heavy-duty trucks) ▪ Other vehicles* (e.g. bicycles, trains, airplanes, boats) ▪ Maintenance materials (e.g. tires, engine oil, spark plugs)	▪ Transportation infrastructure materials* (e.g. roads, signals, gas stations) ▪ Fuels* (e.g. gasoline, diesel fuel)

* This report does not include separate inflow or outflow estimates for these materials.

Direct Materials

Ground motor vehicles are the most common form of transportation in Ann Arbor, and they are the focus for the mass and economic value estimates in this report. Maintenance materials for ground motor vehicles are also included as a direct material because they become part of the vehicles in use. Other vehicles such as bicycles, trains, airplanes, and boats, are not included in the inflow and outflow estimates due to a lack of available data. Trains are technically a form of ground motor vehicle, but they are not included among the other types of ground motor vehicles, all of which can be driven on a road. Note that walking is a form of transportation that does not require any specific material except perhaps for shoes.

Indirect Materials

Transportation infrastructure materials and fuels are not included in the inflow and outflow estimates for transportation because they are indirect materials. Transportation infrastructure materials include the roads, bridges, signals, signs, and gas stations required to enable ground transportation to occur. Fuels such as gasoline reasonably might be considered direct materials because they are an integral part of a motor vehicle's operation. The decision to classify fuel as an indirect material is influenced by the preexistence of significant research focusing on how energy flows through the community in the form of fuel and electricity.

Inflows and Outflows

Figure 4-22 shows the material stocks, inflows, and outflows associated with ground motor vehicles and their maintenance materials. The four material inflows and outflows to the community that are included in the reported mass and economic value estimates are represented as solid arrows. Flows without an estimate are represented by dotted lines.

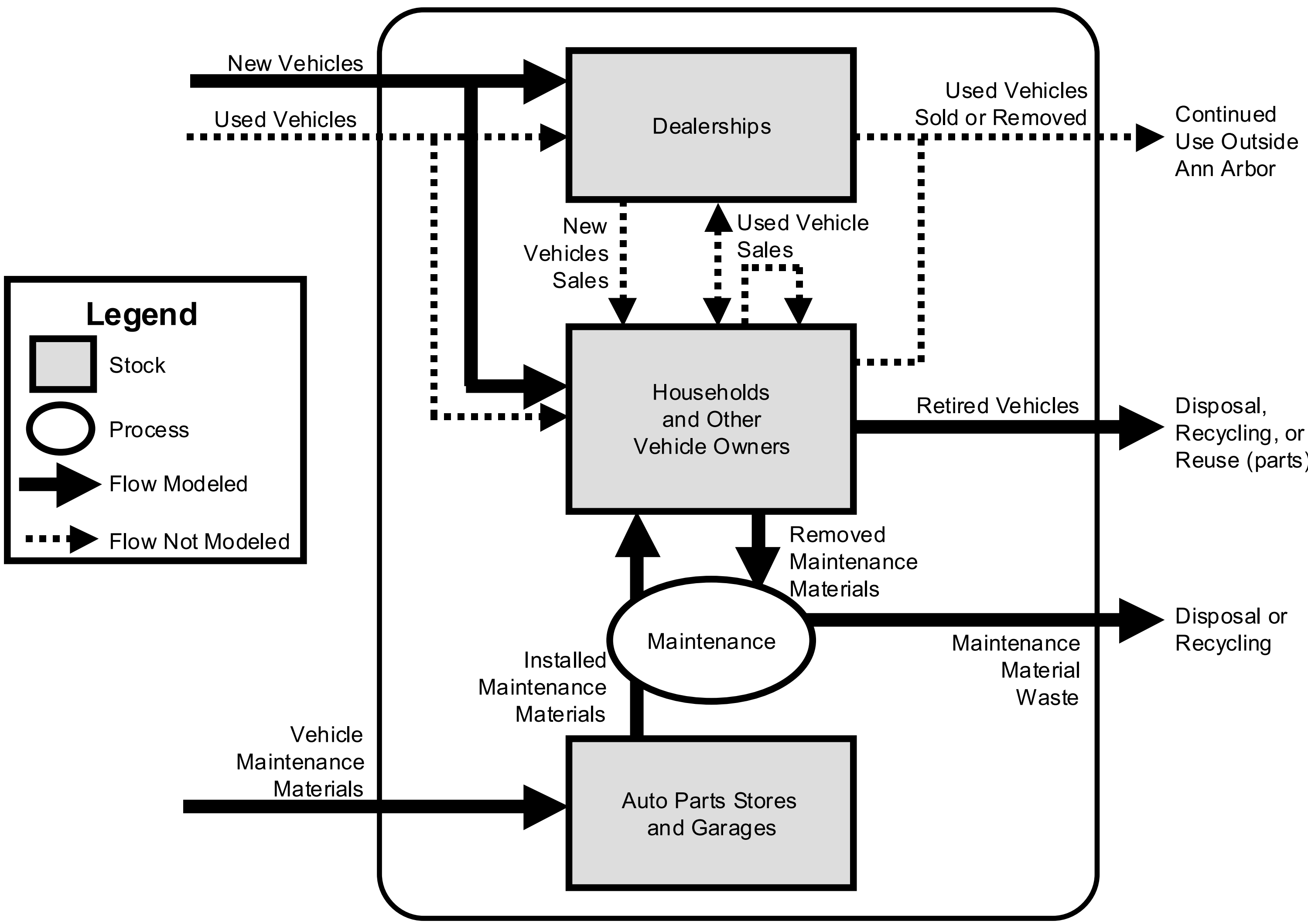

Figure 4-22 Transportation Direct Material Flows Through Ann Arbor

Ground Motor Vehicles

The Ann Arbor community uses many ground motor vehicles for transportation, such as cars, trucks, tractor-trailers, ambulances, dump trucks, and motorcycles. Vehicle types not registered with the Michigan Department of State, such as construction and farm equipment, are not included in this report.

The inflow estimates for vehicles only includes new vehicles, whether purchased through dealerships inside or outside of the community. Vehicles are not counted as an inflow when they are brought into local dealerships but instead when they are in the possession of the owning household or institution.

Vehicles are only counted as an outflow when they are retired at end of their useful life. Most retired vehicles are eventually dismantled to harvest usable parts and remove materials for recycling. The remaining hulk is shredded to recover metals for recycling. Leftover wastes from dismantling and shredding are sent to a landfill.

The purchase and sale of used vehicles into and out of the community have not been included in the estimates. Similarly, the movement of vehicles into and out of the community without a transfer of ownership has not been included. Examples of this form of movement include temporary entrances and exits of vehicles passing through on the highway and permanent movements due to the immigration or emigration of a vehicle's owner. It is assumed that these inflows and outflows are the same so that there is no effect on the stock of vehicles in the community.

Daily commuting for work occurs in both directions, with Ann Arbor residents traveling to outside employers in the greater Detroit area, and individuals living outside the community entering each day for jobs within Ann Arbor. The estimates in the study are based on the vehicles owned by Ann Arbor residents wherever they are used and do not include other vehicles that may enter the community each day. Similarly, tractor-trailers used for long-haul freight transport are included in the community stock of vehicles if they are registered locally, even if they are out of the community most of the time.

Vehicle Maintenance Materials

Only maintenance materials used in registered ground motor vehicles are included in this material type. Materials such as batteries, engine oil, tires, and brake pads must be replaced regularly throughout the life of a vehicle. These basic maintenance materials are needed during the normal use of a vehicle. Other materials such as engines, transmissions, doors, and other car parts must be replaced due to a vehicle accident or malfunction not encountered in normal use. These other car parts are not included in the inflow and outflow estimates due to a lack of data.

Maintenance materials are counted as an inflow as they are installed for use in vehicles. Vehicle owners may purchase maintenance materials from an auto parts store and perform the installation, or the owner may bring the vehicle to a garage to pay for the service of installation. This study does not account for any stock of maintenance materials outside of those currently in use in vehicles, such as the stock of an auto parts store.

As the maintenance materials are installed, the same type of material usually is removed at the same time. For example, as new tires are installed on a car, the old tires are removed and disposed, ending up in a landfill or becoming recycled rubber. These disposed materials make up the outflow for maintenance materials. Losses of maintenance materials during use such as tire wear is not modeled.

Note that these materials are also a part of the inflow, outflow, and stock of vehicles. For example, tires on a new car would enter the community as part of the vehicle inflow, but they would leave as part of the maintenance materials outflow if they are removed. Similarly, the replacement tires would enter as part of the maintenance materials inflow, but they would leave as part of the vehicle outflow if they are still on the vehicle when it is retired.

Data Sources

The data sources used for the transportation estimates are described below and are also described in further detail in Appendix E.

TR/9050 Reports

These reports are used as the primary source for data to estimate the stock, inflow, and outflow of vehicles. The Department of State for Michigan maintains records of all vehicles registered within the state of Michigan. The Department of State's Office of Policy and Planning has a report available called TR/9050 that contains the number of passenger and commercial vehicle registrations for the state.[105]

This report shows vehicle registrations for various body styles. Examples of body styles include two and four door cars, pickup trucks, motorcycles, utility trucks, tractors, and trailers. The Michigan Department of State body style classification system is used throughout this report, but this system has several limitations. The definitions for each body style are often vague, requiring subjective judgement to classify individual vehicles. More importantly, the body styles do not match those used in other sources of information on vehicles.

The Department of State vehicle registration reports are the single most important source of data on the changes of stocks of vehicles from year to year. The TR/9050 reports show vehicle registrations at the state level, and since 1999 they have begun reporting data at the county level. However, what would enable this data source to be more useful and accurate for a community material flow analysis is to provide data for cities and/or zip codes. Also, a breakout of vehicles by model year for each body style would have made the analysis much simpler and more accurate. A clearer breakout of ownership groups, such as individuals and corporate fleets, would also be helpful.

The Department of State collects the addresses of owners, the model year, and the body style as part of the vehicle registration process, so they already have the necessary information. The gap occurs because the TR/9050 is the only available report with registration data, and its format is fixed unless a programming change is made.[106]

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[105] Michigan Department of State, Office of Policy and Planning. TR/9050 Report. Michigan Department of State, 28 Apr. 2000.

[106] Coin, Liz. Michigan Department of State. Office of Policy and Planning. Personal interviews. July 1999 through Apr. 2000.

Additional reports could be created that would provide the more detailed information described above. However, a more robust solution would be to create a dynamic reporting system in which the user can select the pieces of data and the level of detail (down to the ZIP code or city level) as she is requesting the report. Ideally such a system would be available to the public via a World Wide Web interface.

Other Vehicle Fleets

The TR/9050 report is supplemented by interviews with managers of nonprofit and government vehicle fleets that are not represented in the TR/9050. These fleets include Ann Arbor City government, University of Michigan, the local School District, the Ann Arbor Transportation Authority (AATA), and Huron Valley Ambulance (HVA). The municipal government and University fleets are made up of diverse types of vehicles, while the others have one predominant type (school buses for the school district, transit buses for AATA, and ambulances for HVA). Some fleets are not included due to time and data availability limitations, the most significant one arguably being the local fleet of post office trucks.

Average Price and Mass

The average price and mass for various types of vehicles are gathered from a wide variety of phone interviews and reports to complete the inflow and outflow estimates. True average unit mass and price are difficult to obtain for most body styles. Each body style may contain vehicles with a wide variety of curb weights and prices. The most extreme case may be the utility body style, which contains vehicles whose prices range from $24,000 to over $300,000. For most personal mobility vehicles, the manufacturer's suggested retail price is used as basis of the value, leaving out the additional value of options such as air conditioning, sun roof, and power locks and windows.

Average prices and masses for automobiles are available in the Transportation Energy Data Book, but not for other body styles. For example, heavy trucks are described in terms of gross vehicle weight (includes weight of cargo) but not curb weight (base vehicle weight). The few good pieces of information found are for body styles that do not match the Department of State body styles and so cannot be used directly.

A solution would be the development of a set of vehicle body styles with clear definitions that could be adopted by multiple federal, state, and local government and researchers. This classification system would be similar to the Standard Industrial Classification (SIC) index and the new North American Industry Classification System (NAICS) used to classify businesses. This would enable independent research on various body styles to be combined with census-like data provided through registrations to give a more complete picture of the vehicles in a given region.

Maintenance Materials

A 1998 life-cycle analysis of a mid-sized automobile provides information on the mass of maintenance materials used throughout the vehicle's lifespan of 120,000 miles over eleven years.[107] Price quotes for most maintenance material prices are gathered through AutoZone, a local auto parts store.[108,109] These data sources, along with estimates of the total stock of vehicles, form the core of the estimates for maintenance materials.

Assumptions

The methods used to estimate the mass and economic value of material flows related to transportation rely on several assumptions described in detail in Appendix E. A few of the more important assumptions are listed below in Table 4-2.

Table 4-30 Major Assumptions for Transportation Estimates

Assumptions
1. Ann Arbor's population remains static throughout the year.
2. All used car sales occur between community residents, not with others outside Ann Arbor.
3. The proportion of new and retired vehicles to the stock for each body style is the same for Michigan, Washtenaw County, and Ann Arbor.
4. The number of vehicles of each body type per capita is the same in Washtenaw County and Ann Arbor.
5. All vehicles of a particular body style have the same mass and price.
6. All vehicles (including heavy trucks) require the same amount of maintenance materials each year as a four door automobile.
7. For maintenance materials, the inflow mass and outflow mass equals the mass used.

Each of these assumptions is discussed further below.

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[107] Center for Sustainable Systems. op. cit.

[108] AutoZone Auto Parts. Personal interview. 24 May 2000.

[109] AutoZone. <http://www.autozone.com/> 17 May 2000.

Assumption 1: Ann Arbor's population remains static throughout the year.

It is assumed that there are no immigrants or emigrants moving into or out of the community who are bringing in or removing vehicles. This assumption also implies that the population does not experience seasonal changes that would reduce the stock of vehicles. Given that many students leave Ann Arbor during the summer, it is likely that the stock of vehicles is reduced during these months. The most significant impact of this assumption is that the estimates of the use of maintenance materials is based upon the stock of vehicles in the community, so these estimates may be overstated.

Assumption 2: All used car sales occur between community residents, not with others outside Ann Arbor.

As mentioned earlier, it is assumed that Ann Arbor residents never buy used vehicles from sources outside the community. Similarly, it is assumed that used vehicles are never sold to buyers outside the community. Another way to interpret this assumption is that the mass and economic value of used vehicles purchased from outside the community are roughly equal to the mass and economic value of used vehicles sold to other communities. Under this assumption there is no net effect on the stock of vehicles in Ann Arbor. An exception to this assumption is that the City of Ann Arbor purchases many of its vehicles used, and the lowered price for used vehicles paid by the City is used in this report.

Assumption 3: The proportion of new and retired vehicles to the stock for each body style is the same for Michigan, Washtenaw County, and Ann Arbor.

The number of new and retired vehicles is estimated based on comparing stocks of vehicles between years (see Summary of Estimation Process below), but the TR/9050 reports only show vehicle stocks for multiple years at the state level. This assumption allows information about the change in stocks for Michigan to be applied to Washtenaw County and Ann Arbor. This assumption ignores the effect of relative differences in population growth. Between July 1, 1996 and July 1, 1997, Michigan's population grew by 0.47%, while Ann Arbor's population fell by 0.37%.[110] Any new vehicles purchased

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[110] Nutting, op. cit.

by Michigan's 46,000 new residents in 1997 create an inflation in the Ann Arbor inflow estimate.

Assumption 4: The number of vehicles of each body type per capita is the same in Washtenaw County and Ann Arbor.

The TR/9050 report contains stock data for Washtenaw County for one year, but none for Ann Arbor. This assumption allows this information to be used to estimate the stock of vehicles in Ann Arbor. In other words, the stock of vehicles in Ann Arbor is set by County level data, and changes to that stock are set by State level trends. Ann Arbor is very different from the County, however, in that it is more urban (100% versus 76.3% for the County[111]), it has a large student population (one-third of Ann Arbor residents are undergraduate or graduate students of the University of Michigan[112]), and it is the center of Washtenaw's public transit system run by AATA. Ann Arbor is likely to have fewer vehicles per capita than the County due to increased reliance on walking, biking, and buses (see Table 4-31 below). Ann Arbor may also have a different proportion of body styles with the stock of vehicles. For example, Ann Arbor may have fewer pickup trucks than more rural areas. However, using Washtenaw County data creates a more accurate estimate of stock vehicles than using only Michigan-level data because most of the state of Michigan is more rural (70.5%) than Washtenaw County.

Table 4-31 1990 Census Commuting Data[113]

Commuting Data	Ann Arbor	Washtenaw	Michigan
Mean travel time to work (minutes)	17.0 minutes	19.5 minutes	21.2 minutes
% drove alone	61.8%	73.5%	81.5%
% in carpool	9.2%	9.6%	10.5%
% using public transportation	5.7%	3.0%	1.6%
% using other means	0.5%	0.5%	0.7%
% walked or worked at home	20.9%	12.5%	5.5%

[111] United States Bureau of the Census. 1990 Census of Population and Housing: Ann Arbor City Social Characteristics. Michigan Information Center. <http://www.state.mi.us/webapp/dmb/mic/census/stf1a3a_1990.asp?cmd=data&lev=place&id=1421&cat=soc> 6 Jun. 2000.

[112] Frequently Asked Questions. City of Ann Arbor Planning Department. <http://www.ci.ann-arbor.mi.us/framed/planning/index.html> 7 Feb. 2000.

[113] United States Bureau of the Census. 1990 Census of Population and Housing: Ann Arbor City Social Characteristics. op. cit.

Assumption 5: All vehicles of a particular body style have the same mass and price.

Errors in choosing average masses and prices could have made the estimates in the report either too low or too high. For example, the estimates for the unit price of vehicles are based on the manufacturer's suggested retail price for many body styles. These prices do not include the cost of options such as air conditioning and power steering that add to the cost of vehicles, so the estimates of the economic value of vehicle inflows is likely to be understated for many body styles. As discussed later in Observation 8, the unit mass of vehicles used is based upon the mass of currently available vehicles, which in the case of automobiles may be slightly heavier than the automobiles retired in 1997 that were purchased in the 1980s. This difference may create a small overstatement of the outflow mass for vehicles.

Despite these issues, it should be noted that the unit mass and price used for the two most common body styles are probably the most accurate of all the unit mass and price values used. The unit mass and prices for two door and four door cars came from a U.S. Department of Energy study that estimated average curb weights and prices in 1997. [114] Two and four door cars make up 51% of all vehicles in Michigan and about half of the inflow and outflow estimates in this report (45% of inflow mass, 55% of inflow value, and 52% of outflow mass).

Assumption 6: All vehicles (including heavy trucks) require the same amount of maintenance materials each year as a four door automobile.

The maintenance material data available are for a four door automobile. This assumption allows these data to be applied to all body styles. The assumption is probably fairly accurate for other passenger vehicles, which have similar mileage each year and maintenance requirements. However, other body styles may require significantly more maintenance each year, making the estimates too low for these body styles. For example, transit buses are typically in year-round daily use in stop and go traffic and require more

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[114] Davis, Stacy, ed. Transportation Energy Data Book: Edition 18. Oak Ridge: U.S. Department of Energy: Center for Transportation Analysis, Oak Ridge National Laboratory, Sep. 1998.

frequent maintenance work. On the other hand, trailers and trailer coaches would require fewer maintenance materials because they do not have propulsion systems of their own.

Assumption 7: For maintenance materials, the inflow mass and outflow mass equals the mass used.

Data are not available for the inflow and outflow of maintenance materials, but this assumption enables estimates to be made based upon their usage. Assuming that inflows equals use implies that stocks of maintenance materials remain constant and parts are brought into the community as they are needed. Assuming that outflows equal inflows implies that when new maintenance materials are installed in a vehicle, they replace used materials of equal mass that are removed from the vehicle and from the community. This assumption ignores the loss of materials during use, such as windshield cleaner.

Summary of Estimation Process

The estimates for transportation are created using the steps described below. A step-by-step description of the estimation process can be found in Appendix E.

Residential and Commercial Fleets - TR/9050

The ending stock of vehicles in 1997 for Ann Arbor is estimated based on adjusting Washtenaw County vehicle registration data for each body style down to Ann Arbor on a per capita basis. The ratio of new vehicles to the stock of vehicles for Michigan, described below, is multiplied by the Ann Arbor stock for each body style to estimate the number of new vehicles in Ann Arbor. Similarly, the Michigan ratio of retired vehicles to the ending stock, described below, is multiplied by the Ann Arbor stock to estimate Ann Arbor retired vehicles.

Estimating the ratios, used above, of new and retired vehicles to the stock of vehicles for Michigan requires several steps. State level vehicle registration data from the TR/9050 reports are manipulated to build an estimate of the stock of vehicles in Michigan at the end of 1996 and 1997, broken out by vehicle body style and model year. The number of new vehicles for each body style is estimated by comparing changes in the number of vehicles with recent model years between 1996 and 1997. The number of retired vehicles is then estimated based on the assumption that the difference between the total stocks of

1996 and 1997 equals the number of new vehicles minus the number of retired vehicles. Finally the estimated number of new and retired vehicles are each divided by the estimated number of stock vehicles to create the ratios.

Other Vehicle Fleets

The numbers of new, retired, and purchased vehicles in non-profit and government fleets not included in TR/9050 are gathered through interviews with fleet owners, including Ann Arbor City government, the University of Michigan, the local School District, the AATA, and the HVA. In some cases, estimates are created to best fit available data when only partial data for a fleet are available.

Mass and Value Estimates

New vehicles represent the material inflow, and retired vehicles represent the material outflow. The numbers of new and retired vehicles estimated in the previous steps are converted to mass and economic value estimates by multiplying them by an average unit mass and price for each body style.

Maintenance Materials

Data on the mass of maintenance materials are available for a vehicle's total life, so an annual estimate is created by comparing the average annual mileage for an automobile with mileage over its total lifespan. This mass of maintenance materials associated with annual mileage per vehicle is multiplied by the total stock of vehicles in Ann Arbor to estimate inflow and outflow mass, which are assumed to equal each other. The prices of maintenance materials are also estimated per vehicle on an annual basis and multiplied by the stock of vehicles to get inflow value. Note that the methods and data used are all based on automobiles even though they are applied to all vehicle types.

Results and Analysis

The final estimates for the mass and economic value of material inflows and outflows related to transportation are shown in Table 4-32.

Table 4-32 Transportation Inflow and Outflow Estimates

Material Type	Inflow Value (in millions)	Inflow Mass (in tons)	Outflow Mass (in tons)
Ground Motor Vehicles	$190	15,000	13,000
Maintenance Materials	$13	2,900	2,900
Total	$200	18,000	16,000

In Figure 4-23, the width of the arrows is proportional to the mass of the inflow and outflow of each material type.

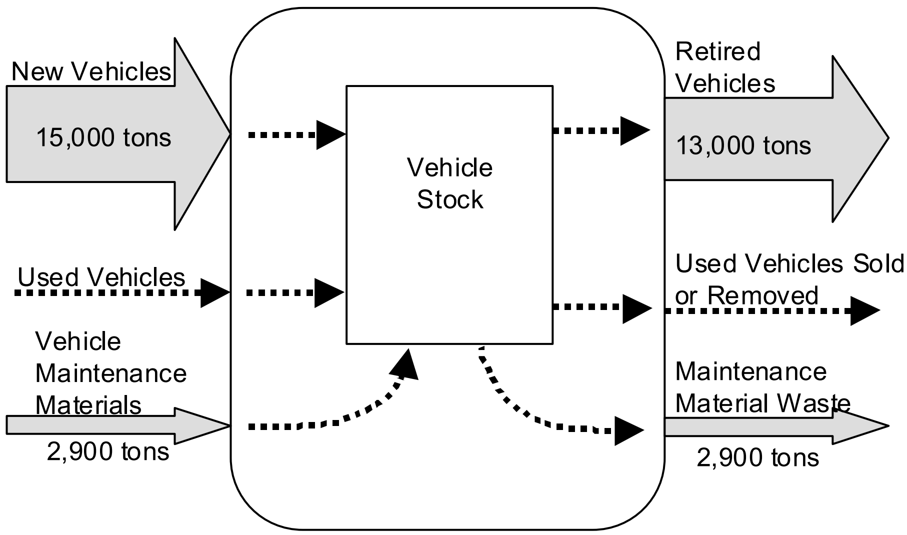


Figure 4-23 Transportation Mass Flow Diagram

Dotted lines outside the community boundary represent direct material flows not modeled. Dotted lines inside the boundary show connections between the inflow and outflow materials.

Analyzing the details behind these estimates results in several observations, stated in Table 4-33 below. The data upon which these observations are based can be found in Appendix E.

Table 4-33 Observations of Transportation Estimates

Observations
1. The stock, inflow, and outflow of vehicles used for personal mobility were much larger than those for freight and other transport vehicles.
2. Four door cars had the largest inflows and outflows among vehicles used for personal mobility, followed by station wagons (including SUVs*), two door cars and jeeps, and pickup trucks.
3. Trailers had the largest inflows and outflows among vehicles used for freight and other transport.
4. Station wagons (including SUVs*) were the strongest contributor to the growth of vehicle stocks, while two door cars accounted for the largest decline in stocks.
5. The University of Michigan had the largest fleet among government and non-profit organizations, but private and commercial vehicles account for the vast majority of Ann Arbor's use of vehicles.
6. Tires were the most significant maintenance material used in terms of their mass and value.

* The Michigan Department of State classifies sport utility vehicles (SUVs) in the station wagon body style[115].

Each of these observations is described in further detail below.

Observation 1: The stock, inflow, and outflow of vehicles used for personal mobility were much larger than those for freight and other transport vehicles.

The body styles used by the TR/9050 reports have been categorized into two groups in Table 4-34. As described earlier, personal mobility vehicles provide general transportation for people while freight and other transport vehicles are designed to carry specific types of materials.

[115] Coin, United States Bureau of the Census. 1990 Census of Population and Housing: Ann Arbor City Social Characteristics. op. cit.

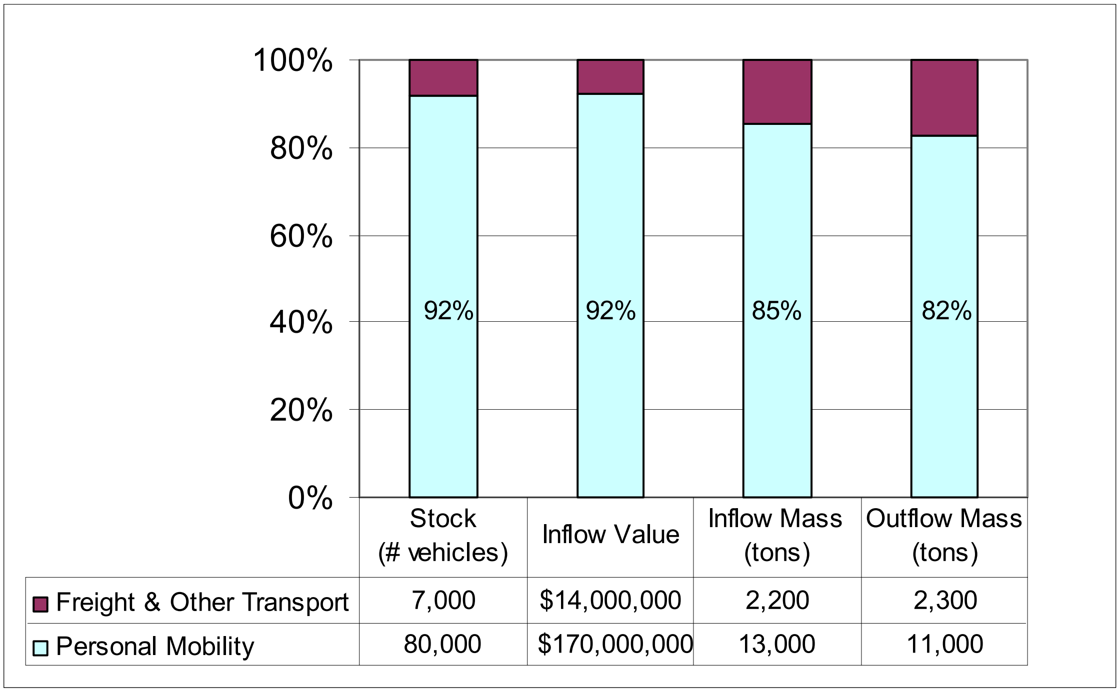
Table 4-34 Body Styles used for Personal Mobility vs. Freight and Other Transport

Personal Mobility		Freight and Other Transport	
Body Style	**Notes**	**Body Style**	**Notes**
Bus	Vehicle designed to carry more than 15 passengers	Ambulance	Medical transport vehicle
Convertible	Car with soft top, removable roof	Dump	Garbage truck, dump box truck, gravel truck
Four Door	Sedan, limousine	Hearse	Funeral transport vehicle
Motor Home	Vehicle with living quarters	Mixer	Cement truck
Motorcycle	Two or three wheels; does not include mopeds	Panel	Delivery sedan
Pickup	Pickup trucks	Stake	Flat bed, glass rack, box truck, and other types
Roadster	Open automobile having a front seat and a rumble seat; includes dune buggies	Tank	Trucks that carry liquids such as water, asphalt, sludge, and gas
Station Wagon	Station wagons and sport utility vehicles (SUVs)	Tractor	Truck tractor or semi tractor, not farm equipment
Trailer Coach	Camping trailer, travel trailer	Trailer	All trailers (such as semi trailers) except for trailer coaches
Two Door	Coupes and jeeps	Utility	Specialized trucks used to move equipment such as maintenance tools, tree trimmer, camera, cable, etc.
Van	Passenger and cargo vans	Wrecker	Tow truck, flatbed wrecker

Adopted from descriptions provided by the Michigan Department of State included in Table E-1 in Appendix E.

Note that some body styles can play more than one role, making the line between personal mobility and freight and other transport a blurry one. For example, some vans are designed as passenger vehicles while others are designed to carry cargo. Some pickup trucks are used for personal transportation while others are used primarily for hauling materials. The ambulance body style is classified as freight and other transport because it is not used for general personal transportation.

Figure 4-24 contrasts the size of vehicle stocks and the mass and value of inflows and outflows for vehicles used for personal mobility and freight and other transport in Ann Arbor in 1997. For each of these measures, personal mobility accounts for over 80% of the total use of vehicles. Any set of recommendations to improve the efficiency of material flows for transportation should address vehicles used for personal mobility as a high priority.



	Stock (# vehicles)	Inflow Value	Inflow Mass (tons)	Outflow Mass (tons)
Freight & Other Transport	7,000	$14,000,000	2,200	2,300
Personal Mobility	80,000	$170,000,000	13,000	11,000

Figure 4-24 Comparison of Personal Mobility and Freight and Other Transport Stocks and Flows in Ann Arbor, 1997

Observation 2: Four door cars had the largest inflows and outflows among vehicles used for personal mobility, followed by station wagons (including SUVs), two door cars and jeeps, and pickup trucks.

Two figures show the pattern of flows for various body styles for personal mobility vehicles. The economic values of new personal mobility vehicles in Ann Arbor in 1997 are shown in Figure 4-25. The masses of new and retired personal mobility vehicles in Ann Arbor in 1997 are shown in Figure 4-26. The values shown are directly dependent on the unit mass and price assumed for each body style, as described in Assumption 5, so the accuracy of these estimates may vary widely between body styles.

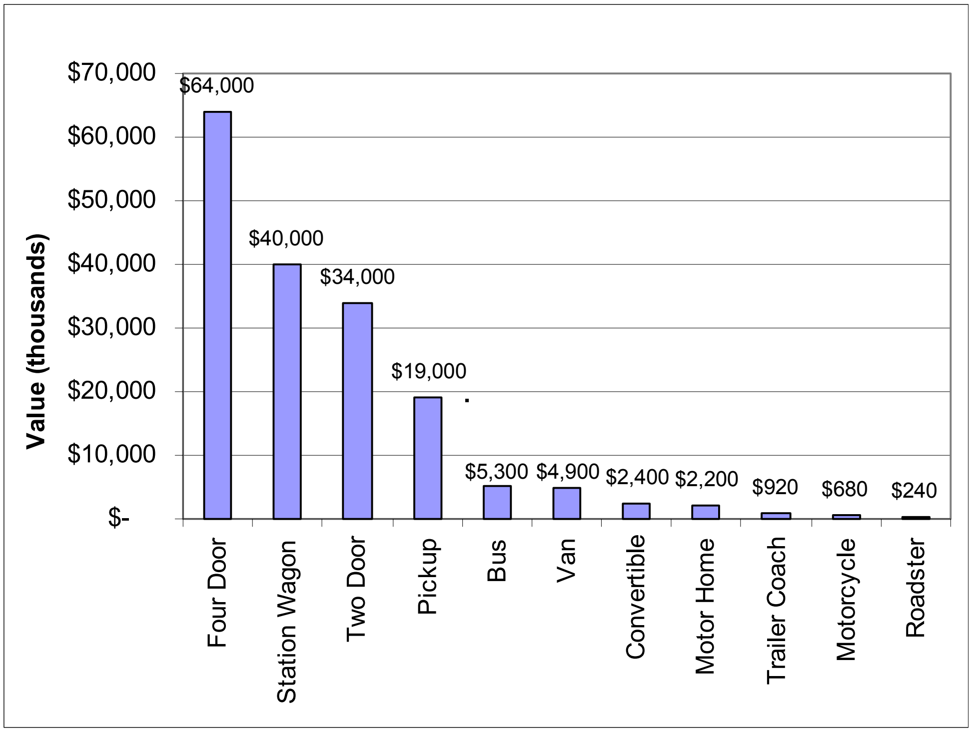
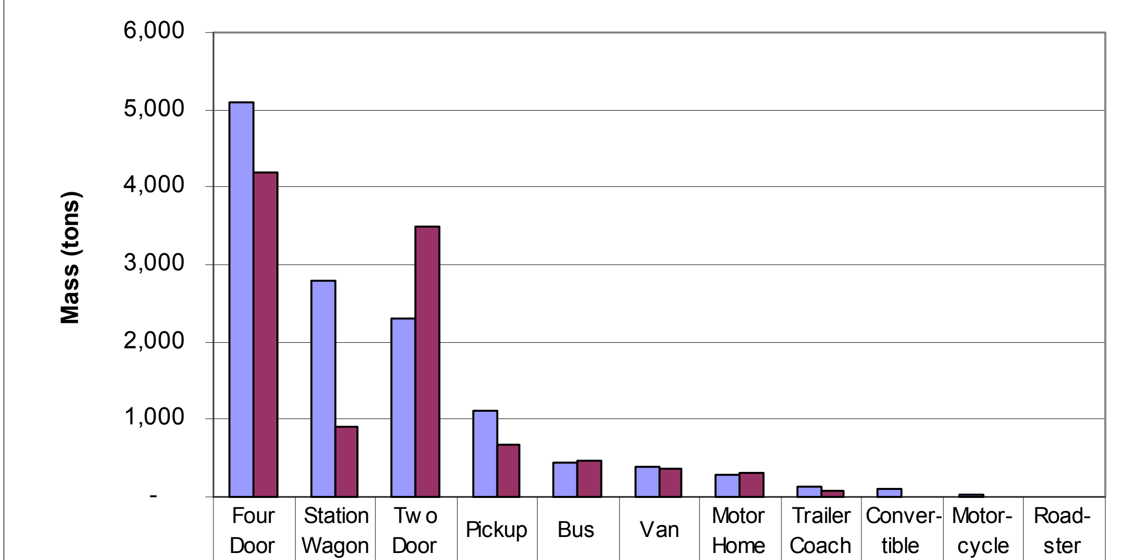


Figure 4-25 Inflow Value of Personal Mobility Vehicles for Ann Arbor in 1997



	Four Door	Station Wagon	Two Door	Pickup	Bus	Van	Motor Home	Trailer Coach	Conver-tible	Motor-cycle	Road-ster
Inflow Mass	5,100	2,800	2,300	1,100	430	390	280	130	110	17	8
Outflow Mass	4,200	900	3,500	670	470	360	320	80	9	4	4

Figure 4-26 Inflow and Outflow Mass of Personal Mobility Vehicles for Ann Arbor in 1997

Four door cars stand out as having the largest inflows and outflows. Their inflow value represents 37% of the total value for personal mobility vehicles and 34% of the value of all vehicles. Four door cars represent 40% of the total mass for new personal mobility vehicles and 34% of the mass of all new vehicles.

Station wagons, two door cars, and pickup trucks make up most of the rest of the value and mass for personal mobility vehicle inflows and outflows. The flows of group transit vehicles such as buses and vans and other specialized personal mobility vehicles are smaller, each representing under six million dollars for inflow value and less than 500 tons for inflow and outflow mass.

Observation 3: Trailers had the largest inflows and outflows among vehicles used for freight and other transport.

Two figures show the pattern of flows for various body styles for freight and other transport vehicles. The economic values of new freight and other transport vehicles in Ann Arbor in 1997 are shown in Figure 4-27. The mass of new and retired freight and other transport vehicles in Ann Arbor in 1997 are shown in Figure 4-28.

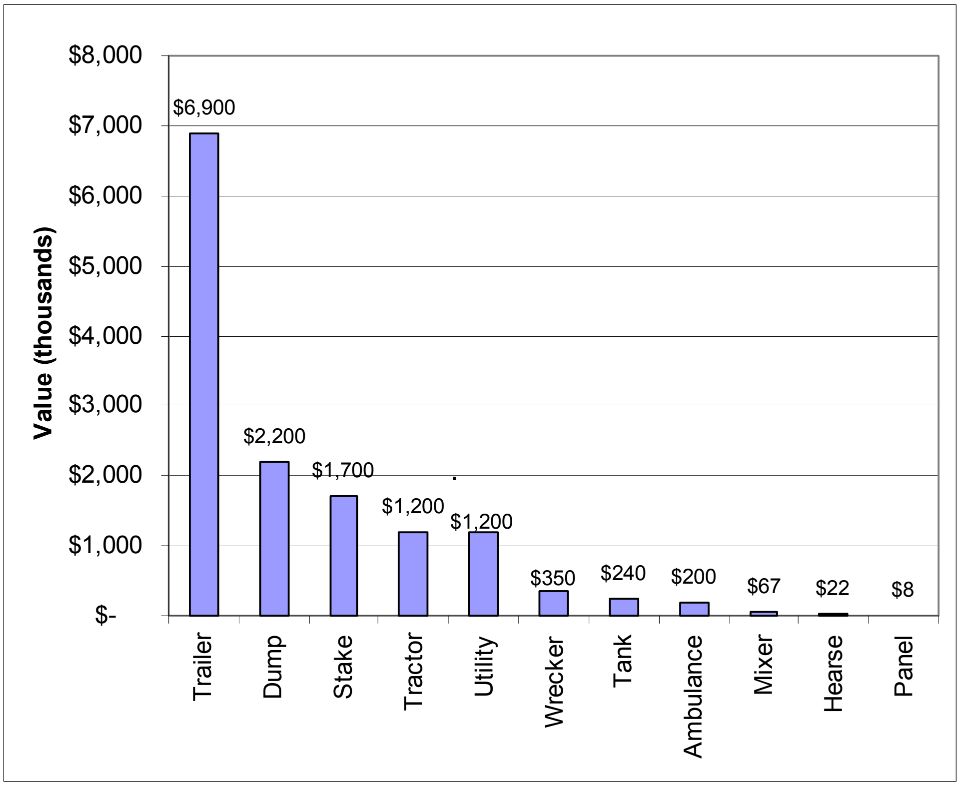
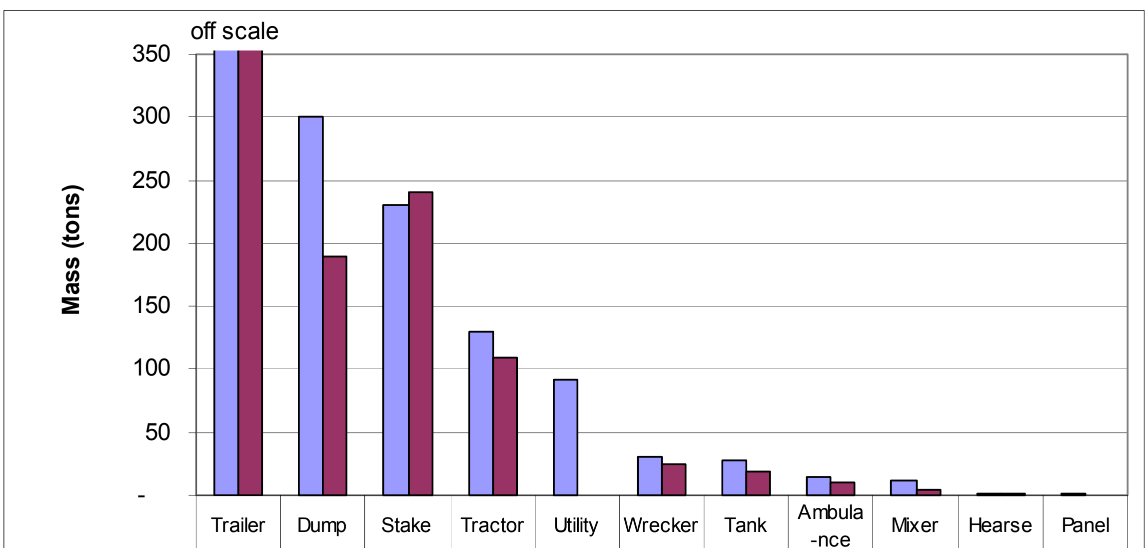


Figure 4-27 Inflow Value of Freight and Other Transport Vehicles for Ann Arbor in 1997



	Trailer	Dump	Stake	Tractor	Utility	Wrecker	Tank	Ambula-nce	Mixer	Hearse	Panel
Inflow Mass	1,400	300	230	130	92	31	28	15	11	1	1
Outflow Mass	1,700	190	240	110		25	19	10	5	1	0

Figure 4-28 Inflow and Outflow Mass of Freight and Other Transport Vehicles for Ann Arbor in 1997

Trailers dominate the inflow and outflow of freight and other transport vehicles. Trailers are registered with the State of Michigan and are therefore included among the other body styles even though they lack a motor and are not independent vehicles. Although worth less than 4% of inflow value for all vehicles, trailers make up about half of the value for new freight and other transport vehicles. Trailers are even more important in terms of mass, representing over 9% of the mass of all new vehicles and 62% of the mass of new freight and other transport vehicles.

After trailers, dump trucks, stake trucks, tractors, and utility trucks are the most significant freight and other transport vehicles in terms of both value and mass. The lack of an outflow mass for utility trucks is caused by unusual patterns in the TR/9050 data for that body style, and this issue is further described in Appendix E.

Observation 4: Station wagons (including SUVs) were the strongest contributor to the growth of vehicle stocks, while two door cars accounted for the largest decline in stocks.

Figure 4-29 shows how the differences between the mass of inflows and outflows for various body styles contribute to changes in the total stock for Ann Arbor.

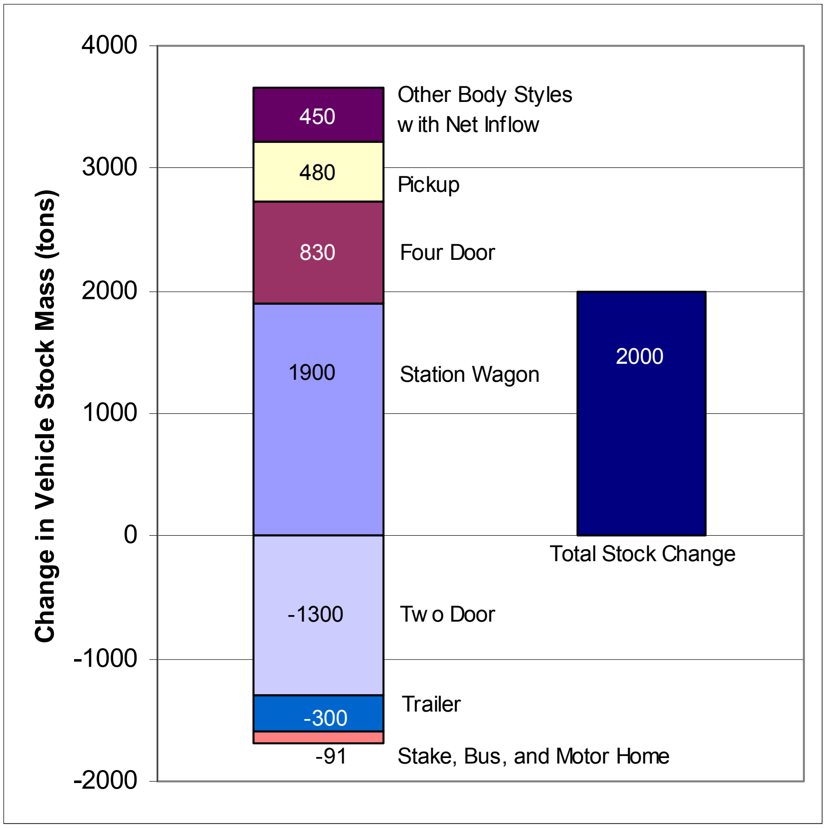


Figure 4-29 Changes in Vehicle Stock Mass for Ann Arbor in 1997

The difference between the total mass of inflows and the total mass of outflows is about 2000 tons, which represents the increase in the stock of vehicles in Ann Arbor that occurred in 1997. Body styles whose inflow mass is greater than their outflow mass are being brought into Ann Arbor as new vehicles faster than they are being retired, thus growing the stock of vehicles in Ann Arbor. In contrast, body styles whose outflow mass is larger than their inflow mass are declining in their total Ann Arbor stocks because the rate of purchases is less than the rate of vehicle retirement.

Among body styles with positive growth, station wagons accounted for over half of the growth in stocks with a net increase of 1900 tons in 1997. Sport utility vehicles are included in the station wagon body style, and their large unit mass and popularity in the late 1990s drives the growth of the station wagon body style. The average unit mass for new automobiles in 1997 was 2,977 pounds[116], compared to an average unit mass of 3,800 pounds for SUVs estimated by sampling weights of 2000 model year SUVs[117]. Many SUVs weigh over 4,000 pounds, and with certain options the Ford Excursion SUV can reach a mass of over 7,000 pounds.

The growth of body styles such as station wagons, four door cars, and pickup trucks is offset by reductions in other body styles, especially two door cars and trailers. The purchases and retirement of vehicles occur as independent transactions, yet at a community level Ann Arbor can be thought of as transitioning from two door cars to station wagons.

Observation 5: The University of Michigan had the largest fleet among government and non-profit organizations, but private and commercial vehicles account for the vast majority of Ann Arbor's use of vehicles.

Private and commercial vehicles whose registrations appear in the Michigan Department of State's TR/9050 reports are much larger in aggregate than fleets owned by local non-profit and government organizations. Private and commercial vehicles represent between 93% and 98% of the total stock of vehicles, the number of new and retired vehicles, the value of inflows, and the mass of inflows and outflows for Ann Arbor. Figure 4-30 shows fleets of vehicles, not included on the TR/9050 reports, owned by non-profit and government organizations.

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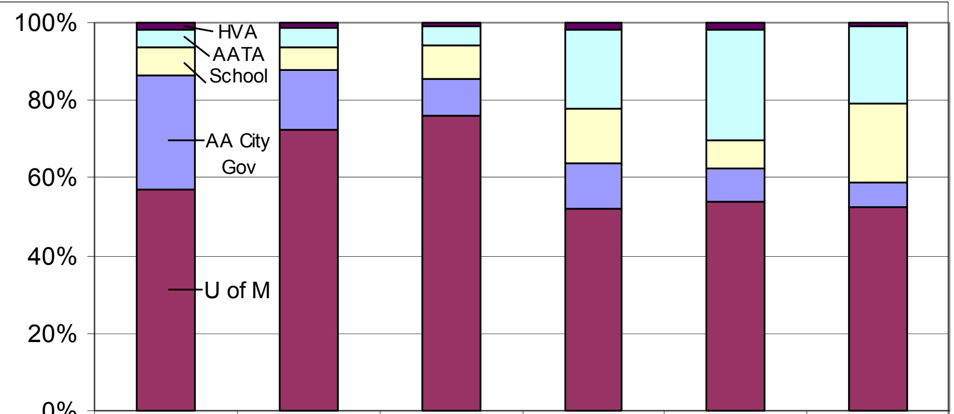
[116] Davis, Stacy, ed. Transportation Energy Data Book, Edition 19. Oak Ridge: U.S. Department of Energy: Center for Transportation Analysis, Oak Ridge National Laboratory, Sep. 1999.
[117] New Car Buyer's Guide. The Auto Channel. <www.theautochannel.com/db/newcars/htm> 2 Jun. 2000.



	Stock Vehicles	Inflow Vehicles	Outflow Vehicles	Inflow Mass (tons)	Inflow Value	Outflow Mass (tons)
HVA	30	3	2	15	$200,000	10
AATA	81	14	13	190	$3,200,000	180
School District	126	15	22	130	$770,000	190
Ann Arbor City Government	517	41	24	110	$1,000,000	58
University of Michigan	1007	192	192	480	$6,000,000	480

Figure 4-30 Government and Non-Profit Vehicle Fleets in Ann Arbor in 1997

The University of Michigan owns and operates the largest non-commercial fleet in Ann Arbor, representing over half of all non-profit and government vehicles. Vans are the most significant body style in the University's fleet, followed by buses and four door cars.

The Ann Arbor City government owns a large number of vehicles, but these vehicles are lighter and cheaper on average than vehicles owned by the other fleets. The mass and economic value associated with the Ann Arbor Transportation Authority and the local school district's bus fleets are large due to the high unit mass and price of buses relative to other vehicles. AATA buses are the most expensive and the heaviest of all vehicles included in this study, with a mass of 27,000 pounds and a price of $230,000 each.

There may be up to several hundred vehicles unaccounted for in other federal and state government and nonprofit fleets. One of the most significant of these missing fleets, for which appropriate data were not available in time for inclusion in this study, is owned by the United States Postal Services, which operates about 100 vehicles in Ann Arbor.[118]

Observation 6: Tires were the most significant maintenance material used in terms of their mass and value.

Figure 4-31 shows the mass of various types of maintenance materials used in Ann Arbor in 1997, while Figure 4-32 shows their economic value.

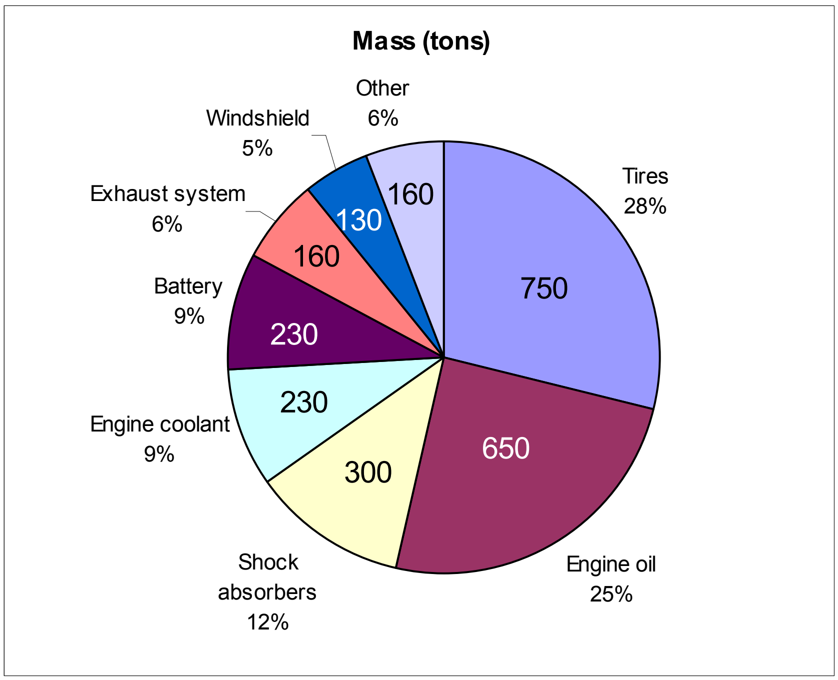


Figure 4-31 Mass of Maintenance Materials Used in Ann Arbor in 1997

Source: Center for Sustainable Systems. Research database. University of Michigan. 23 Apr. 2000.

[118] Ann Arbor Post Office Maintenance Department. Personal interview. 25 May 2000.

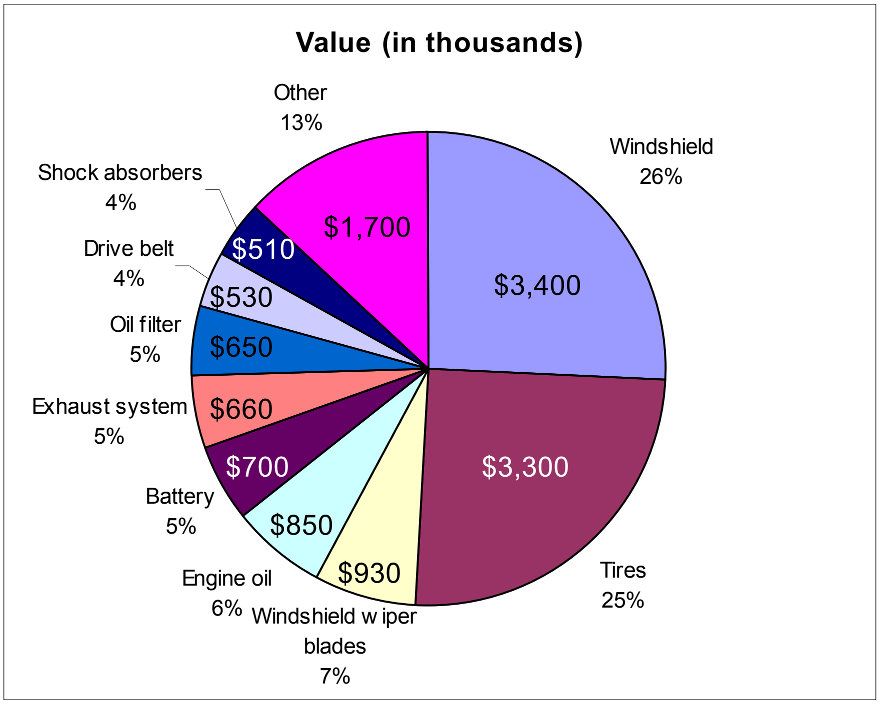


Figure 4-32 Value of Maintenance Materials Used in Ann Arbor in 1997

Tires are the only type of maintenance material that have both a large mass and large economic value relative to the other maintenance materials. The mass of tires used, 750 tons, is larger than the mass of retired pickup trucks. The value of tires used, $3.3 million, is about the same as the combined value of all new tractors, utility trucks, wreckers, tank trucks, ambulances, mixer trucks, hearses, and panel trucks.

The large mass of engine oil used does not have a large value due to a low price of five dollars per gallon. At a price of over $400 each, windshields are the most expensive maintenance material, even though only one windshield replacement over the life of a vehicle is assumed. The mass of windshields used is much smaller in proportion to other maintenance materials.

As described earlier, the estimates for maintenance materials are based on an automobile. Figure 4-33 shows the percentage of stock vehicles that are likely to have similar maintenance requirements (two and four door cars, station wagons, pickup trucks, vans, convertibles, and roadsters). These vehicles are 88% of all vehicles in Ann Arbor and therefore account for about 2,600 tons out of the 2,900 total tons of maintenance material estimated. About 7,000 vehicles are trailers and trailer coaches that require significantly fewer maintenance materials because they do not have engines. The remaining 3,400 are a mix of vehicles which may require more (heavy trucks) or less (motorcycles) maintenance relative to an automobile. In summary, a reasonable estimate is likely to be between 2,600 and 2,900 tons.

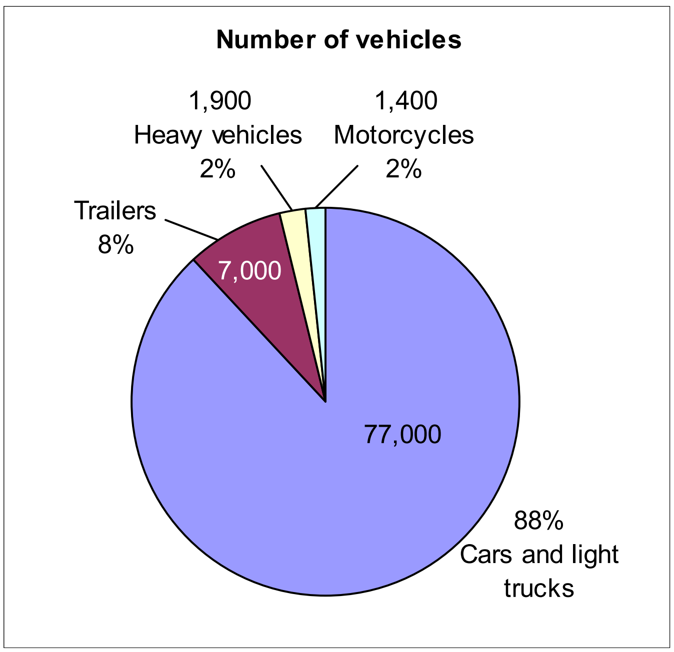


Figure 4-33 Maintenance Groupings of Stock Vehicles for Ann Arbor in 1997

Additional Discussion

Placing these results into a broader context of information about transportation results in the discussion points listed in Table 4-35.

Table 4-35 Additional Transportation Observations

Observations
7. The indirect materials of fuel and transportation infrastructure have flows larger than the flows of vehicles. 8. Despite the increasing availability of lighter weight vehicles, vehicles in use have grown heavier on average since the 1980s for many vehicle types.

Observation 7: The indirect materials of fuel and transportation infrastructure have flows larger than the flows of vehicles.

Indirect materials such as road infrastructure and fuel have not been included in the inflow and outflow for transportation, but these materials represent large inflows and outflows for Ann Arbor.

The City of Ann Arbor's Public Services Department has catalogued a subset of materials used for transportation infrastructure in 1997.[119] Despite not being a complete accounting of infrastructure materials, the study shows a use of over 50,000 tons and $1.5 million of asphalt, over three times the mass of new vehicles in the same year. If the full use of asphalt and all other transportation infrastructure materials is included, the total would be yet higher. Additional details are included in Appendix E.

The fuel used in 1997 was even more significant. If all vehicles in Ann Arbor are assumed to use gasoline at the same rate as an average automobile, then the total mass of gasoline used in 1997 was 108,000 tons at a cost of $45,000,000. The details behind this estimate can be found in Appendix E.

A connection exists between the mass of vehicles in Ann Arbor and the mass of fuel and infrastructure materials used. Using lighter vehicles would reduce the consumption of fuel because lighter vehicles usually have better fuel efficiency. A link exists with transportation infrastructure because the traffic of heavy vehicles can weaken a road and require additional maintenance and repair.

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[119] City of Ann Arbor Public Services Department. The Flow of Materials Through the City of Ann Arbor: Hot Asphalt, Road Salt, and Cold Patch (1997-1998 fiscal year). Ann Arbor: City of Ann Arbor Public Services Department, Aug. 1999.

Observation 8: Despite the increasing availability of lighter weight vehicles, vehicles in use have grown heavier on average since the 1980s for many vehicle types.

The estimates used in this reports assume that the average unit mass for each body type does not change over time. However, changes in the materials and designs of vehicles do lead to changes in their weight.

Figure 4-34 shows the average weight of various classes of automobiles over time.[120] In general, automobile weights dropped sharply in the late 1970s, remained stable in the 1980s, and grew slowly throughout the 1990s. On average, a new car brought into Ann Arbor in 1997 weighed more than the cars from the 1980s being retired, resulting in an increase in stock larger than that estimated.

Note that in 1997 many residents purchased heavier vehicles such as SUVs as personal mobility vehicles in the place of cars. As the mix of vehicles changed to include heavier vehicles (that do not appear in Figure 4-34 because they are classified as light trucks and not as automobiles), the average mass of vehicles used for personal mobility has grown higher than the masses of automobiles shown in Figure 4-34.

[120] Davis, Stacy, ed. Transportation Energy Data Book, Edition 19. op. cit.

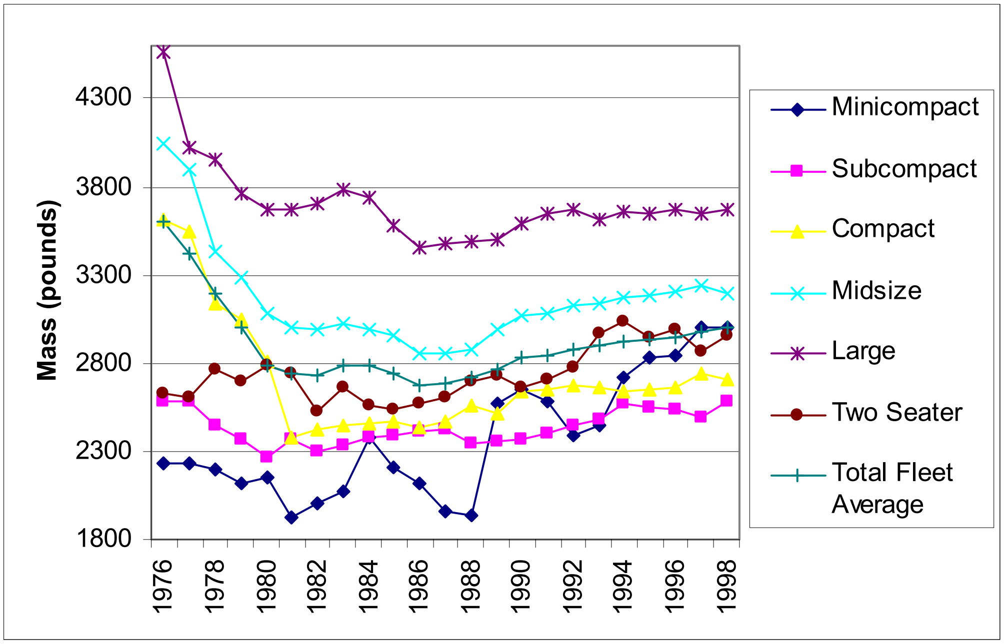

Figure 4-34 Sales-Weighted Mass of New Automobiles in the United States, 1976-1998

Source: Davis, Stacey, ed. Transportation Energy Data Book, Edition 19. Oak Ridge: U.S. Department of Energy: Center for Transportation Analysis, Oak Ridge National Laboratory, Sep. 1999.

The potential exists for this trend towards heavier vehicles to shift course. In 1991, the Rocky Mountain Institute created a design for a car called the Hypercar that would weigh as little as one-half of the current weight of a car due to a shift from the use of steel to the use of carbon-fiber composites. The Hypercar would also be redesigned to reduce drag and would use a hybrid-electric engine for propulsion. In its most advanced form, a Hypercar could use a much simpler design with fewer components, resulting in a smaller use of maintenance materials.[121]

The Honda Insight is the first hybrid-electric vehicle available in the United States and incorporates many features characteristic of a Hypercar. The Insight's aluminum body gives it a mass of 1,856 pounds, significantly lower than the average mass over 2,700 for other two door cars. It is highly aerodynamic, with a low drag coefficient of 0.25, and is

[121] Hawken, op. cit. 22-47

EPA-rated at 61 miles per gallon in city driving.[122] It remains to be seen whether or how quickly lighter vehicles such as the Insight will become a significant portion of the fleet of personal mobility vehicles.

Improvements are also occurring with larger vehicles. For example, new school buses are becoming lighter as manufacturers replace heavier metals with aluminum for the body and plastics and fiberglass for internal components such as seats.[123] Most new semi-trailers are made primarily of aluminum, resulting in a weight saving of about 1,700 pounds per trailer over earlier designs.[124]

Material Flow Recommendations

Table 4-36 contains suggestions for ways to improve the efficiency of material flows related to transportation. The table also indicates whether the suggestion is already in place in Ann Arbor or if there a recommendation for Ann Arbor for further action.

Table 4-36 Material Flow Recommendations for Transportation

Idea/Suggestion	Ann Arbor	Recommendation
Public transit	AATA and University of Michigan transit programs	Explore opportunities for expansion
Bicycle and pedestrian infrastructure	Bike lanes, bike parking, and sidewalks	Explore opportunities for expansion
Vehicle and maintenance material recycling	Municipal and commercial recycling programs	Explore opportunities for expansion
Commuter trip reduction program	get!Downtown and related programs	Include telecommuting and flex time recommendations
Car Sharing Service	none	Private start-up opportunity
Community bicycles	none	Non-profit or government start-up opportunity
Other Programs • Light weight vehicles • Land use planning • Full cost of vehicle use		

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[122] Moore, Bill. "Inside the Insight," EV World. 29 Nov. 1999. <http://www.evworld.com/reports2/inside_insight.html> 25 May 2000.

[123] Williams, Dick. Ann Arbor School District's Transportation Department. Personal interview. 3 May 2000.

[124] Gaines, Linda, et al. "Life-Cycle Analysis for Heavy Vehicles." Air & Waste Management Association Annual Meeting. Jun 1998. <http://www.transportation.anl.gov/ttrdc/publications/papers_reports/heavylifecycle/heavylifecycle.html> 10 Mar 2000.

Most of these suggestions relate to personal mobility rather than freight and other transport, because material flows for personal mobility are significantly larger. A general recommendation to reduce the need for freight and other transport is to reduce the amount of materials consumed within the community. As an indirect material to other functional needs, fewer freight and other transport vehicles would be required if the efficiency of material flows used to meet these other needs is improved.

Public Transit

A good public transit system allows some community residents to leave their personal vehicles at home as they commute to work or travel around the city for shopping or recreation. Using public buses and trains reduces traffic congestion, reduces the use of fuel, and decreases the mileage on personal vehicles and therefore their need for maintenance materials. An even better outcome occurs if residents feel confident enough in the transit system to avoid purchase of a personal vehicle.

The Ann Arbor Transportation Authority provides public transit throughout Ann Arbor and surrounding communities, primarily through buses. It is an award-winning model that has consistently been rated highly on customer satisfaction surveys and has even gained the attention of executives at Disneyland and the transportation minister of Beijing.[125]

The University of Michigan also provides transit services for students and employees.

Bicycle and Pedestrian Infrastructure

Bicycle and pedestrian travel share many benefits with mass transit in the reduction of the use of personal ground motor vehicles. The 1990 Ann Arbor Transportation Plan and the 1992 Ann Arbor Bicycle Plan recognize the value of these alternative modes of travel by planning for infrastructure improvements. These improvements have included bicycle

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[125] Lienert, Anita. "Ann Arbor Public Transit Wins Kudos." Detroit News Online, 9 May 1999. Detroit News. <http://detnews.com/1999/specials/development/990509/success/success.htm> 20 May 2000.

paths, bicycle parking, and sidewalks. The AATA recently added bicycle racks onto its buses, creating new transit options for residents.

Vehicle and Maintenance Material Recycling

Recycling and reusing the components of retired vehicles and used maintenance materials is important to capture the full value of the materials and to avoid environmental problems associated with improper disposal.

Tires have long been a major solid waste issue. Historically, about 63% of tires of the 250 million tires disposed nationally each year have ended up in landfills or stockpiles or were dumped illegally.[126] Over the years, Washtenaw County has built up a store of at least 157,500 stockpiled tires.[127] The State of Michigan recently banned the disposal of tires in landfills because of their overwhelming volume and because, when improperly discarded, piles of old tires can lead to hazardous fires or serve as a breeding ground for mosquitoes. Today, tires can be dropped off at the Ann Arbor Drop-Off Center or other area businesses for a fee ($2-$8). This fee is also paid to a garage when tires are removed and replaced during service. These businesses store the tires until they are picked up and taken to the facilities of recycling companies outside of Ann Arbor who use the tires to produce fuel or grind them for use in asphalt manufacturing.

Tires and engine oil make up 53% of the mass of maintenance materials used each year estimated in this report. Engine oil can be recycled, yet approximately 250 million gallons are released into the environment each year in the United States. Used engine oil contains toxic elements such as lead and cadmium, and oil runoff is a significant water pollution problem in our nation's lakes, streams, and even drinking water.[128] In Ann Arbor, engine oil, oil filters, other automotive fluids, and car batteries also can be given to the Drop-Off Center and to other businesses, some for a fee and others for free.

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[126] Keoleian, Gregory A., et al. Industrial Ecology of the Automobile: A Life Cycle Perspective. Warrendale: Society of Automotive Engineers, Inc., 1997.

[127] Scrap Tire Disposal Sites in Michigan: 1996. Michigan Department of State Police. <http://www.msp.state.mi.us/division/emd/haz_ann98/tire_fir.htm> 27 May 2000.

[128] Keoleian, Gregory A., et al. Industrial Ecology of the Automobile: A Life Cycle Perspective. op. cit.

Garages regularly store removed fluids for recycling. Engine oil and oil filters can also be left alongside other recyclable materials for household pickup.

Retired vehicles in Ann Arbor are towed to one of the two salvage businesses in the City or to salvage businesses in the metropolitan area. These businesses remove valuable parts to be resold in the community, remove other parts and fluids for recycling, and send the remaining hulk to a shredder such as one 30 miles away in Taylor, Michigan. The shredder separates metals for recycling from all other materials in the hulk which are sent to a landfill. Table 4-37 shows typical costs and revenues associated with dismantling and shredding an automobile. The figure also shows the resulting profit per vehicle multiplied by the retired two and four door cars in Ann Arbor in 1997 to show the profits from just these two body styles.

Table 4-37 Profit from Automobiles Registered as Two and Four Door Body Styles Retired in Ann Arbor in 1997

Costs and Revenues per Automobile*			Profit for 6,400 Automobiles
Dismantler	Fixed and Variable Costs	$ (145.58)	
	Revenues	$ 215.54	
	Profit	**$ 69.96**	**$ 450,000**
Shredder	Fixed and Variable Costs	$ (116.64)	
	Revenues	$ 125.21	
	Profit	**$ 8.57**	**$ 55,000**

* Source: Keoleian, Gregory A., et al. Industrial Ecology of the Automobile: A Life Cycle Perspective. Warrendale: Society of Automotive Engineers, Inc., 1997.

Commuter Trip Reduction Program

The AATA offers several innovative programs targeted towards commuters.

- get!Downtown is a partnership with the AATA, the Ann Arbor Area Chamber of Commerce, the Downtown Development Authority, and the City of Ann Arbor to inform individuals and businesses of their commuting options and encourage alternative means of travel.
- The go!Pass, part of the get!Downtown program, provides free bus passes to all employees who work downtown. In its first season in the fall of 1999, over 8,900 passes were distributed.

- Park & Ride allows commuters to park their vehicles on the outskirts of Ann Arbor and bus into downtown.
- RideShare is a free, computerized carpool/vanpool matching service for commuters who live or work in Washtenaw County.
- The Transplan is a communication tool used by the AATA to explain to employers the federal tax benefits of subsidizing alternative commuting modes for employees and to explain relevant AATA services.

These commuter trip reduction programs could be enhanced by adding an emphasis on telecommuting and flex time. These solutions reduce commuting traffic by enabling employees to work at home or to concentrate the same amount of work into a smaller number of workdays. Telecommuting may be especially appropriate for Ann Arbor due to the presence of technology companies and knowledge workers. The program should provide employers with information on the costs and benefits of telecommuting, a description of jobs that are well suited for telecommuting, and possibly even technical assistance.

Car Sharing Service

Typically, a person must spend the time and expense required for maintaining and insuring a vehicle to receive the service of personal mobility provided by the vehicle. Car sharing services provide the service of personal mobility without vehicle ownership by giving participants access to a pool of vehicles in exchange for membership and usage fees. The service is best suited for individuals who do not drive a vehicle often during the year.

Car sharing services have been most popular in Europe and more recently have grown in Canada. For example, Mobility CarSharing in Switzerland boasts a fleet of 1,300 cars and 33,000 members. Programs are now starting in the United States in cities including Boston, Boulder, Cleveland, Portland, San Francisco, Seattle, and Washington D.C., with the closest program in Traverse City, Michigan. These programs are smaller than most of the European services, with membership size ranging from a small handful to several hundred.

Multiple surveys have shown that 6% or less of car sharing members own a personal vehicle outside of the car sharing service, though some members would not have owned a vehicle even if a car sharing service was unavailable.[129] To the degree that car sharing programs act as a substitute for individual ownership, it has the potential to reduce the number of vehicles in the community while at the same time expanding mobility options such as having access to multiple types of vehicles at multiple locations. Car sharing hubs are often placed near access to public transit, so members often use transit more often than before. Because members pay per use of a vehicle, they are more aware of per-trip costs and therefore are more likely to reduce the total amount of travel.

Because many Ann Arbor residents are more likely to use alternative modes of travel on a regular basis than the national average (see Table 4-31), Ann Arbor may be a good location for a new car sharing service. Based upon the past experience of other car sharing services, the initiative should be formed as a private company, though local government may want to help with early funding or organization to get it started.

Community Bicycles

In the 1980s, a program was started in Ann Arbor to provide a fleet of free bicycles for public use to encourage bicycle use for short trips around the city instead of the use of automobiles. It was hoped that the bicycles would be left on the street after each use and thus continue to be available to the community. The program ended after a few months due to theft and vandalism of the bicycles. Similar programs have been attempted in several other U.S. cities, such as a well-publicized program begun in Portland that lasted over two years with a fleet of over 800 bicycles, but these have all met a similar fate as the Ann Arbor program.

[129] Sperling, Daniel, Susan Shaheen, and Conrad Wagner. "Car Sharing and Mobility Services." ECMT/OECD Workshop on Managing Car Use for Sustainable Urban Travel. 1-2 Dec. 1999. Dublin, Ireland: WestStart-CALSTART, Feb. 2000. <http://www.calstart.org/resources/papers/car_sharing.html> 16 Apr. 2000.

After a similar failure, the Minneapolis/St. Paul Yellow Bike Program tried a different approach and copied the idea of bike hubs from successful European programs. In this model, bicycles are locked at participating businesses, and users pay a small refundable deposit to check out the bike. This approach has reduced theft and enabled the use of better quality bicycles, creating a more sustainable program.

Ann Arbor should consider restarting a community bicycle program following the Minneapolis program as a model. As discussed earlier, promoting bicycle use as a frequent mode of transportation has the potential to reduce the number of motor vehicles on the streets.

Other Programs

Ann Arbor should consider the potential for several other types of solutions to address the material flows associated with transportation.

- Light Vehicles: The adoption of lighter weight vehicle would decrease the use of fuel in the community and extend the life of Ann Arbor's roads. As lighter weight vehicles become available, the City of Ann Arbor and the University of Michigan should consider adopting them for their fleets. Residents should consider purchasing smaller vehicles that match their occupancy and hauling needs.
- Full Cost of Vehicle Use: Though the issues involved are too complex to review in detail in this report, Ann Arbor should consider ways to shift the public costs associated with transportation to those who create the need for those costs. Examples include toll roads and removing subsidies for parking.
- Land Use Planning: Ann Arbor should encourage a high density of urban development and the formation of natural clusters of development where goods and services are within walking distance of residential homes. Though also too complex to review in detail in this report, the concept of land use planning is critical to the transportation category. Improving the design of neighborhoods to increase residential access to goods, services, and work meets the need for transportation while simultaneously reducing the human activity and the material flows required for this need.

Chapter 4.5: Communication

Communication is the exchange of thoughts, messages or information through a common system of symbols via print, image, sound, or some combination of the three. Communication has played a critical role in our communities. Throughout history, various forms of communication and related enabling technologies have been developed, allowing humans to share information across time and space. Today, not only do humans communicate across continents via land-based telephone systems, but also satellite systems enable us to send and receive signals to the spacecraft sent beyond the earth's atmosphere. We can see images and listen to recorded sounds of history in the making over a century ago, and, at the same time, get almost instantaneous feeds from the floor of the New York Exchange to a personal computer sitting in an office half way around the world. The following is a description of the work done to estimate the mass and economic value of material flows that are associated with meeting the communication needs of the population within the City of Ann Arbor, Michigan in 1997.

Category Description

In order to identify and estimate the material flows associated with communication, this study focuses on the media used for communication. There is a wide range of vocal and non-vocal methods used for communication among humans. These include books, magazines, film, photography, compact discs, television, and radio.

Table 4-38 shows the types of material flows that fall under the category of Communication.

Table 4-38 Materials Associated with Communication

Direct Materials	Indirect Materials
• Print (e.g. Books, Newspapers, Personal and business correspondence) • Image* (e.g. Painting, Photography) • Sound* (e.g. Music CD, Cassette tape, Voice) • Combination* (e.g. Video cassette, Motion Pictures)	• Production systems* (e.g. Publishing industry equipment) • Packaging* (e.g. CD case, Plastic wrap) • Distribution systems* (e.g. Retail outlets, US Postal Service, Theatres, Vehicles used for transportation) • Enabling technologies* (e.g. CD player, Telephone, Computer System, Television)

* This report does not include separate inflow or outflow estimates for these materials.

Direct Materials

Direct Materials are those products or materials used specifically to fulfill the need of Communication. Direct materials examined in this study are all classified as printed media. Forms of communication that are based on image, sound or a combination of different forms are not in the scope of this project due to time and data availability constraints. The material flows specifically examined are: printed materials, blank paper, envelopes, and personal and business correspondence handled by the United States Postal Service. Printed material in this study refers to books, magazines, telephone directories and newspapers.

Indirect Materials

Indirect Materials are those which contribute to the production, packaging, distribution, or use of direct materials. For example, in the case of books, there are product and material flows associated with the production of books such as printing presses and computer systems. This study does not estimate material flows of any indirect materials for this category.

Inflows and Outflows

The communication of information is enabled by and results in countless associated flows of materials into, within, and out of our communities.

Figure 4-35 is a graphic description of how the flows of these materials through Ann Arbor are modeled for this study. Though other forms of communication are widely used and have an important impact on our community, the scope of this study is limited

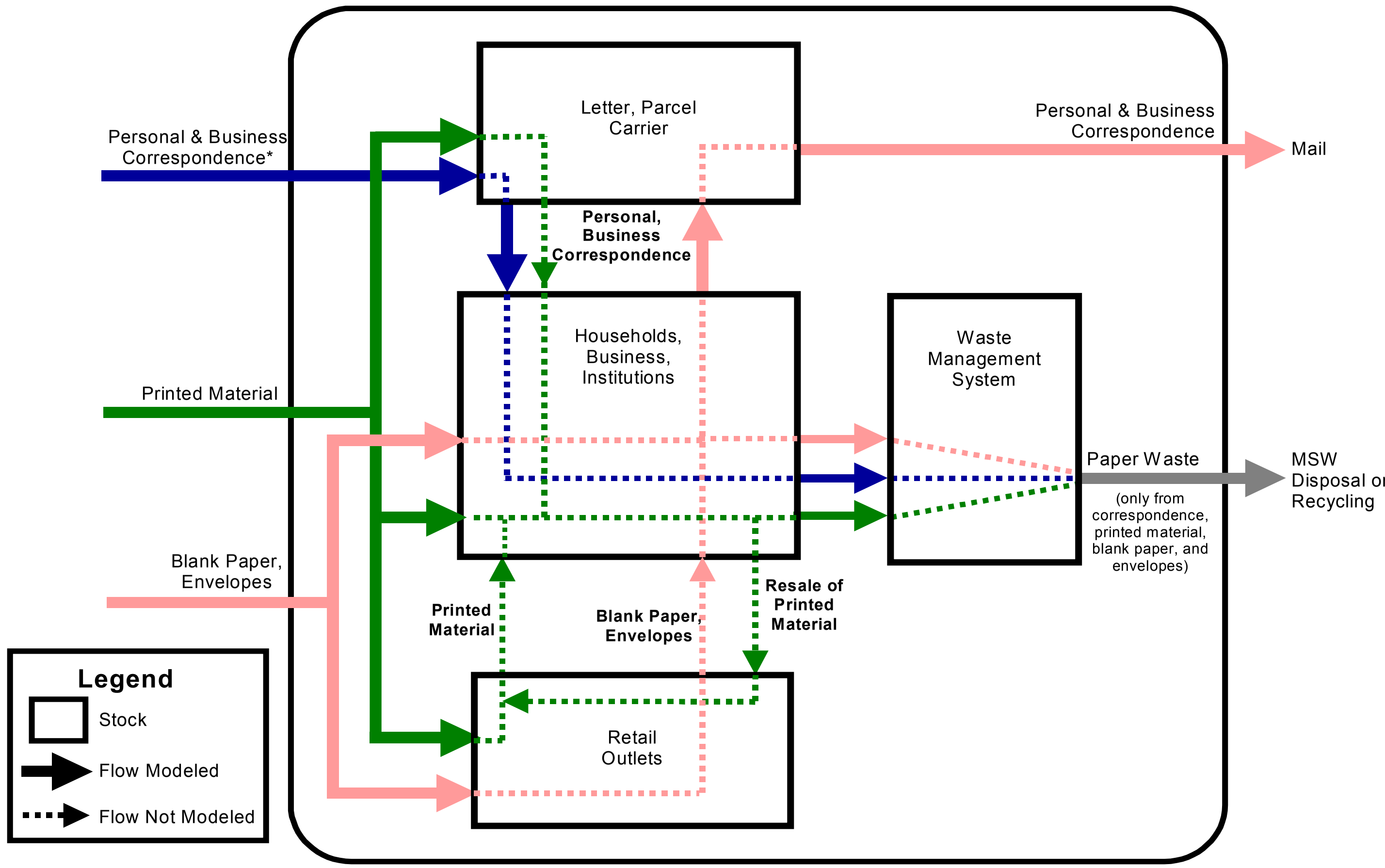

Figure 4-35 Communication Direct Material Flows Through Ann Arbor

The presence of dotted lines inside stocks and the shading of arrows are used to help trace the movement of materials from each inflow.
* Correspondence from all carriers is shown here as a material type with a single inflow. Correspondence from non-USPS carriers is actually modeled along with blank paper and envelopes, separately from the estimates for USPS correspondence.

based on the availability of existing data. Thus efforts are focused in areas where the flow of material is either regulated at some level so that it is tracked, as in the case of mail, or enough studies have been done that the material flows can be reasonably estimated, as in the case of printed materials. The materials associated with printed material, blank paper, envelopes, business and personal correspondence, and the resulting MSW are the flows examined in this analysis. The following text supplements Figure 4-35 and provides a description of those flows.

Personal and Business Correspondence

This study includes only personal and business correspondence that is handled by the United States Postal Service; therefore, flows through competing carriers, such as FedEx, DHL and UPS are not included. The omission of this data is more likely to have an impact on estimates for business correspondence than for residential mailings, but it has not been determined how significant this factor is. This study makes use of the categorization established by the United States Postal Service (USPS). Included categories are First-Class Mail, Priority Mail, Express Mail, Standard Mail (A), International Mail, Postal Service Mail, and free mail service provided for the blind.

This flow does not include mailgrams and material classified as "special services" which include certified mail, money orders and registered mail. Periodicals and Standard Mail (B), which consists of bound materials, including books that are transported by the USPS, are excluded from "Personal and Business Correspondence" and are included in the "Printed Materials" category.

The incoming flow of personal and business correspondence to the community first enters as mail through the USPS, which serves as a point of distribution for this material. Through post offices and a fleet of vehicles, the USPS delivers mail to households, businesses and institutions throughout the community. Some mail may be retained within the community by the recipient for record keeping, but most of this material ends up in the waste management system and is processed as municipal solid waste.

The flow of mail delivered out of the community is traced back to a supply of blank paper and envelopes that is consumed by households, businesses, and institutions. This material may go through retail outlets in the community or go directly to consumers, if they bring it into the community themselves or arrange for a delivery from a source outside of the community. This study does not include the material flow associated with pens, typewriters, copiers, or printers that are used to create letters and documents sent in the mail. Mail sent from one address Ann Arbor address to another is captured in the outflow and inflow numbers because all mail collected in the city, including local mail, is sent out of the community for processing.

Printed Material

For this study, printed material refers to books, magazines, directories, and newspapers. After entering the community, printed material may be distributed by the USPS or retail outlets. It may also enter the community directly through households, businesses, and institutions when material is purchased outside of the community boundary and transported in by an individual or by some other means from an outside source. Much of the printed material ends up as part of MSW.

Blank Paper and Envelopes

The flow of blank paper and envelopes into the community is assumed to enter the community through retail outlets and sometimes directly to businesses, households, and institutions. It is assumed that a portion of this material leaves the community as mail or as MSW in the form of office paper and other commercial print. Office papers are high-grade papers such as copier paper, computer printout, and stationery. Despite its name, the category of "office papers" includes materials that are generated at locations other than offices, including homes and institutions. Other commercial print includes items such as brochures, reports, menus, and invitations.

Data Sources

Five main data sources provide the basis for the estimates made of material mass and economic value for flows attributable to the communication needs within the City of Ann

Arbor. They are: the EPA's Characterization of MSW: 1998 Update,[130] a working paper provided by Franklin Associates[131] which details the methodology used in generating the EPA's Characterization of MSW report, the United States Postal Service's 1998 Annual Report[132], the US Census Bureau's 1997 Economic Census[133], and the Association of Research Library Statistics[134]. Additional details regarding data sources are provided in Appendix F.

Characterization of Municipal Solid Waste in the United States: 1998 Update

The EPA's waste characterization report provides outflow estimates for MSW attributable to printed materials, blank paper, envelopes, and mail for the United States. The waste characterization study uses a materials flow methodology based on production data for materials and products to quantify the mass of materials contained in the MSW stream. Unfortunately, the EPA's report does not provide details of the entire flow of materials from new supply through to MSW generated. It is for this purpose that a supplementary Franklin Associates report is used.

Franklin Associates Working Paper: Methodology for Characterization of Municipal Solid Waste in the United States

Franklin Associates was contracted by the EPA to research and write the Characterization of MSW report. Franklin Associates provided a series of notes detailing the assumptions used to generate the published 1993 MSW data. After discussions with representatives of the organization, it was determined that, though slight changes may have been made in the methodology between 1993 and 1997, they were not deemed significant enough to invalidate the method as an approximation for the flow. The decision is thus made to use

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[130] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update, op. cit.

[131] Franklin Associates. Working paper: Methodology for Characterization of Municipal Solid Waste in the United States: Paper and Paperboard. Apr. 1995.

[132] United States Postal Service. United States Postal Service 1998 Annual Report. USPS, May 2000. <http://new.usps.com/cgibin/uspsbv/scripts/category.jsp?C=8004&B=Inside_USPS&A=H&U=X&U1=B&U2=H25> 25 May 2000.

[133] United States Bureau of the Census. United States 1997 Economic Census, Retail Trade – Geographic Area Series. op. cit.

[134] Data Tables for Academic Institutions. Association of Research Library Statistics. <http://fisher.lib.Virginia.EDU/newarl/listyear.html> 20 Apr. 2000

this 1993 methodology to estimate part of the 1997 materials flow for printed materials, newspapers and mail. Details of the calculations are provided in Appendix F.

United States Postal Service 1998 Annual Report

Estimates of flows for mail are made using data from the United States Postal Service. The USPS provides access to its database of operating statistics.   The data provided include number of pieces of mail processed, the associated weight, and the revenue generated for the USPS. This provides a basis for estimating the inflow of mail to the community. In addition, mass data associated with all classes of mail processed by the United States Postal Service provides a way to estimate the mail generated by the Ann Arbor community. The classification system used by USPS allows for discretion in including and excluding certain types of mail from this study. The class of mail called "Periodicals" is excluded from Personal and Business Correspondence because periodicals are separately analyzed as part of "Printed Materials." In some cases, the level of detail in the USPS classification system is not detailed enough to distinguish the mass associated with correspondence versus other types of packages. For example, though Express and Priority mail is included in this study, it can be assumed that some percentage of that mail is packages, not necessarily associated with personal or business correspondence.

United States Census Bureau 1997 Economic Census

The data source used to estimate the economic value associated with material inflows to the community is the Retail Trade Geographic Study, which is contained in the 1997 Economic Census. The report provides data including retail sales, annual payroll, and number of establishments within economic sectors for designated metropolitan areas. Estimates of economic value for material inflows of printed material are based on the retail sales data for businesses classified as book stores and news dealers.

Association of Research Library Statistics (ARLS)

The website for ARLS provides an estimate for expenditures by the University of Michigan library system for printed material. Most of the material purchased by the university for its library system is not purchased through local retailers. Therefore this number is not included in the numbers taken from the Economic Census.

Assumptions

A number of assumptions have been made in estimating material flows. Details of all assumptions made are provided in Appendix F. A few of these assumptions are worth discussing in a detail, as they may have significant implications for accuracy of estimates made in this study.

Table 4-39 Major Assumptions for Communication Estimates

Assumptions
1. Ann Arbor consumption and MSW generation patterns per capita are equivalent to the national per capita average.
2. Seasonal fluctuations in the population of Ann Arbor do not significantly impact the estimates.
3. National estimates of per capita net material accumulation in the US made by Franklin Associates in 1993 are valid for 1997 in Ann Arbor.
4. Personal or business correspondence is the primary component of all classes of mail included in the study.

Assumption 1: Ann Arbor consumption and MSW generation patterns per capita are equivalent to the national per capita average.

Many of the estimates regarding flows of material associated with printed materials and mail are based on national figures for both consumption of material and generation of waste. By using these numbers, the study assumes that demand and practices of Ann Arbor for these particular flows are in line with the national average. Wherever local data are not available, national averages are used without adjustment.

It is likely that this assumption results in an underestimation for inflows of printed media associated with communication in Ann Arbor. According to a study carried out by the OECD three main forces drive paper consumption globally: income level, literacy and cultural use of paper. In addition, advertising influences consumption of specific types of paper, like newsprint.[135] In Ann Arbor, the income level and educational attainment are higher than the national average, and the community is strongly influenced by the presence of the University of Michigan. It is also likely that the high level of

[135] Robins, Nick and Sarah Roberts. "Rethinking Paper Consumption." Sep 1996. Information Center. Organisation for Economic Co-Operation and Development (OECD). <http://www.iied.org/scati/pub/rethink1.htm> 9 May 2000.

participation in Ann Arbor material recovery programs would yield a higher percentage of material recovery than the estimates show.

Assumption 2: Seasonal fluctuations in the population of Ann Arbor do not significantly impact the estimates.

Ann Arbor is characterized by the presence of the University of Michigan, which has a student body that represents a third of the population of the City of Ann Arbor. This segment of the population does not remain in the community year-round, and as a result the Ann Arbor population fluctuates according to the academic calendar. It is likely that patterns of material consumption and the associated flows do fluctuate during the year; however, estimates presented in this study are not adjusted for this.

Assumption 3: National estimates of per capita net material accumulation in the US made by Franklin Associates in 1993 are valid for 1997 in Ann Arbor.

Despite the fact that many studies have been done around the issue of paper use, the only study found which provides an estimate for the percentage of material that is stored, and therefore does not end up in the MSW stream, was a Franklin Associates working paper[136]. The Franklin estimates apply to materials such as office papers that are retained for record keeping and books that become part of private or public libraries. These diversions, as they are called, add to the community stock of material. This study has made use of the Franklin Associates estimates made in 1993, and it is assumed that the estimates are valid for 1997.

It is likely that, because of the presence of the library system and the research offices affiliated with the University of Michigan, Assumption 3 would result in an underestimate of the actual material accumulation in Ann Arbor.

[136] Franklin Associates. Working paper: Methodology for Characterization of Municipal Solid Waste in the United States: Paper and Paperboard, op. cit.

Assumption 4: Personal or business correspondence is the primary component of all classes of mail included in the study.

This study assumes that one hundred percent of all classes of mail included in this analysis are composed of personal or business correspondence. This may be a valid assumption for First-Class mail; however, it is likely that Priority Mail, Express Mail and International Mail may contain other items that people typically send in the mail, including food, clothing, or small appliances. This assumption no doubt overestimates the informational content of the material processed as Priority Mail, Express Mail and International Mail, but, in the absence of any estimates, it would be arbitrary to assume anything else.

Overall, Assumption 4 likely results in an overestimation of the mass of mail associated with personal and business correspondence.

Summary of Estimation Process

The following is a summary of the process used to estimate the flow of material associated with printed material, blank paper, envelopes, and mail moving into and through the City of Ann Arbor. Table 4-40 provides some detail to show how data are used to derive the estimates.

For the purpose of making mass estimates these materials are modeled as two flows. Based on the limited availability of data capturing the entire flow of these materials, the process for estimation starts from the outflow of materials. Therefore, flows modeled are distinguished by the form in which the materials leave Ann Arbor. Flow 1 consists of materials that leave Ann Arbor as MSW. Flow 2 consists of materials that leave Ann Arbor as personal and business correspondence.

Table 4-40 Material Flows Associated with Communication

Flows Modeled	Inflow	Outflow
Flow 1 Materials that Leave Ann Arbor as MSW	**Printed Material** ▪ Books ▪ Magazines ▪ Directories ▪ Newsprint ▪ Newspaper Inserts	**MSW** ▪ Books * ▪ Magazines * ▪ Directories * ▪ Newsprint * ▪ Newspaper Inserts *
	Personal & Business Correspondence ▪ via USPS *	**MSW** ▪ Office Paper *
	Personal & Business Correspondence ▪ via other carriers **Blank Paper & Envelopes**	**MSW** ▪ Other Commercial Print * ▪ Office Paper *
Flow 2 Materials that Leave Ann Arbor as Personal & Business Correspondence	**Blank Paper & Envelopes**	**Personal & Business Correspondence** ▪ via USPS *

***** Data are available for inflows and outflows marked with an asterisk. These data are used to estimate the remaining inflows and outflows using the relationships shown in the table. For example, the inflow mass of blank paper and envelopes is estimated based on the outflow masses of Other Commercial Print and Office Paper in MSW and Personal and Business Correspondence via USPS.

Flow 1: Materials that Leave Ann Arbor as MSW

The materials modeled in Flow 1, shown in Table 4-40, result in an outflow of municipal solid waste from Ann Arbor. The outflow categories used in Table 4-40 for outflows of MSW are those used by the EPA.[137] After books, magazines, directories, and newspaper enter the MSW stream, they are classified separately from each other by the EPA. This makes it easy to track these materials from inflow to outflow. Office paper and other commercial print are two additional classifications in the MSW stream. For the purposes of this study, it is assumed that outflows of office paper and other commercial print into the MSW stream are generated by an inflow of personal and business correspondence, blank paper, and envelopes into the community.

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[137] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update, op. cit.

Estimates for mass and economic value are presented for Flow 1. The discussion that follows provides a summary of the process used to calculate these estimates. Additional details, including step-by-step calculations are provided in Appendix F.

Mass Estimates for Flow 1

Throughout this study, books, magazines, directories, and newspaper are referred to as Printed Material for ease of discussion. The material outflow of MSW associated with printed material, personal and business correspondence, envelopes and blank paper from the City of Ann Arbor is estimated based on data provided by the EPA in its Characterization of MSW in the US.

The EPA's waste characterization reports the mass of MSW generated for the new supply of paper and paperboard products sold in the US in 1997. A national per capita number is calculated using the 1997 US estimated population provided by the US Census Bureau, and this per capita number is applied to the 1997 Ann Arbor population figure provided by the Southeast Michigan Council of Governments. The result gives an estimate for the total outflow of MSW from the City of Ann Arbor in 1997 that is associated with incoming mail, printed material, blank paper, and envelopes.

It is assumed, based on research by Franklin Associates, that this outflow of MSW represents a particular percentage of the inflow of material into the community. This provides a way to estimate the inflow of material associated with the MSW generated. For books, other commercial print, and magazines it is assumed that the material mass flowing into the community is 104 percent of the material flowing out as MSW. For office papers, the assumption is 115 percent; for directories the assumption is 103 percent; and for newsprint and newspaper inserts 107 percent is assumed.

The material input to office paper and other commercial print in MSW is assumed to consist of blank paper, envelopes and mail. The inflow of mail is calculated from United States Postal Service data, which enable an estimate of inflows of blank paper and envelopes. Details of the process to estimate inflows and outflows of mail follow.

Economic Value Estimates

Estimates of the economic value of material flows into Ann Arbor have been made based on retail prices from three data sources. The US Census Bureau's 1997 Retail Trade Geographic Study provides the basis for the estimate of the economic value of sales of printed material. The trade report provides retail sales data for 1997 by industry within Ann Arbor. This study uses data for bookstores and news dealers. Using the data in this manner potentially includes data related to the sale of items other than printed material in these establishments. The sale of printed materials outside these establishments would not be captured using this data.

This study also includes purchases of printed materials in 1997 by the University of Michigan Library System as provided by the Association of Research Library Statistics website. An estimate for the City of Ann Arbor public libraries is not be made because of data availability. Given the relatively small stock held in the city's library system compared to the university system, it is not expected that this omission significantly affects the results.

The economic value also includes the estimated cost of the blank paper and envelopes flowing into the community. Though the price of paper varies quite a bit, a typical estimate for office and writing paper is $1000 per ton.[138] This number is multiplied by the inflow mass of blank paper and envelopes to calculate retail cost.

Flow 2: Materials that Leave Ann Arbor as Personal & Business Correspondence

Flow 2 captures the flow of materials that ultimately leave the community as personal and business correspondence. This flow is assumed to be generated from an inflow of blank paper and envelopes that does not end up in MSW. Only mass estimates are made for this flow. Additional details, including step-by-step calculations, are provided in Appendix F.

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[138] Nordman, Bruce. "Paper Efficiency: What It Is…And How To Achieve It." Rethink Paper. 1997. Earth Island Institute. <http://www.earthisland.org/paper/efficiency.html > 20 May 2000.

The USPS provides data for US mail deliveries, which are used to estimate inflows of mail, and data for US mail processed, which is used to estimate mail outflows from the community. For each class of mail, a per capita number is calculated using the 1997 U.S. estimated population. These per capita numbers are then applied to the 1997 Ann Arbor population figure, resulting in an estimate for the total mass of mail moving in and out of the Ann Arbor City population in 1997.

Results and Analysis

Table 4-41 summarizes the results of calculations estimating the flow of materials associated with printed materials, blank paper, envelopes and mail brought into the community. Details of these calculations are presented in Appendix F.

Table 4-41 Communication Inflow and Outflow Estimates

Material brought into the community	Inflow Value (million)	Inflows (tons)	Resulting Outflows (tons)
Printed Material	$87.5	7,300	7,200 MSW
Blank Paper & Envelopes Other Correspondence	$8.9	8,900	8,700 MSW 3,300 Mail
Mail via USPS	N/A	3,200	
Total	**$96.4**	**19,000**	**19,000**

Note: Figures may not sum due to rounding.

Figure 4-36 summarizes the material flows for communication that are examined in this study and the resulting estimates in tons of material.

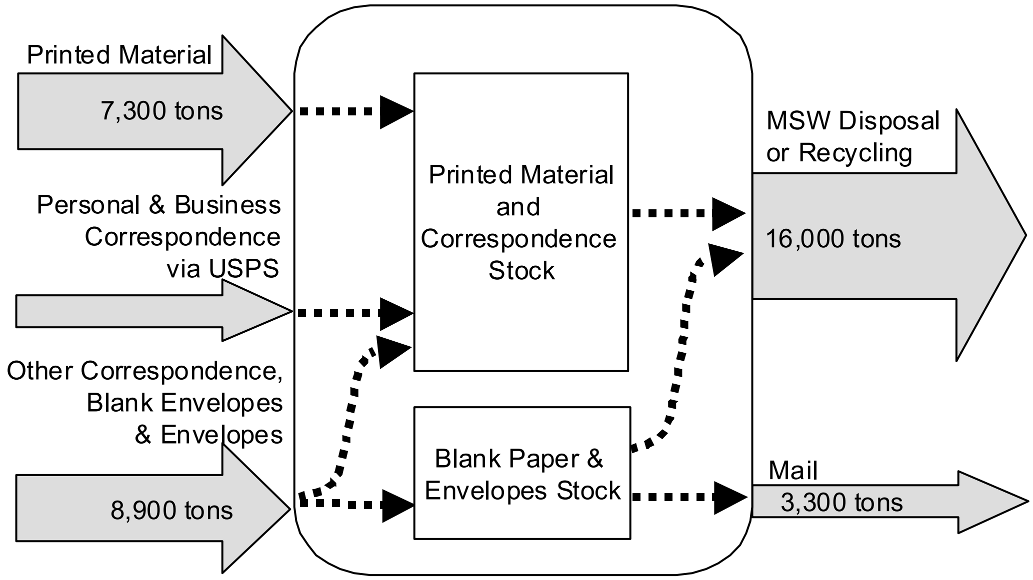


Figure 4-36 Communication Mass Flow Diagram

Dotted lines show connections between the inflow and outflow materials.

The estimates made for material flows associated with Communication are useful for the community to get a general sense and appreciation for the scale of these flows. However, these estimates have largely been made based on national averages, so to some degree the findings may not be accurate for Ann Arbor. If the community is to effectively take on the issue of material consumption and the efficiency of material flows, it may be useful to make adjustments to these numbers in order to better understand what issues may be more or less important to the community of Ann Arbor. Examining the data in Table 4-42 provides more insight into the results presented.

Table 4-42 Detailed Communication Material Inflows and Outflows

	Inflow	Est. Flow (tons)	Outflow	Est. Flow (tons)
Flow 1 Materials that Leave Ann Arbor as MSW	**Printed Material** ▪ Books ▪ Magazines ▪ Directories ▪ Newsprint ▪ Newspaper Inserts	 460 900 200 4,700 1,000	**MSW** ▪ Books ▪ Magazines ▪ Directories ▪ Newsprint ▪ Newspaper Inserts	 450 870 190 4,700 1,000
	Personal & Business Correspondence ▪ Via USPS	3,200	MSW ▪ Office Paper	3.100
	Personal & Business Correspondence ▪ Via other carriers **Blank Paper & Envelopes**	5,700	**MSW** ▪ Other Commercial Print ▪ Office Paper	2,800 2,800
Flow 2 Materials that Leave Ann Arbor as personal & Business correspondence	**Blank Paper & Envelopes**	3,300	**Personal & Business Correspondence** ▪ Via USPS	3,300
Total	**Inflow**	**19,000**	**Outflow**	**19,000**

Note: Data may not sum due to rounding.

Based on the data presented in Table 4-42 three observations can be made which are summarized in Table 4-43.

Table 4-43 Observations of Communication Estimates

Observations
1. Blank paper and envelopes represent the most significant single input to MSW. 2. The mass of mail entering the community is not significantly different than the mass of mail generated by the community. 3. Standard Mail (A) is the most significant component of business and personal correspondence.

Observation 1: Blank paper and envelopes represent the most significant single input to MSW.

Figure 4-37 shows the relative percentages of the material inflows that yield the estimated MSW stream. The inflow of paper and envelopes and correspondence processed by other carriers besides the USPS represents 35 percent of the mass of material flowing out of the community as MSW. For the Ann Arbor population, an inflow of 5,700 tons would imply that on a per capita basis 2 pounds of this material flows into Ann Arbor each week.

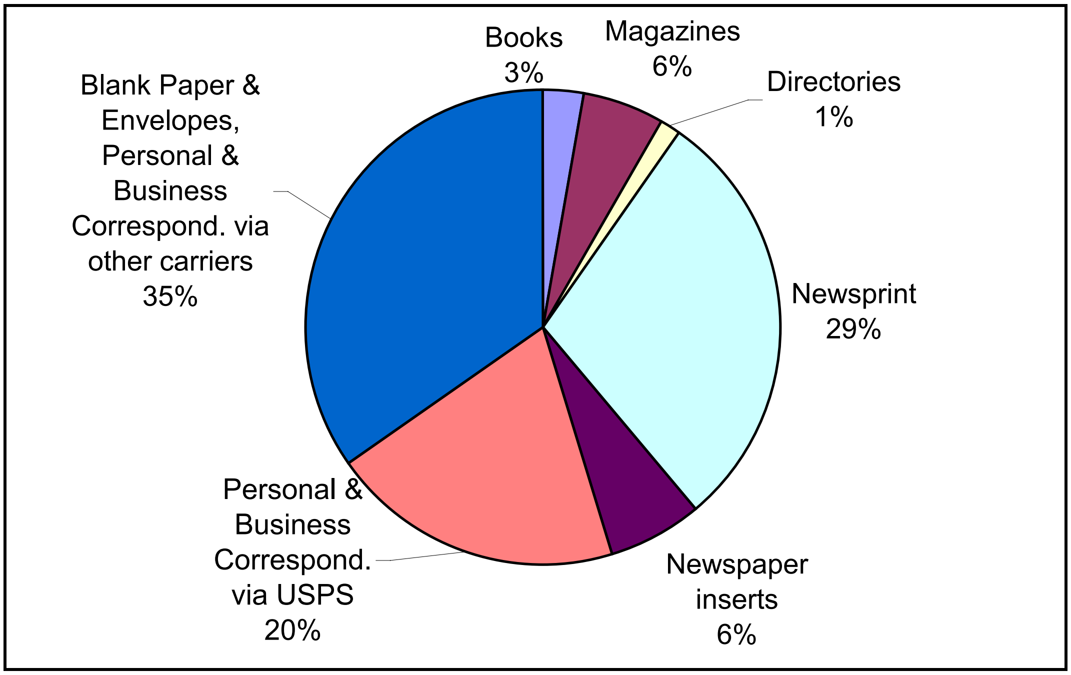


Figure 4-37 Material Inflows Contributing to MSW

The data also show that if the data for newsprint and newspaper inserts are combined, these materials account for 35 percent of the material the mass of material flowing out of the community as MSW. Ann Arbor is a highly literate community, with access to 4 major local newspapers, several university publications, national and international newspapers, and a host of smaller independent publications that are freely distributed in coffee houses, supermarkets, and retail outlets.

Observation 2: The mass of mail entering the community is not significantly different than the mass of mail generated by the community.

Figure 4-38 shows the relative inflows and outflows for correspondence flowing into Ann Arbor. Data are available for inflows and outflows of mail processed by the USPS. Mass flow estimates indicate that the inflow of mail into the community is not distinctly different from the mass of mail generated, with the outflow estimate being just less than 1 percent higher than the inflow. Though the USPS can not provide exact numbers for the mass of mail processed for Ann Arbor, local officials agree that, based on their experience, there is not a significant difference between inflows of mail to and outflows of mail from Ann Arbor.[139]

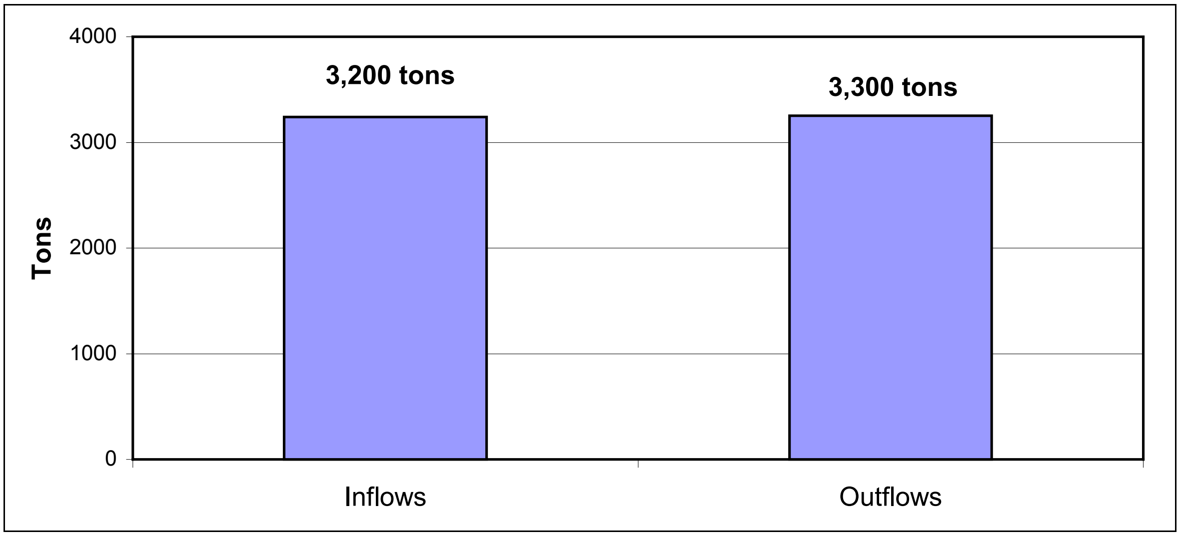


Figure 4-38 Inflows and Outflows of Personal & Business Correspondence

Observation 3: Standard Mail (A) is the most significant component of business and personal correspondence.

Figure 4-39 shows the percentages corresponding to different classes of mail generated by the City of Ann Arbor. The estimate indicates that Standard Mail (A), which includes circulars, pamphlets, catalogues, and newsletters, comprises 59 percent of the mass of mail. This classification includes material commonly referred to as "junk mail." Assuming this percentage applies to both incoming and outgoing mail, it may be inferred that a mass of about 1.7 pounds of this material is delivered to each household every week.

[139] Torrence, Mike. USPS Post Office Operations, Detroit. Personal interview. 12 May 2000.

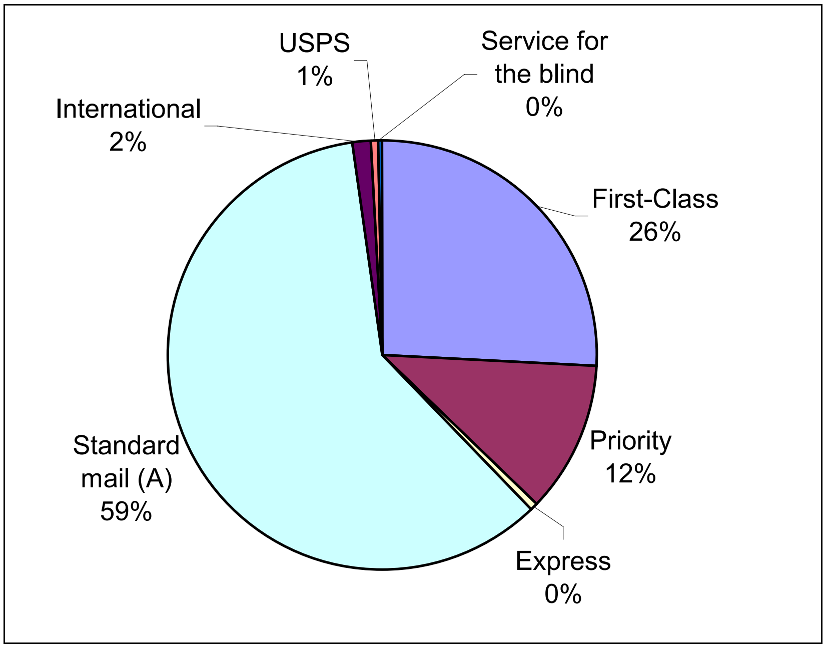


Figure 4-39 Components of Mail Handled by the USPS

Additional Discussion

To put the results in context, the inflows and outflow estimates are compared with other data. Table 4-44 summarizes the additional observations that can be made.

Table 4-44 Additional Communication Observations

Observations
4. The flows of materials associated with meeting the communication needs of the City of Ann Arbor are most likely higher than the national average.
5. According to local data, the community of Ann Arbor recovers more paper-based communication media per capita than national recovery per capita.
6. The flows of materials captured by this study are likely to be only a small portion of the total mass flows associated with communication.

Observation 4: The flows of materials associated with meeting the communication needs of the City of Ann Arbor are most likely higher than the national average.

Many of the calculations performed in obtaining these estimates are based on national statistics. As previously mentioned, implicit in this method is the assumption that Ann Arbor consumption patterns are equivalent to the national average. Studies have shown two key factors that drive the consumption of paper: income level and the literacy rates[140]. In both these regards Ann Arbor is above the national average. Figure 4-40 shows educational attainment as a proxy for literacy, and Figure 4-41 shows median household income. Data for both figures is limited by the availability of national census data. It is assumed that Ann Arbor's characteristics have not changed significantly relative to the national average since 1990.

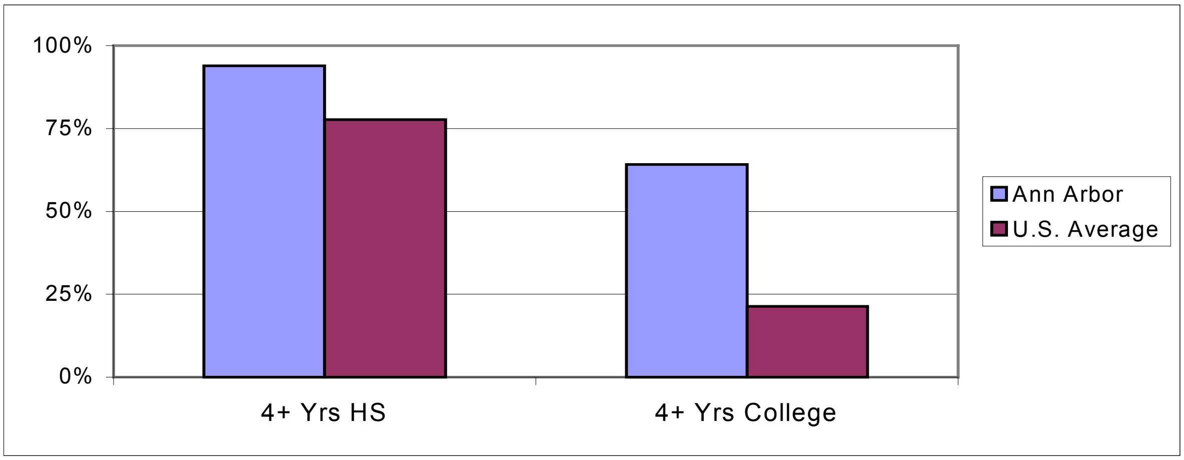


Figure 4-40 Educational Attainment in the U.S. Compared to Ann Arbor, 1990

Source: 1. US Bureau of the Census. 1990 Census of Population and Housing <www.state.mi.us/webapp/dmb/mic/census> Accessed May 21,2000.
2. US Bureau of the Census. Dec 1998Current Population Census <www.census.gov/population/www.socdemo/educ-attn.html> Accessed May 21, 2000.

[140] Robins, op. cit.

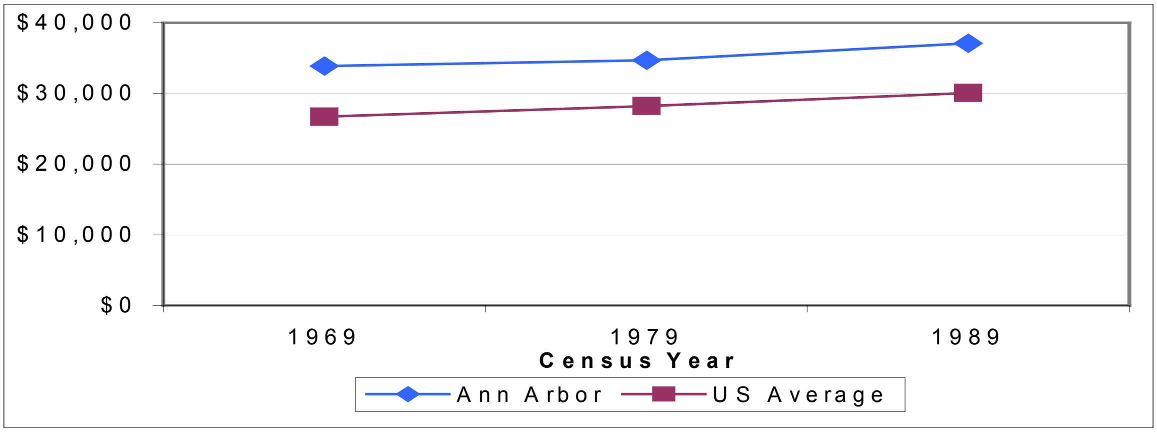


Figure 4-41 Median Household Income in the U.S. Compared to Ann Arbor

Source: US Bureau of the Census. Median Household Income by Metropolitan Statistical Area <www.census.gov/hhes/income/histinc/msa/msa1.html > Accessed May 21,2000.

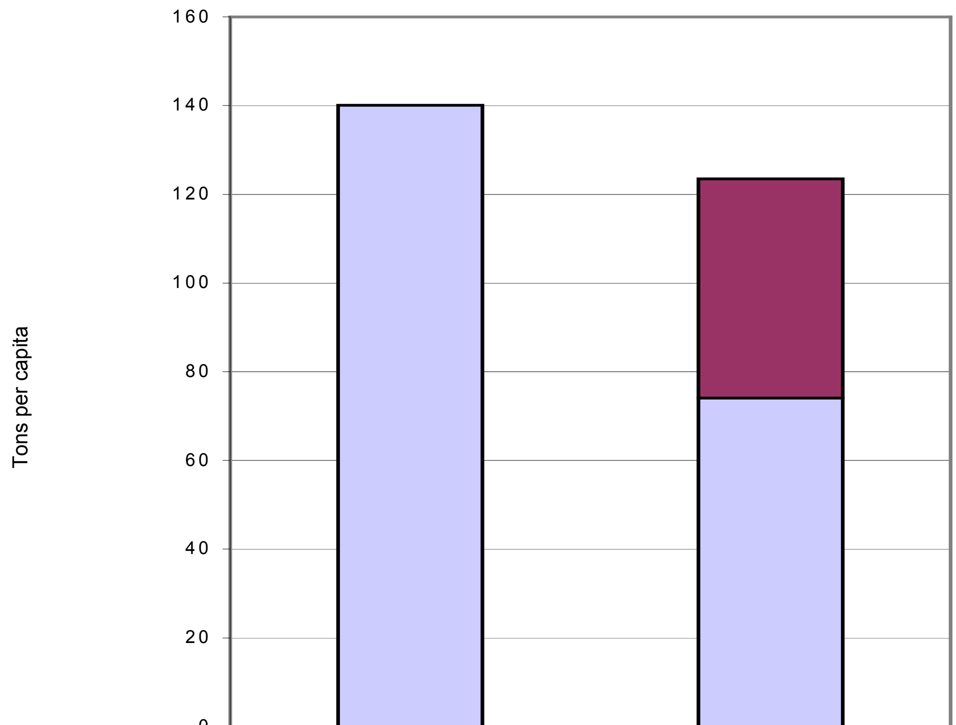
Without the correlation between these factors and consumption of paper products, it is not possible to estimate the factor by which the estimates should be inflated. However, it is likely that mass flows of paper associated with communication are higher than the estimates presented in this study.

Observation 5: According to local data, the community of Ann Arbor recovers more paper-based communication media per capita than national recovery per capita.

An EPA publication[141] published data on the mass of select materials recovered from the residential and small business waste stream in Ann Arbor for the year 1996. Omitted from the report are data regarding recovery from larger business and the University of Michigan, which contract their own private haulers to collect their waste. In Figure 4-42, local data is examined on a per capita basis and compared with national per capita recovery data for the same materials. The EPA estimates that 55 to 65 percent of the nation’s waste stream is residential and 35 to 45 percent is commercial. Therefore it is assumed that 60 percent of the waste recovered is residential. Applying the 60 percent residential waste generation statistic to residential recovery may not be accurate, but the assumption is used lacking any other information. Based on data presented in Figure

[141] United States Environmental Protection Agency. op. cit. p 46.

4-42, Ann Arbor per capita recovery from the residential waste stream is higher than the national per capita recovery. There are two possible reasons for the difference between the local per capita data and the national per capita data presented in Figure 4-42. Possibly, the percentage of material recovered from the MSW in Ann Arbor is greater than the percentage recovered from MSW nationally. On the other hand, generation of MSW in Ann Arbor could be higher on a per capita basis than the national average.



	Recovered paper associated with communication per capita based on local data (1996)	Recovered paper associated with communication per capita based on national statistic (1997)
U of M & Large Commercial Businesses	0	49
Residential & Small Business	140	74

Figure 4-42 Recovered Paper Associated with Communication in Ann Arbor

Sources: 1. United States Environmental Protection Agency. Cutting the Waste Stream in Half: Community Record-Setters Show How. EPA-530-R-99-013. Washington, D.C.: U.S. EPA. 1999.

2. Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update. United States Environmental Protection Agency, July 1999. <http://www.epa.gov/epaoswer/non-hw/muncpl/mswrpt98/98charac.pdf> 16 Mar. 2000.

Observation 6: The flows of materials captured by this study are likely to be only a small portion of the total mass flows associated with communication.

This study is undertaken to get a better understanding of the material flows associated with meeting communication needs of the City of Ann Arbor. The scope of this study is limited by the availability of material mass data, but other data can be used for comparative purposes. The data presented in Table 4-45 were not available in terms of mass, and therefore are not examined rigorously as part of this study, but are presented here to help understand the scale of estimated flows compared to all the communication media used in the community.

Table 4-45 Utilization of Communication Media in the United States in 1997

Media	Statistic	Applied to Ann Arbor Population
Books	1.1 billion adult books sold[1]	440,000 books sold
Newspaper	57 million in daily circulation[2]	8.4 million newspapers sold
Telephone service	99.0% of households[3]	43,000 households serviced
Radio	98.0% of households[2] 5.6 avg. number of sets per household[2]	42,000 households with access 240,000 radios in stock
Television	97.0% of households[2] 2.4 avg. number of sets per household[2]	42,000 households with access 100,000 televisions in stock
VCRs	84.2% of households[2]	36,000 households with access
Computers	36.6% of households[2] 71.3% have a CD-ROM drive[2] 85.5% have a printer[2] 71.1 have a modem[2]	16,000 households with access 11,000 CD ROM drives in stock 14,000 printers in stock 11,000 modems in stock

Sources: 1. American Booksellers Association. “Category Share of Consumer Purchases of Adult Books: The U.S., Calendar 1991-1998” Research and Statistics. BookWeb.org , ABA. <http://www.bookweb.org/research/stats/387.html> 21 May 2000.
2. United States Bureau of the Census. Statistical Abstract of the United States, Section 18: Communication & Information. U.S. Department of Commerce, Jun. 1999. <http://www.census.gov/prod/www/statistical-abstract-us.html> 21 May 2000.
3. Frequently Asked Questions. City of Ann Arbor Planning Department. <http://www.ci.ann-arbor.mi.us/framed/planning/index.html> 7 Feb. 2000.

A mass of 19,000 tons of paper products moves through Ann Arbor, and, in a relatively short period of time, much of it ends up as MSW. There is room to improve the efficiency of these flows, and that will be discussed further in the next section. At the same time, it should not escape attention the extent to which other forms of communication are used which also have implications for the mass of material moving through our communities. All of these products have benefits, but there are costs to be considered that result from the manufacture, distribution, use, and disposal of these materials.

Material Flow Recommendations

As a result of this study four recommendations are proposed (Table 4-46).

Table 4-46 Material Flow Recommendations for Communication

Action	Current Program	Recommendation
Utilize community stocks of printed materials	▪ University library system ▪ Ann Arbor City library system	▪ Utilize library systems as an alternative to private ownership of printed materials
Substitute alternative technology for paper	▪ USPS, FedEx and DHL have current programs for electronic document transfer.	▪ USPS marketing of electronic document transfer within the Ann Arbor community ▪ Use of electronic books in the university environment
Reduce the flow of mail into the community	▪ Used bookstores	▪ Reduction of "junk mail" through consumer action

Utilize library systems as an alternative to private ownership of printed materials

The Ann Arbor City and University of Michigan Library Systems offer over 6 million volumes of printed material for use by the community. Increased usage of those stocks by Ann Arbor residents has the potential to reduce the inflow of materials into the community that results from consumer purchases of material. This recommendation could reduce consumer expenditures for printed materials and provides a wider selection of material that any single private collection in the community. On the other hand, implementing this suggestion has the potential to negatively impact retail business in the community, which may have other impacts.

USPS marketing of electronic document transfer within the Ann Arbor community

At least 20 percent of the MSW stream from the community captured by this study is traced back to material processed by the USPS. Mail generated and physically transported out of the community represented an equivalent mass. There may be an opportunity to reduce the mass of flows of mail into and out of the community. The U.S. Postal Service, along with other carriers, has introduced services that address the growing market for electronic transfer of information. Recently launched was *USPS ebillPay,* which allows residential and business customers to pay bills electronically. USPS has also launched *Post Electronic Courier Service* that allows customers to electronically send documents to any destination in the U.S., Canada or France. A step above e-mail, the service provides encryption as well as document tracking information.

The City of Ann Arbor, working with the University of Michigan and USPS as partners, has the opportunity to cut down paper usage and waste. The university potentially could provide a better service to students, staff and faculty for document transfer. The USPS potentially gains revenues. There is potential that this service will reduce revenues from other revenue sources for the USPS, but this may be inevitable, as other carriers have introduced similar systems. Sources at the USPS have already noted a reduction impact in the mass of First-Class mail processed, which is attributed to the rise in e-mail and the Internet[142]. Given that the City of Ann Arbor has over 60,000 students, faculty and staff affiliated with the local university, there is potential for this recommendation to work in Ann Arbor.

It should be noted that though this recommendation could reduce paper flows, there will be an impact on the material flows associated with computers. Further investigation should be done to find out whether or not this is a net gain to the community.

Reduction of the flow of Standard Mail (A) through consumer action.

This study estimates that almost 60 percent of the mass of mail is comprised of Standard Mail (A), which is largely comprised of unsolicited mail. Consumers can play a role in the reduction of this particular type of mail. There are a number of ways to have an individual's name or name of a business removed from the mass mailing lists. Below are a few suggestions, but the listing is neither an endorsement nor a promise of the complete elimination of unsolicited mailings.

Individual Consumers:

Consumers can contact companies with which they carry out business, and notify them of the desire not to have their names and addresses shared. This includes retailers, credit

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[142] United States Postal Service, op. cit.

card companies, frequent flyer programs, mortgage companies, and any other organizations from which correspondence is received.

Consumers can also contact the Mail Preference Service of the Direct Marketing Association (DMA). The DMA compiles a list of people who do not want to receive unsolicited mail. There is some debate as to the effectiveness of this service, but it is free.

Equifax, Experian, and TransUnion provide names and addresses to almost all of the companies that offer unsolicited pre-approved credit card mailings. Contacting these companies should be help to reduce the flow of unsolicited mailings.

Business to Business Unsolicited Mail:

Dun and Bradstreet and InfoUSA are two firms that conduct research and collect information about businesses around the world. They are also the source of information for many companies sending out unsolicited mailings.

To assist consumers with this effort it is recommended that this information be more widely disseminated to consumers in the community.

Reduction of mass flows through the use of electronic books

An existing technology offers the opportunity for impact on the flow of material associated with books. Particularly in a community such as Ann Arbor, where the university community purchases, uses, and disposes of large volumes of books each year, the use of electronic books as a substitute for paper books could make an impact. In 1997, the University of Michigan library system added more than 140,000 volumes to its collection and purged 43,000 from the shelves. The introduction of electronic books into the community could be done through promotional programs with the Ann Arbor library system, the University of Michigan Library System or in the University's classrooms. Electronic books have been introduced to the library system in Ontario, Canada. They have been tried in at least one classroom setting in Dayton, Ohio, and the school is planning to expand the program to all classes in Fall 2000.

Implementing this recommendation has potential costs that have not been investigated thoroughly as part of this study. Though a reduction in paper may result from the use of technology, the environmental and financial costs of this alternative to paper may not make it viable for implementation.

Chapter 4.6: In Summary

The preceding five sections of this chapter have provided information relevant to the estimation of mass and economic value associated with material flows for the five selected material categories. The goal of this study is to enable community leaders to use this work to develop systems-oriented solutions to materials flow issues within their communities. To be consistent with that aim, it is important to examine results from this chapter in a larger context. Chapter 5 takes that next step by first comparing these estimates across categories, and then placing the results in context of the total community material flows, including materials not modeled in this study.

Chapter 5: Synthesis of Results

As part of this study, five material categories - Food and Water, Shelter, Clothing, Transportation, and Communication - are examined, and estimates made of the associated material flows into and out of Ann Arbor. This analysis leads to recommendations aimed at increasing the efficiency of material flows. Comparing the material flows across categories has several benefits that build upon the understanding of individual categories. From the perspective of the community, efforts to implement change may be better served by focusing resources on areas where there is the most to be gained, or in areas where there is the greatest likelihood of success. Comparing and contrasting all of the material flow estimates may aid in channeling these community resources. Additionally, material flows are not completely independent of each other. For example, meeting our need for food is accomplished in a number of ways that impact material flows associated with transportation. Each time that we eat out in a restaurant we decide whether we will walk, bike, use public transportation or drive to the restaurant. Looking at material flows together may help in identifying material flows that, though small, heavily impact other material flows and thus are worthy of attention.

The scope of this study is limited to specific material categories, and only certain material types within each category. Within each of the five categories, indirect materials and some direct materials are excluded due to limited scope or lack of data. Materials included and excluded are discussed in Chapters 3 and 4; a summary is presented in Table 5-1. The following data and analysis should be examined with these exclusions in mind.

Table 5-1 Summary of Materials Included and Excluded from Analysis

Functional Category	Material Type	Included	Excluded
Food and Water	Food	Fresh produce, packaged foods and beverages, biosolids, landfilled food scraps	▪ Compost ▪ Packaging, dishes, cooking utensils and appliances
	Water	All water used in Ann Arbor	▪ Water treatment and delivery infrastructure
Shelter	Building materials	Building projects registered by permit, including new construction, renovation, demolition	▪ Maintenance and repair materials, carpeting, furnishings, appliances ▪ Construction equipment
Clothing	Clothing	Apparel, footwear	▪ Disposable clothing, surgical and medical gloves ▪ Packaging, maintenance and cleaning materials
Transportation	Vehicles	Registered vehicles	▪ Bicycles, trains, boats, planes ▪ Roads, fuel
Communication	Mail	United States Postal Service mail delivered and generated	▪ Mail processed by private handlers ▪ Mail delivery infrastructure
	Printed material	Books, magazines, newspapers, office paper	▪ Packaging

The following discussion will focus on the data estimated from the five material category studies found in Chapter 4.

Summary of Material Flows Across Five Categories

The mass estimated for material inflows associated with the five categories to the City of Ann Arbor in 1997 is approximately 22 million tons; the associated economic value of those flows is $987 million. The estimated mass of material flowing out of the community in the five categories in 1997 is 21 million tons.

When making comparisons across categories it is important to remember that data have been estimated using different sources and methods. Some estimates are based on Ann Arbor data, while others are based on national per capita estimates which don't reflect the unique consumption patterns present locally. In some categories, such as Clothing, it has been noted that the consumption patterns in Ann Arbor are likely to be higher than national estimates. Therefore, caution must be taken when making comparisons between categories, to account for the degree of uncertainty in the estimates.

Comparing Total Inflows and Outflows

The mass of both inflows and outflows are significantly impacted by the mass of water estimated to be moving through the community. The significance of the mass of water flows in the community is illustrated in Figure 5-1. Though water has until this point been included with the Food and Water category, it is selectively excluded from some of the later analyses because all detail for other categories is lost. It is important to note that beverages are categorized with Food.

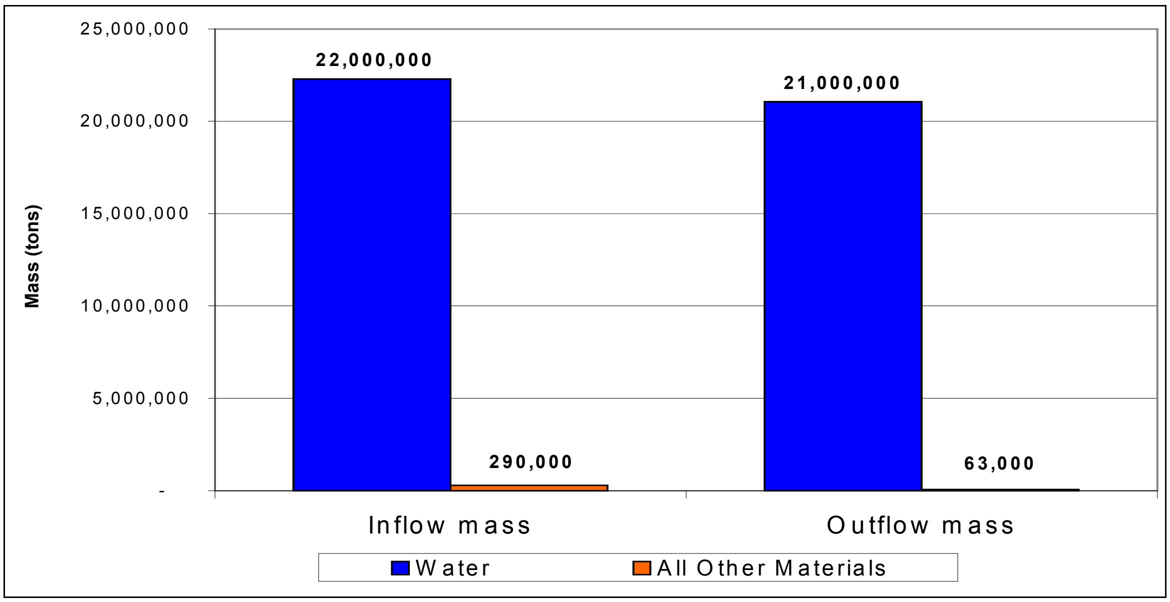
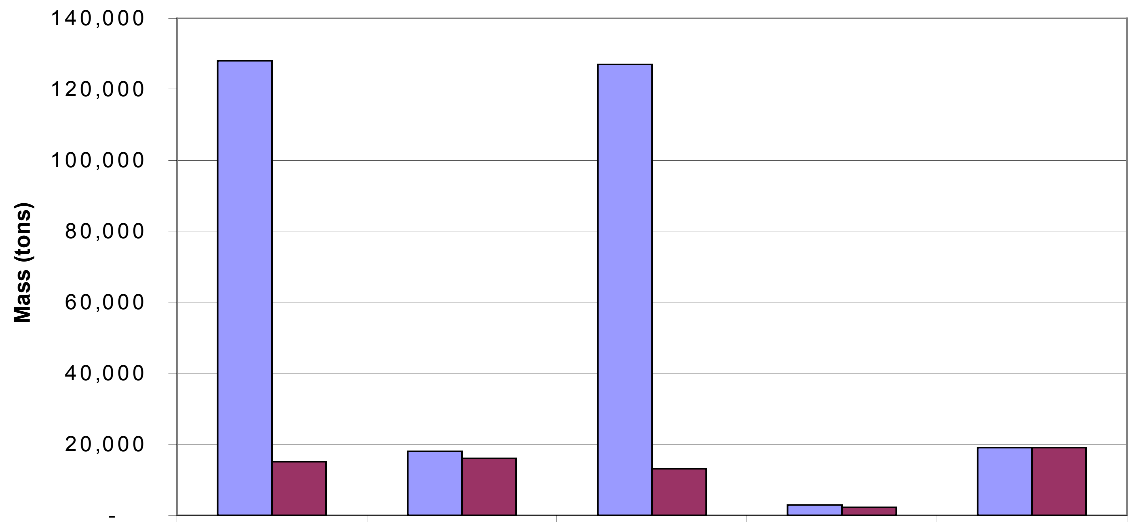


Figure 5-1 A Comparison of the Mass of Water and Other Material Inflows and Outflows

As shown in Figure 5-1, the inflow mass of water is about 76 times that of all other materials in this study combined, and the outflow mass is about 335 times that of all other materials combined. The inflow of water into Ann Arbor is about five percent higher than the outflow. Detailed explanation for this difference can be found in Chapter 4. Excluding water, the mass of materials examined in this study that flow into the City of Ann Arbor are about 4.6 times that of the mass of materials that flow out of the city.

Figure 5-2 provides more detail about the material flows by category. This is helpful in explaining the apparent disparity between the total mass inflow and outflow.



	Shelter	Transportation	Food	Clothing	Communication
Inflow - mass	128,000	18,000	127,000	2,900	19,000
Outflow - mass	15,000	16,000	13,000	2,200	19,000

Figure 5-2 Mass Flows In and Out of Ann Arbor by Category as Specified in Table 5-1

The mass of Water inflows to the community is about 170 times that of the largest material flow shown, e.g. Food and Shelter; therefore Water is excluded from this analysis. For all categories except Communication, the inflow mass is greater than the outflow mass. It is also apparent that the disparity between material inflows and outflows across all the categories is driven primarily by two categories: Shelter, where inflows are 113,000 tons greater than outflows; and Food, where there is a 114,000 ton difference.

There are two main explanations for the disparity in the flows of mass in the Food category. First, the water content of food and beverages, both of which are in the Food category, is high. Though this water content is captured in the inflows of Food, it is not captured in the outflows shown in Figure 5-2 because much of the content leaves as part of the outflow of water, which is excluded from this figure. The second explanation is that a lot of food and water leave as carbon dioxide and water vapor as a result of human metabolism. These flows are not in the scope of this study.

In the case of Shelter, the difference is explained by a growing stock of buildings within the community. Materials flowing into the community are new building materials that contribute to the stock of newly constructed structures and renovations. Outflows are smaller because there is less activity associated with demolition and removal of material due to renovation.

Material Inflows

Table 5-2 presents the estimated economic values calculated for each of the material category inflows.

Table 5-2 Estimated Economic Value for Inflows by Material Category as Specified in Table 5-1

Material	Economic Value of Inflows
Shelter	$ 120,000,000
Transportation	$ 200,000,000
Food	$ 330,000,000
Water	$ 9,700,000
Clothing	$ 240,000,000
Communication	$ 96,000,000
Total	**$ 990,000,000**

Food has the highest economic value of the six material types listed. Water, in contrast to its position with the highest mass flow, has the lowest economic value of the inflows. Water is unique among these material types in that it undergoes the least processing prior to consumption by the community. Easy access to a relatively clean supply of water, combined with an efficient distribution system, makes the delivery cost of water relatively inexpensive. In contrast, products in all the other material categories generally require more processes to transform raw material into a usable consumer product prior to distribution. All of these costs are reflected in the retail price, which is used for economic value calculations.

Figure 5-3 examines the estimated annual per capita expenditure by the community of Ann Arbor for each material category. Figure 5-4 examines the estimated annual per capita mass inflow by the community of Ann Arbor for each material category. Water is excluded from Figure 5-4 because the inflow mass of water is estimated to be 409,000 pounds per capita.

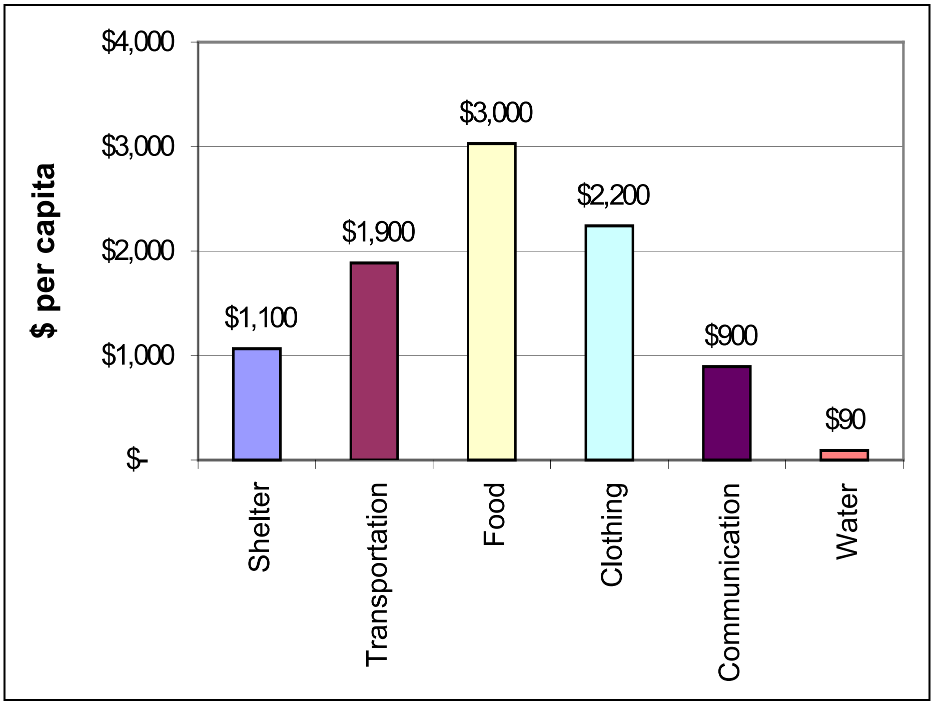


Figure 5-3 1997 Per Capita Expenditure for Material Inflows as Defined in Table 5-1

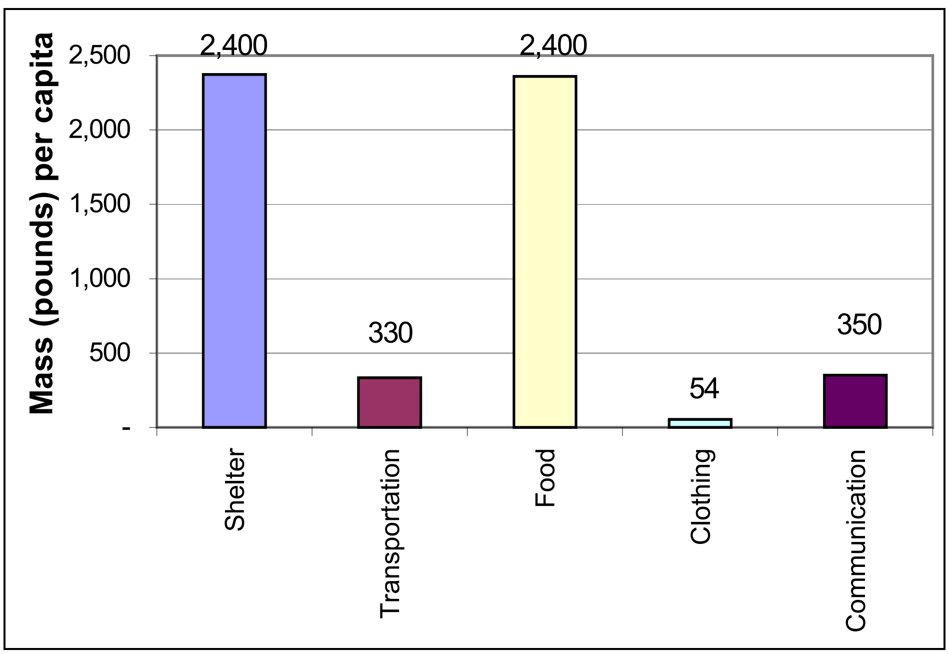


Figure 5-4 1997 Per Capita Material Mass Inflow as Defined in Table 5-1

Figure 5-3 is a partial indicator of how the residents of Ann Arbor spend their money. Food, Clothing, and Transportation are the leading categories by expenditure for the materials included in this study. Water is the material on which Ann Arbor residents spend the least.

Figure 5-4 shows that a large percentage of the mass consumption of the individual is linked to Food and Shelter. As far as Food is concerned, this is not surprising considering the daily nutritional requirement of humans. The fact that Shelter is so high on a per capita basis is probably because of the scale of construction projects, including numerous new buildings, and the high density of building materials used, i.e. concrete. The Food category is one of the two largest inflows in terms of mass and is the category on which individuals spend the most on average.

Figure 5-5 shows the expenditure per pound of material.

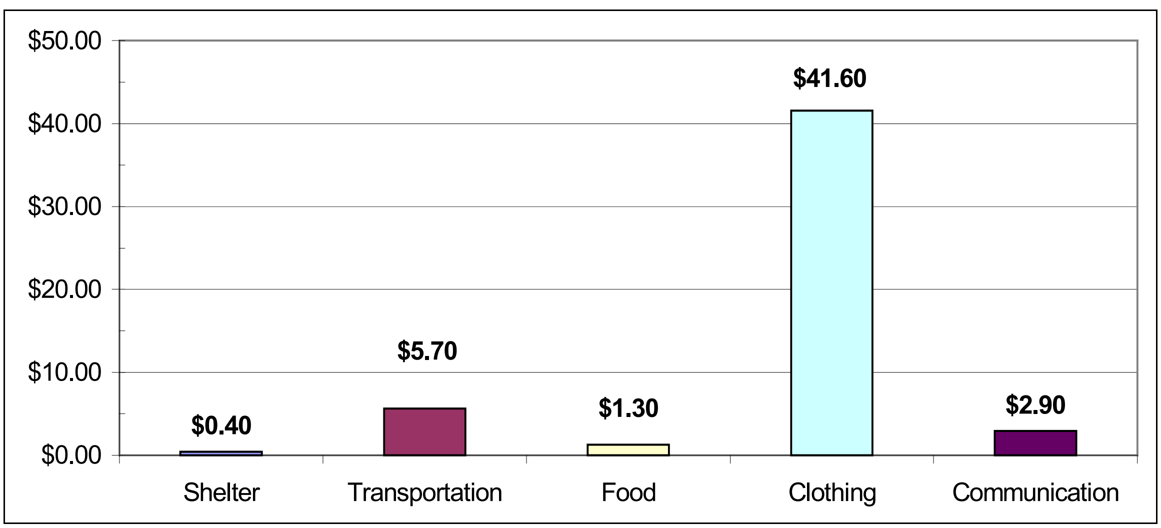


Figure 5-5 Expenditure Per Pound of Material as Specified in Table 5-1

In Figure 5-5 Clothing stands out as the most costly material type per pound. Water is again not included in this figure because of scale, but the cost per pound of water is actually the lowest of all the categories at 44 cents per ton, not including sewage fees. The high value for Clothing is a reflection of the unique market for clothing in which retail price includes material processing charges, labor charges and a sometimes significant markup based on fashion trends. Shelter stands out here as the least expensive material per pound. This is likely reflective of the types of materials that fall into this category. The products in this category, such as concrete, wood, and drywall, in general all require significantly less processing than products in other material categories, and their retail prices reflect that. Still, the total estimated cost for many of the building projects does include labor, in addition to materials.

In summary, the comparisons across categories lead to the following observations:

- Water represents the largest flow in and out of the community in terms of mass.
- Total inflow mass is significantly greater than outflow mass. The difference between inflow and outflow mass according to this study is driven largely by the Food and Shelter categories.
- Spending is highest for Food, Clothing and Transportation.
- The masses of Shelter and Food are the most significant.
- Water is the least expensive per pound, while clothing is the most expensive per pound.

Estimated Flows in Context of Total Flows

The estimates described in this report represent only a fraction of the total flows of materials used to satisfy the human needs of Ann Arbor residents. Understanding the total material flows can help place this report's results in a broader context.

Table 5-3 contains a detailed inventory of material types that are part of the inflows and outflows of the five functional categories. The inflow mass estimate for Food includes all direct materials for the category, but all other categories have one or more direct materials excluded from the inflow and outflow estimates. All categories have indirect materials excluded from the estimates, but the discussions of Food, Transportation, and Clothing in Chapter 4 provide rough estimates for a limited set of indirect materials.

Table 5-3 Inventory of Direct and Indirect Materials in Inflow and Outflow Estimates

Functional Category	Direct vs. Indirect	Mass Estimated?	Inflow Material Types	Outflow Material Types
Food	Direct	Yes	- Food and beverages	- Food scraps - Biosolids and scum
		No	None	- Respiration gases - Compost
	Indirect	Yes *	- Primary packaging	- Primary packaging
		No	- Secondary packaging - Retail stores [a] - Transportation [b] - Food infrastructure - Food preparation equipment - Eating utensils - Toilet paper	- Secondary packaging - Retail stores [a] - Transportation [b] - Food infrastructure - Food preparation equipment - Eating utensils
Water	Direct	Yes	- River and well water	- Treated wastewater
		No	- Rain water	- Evaporated water - Storm water
	Indirect	No	- Water infrastructure - Water treatment chemicals	(same as inflow)
Shelter	Direct	Yes	- Building materials	- Building-related C&D debris
		No	- Misc. building materials (from 8% of building permits not estimated) - Appliances - Flooring (carpet, tile) - Furnishings	- Misc. building-related C&D (from 8% of building permits not estimated) - Appliances (some may be in building-related C&D) - Flooring (some may be in building-related C&D) - Furnishings
	Indirect	No	- Maintenance and repair - Packaging - Construction equipment - Retail stores [a] - Transportation [b]	(same as inflow)
Clothing	Direct	Yes	- New clothing, footwear, and accessories	- Disposed and recycled clothing - Thrift store donations to non-Ann Arbor organizations
		No	- New clothing purchased through mail order - Used clothing - Uniforms	- Household donations to outside organizations - Clothing purchased at Ann Arbor stores by non-residents
	Indirect	Yes *	- Cleaning water [c]	- Cleaning water [c]
		No	- Packaging - Storage (hangers, dressers, suitcases) - Retail stores [a] - Transportation [b]	(same as inflow)

Table 5-3 Continued

Functional Category	Direct vs. Indirect	Mass Estimated?	Inflow Material Types	Outflow Material Types
Transportation	Direct	Yes	- New ground motor vehicles - Maintenance materials	- Retired ground motor vehicles - Maintenance materials
		No	- Other vehicles (bicycles, trains, airplanes, boats)	(same as inflow)
	Indirect	Yes *	- Transportation infrastructure (partial) - Fuel	none
		No	- Other transportation infrastructure - Wash water [c] - Dealership and garage buildings [a]	- Transportation infrastructure - Fuel emissions - Wash water [c] - Dealership and garage buildings [a]
Communication	Direct	Yes	- Incoming USPS mail - Printed material - Blank paper, envelopes	- Outgoing USPS mail - Disposed and recycled paper
		No	- Mail through other carriers - Image (painting, photography) - Sound (music CD, cassette tape) - Combination (video cassette, motion picture)	(same as inflow)
	Indirect	No	- Packaging - Enabling technologies (CD player, telephone, computer system, television) - Distribution centers [a] - Retail stores [a] - Transportation [b]	(same as inflow)

Several types of indirect materials are not included in this analysis because they are already included as direct materials for another category. These indirect material types include:

[a] Buildings – included in Shelter

[b] Vehicles – included in Transportation

[c] Water – included in Food and Water

* Rough estimates for some indirect materials are made in the discussion of results in Chapter 4, but these estimates for indirect materials are not included in the main inflow and outflow estimates for each category analyzed earlier in this chapter.

Inflows and outflows of the material types shown in Table 5-3 are analyzed separately in the context of total flows.

Inflows

The work of Wernick and Ausubel[143] includes estimates of U.S. per capita material flows in the US for 1990 and provides a basis for the total flow of materials used to meet the needs of Ann Arbor residents. Table 5-4 is a summary of data from Wernick and Ausubel's research applied to Ann Arbor.

Table 5-4 Total Material Inputs Per Capita and for Ann Arbor

Material Input Categories	Per capita in 1990 (pounds per day)	Per capita 1997 (pounds per day)	Inputs for Ann Arbor in 1997 (tons)	Raw Materials Included
Fossil Fuels	47	60	1,200,000	coal, crude oil, natural gas, petroleum products
Construction Minerals	47	59	1,200,000	crushed stone, sand, gravel, dimension stone
Agricultural Products	15	19	380,000	hay, grains, fruit, vegetables, milk, milkfat, sugar crops, oilseeds, meat, poultry, other
Forest Products	6	8	160,000	saw timber, pulpwood, fuelwood, cotton, hides, wool, other
Industrial Minerals	6	8	150,000	salt, phosphate rock, clays, industrial sand and gravel, gypsum, nitrogen compounds, lime, sulfur, cement, soda ash, other
Metals	3	3	66,000	iron, steel, aluminum, copper, other
Total without Water	**124**	**160**	**3,100,000**	
Water	3100	4005	79,000,000	

Source: Wernick, Iddo K., and Ausubel, Jesse H., "National Material Flows and the Environment." Annual Review of Energy and the Environment. 1995. 20:463-92.

Wernick and Ausubel's data are for 1990, but since this study is primarily based on 1997 data, projections are made to account for the growth in per capita consumption that may have occurred between 1990 and 1997. Projections are based on estimated changes in consumption and population size over that period. Population estimates are provided by

[143] Wernick, Wernick, Iddo K., and Ausubel, Jesse H., "National Material Flows and the Environment." Annual Review of Energy and the Environment. 1995. 20:463-92.

the Michigan Information Center,[144] and consumption data are provided by Matos and Wagner[145].

Before comparing these total material inputs with the inflows in this study, it is necessary to understand the fundamental difference between the two sources. The Wernick and Ausubel data are based on an estimate of the mass of all materials used for human activity in the United States, whether these materials are in the form of goods or in the form of materials consumed during raw material extraction, manufacturing, and transportation associated with goods. In contrast, most of the estimates of inflow mass in this report only include goods that can be bought at a retail or wholesale establishment. When the mass estimates for total material inputs are applied to Ann Arbor on a per capita basis, they can be interpreted to represent the total amount of materials used to meet the human needs of Ann Arbor, even if these materials do not enter the community. Figure 5-6 illustrates the relationship between the two sets of mass estimates.

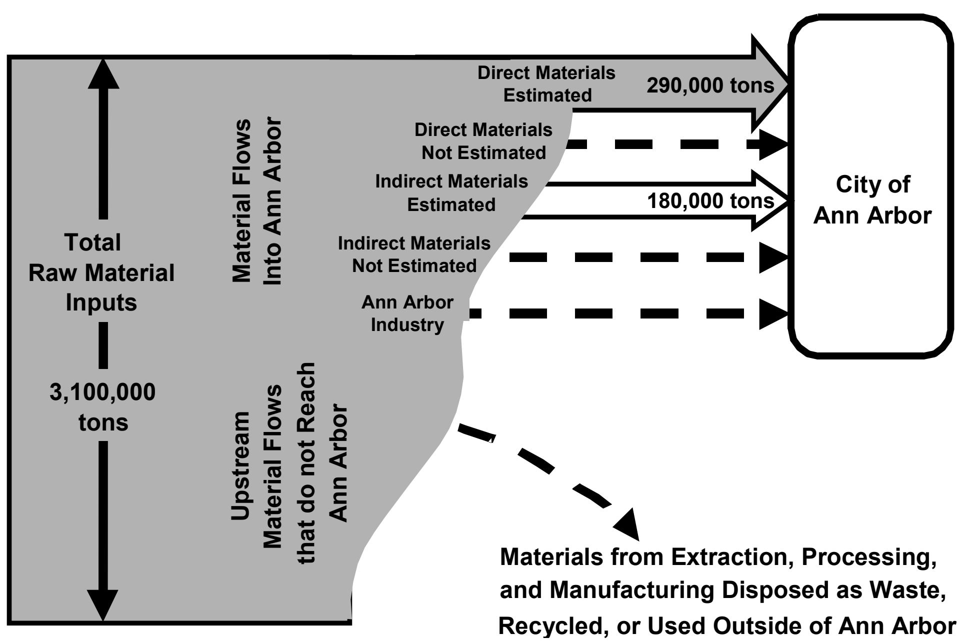


Figure 5-6 Total Material Inputs for Ann Arbor, Excluding Water

Total material inputs based on national per capita data in Table 5-4.
Material flows into Ann Arbor based on estimates developed in Chapter 4.

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[144] Estimated Resident Population for States and Regions of the U.S., 1990-1998. Michigan Information Center. <http://www.state.mi.us/dmb/mic/census/demo/pop_est/st9098.htm> 7 Feb. 2000.

[145] Matos, op. cit.

The total material inputs shown in Figure 5-6 represent the total mass of materials used to meet Ann Arbor's needs. A significant amount of this material never enters the City of Ann Arbor, even though its use ultimately serves the community. For example, an automobile used in Ann Arbor requires the use of a wide variety of materials during manufacturing that do not become part of the automobile, ranging from scrap metal wastes to manufacturing facilities and equipment. Similarly, hay is grown not for import to Ann Arbor but to feed livestock which in turn may be used for food or leather goods for use in Ann Arbor. Other material inputs enter the community as a direct or indirect material used to meet the needs of Ann Arbor residents. These materials are listed in Table 5-3. Alternatively, the material inputs may enter the community as raw materials or parts for industrial and manufacturing operations within Ann Arbor, a type of material inflow excluded from the scope of analysis for this study.

The direct and indirect materials for which this study includes mass estimates represent at least 15 percent of the mass of total material inputs defined by Wernick and Ausubel. The rest of the mass: (1) enters the community as direct and indirect materials that are not estimated in this study, (2) is used as raw materials for manufacturing in Ann Arbor, or (3) is used in extraction, processing, and manufacturing activities and disposed or recycled without ever entering Ann Arbor. The proportion of material inputs for each of these uses is unknown.

Figure 5-7 provides additional detail for both the material inputs associated with Ann Arbor and the community inflows as organized in this study. The leftmost column, titled "Total Material Inputs," shows the categories of material inputs from Table 5-4, with the height of each rectangle proportional to the total mass for each category associated with Ann Arbor. The rightmost column, titled "Inflows to Ann Arbor Classified by Functional Category," shows the direct and indirect materials listed in Table 5-3, with the height of the arrows also proportionate to mass for those inflows with mass estimates. The rightmost column also includes an arrow, titled "Industry," representing raw materials and parts used for industrial processes, such as manufacturing, inside Ann Arbor in order to provide a complete picture of material inflows to the community.

The area between the two columns, titled "Components to Direct Materials," contains arrows drawn to connect the two sets of data, showing which material inputs are used as components of the direct materials with mass estimates. These connecting arrows are only shown for the most significant components for each direct material. For example, an arrow connects the material input category of Forest Products with the direct materials for Communication because mail, printed material, and blank paper all have paper made from pulpwood as their primary component.

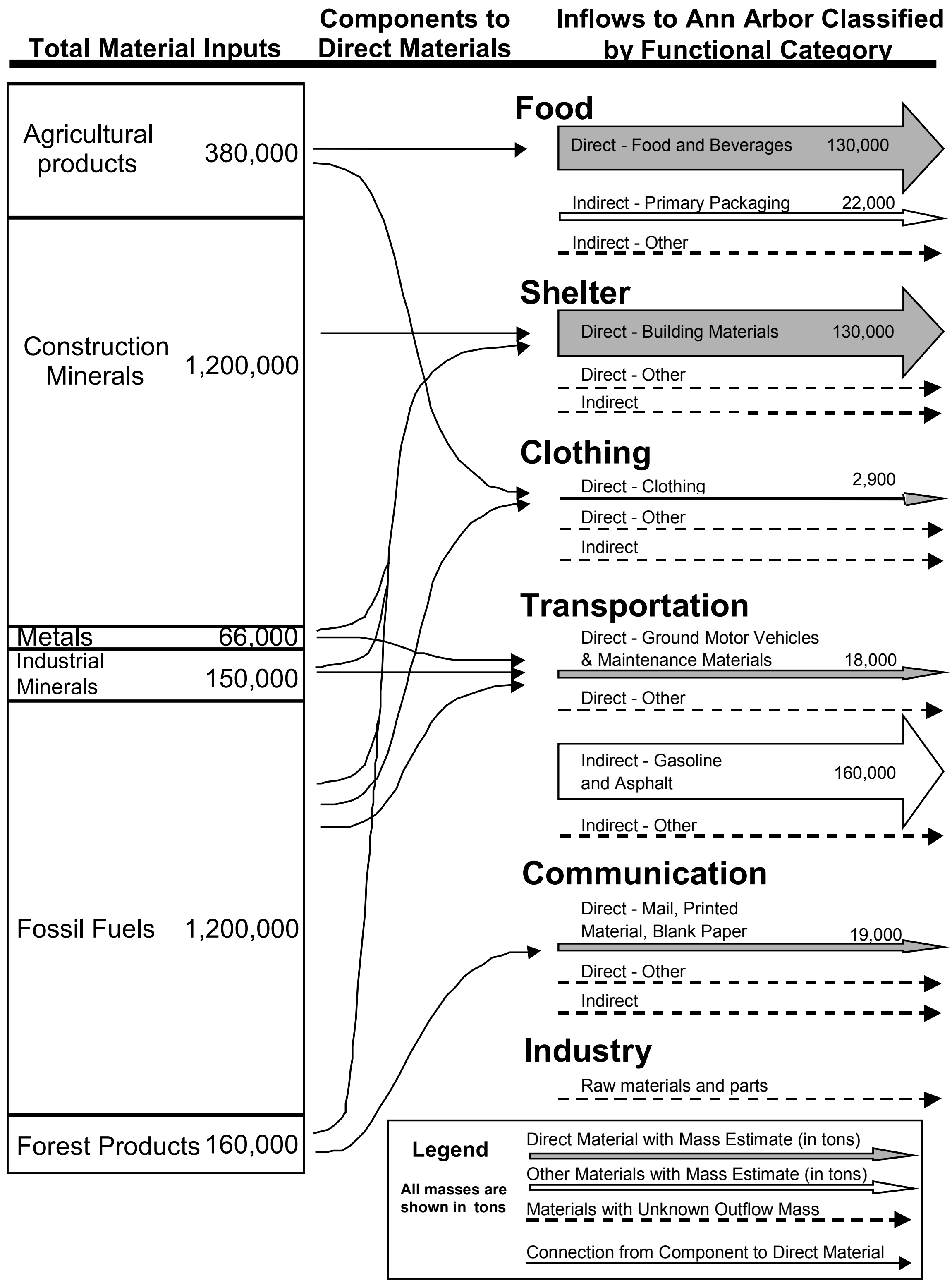

Figure 5-7 Mass of Material Inflows to Ann Arbor in Relation to Material Inputs, Excluding Water

The relationships between the Wernick and Ausubel material input categories and the material inflows to the community examined in this study are described in more detail below.

Agricultural Products

A significant but minority share of the total mass of Agricultural Products modeled by Wernick and Ausubel can be accounted for among the estimates of this study. A portion of Agricultural Products becomes part of the food and beverages inflow together with water added during the processing of beverages and packaged foods. A small amount of agricultural production enters the community in the form of clothing, footwear, and other textile and leather goods. Uses of Agricultural Products excluded from this study's estimates include food used to feed animals and post-harvest food losses during processing and wholesaling. Also excluded from this study's estimates is about one-fifth of the food production in the United States that is exported to other countries. These exports, based on a per capita calculation for Ann Arbor, are included in the Total Raw Material Inputs represented in Figure 5-6.

Construction Minerals

A small portion of Construction Minerals is included in the inflow estimates for Transportation and Shelter. Stone, sand, and gravel are used in asphalt for road construction and in concrete and cement as a building material. This study does not include estimates for gravel used for road maintenance nor any Construction Materials used to create cement and concrete for a broader set of purposes beyond Shelter.

Metals

A significant portion of the Metals material input category is found in vehicles and buildings, both of which are included in this analysis. A small amount of metal, 1800 tons, is included in the estimate for primary packaging of steel and aluminum cans for food. However, other uses of metal include appliances, manufacturing equipment, construction vehicles, pipes, and rail cars are not included in this analysis and represent a large use of metal both inside and outside of Ann Arbor.

Industrial Minerals

Industrial Minerals are used in a variety of applications ranging from construction to agriculture to manufacturing. A small amount of minerals used to produce materials such as glass and drywall are included in the inflow estimates for vehicles, buildings, and glass packing for food. The largest fraction of industrial minerals modeled in this study is used in the construction industry and includes lime and gypsum for cement and clay for bricks. However, about a fourth of all Industrial Minerals, such as nitrogen, sulfur, and phosphate, are used for agriculture outside of Ann Arbor and are not included as an inflow estimate in this study.

Fossil Fuels

Nine percent of this material input category is accounted for in the estimate of gasoline used to power vehicles in Ann Arbor. A smaller amount of Fossil Fuels is used to create petroleum products such as plastics for use as food packaging, vehicle parts, and synthetic clothing. However, the most significant uses of Fossil Fuels are to provide Ann Arbor's electricity and to provide the energy for all material production and transportation activities that occur outside of the community. These uses of Fossil Fuels are not included in the inflow estimates for this study.

Forest Products

A large portion of Forest Products are accounted for in the inflow estimates for Shelter and Communication, because the direct materials for these functional categories make extensive use of saw timber and pulpwood in the form of buildings and paper. Saw timber and pulpwood together account for about 75 percent of the total Forest Products material input.

Outflows

The prevalence of data quantifying the generation of solid wastes enables a detailed comparison of the material outflows modeled in this study with the total mass of materials flowing out of the community. Estimates for the total community outflows have been developed using the following data sources:

- Characterization of Municipal Solid Waste[146]: This report contains estimates of national municipal solid waste (MSW) for 1997.
- Ann Arbor Solid Waste Report[147]: This report contains mass data for municipal solid waste managed by the City of Ann Arbor, which includes MSW from residents and small businesses but not the University of Michigan or large businesses.
- University of Michigan Solid Waste Data[148]: Data collected from an interview with the Plant Operations Department includes the University's MSW except for yard trimmings, which are composted on University land.

The Resource Conservation and Recovery Act (RCRA) regulates the management of non-hazardous and hazardous solid wastes generated by industrial, commercial, agricultural, and mining operations, and from community activities.[149] Table 5-5 shows the different RCRA solid waste types used to characterize total material outflows. The table shows how the direct materials modeled in this study fit within these solid waste types.

The table also contains notes on the data sources used to create mass estimates for solid waste outflows. A detailed discussion of the steps used to create the estimates is included in Appendix H. Gaseous wastes and wastewater are excluded from this analysis. The solid waste mass estimates do not distinguish between landfill disposal, recycling, or reuse. Waste categories associated with agriculture, mining, and oil and gas extraction are not included because these activities are negligible within Ann Arbor.

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[146] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update. op. cit.

[147] City of Ann Arbor Department of Solid Waste. op. cit. "Waste Reduction Report for the Period of July 1993-1998"

[148] Plant Operations, University of Michigan. Personal interview. 8 Jun 2000.

[149] National Archives and Records Administration. Code of Federal Regulations, Title 40, Volume 17, Part 258.2. U.S. Government Printing Office, Jul 1999 <http://frwebgate.access.gpo.gov/cgi-bin/get-cfr.cgi> 14 Jun 2000.

Table 5-5 Total Solid Waste Outflows Based on RCRA Solid Waste Categories

Waste Category	Materials Included	Data Sources
▪ **Municipal Solid Waste**	MSW from Ann Arbor residents, small businesses, and the University of Michigan	Sum of Ann Arbor and University of Michigan data
Durable Goods	Major appliances, small appliances, furniture and furnishings, carpets and rugs, miscellaneous durables	Characterization of MSW
Nondurable Goods		
Communication	Outgoing USPS mail Disposed and recycled paper	Communication outflow estimates
Clothing	Disposed and recycled clothing Thrift store donations to outside organizations	Clothing outflow estimates
Other Nondurable Goods	Tissue paper and towels, paper and plastic plates and cups, trash bags, disposable diapers, other nonpackaging paper, towels, sheets, pillowcases, other miscellaneous nondurables	Characterization of MSW
Containers and Packaging	Glass, steel, aluminum, paper, plastic, and wood; bottles, jars, cans, foil, boxes, cartons, bags, wraps, and pallets	Characterization of MSW
Food Scraps	Food scraps disposed in landfill; does not include composted food	Food and Water outflow estimates
Yard Trimmings	Grass, leaves, and tree and brush trimmings in municipal compost; does not include University of Michigan or residential backyard composting	Ann Arbor data
Miscellaneous Inorganic Wastes	Soil, bits of concrete, stones	Characterization of MSW
Other Large Commercial MSW	Durable goods, other nondurable goods, containers and packaging, and misc. inorganic wastes from large corporations who hire independent waste haulers. Does not include materials associated with Communication, Clothing, or food scraps	Comparison of Characterization of MSW with Ann Arbor of University of Michigan MSW data
▪ **Automotive**		
Ground Motor Vehicles and Maintenance Materials	Retired ground motor vehicles Maintenance materials	Transportation outflow estimates
Other Vehicles	Bicycles, trains, airplanes, boats	Unknown
▪ **Municipal Sludge**	Biosolids and scum	Food and Water outflow estimates
▪ **Construction and Demolition Debris**		
Building-related C&D	Most building-related C&D debris	Shelter outflow estimates
Other C&D	Roadway and bridge construction waste, land clearing and inert debris waste, misc. building-related C&D (from 8% of building permits not estimated in this study)	Unknown
▪ **Industrial Waste**	Wastes from manufacturing or other industrial processes	Unknown
▪ **Other Hazardous Waste**	All hazardous wastes except for automotive wastes	Unknown

Figure 5-8 shows a visual representation of the outflows catalogued in Table 5-5. The right side of the figure, titled “Solid Outflows Classified Using Waste Categories,” uses the RCRA waste categories to organize the total solid waste outflows from Ann Arbor. The left side of the diagram, titled “Solid Outflows Classified Using Functional Categories,” shows total outflows organized by functional categories as catalogued in Table 5-3. An additional outflow, titled “Industry,” for industrial wastes has been added to the functional categories to provide a complete set of outflows. The thickness of the arrows throughout the figure is proportional to the mass of the outflow they represent. Dotted arrows represent outflows that do not have a mass estimate.

Several observations can be made based on an analysis of Figure 5-8

Solid Outflows Classified Using Functional Categories

As the focus switches from the inflows shown in Figure 5-7 to the outflows shown in Figure 5-8, the relative importance of various materials changes in terms of the mass of flows. For example, paper-based communication and primary packaging for food do not appear to be significant material inflows in Figure 5-7 compared to other materials. Yet these two materials have the two largest outflow masses even though their outflow masses are close or equal to the mass of their inflows.

This change in the relative importance of paper-based communication and food packaging is caused by the disparity between the inflow and outflow mass for other materials. Among the inflows, food and shelter have large inflows for direct materials, but the solid outflows for these categories are smaller because most of the food inflow leaves the community in gas or liquid form, and shelter grows in stock rather than having a large outflow. Transportation’s indirect materials of asphalt and gasoline have large inflow masses, but they do not have outflow estimates due to a lack of available data or because they leave the community in gaseous form. The smaller size of outflow masses for other materials makes primary packaging for food and paper-based communication assume a prominent role among total solid wastes.

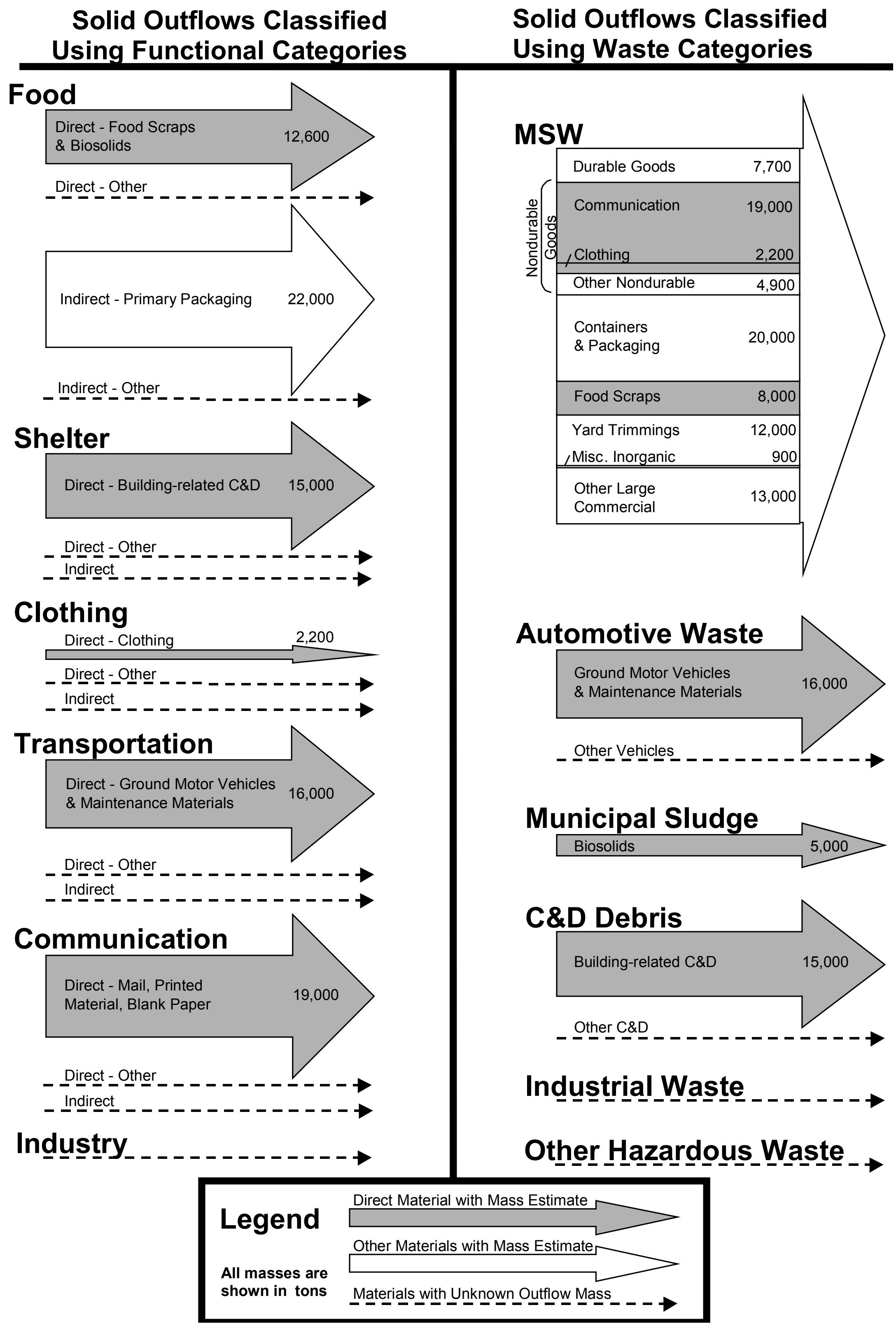

Figure 5-8 Mass of Total Solid Outflows by Functional Categories, based on Chapter 4 results, and Waste Categories, from sources given in Table 5-5

Solid Outflows Classified Using Waste Categories

The direct materials associated with communication, clothing, and food scraps represent about 37% of the total MSW for Ann Arbor. However, the largest outflow shown within MSW is containers and packaging, and this outflow is even larger if containers and packaging within the MSW of large commercial businesses are included. This result confirms that containers and packaging are an important outflow to evaluate in studies of municipal solid waste management.

The direct materials associated with the five functional categories account for slightly over half of all solid outflows with mass estimates in Figure 5-8. However, the mass of outflows not modeled such as other C&D debris and industrial waste should not be underestimated. For example, manufacturing wastes represent over half the mass of all RCRA wastes nationwide[150], though it is not clear that this would be the case for Ann Arbor because the community's economy is focused more on education, information technology, and the service industry and less on heavy industry.

Comparing Results From the Two Approaches

Yard trimmings represent a large outflow mass among the waste categories, but it does not appear among the functional categories. Yard work and grounds maintenance do not clearly satisfy any of the needs associated with the five functional categories included in this report, but perhaps could be modeled as part of Shelter due to the common ownership and proximity of buildings and their grounds. Note that one of the functional categories left out of this report is recreation, which could be interpreted to include material flows associated with yard work. The absence of yard trimming among the functional categories highlights a difficulty of using a functional category scheme. As mentioned previously in the discussion of methodology in Chapter 3, a basic material categorization scheme can provide a better framework for understanding total material flows than a functional use categorization scheme.

Primary packaging for food is only one of many types of containers and packaging included in MSW, so it would be expected that the outflow mass of total containers and packaging would be larger than the outflow mass of primary packaging for food. However, the mass of primary packaging for food, shown among the functional categories in Figure 5-8, has a mass estimate of 22,000 tons, while the total for all containers and packaging, shown among the waste categories, is only 20,000 tons. One factor contributing to this seeming discrepancy is that the containers and packaging mass shown does not include these materials present in the MSW of large commercial businesses. Also, different methods are used to create the two estimates, leading to varying results. The estimation of the outflow mass of primary food packaging is found in Appendix B, while Appendix H describes the methods used to estimate the outflow mass of containers and packaging.

Both methods shown in Figure 5-8 only show solid outflows. The large mass of water inflows and outflows has already been discussed, but there are also other outflows not represented as solid waste. Wernick and Ausubel estimate that atmospheric emissions represent over three times the mass of solid material wastes in the United States[151]. Many of these emissions occur outside of Ann Arbor, such as methane releases resulting from coal mining and agriculture. However, other emissions are common in a community such as Ann Arbor, including emissions of carbon dioxide, carbon monoxide, and nitrogen oxide from the combustion of fuels.

In summary, this analysis is a start at modeling the total mass flows through a community. Broadening the scope to include production and indirect materials and comparing the estimates to other available data on community flows provide a more robust understanding of this report's findings.

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[150] United States Congress, Office of Technology Assessment. Green Products by Design: Choices for a Cleaner Environment. OTA-E-541. Washington, D.C.: U.S. Government Printing Office. October 1992. p. 6.

[151] Wernick, op. cit.

Recommendations

In developing recommendations to improve the management of material flows in the City of Ann Arbor, an important consideration is programs already in place. Ann Arbor has been among the most progressive cities in terms of material management, particularly in waste reduction. Additional information on Ann Arbor is presented in Appendix A.

Table 5-6 offers a brief description of existing programs in the community and recommendations. The recommendations, presented previously among the results in Chapter 4, are categorized according to general strategies that can be employed to reduce material flows or to increase the efficiency of material flows. The six potential strategies include Rethink, Redesign, Reduce, Reuse, Recycle, and Remanufacture, as discussed in Chapter 3. The remainder of this section focuses on recommendations based on the comparisons across categories, putting the data into context of total flows, the presence of existing programs, and the unique characteristics of Ann Arbor. These recommendations will help identify material flows to which the community should give higher priority when developing solutions. Solutions may entail new programs or enhancements to existing programs.

A number of common themes have been identified that may reduce material flows or increase the efficiency of material flows in the community.

- To increase the efficiency of material flows in the community, the city should consider expanding its communication to the public to focus beyond waste management to other stages of the materials life cycle. The Ann Arbor Solid Waste Department works with residents, local businesses and institutions to reduce and manage the community's waste stream. Ann Arbor has been recognized by the United States Environmental Protection Agency as a record-setter in reducing their solid waste stream. However, in terms of the inflow of materials, Ann Arbor residents exceed national per capita spending on goods such as clothing. Informing people about ways of reducing material inflows or personal expenditures through their purchase decisions or how they use products may be helpful. The City also may consider changing the mode of communication to target specific groups within the community. For example, the student population may be more effectively reached through the Internet, or via e-mail.

- Some communities use fees or a taxes based system to create an incentive for local residents and businesses to more actively manage the mass or volume of waste they generate. In communities with pay-as-you-throw programs, also known as unit pricing or variable-rate pricing, residents are charged for the collection of municipal solid waste based on the amount they throw away. The degree to which waste can be reduced through pay-as-you-throw programs varies, but a number of communities report significant improvement. Between 1990 and 1994, residents in Grand Rapids, Michigan were charged 3 cents per gallon per week for waste, which contributed to a reduction of 22 percent per household in waste incinerated[152]. The pay-as-you-throw program is not currently used in Ann Arbor, but similarly structured programs could be introduced in Ann Arbor at the community level.

Table 5-6 presents a summary of category specific recommendations, along with programs that currently exist in Ann Arbor.

[152] Miranda, Marie Lynn and Joseph E. Aldy. Unit Pricing of Residential Municipal Solid Waste: Lessons from Nine Case Study Communities. Office of Policy, Planning and Evaluation U.S. Environmental Protection Agency, Mar. 1996. < http://www.epa.gov/epaoswer/non-hw/payt/research.htm#comm> 17 Jun. 2000.

Table 5-6 Summary of Current Programs and Recommendations[153]

Current Local Effort or Program	Recommendation
Rethink	
▪ University of Michigan eXchange Files is set up as a way for University of Michigan faculty, students, and staff to offer or request office supply items for reuse [154] ▪ Project Grow: public land for community gardening ▪ Washtenaw County community supported agriculture ▪ Ann Arbor Transit Authority ▪ University of Michigan free bus system	▪ Targeted marketing of e-document services by USPS ▪ Initiation of electronic books in the community library system or university environment ▪ Utilization of library system as an alternative to private ownership of printed materials ▪ Community network for joint effort composting program for local businesses ▪ Commuter trip reduction ▪ Car sharing service ▪ Community owned bicycles
Redesign	
▪ Transportation planning including pedestrian and bicycle friendly policies	▪ Use innovative structural design to maximize use of space in smaller buildings ▪ Use grey water in new construction
Reduce	
▪ University of Michigan charges for student printing above established quota	▪ Food loss reduction education ▪ Use longer lived building materials ▪ Use construction methods that reduce scrap ▪ Reduction of "junk" mail through consumer action ▪ Better match between household size and house size ▪ Better match between vehicle size and occupancy and hauling needs
Reuse	
▪ Donation and redistribution programs for clothing ▪ Donation and redistribution programs for building materials: ReUse Center ▪ Donation and redistribution programs for food: Food Gatherers ▪ Retail outlets for used books, CDs, computers ▪ Retail outlets for used clothing & used building materials ▪ Washtenaw County Materials Exchange website with listings for wanted and available materials	▪ Annual or semi-annual community sponsored effort to clean out closets ▪ More widespread deconstruction of structures rather than demolition to enable reuse of materials
Recycle	
▪ Curbside pickup for clothing ▪ Curbside pickup for paper ▪ Drop off site for construction materials ▪ City program supporting home composting ▪ University of Michigan dining hall composting	▪ Local textile recycling business based on existing model ▪ Initiate local program for recycling of shingles & drywall ▪ Better promotion of existing textile recycling program

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[153] Additional detail may be found in specific sections of Chapter 4 of this report.

[154] The eXchange Files. University of Michigan Plant Operations. <http://www.recycle.umich.edu/grounds/recycle/Exchangefiles/> 20 May 2000.

The feasibility of solutions should be examined from a variety of perspectives. A community is made up of individuals, institutions, and businesses, each of which has unique motivations, including individual traits, social pressure or support, and economic factors. Solutions designed to take the motivations of community stakeholders into account are more likely to achieve success.

Human Behavior Issues to Consider

Reducing the total flow of materials through a community can be accomplished if people purchase fewer goods or switch to technologies that are less material intensive. However, many social and technological issues impede implementation of this strategy.

Social Issues

The quantity of materials consumed has grown substantially since 1900, as a result of population growth, public demand, and industrialization. Temporary decreases in the U.S. materials consumption pattern have occurred during major economic and military events, including the depression of the 1930s, World War I, World War II, the oil crises of the 1970s, and the recession of the 1980s.[155] During the World Wars, attention was paid to amount of materials used and the fate of those materials due to shortages. Through collective efforts like scrap metal drives, recycling rates were high, materials consumption was low, and there was a general concern for not using up our resource supply. During economic downturns, spending was low, new building projects were cut, resource conservation was high, and while basic needs may have been met, the standard of living of most people was reduced.

Since the early 1990s, the United States has been in the midst of an economic expansion. Unemployment is low and spending is up. Disposable income has more than doubled between 1969 and 1996[156]. People like a level of material consumption that goes beyond meeting basic needs, including bigger houses, bigger cars, more food, and more clothes.

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[155] Matos, op cit.

[156] United States Bureau of the Census. Changes in Median Household Income: 1969 to 1996 Table 1. Percent Difference Between 1969 and 1996 in Selected Economic Measures. U.S. Department of Commerce, 1999. <http://www.census.gov/hhes/income/mednhhld/t1.html> 29 May 2000.

We have shifted to purchasing more disposable products and discarding goods, like clothing, frequently after a few uses, rather than when worn out, only because fashions change and the style is no longer "in."

While recycling rates have increased and professed environmental consciousness is high, conservation of material resources is not inherent in our culture. The shifts in material consumption during economic and military events provide evidence that Americans do have the capacity to reduce materials use. However, this downturn in materials use seems to be stimulated by crisis or loss of income, and is often associated with a reduction in standard of living. Today our inefficiency of materials use isn't a concern to the average American; it appears that there is a sufficient supply of resources to last for decades.

Therefore strategies to reduce materials use, while the U.S. is in the midst of a booming economy, cannot depend on crisis. For example, encouraging dedication to purchasing durable products, making products that can be remanufactured, disassembled, and easily repaired are solutions that reduce the dependence on new products to replace worn out ones. These methods improve resource productivity by finding products that meet the same needs while using less material over the lifetime of the product.

Technology lag

Some potential solutions are hampered by inadequate technological solutions. For example, development of electronic books is under way. However, many people are still more comfortable reading on paper than on a computer screen. It is unclear if the tradeoffs associated with increased use of electronics, and the necessary batteries, outweigh the disadvantages associated with paper usage. Research into new building techniques and materials that reduce resource use has been limited. Ultralight cars have been proposed by the Rocky Mountain Institute, but major auto-makers have yet to mass produce vehicles using this strategy. Telecommuting is often held up by a lack of fully developed networking technologies.

Lessons from Environmental Psychology

Some reasons why we buy goods include peer pressure (to "keep up with the Jones'"), to satisfy a longing such as looking for peace or acceptance, or as a result of directed attention fatigue - the loss of putting thought into why we do things.[157]

Research on conservation behavior indicates that positive outcomes, e.g. increased frugality or recycling, can be achieved by requiring people to conserve, but future conservation behavior is less likely if the original motivation is perceived as having been caused by external forces.[158] Creating situations in which people feel that their actions are, at least partly, derived from an internal sense of concern and competence has the greatest potential for success.

Focusing Community Efforts

This study presents estimates for mass of material inflows and outflows, as well as the economic value of the inflows to the community. The estimates are compared across material categories and the flows are examined in the larger context of the total estimated flow of materials through the community.

One objective of this study is to use the estimated material mass and economic analysis to provide community leaders with a way of deciding how best to allocate resources in their attempts to increase the efficiency of material flows. Table 5-7 is a matrix that offers one possible way to identify important flows and prioritize recommendations. Further discussion on the matrix is presented in Chapter 3.

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[157] DeYoung, Raymond. Home page. <http://www-personal.umich.edu/~rdeyoung> 20 May 2000.
[158] DeYoung, op. cit.

Table 5-7 Summary of Comparisons and Evaluations of Material Flows

Material Category	Comparing Data Across Categories	Summary of Existing Community Programs[159]	Type(s) of Recommendations as Shown in Table 5-6		Barrier to Success	Enabler of Success
			Inflow	Outflow		
All categories		▪ Extensive recycling programs			▪ Ann Arbor residents have higher buying power than national average	▪ High environmental awareness
Food	▪ Large inflow mass ▪ Highest per capita inflow expenditure	▪ Food redistribution ▪ Local agriculture ▪ U of M, local business composting	Reduce	Recycle	▪ Limited space for composting ▪ Limited awareness of food loss	▪ Awareness of residential composting
Water	▪ Largest inflow and outflow mass ▪ Lowest per capita inflow expenditure	▪ Consumer education program	Redesign Reduce Reuse	Reuse	▪ Local concern focused on water quality not quantity	▪ None identified
Shelter	▪ Large inflow mass	▪ Materials reuse program	Rethink Redesign Reduce Reuse	Reuse Recycle	▪ Social trend towards larger houses ▪ Increased investment in commercial buildings.	▪ Existing education programs sponsored by ReUse Center
Clothing	▪ High per capita inflow expenditure ▪ Lowest inflow and outflow mass	▪ Donation and reuse programs	Reuse	Reuse Recycle	▪ Social attitude towards clothing ▪ Lack of public awareness of alternative disposal methods	▪ Existing business model for textile recycling in other communities

[159] Details provided in Table 5-6 and in Chapter 4 Material Flow Recommendation section for each material category

Table 5-7, continued

Material Category	Comparing Data Across Categories	Summary of Existing Programs	Type(s) of Recommendations as Shown in Table 5-6		Barrier to Success	Enabler of Success
			Inflow	Outflow		
Transportation	▪ High per capita inflow expenditure	▪ Award winning public transportation	Rethink		▪ Convenience of personal vehicle ownership	▪ Accepted social norm to use alternative modes of transportation ▪ Prevalence of white-collar jobs, lend themselves to telecommuting
Communication	▪ No significant findings	▪ Retail outlets for used books ▪ Extensive library system	Rethink Reduce		▪ Preference for paper-based media ▪ Presence of university	▪ Well educated and technology- sophisticated population

The Food category has a large inflow mass and large per capita inflow expenditure. The recommendation addressing inflows, reducing food losses, faces a barrier of limited awareness of the magnitude of food wasted in this manner. However, the community's history of environmental leadership offers hope that with education and public recognition of participants, this recommendation may be successful.

The Water category has the largest inflow and outflow mass, but because water is abundant, the primary concern in the community is quality, not quantity. At both the individual and municipal level, the expenditure per ton of water is significantly lower compared to other material categories, so economic incentives to reduce water use are not strong in Ann Arbor.

The Shelter category has a large inflow mass compared to other material categories. Though the current trend of increasing number and scale of residential and commercial construction projects is a potential barrier to reducing flows, the proposed recommendations target the method of construction and the choice of materials, so that the same level of service is achieved with reduced mass. A better match between household size and house square footage represents a more efficient use of materials. Current educational programs offered by the Recycle Ann Arbor ReUse Center may help to promote the use and donation of used building materials which also could reduce inflow mass.

The Clothing category is characterized by high per capita expenditures. Reducing these inflows through reuse is made more difficult by frequently changing fashion trends. These social attitudes towards clothing may assist in the generation of the mass of clothing necessary to support a regional textile recycling/exporting business. However, this category may not be the primary area of focus due to the low outflow mass of clothing relative to other material categories.

The Transportation category has a high per capita inflow expenditure, which is addressed through recommendations that focus on rethinking the concept of transportation. The use of car sharing and community bicycles faces a barrier of both a real and perceived lack of convenience associated with using shared resources. A commuter trip reduction program focusing on telecommuting and flextime may be helped by the prevalence of white-collar jobs, especially in the technology and academic arenas, that lend themselves to non-traditional work environments and scheduling. A recommendation targeting reduction is for residents to consider purchasing smaller vehicles that match their occupancy and hauling needs.

Communication, limited to printed media, does not stand out in terms of mass or economic value of flows relative to the other material categories. There is potential for technology to displace some of the mass associated with printed media. The highly educated and technology-literate population of Ann Arbor could enable the success of the proposed recommendation because of the community's ability and willingness to adopt new technology. However, the use of electronic media may not serve as a substitute due to our preference for paper-based media. Efforts to reduce material flows may also be hampered by observed trends of increased paper consumption associated with higher levels of income and literacy, both of which are characteristic of Ann Arbor. By making use of the resources held by the libraries in Ann Arbor, instead of purchasing printed materials, consumers could potentially reduce the inflows of the mass of printed materials into the community. The University of Michigan Library System, which is open to the entire community, holds approximately 7 million volumes of printed material[160] and the Ann Arbor District Library has a total collection of about 460,000 items[161]. One potential issue with this idea is that it challenges the idea of personal ownership of materials like books and magazines. Owning these materials allows the freedom of using them over an unlimited period of time and in an unrestricted manner.

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[160] Data Tables for Academic Institutions, op. cit.

[161] Andersen, Beth. Ann Arbor District Library. Personal interview. 17 Jun. 2000.

The above summaries are a starting point for community leaders to decide where to focus their efforts on improving the efficiency of material flows and for researchers to choose material flows and recommendations for more detailed study. Supplementary research could focus on a targeted set of material flows associated with a specific issue of current importance to Ann Arbor. Additionally, further development of the recommendations, such as gaining a better understanding of stakeholder support and assessing the feasibility of the recommendations, is needed prior to implementation. Community leaders involved in evaluating and implementing recommendations could include commercial groups such as the Ann Arbor Chamber of Commerce, institutions such as the University of Michigan and Ann Arbor Public Library, environmental non-profit organizations such as the Ecology Center of Ann Arbor, and various departments within the City of Ann Arbor government such as the Building Department, Planning Department, Water Utilities Department, Public Services Department, and Solid Waste Department. Community material flows cross multiple sectors of society, so collaborative approaches may prove to be the most successful in improving the efficiency of material flows.

Chapter 6: Final Remarks

This study has been undertaken with several goals in mind:

- To increase the understanding of material flows moving through Ann Arbor;
- To develop a methodology by which community leaders may analyze material flows at a community level;
- To stimulate further research into the use of material flow analysis.

Understanding Material Flows

Understanding the material flows moving through Ann Arbor allows for the development of appropriate local solutions for increasing the efficiency of those flows. This study has been undertaken with the intention of quantifying material flows moving through Ann Arbor in terms of mass and economic value. Material categories, including Food, Water, Shelter, Clothing, Transportation, and Communication, were chosen for this analysis to group materials based on the human needs they satisfy. The most significant category in terms of the mass of inflows and outflows is Water. Shelter and Food account for the second and third largest mass inflows. Outflow masses associated with the other categories, including Shelter, Transportation, Food, and Communication, are of a similar magnitude with each other. The inflows with the largest economic value are associated with the Food and Clothing categories. These inflows and outflows are then placed in the context of total material inputs and total solid waste as estimated in other research. Based on these analyses, potential recommendations for community leaders in Ann Arbor have been suggested to improve the efficiency of material flows with a focus on reducing the size of the community's material flows. For this study, efficiency is defined as minimizing the mass of material flows per unit of service provided. Ann Arbor has one of the nation’s most progressive waste management programs, so the community should focus on strategies to reduce its inflow of materials. This can be accomplished by increasing the efficiency with which materials are used to meet functional needs in order to reduce consumption, or by redesigning or rethinking the way functional needs are met to develop alternative systems.

Developing a Methodology

A methodology for analyzing material flows at a community level can help a community to identify approaches to increase the efficiency of material flows. A method to estimate the inflows and outflows of materials has been defined in this study, as well as frameworks to help identify and prioritize potential opportunities.

As in any research project, the act of going through the study yields valuable experiences that should be considered in future undertakings of materials flow analysis at the community level. Following are observations that may help future efforts in this area.

1. Establishing the appropriate community boundary is critical in this process because it largely determines data availability and the general scope of analysis and recommendations. This study's choice of the City of Ann Arbor's political boundary creates an analysis focused on a single community rather than a loosely connected set of communities that the county level would provide. However, many key data sources present data at a national or county level and not at a city level, limiting the ability of this study to include data specific to Ann Arbor for some categories. This study did not include material flows associated with production, but a study including such activity may prefer to use a county level in order to include broader set of economic activities such as agriculture, mining, or manufacturing. The community boundary used in future research should be defined based upon the intended purpose of the study and the availability of community-specific data.
2. Though the extent of research in the field of materials flow is limited, a thorough investigation into existing research on the flow of materials through a community should be conducted prior to beginning a similar study. Studies have been conducted in Europe, tracking several types of materials at different geographic scales. Drawing upon the successes and difficulties encountered with existing research and methodologies, a decision can be made whether to use an existing methodology, modify an existing one, or create an entirely new methodology.
3. It is important to understand the limitations of choosing any particular unit of measure. The choice of unit of measurement needs to be aligned with the goals of the study. For certain purposes, examining only the mass of materials may be limiting.

For example, a community concerned with the human health impacts of material consumption might find it appropriate to examine toxicity as well as mass.

4. Adjustments to a project's scope must be made to fit the limits of both data and time available for research. For example, potential material categories of Health and Recreation are excluded here in order to reduce this project's scope because the wide diversity of materials in these functional categories complicates data collection. Other analyses not included are the quantification of flows of indirect materials and the analysis of the economic value of outflows. The scope of any similar project should be carefully defined based on project goals.

Stimulating Further Research

A third goal of this analysis is to stimulate further research into the use of materials flow analysis to address sustainability issues in the community. It is intended that carrying out this study will increase awareness of materials flow analysis as a tool for community leaders. This awareness currently is more prevalent in Europe, where some countries are incorporating materials flow statistics into their standard public statistics. Until similar practices are adopted in the U.S., efforts such as this study can be used to align existing collected data with the concepts of materials flow accounting. A broader availability of material flow data at local and national levels would enable future research to focus less on data collection and modeling and more on the analysis of material flows and solutions to improve their efficiency.

Many opportunities exist for future research to extend the results of this study.

1. One part of this study focuses on the analysis of the mass of inflows and outflows and understanding the dynamics behind disparities in the inflows versus the outflows. A similar analysis could have been done for the economic value of flows, had estimates been made for the economic value of outflows. In particular, it might be useful to a community to examine how the value of materials changes as they move through the community. Such an analysis may suggest ways that a community can capture the full economic value of the materials it imports through extended use and sale for reuse or recycling.

2. A complete materials balance is not achieved in this study. In some cases the increase in the stock of materials in the community can be estimated based on the difference between inflows and outflows. However, this study does not include independent estimates of the change in stocks to compare to the difference in flows. Also, in most cases this study does not estimate the total stock of materials. Methods for calculating and verifying the total stock of materials at a point in time and the change in stock over a period of time are needed to provide a more accurate reflection of the material balances in the community. Developing a means of estimating the mass, average age, and other characteristics of stocks within the community would add to the overall understanding of how materials are used.
3. This study analyzed materials based on the functions they provide. Other studies have tracked basic materials such as cadmium or iron in order to facilitate material management opportunities. A combination of these functional use and basic material categorization schemes could be used to explore the basic material composition of the direct and indirect materials that satisfy a functional need. Linking the material composition with the functional need could better quantify upstream and downstream burdens and lead to an enhanced understanding of impacts of material and product consumption. For example, quantifying the mass of specific materials associated with vehicles would enable the use of data on the environmental impacts of materials such as steel or glass to estimate the environmental impact of transportation in a community. In this way, a comparison of the relative environmental burdens associated with two product system alternatives that meet a functional need could be evaluated.
4. The research presented here focuses on the flow of materials coming into and out of the city boundary. Tracking the mass of materials moving between economic sectors within the community could help identify where to focus efforts to increase the efficiency of specific material flows. For example, research by Burström [162] tracks the flows of nitrogen between economic sectors internally within a community in order to target specific material management recommendations.

[162] Burström, op. cit.

5. This study includes a broad variety of functional categories and material types in order to achieve its goals of developing an understanding of material flows in Ann Arbor and a methodology for this form of analysis. Researchers may choose instead to focus on a specific issue of current concern to their community and study only those material types that relate to that issue. A more targeted scope would allow for further development of solutions best able to increase the efficiency of specific material flows and address local concerns.
6. Recommendations could be further evaluated by identifying key indicators or metrics for the specific problem and then estimating the impact each recommendation would have for each key indicator or metric. Each recommendation could also be evaluated for economic, technical, and political feasibility, costs, and benefits.

This study contributes to the growing body of knowledge regarding material flows resulting from human activity. Material usage provides multiple benefits to our communities, but there are social, environmental, and economic costs associated with the extraction, production, use, and disposal of materials. Many communities suffer the economic costs of not realizing the full value of the materials they import or of missing economic opportunities to meet local demands through local production. The current rate of material flows through our communities depletes the limited supply of natural resources for future generations and threatens the current and future quality of water, air and soil[163]. Even though harm to human health and ecosystems associated with material flows is often difficult to quantify, recent experiences such as the threat of global warming suggest that the explosive growth of our material flows in recent history has the potential to create irreversible environmental consequences[164]. An understanding of the choice of materials used to satisfy human needs in our communities can help to move away from activities that degrade the environment and our quality of life and towards new approaches that enhance ecological, social, and economic well-being[165]. Approaches to materials management are more likely to promote a society in which the use of materials is sustainable if they contribute to a quality of life that is perceived

[163] Baccini, op. cit., p 150.
[164] United States Congress, Office of Technology Assessment. op. cit., p.23

positively by its inhabitants. Human and natural systems are closely intertwined, and satisfying the needs of either will ultimately require satisfying the needs of both.

[165] Matos, op. cit.

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Appendix A: Characterization of Ann Arbor, MI

This appendix provides information about the City of Ann Arbor, the model community chosen for this study.

Unless otherwise stated, the data in this appendix comes from "Cutting the Waste Stream in Half: Community Record-Setters Show How."[166]

Location and Size

The City of Ann Arbor is located in Washtenaw County in southeastern Michigan and it is 45 miles west of Detroit

- Land area: 27 square miles[167]
- The City of Ann Arbor Department of Parks and Recreation provides over 1,900 acres of parkland at 147 park sites[168]

Demographics

Ann Arbor is an urban college town. There is one college and one university in the city. Concordia College is a small liberal arts college. University Michigan has a total enrollment of approximately 37,000 students, including 24,000 undergraduates and 13,000 graduate students.

- Population 107,604 (Estimated July 1997)[169]
- Households: 43,381 (Estimated July 1997)[170]
- Median age: 27 years[171]

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[166] United States Environmental Protection Agency. op. cit.

[167] Frequently Asked Questions. op. cit.

[168] Parks and Recreation. City of Ann Arbor Department of Parks and Recreation. <http://www.ci.ann-arbor.mi.us/framed/parks/index.html> 7 Feb. 2000.

[169] Nutting, op. cit. Table 15 Washtenaw County Population Estimates, 1995-1998.

[170] Nutting, op. cit. Table 16 Washtenaw County Household Estimates, 1995-1998.

[171] United States Bureau of the Census. 1990 Census of Population and Housing: Ann Arbor City Income and Poverty. Michigan Information Center.

- Per Capita Income: $17,786 (1990)[172]. This includes the student population.
  U.S. Per Capita Income: $ 14,420 (1989)
- Median Household Income: $33,344 (1990)
  U.S. Median Household Income: $ 30,056 (1989)
- Educational attainment, completion of 4 years college: 66 percent
  Significantly higher than national average of about 20 percent.[173]

Employment

42 percent of the total work force in Ann Arbor is employed in managerial and professional occupations. The largest proportions of these workers are in the health service, education and research, retail and manufacturing industries.
In 1997, the average unemployment rate was 1.8 percent as compared to 4.2 percent for the State of Michigan.[174] Table A-1 summarizes information about the city's largest employers.

Table A-1 Largest Employers in the City of Ann Arbor

Employer	Product / Service	Number Employed
The University of Michigan	Education	15,000
Ann Arbor Public Schools	Education	1,900
Borders Group Inc	Book Wholesaler & Distributor	1,500
Washtenaw County	Government	1400
Warner-Lambert & Parke-Davis	Pharmaceutical	1400
City of Ann Arbor	Government	1,000
Gelman Sciences, Inc.	Surgical, Medical Instruments	800
JPE, Inc.	Motor Vehicle Parts	700

Source: Stauder, Barch & Associates, Inc. Prospectus for City of Ann Arbor Sewage Disposal System and Water Supply System Revenue and Revenue Refunding Bonds. City of Ann Arbor. 17 Dec. 1998.

Waste Reduction Background

Recycling in Ann Arbor began in 1970 when a community based non-profit organization, the Ecology Center, opened a drop-off center. A volunteer group called Recycle Ann

<http://www.state.mi.us/webapp/dmb/mic/census/stf1a3a_1990.asp?cmd=data&lev=place&id=1421&cat=inc> 7 Feb. 2000.

[172] Ibid.

[173] Stauder, Barch & Associates, Inc. op. cit. p. A18

[174] Ibid, p A19-20

Arbor began a curbside recycling program a few years later, and today contracts with the city to collect recyclables from all residents. In fiscal year 1996, Ann Arbor residents reduced their waste by 53%; 31% through recycling and 22% through composting. Ann Arbor has a mandatory recycling ordinance with a $500 fine for non-compliance.

The state of Michigan instituted a bottle bill in 1976, with a $0.10 return deposit on glass, aluminum, and PET. In 1995, a statewide ban on landfilling yard debris was completely phased in.

Local Waste Statistics

The City of Ann Arbor Sanitary Landfill was constructed in the 1930's and served the needs of much of Washtenaw County into the early 1980's. The facility was officially closed in 1994 following discovery of elevated levels of vinyl chloride and dioxane in the groundwater.[175] Currently the City of Ann Arbor's solid waste is disposed at the Arbor Hills Landfill in Salem Township, Michigan.

Curbside recycling participation is approximately 92%. In 1996 46,574 tons waste were generated; 23,016 tons went to disposal and 23,558 tons were diverted (31% recycled, 22% composted). From FY1989 to FY1996 waste reduction increased from 16% to 53%. Michigan's bottle bill recovers an estimated 5% to 7% of the Ann Arbor waste stream.

It is estimated that over 80% of the recyclables collected within Washtenaw County originate from the commercial/industrial sector. Based on studies conducted by the Washtenaw County Solid Waste Planning Committee, it was determined that approximately 37% of the County's waste stream originates from the residential sector and 63% from the commercial/industrial sector. [176] The commercial/industrial sector contracts independently for their collection and recycling services, so reliable information is not available.

[175] Washtenaw County Board of Public Works. Washtenaw County Solid Waste Management Plan 1999 Update. Washtenaw County Department of Public Works, 15 April 2000.
[176] Washtenaw County Board of Public Works. op. cit.

The City of Ann Arbor Material Recovery Facility (MRF) is a 31,000 square foot facility where all of the MSW collected by the City is processed. Discards are compacted and sent to the Arbor Hills landfill. Recyclable materials are sorted and prepared for sale. In additin to the City of Ann Arbor, the MRF serves the City of Ypsilanti, Ypsilanti Township, Eastern Michigan University, and other private waste haulers.

Based on national statistics collected by the EPA in 1996, the following data was generated for Washtenaw County (Table A-2). Data is presented in tons.

Table A-2 Solid Waste generated in Washtenaw County

Material Description	% Total Waste generated by wt	Washtenaw Co. waste generated	Washtenaw Co. waste disposed	Washtenaw Co. waste recovered
Paper & Paperboard	38.1%	175,097	96,867	83,855
Glass	5.9%	27,174	18,841	8,231
Ferrous Metals	5.6%	25,859	14,950	11,575
Aluminum	1.4%	6,574	4,096	2,572
Other Non-Ferrous metals	0.6%	2,849	1,024	2,058
Plastics	9.4%	43,391	38,296	2,829
Rubber & leather	3.0%	13,587	11,468	1,543
Textiles	3.7%	16,874	13,721	2,572
Wood	5.2%	23,668	21,094	1,286
Other	1.8%	8,108	5,939	2,058
Food Wastes	10.4%	47,993	43,826	1,286
Yard Trimmings	13.4%	61,361	35,225	27,780
Misc. Inorganics	1.5%	7,013	6,553	-
Total	**100%**	**459,548**	**311,901**	**147,647**

In 1995, Washtenaw County conducted a study to characterize the Ann Arbor waste stream. A waste sort was performed by sampling material sent to Browning Ferris Industries' (BFI) Arbor Hills Landfill, located in Salem Township. Based on samples collected (Table A-3), 40% of the weight of waste were paper products. Plastic accounted for 18%, glass was less than 3.5%, metals were less than 5%, food waste accounted for 18%, and yard waste was at insignificant levels.[177]

[177] Swindlehurst, Susan. "Washtenaw County's 1995 Waste Characterization Study – What's in our Waste?" Report to the Board of Public Works, 16 Nov. 1995.

Table A-3 Characterization of Waste Generated Based on a Waste Sort

Category	Ann Arbor % of Total	Canadian loads % of Total	Village of Chelsea % of Total
Paper	39.87	18.59	19.73
Plastic	18.13	9.11	11.56
Glass	3.33	1.48	2.04
Metal	2.71	4.42	3.98
Special Waste: Textiles, food, building materials	27.56	46.57	46.20
Home Toxics	.36	.41	0

Examples of current waste management programs

- Curbside recycling and organic material collection for all households.
- Curbside recycling collection for business customers contracted with City of Ann Arbor (approx. 50%).
- Drop-off Station for collecting recyclables, yard debris, building materials, household appliances.
- ReUse Center for building materials, household items
- *WasteWatcher* publication sent out twice yearly to every household
- Weekly “Recyclers’ Guide” column in local newspaper
- “EarthBeat” radio program
- Pilot program with University of Michigan dining facilities studying the feasibility of composting food discards.
- Waste Knot commercial business recognition program, in partnership with Washtenaw County
- Methane gas-to-energy facility at closed landfill within the City of Ann Arbor

Appendix B: Food and Water

This appendix provides supplementary information for the study completed on material flows associated with the food and water needs of Ann Arbor, which is presented in Section 1 of Chapter 4.

Data Sources

USDA Report – Food Consumption

All consumption data shown for food and for beverages in this analysis is based on the USDA report, *Food Consumption, Prices, and Expenditures, 1970-97.* [178] The USDA report estimates the total consumption of food and beverage in the United States, but does so indirectly by estimating "food disappearance." The equations below illustrate this concept. The USDA states that the total supply for any particular type of food in a year must equal the total uses or fates of that food type on a mass basis.

$$\text{Supply} = \text{Utilization}$$

Supply is defined as the domestics stocks of that food type at the beginning of the year plus any additional food made available.

$$\text{Supply} = \text{Beginning Stocks} + \text{Production} + \text{Imports}$$

Utilization is defined as the sum of domestic use, exports, and the stock of that food type at the end of the year.

$$\begin{aligned}\text{Utilization} &= \text{Ending Stocks} + \text{Farm and Industrial Use} \\ &\quad + \text{U.S. Food Consumption} + \text{Exports}\end{aligned}$$

The USDA has estimates for all of these variables except U.S. Food Consumption, which it creates a new estimate for using the other variables:

$$\begin{aligned}\text{U.S. Food Consumption} &= \text{Beginning Stocks} + \text{Production} + \text{Imports} \\ &\quad - \text{Ending Stocks} - \text{Farm and Industrial Use} - \text{Exports}\end{aligned}$$

[178] Putnam, op. cit.

Therefore, the USDA report measures the “food disappearance,” which is the food otherwise unaccounted for, instead of directly measuring consumption.

Therefore, the mass of foods is estimated based upon their form at the time of production, not their final form in food products. However, what is needed to estimate the mass of the flow of food coming into Ann Arbor are estimates for food consumption based on the mass of food products as they enter food retailing systems. Many values in the USDA report are shown as "primary weights" and show the mass of food at the primary distribution level such as at the farmgate or slaughter plant. However, the USDA report also contains estimates for the "retail weights," which reflect the processing, trimming, shrinkage, or loss that occurs in the processing and distribution systems between the primary and retail sites.

For example, the USDA assumes a primary to retail conversion factor of 0.636 when raw potatoes are processed for canning, meaning that 63.6% of the original potatoes will end up in the canned product while 36.4% of the potatoes become a waste product, possibly used for another industrial purpose. In contrast, a conversion factor of .96 is used for fresh potatoes purchased in the produce section of a grocery store. This higher conversion factor reflects the fact that losses are minimal due to the lack of processing.

These retail weights are used to estimate the mass of food inflows for Ann Arbor. The retail weights estimate the mass of food products before any further losses by retailers, consumers, and foodservice that occur due to spoilage or food preparation. These losses predominately occur within the local community, so the retail level is the correct stage at which to estimate the inflow mass of food.

USDA Report – Food Expenditures

Information on food expenditures for 1997 is included in the USDA report described above. However, the USDA provides a website with revised food expenditures data based upon recent updates to sales data.[179] This analysis uses the website for all expenditure data.

The USDA report helps the reader interpret its expenditure estimates with the following explanation,

> "Each category is divided between sales and the quantity acquired without payment, such as home production, game and game fish, donations, and meals in military mess halls, hospitals, institutions, and on airlines. Each category of food and alcoholic beverage is valued at the last point where the product is sold separately. That means different components are valued at different points in the flow of food from farm to consumer. Food in hospitals is valued when sold to the hospital, whereas restaurant food is valued as sold to the customer and includes taxes and tips. In a separate calculation, all food is valued at the retail price level so that food is priced consistently regardless of where used."

Thus the expenditures data represent the price paid for food by the last paying customer, not the price paid as it enters the community. For example, the expenditures data represents the retail price paid by the consumer at a local grocery store, not the wholesale price paid by the grocery store for the food trucked into Ann Arbor. This data set is consistent with the approach used by other categories that base estimates of economic value of inflows on retail price.

The USDA report assigns an economic value to foods grown in personal gardens and gathered through hunting as if they had been purchased through a retail channel. This study does not include local production among its estimates, so this category of "produced at home" foods is not included in the estimate of inflow value.

Food Outflows

Local data for the mass of food composted by Ann Arbor residents are not available, so national estimates are used on a per capita basis and adjusted to reflect the higher frequency of residential composting in Ann Arbor. Available estimates of food scraps in the City's MSW seemed unreliable due to small sample sizes, so national estimates of food waste are used on a per capita basis.

[179] Food Expenditure Indicators, op. cit.

Local Water Systems

Data for water consumption, wastewater treatment, biosolids and scum were collected through interviews with various Ann Arbor city government divisions and through reports provided by those division. The data is all local, however it should be recognized that the service area for these water systems are larger than the City of Ann Arbor and include other townships. Thus each piece of data related to the city's water systems must be adjusted downward on a per capita basis to reflect only the City of Ann Arbor's use of these systems. All data was taken for the 1997/98 fiscal year for Ann Arbor city government.

Assumptions

The methods used to estimate the mass and economic value of material flows related to food and water rely on the following assumptions:

Food Inflow

- Ann Arbor resident eat all meals year-round within the community, and nonresidents do not eat any food within the community. An equivalent assumption is that these two quantities of food (residents eating outside and nonresidents eating inside the City) are equal in mass and value.
- The population remains constant year-round. This is a significant assumption given that about one-third of the population of Ann Arbor is undergraduate and graduate students, many of whom leave the community during the summer.
- No significant agriculture takes place within Ann Arbor. Only eight acres within the city are used for agriculture.[180]
- Ann Arbor residents consume the same quantities of food as the average per capita consumption of the United States for each type of food.
- Ann Arbor residents, businesses, and government agencies spend the same amount of money on food as the average for the United States as a per capita basis.
- Several assumptions specific to particular food types were made to aid the interpretation of the USDA food consumption data:

[180] City of Ann Arbor Planning Department. Current Land Uses. City of Ann Arbor Planning Department, 15 Aug. 1998.

- Packaged foods do not contain added water. The mass of water is not included for canned or bottled fruit and vegetables, soups, etc. This assumption applies only to foods and not to packaged beverages.
- All carbonated soft drinks and fruit juices are brought fully constituted with water. These drinks are not imported into the community as syrups or concentrates without water.
- All coffee and tea is brought into the community as dry ground coffee or tea leaves. Coffee and tea is then made using tap water. An exception is bottled iced tea, which is accounted for as a packaged beverage.
- All turkey brought into Ann Arbor is boneless. All chicken and beef brought into Ann Arbor is not boneless.
- All processed vegetables have the same primary to retail conversion factor as potatoes for each type of processing.
- All tree nuts and peanuts are shelled before being brought into Ann Arbor.
- The mass of flour and other grains in a processed food product is the same as the mass of the grains used as a raw material (i.e. the primary to retail conversion factor is 1).

Food Outflow

- Ann Arbor generates the same amount of MSW food scraps each year (before composting and food rescue) as the United States on a per capita basis.
- Ann Arbor composts twice as much per capita as the national average.[181] The University of Michigan composting program, which composted 31 tons of food waste during the 1997-98 school year is assumed to be a part of this estimate.[182]
- All food compost is created and used by local households and institutions to fertilize local soil and therefore is not included as an outflow from Ann Arbor. Note that the University of Michigan composting program sends food wastes to the yard waste composting facility within the City.

[181] Ayers, Ray. Ann Arbor Department of Solid Waste. Personal interview. 29 Mar. 2000.
[182] University of Michigan Recycling, op. cit.

Water

- Ann Arbor consumes water at the same rate as the entire service area of the Ann Arbor Water Treatment Plant on a per capita basis.
- Ann Arbor creates sewage at the same rate as the entire service area of the Ann Arbor Wastewater Treatment Plant.
- The volumes of water reported by the City of Ann Arbor as "billed consumption" and "treated sewage" reflect the inflow and outflow of water through the water and wastewater treatment plants. This assumption ignores the existence of dirt, rocks, biological material, and other matter in the water that count towards the reported volumes.

Estimation Details

Estimates of the mass and economic value of inflows and outflows will be presented in the following order:

- Food – Inflow Mass
- Beverages – Inflow Mass
- Food and Beverages – Inflow Value
- Food – Outflow Mass
- Water

Food - Inflow Mass

All data used for the inflow mass estimate for food and beverage is taken from the USDA report, *Food Consumption, Prices, and Expenditures, 1970-97.*[183]

Method

1. For each type of food, find the per capita retail weight of food consumed in 1997. Some food types may require additional steps to estimate the retail weight.
2. Multiply the per capita retail weight for each food type by the population of Ann Arbor to estimate the total food of that type consumed by the City in 1997. Also convert the mass estimate from pounds to tons.

[183] Putnam, op. cit.

3. Add the Ann Arbor estimates for each food type to get a total estimate for the mass of food inflows in 1997.

Calculations

1. Table B-1, the column titled "Per Capita" shows an estimate for the pounds of each type of food consumed in 1997 in the United States on a per capita basis. All per capita values shown in the table have been taken directly from various tables within the USDA report with the exception of those food types marked with an asterisk (*). The steps taken to estimate per capita retail weight for food types with an asterisk will be explained later.
2. Convert each weight to an Ann Arbor estimate.
   (retail weight in pounds) * (1997 population of 107,604) / 2000 lb/ton
   Example calculation for fresh fruit:

   126.9 pounds * 107,604 / 2000 = 6,827 tons
3. Total mass inflow equals sum of all food type estimates = **77,281 tons**

Table B-1 1997 Food Consumption

Food Category	Per Capita (pounds)	Ann Arbor (tons)	Notes
Meat, poultry, and fish			
Red meat	117.4	6,316	based on retail weight, not boneless; includes beef, veal, pork, and lamb
Poultry			
Chicken	72.7	3,911	based on retail weight, not boneless
Turkey	13.9	748	based on boneless weight (retail weight not given)
Fish and shellfish	14.5	780	
Eggs	30.8	1,657	includes eggs purchased in shells and eggs used in food processing
Dairy Products			
Fluid milk and cream	221.1	11,896	includes yogurt, egg-nog, sour cream, three kinds of cream, and seven categories of beverage milk
Other dairy products*	73.4	3,949	based on retail weight, not milk equivalent; includes fourteen kinds of cheese, four kinds of frozen dairy products, condensed and evaporated milk, nonfat dry milk, and dried whey
Fats and oils	68.2	3,669	based on product weight, not fat content; includes seven kinds of fats and oils such as butter, lard, cooking oils, etc.
Selected fruits			based on retail weight, not farm weight
Fresh	126.9	6,827	includes 23 varieties of fruit
For processing			fruit used to make juice and wine has been removed because it is redundant with beverages
Frozen	3.3	178	includes nine varieties of berries and other fruits
Dried	2.7	145	includes eight varieties of fruit
Canned	18.0	968	includes eight varieties of fruit
Selected vegetables			based on retail weight, not farm weight
Fresh*	172.8	9,297	includes 24 varieties of vegetables
For processing			
Canning*	66.2	3,562	includes twelve varieties of vegetables
Freezing*	40.8	2,195	includes nine varieties of vegetables
Dehydrated vegetables and chips*	6.5	350	includes onions and potatoes
Pulses	8.5	457	includes dry peas, lentils, and dry edible beans
Mushrooms*	1.2	65	includes all processing mushrooms
Treenuts and peanuts			
Tree nuts	2.2	118	based upon weight of kernals
Peanuts	5.8	312	based upon shelled peanuts
Coconut	0.5	27	based upon dessicated coconut
Flour and cereal products	200.1	10,766	based upon mass of grains at processing level, not mass in the final food product; includes four types of flour, rice, thre types of corn products, and oat and barley products
Caloric Sweeteners	154.1	8,291	estimated on a dry-weight basis; includes cane and beet sugars, three corn sweeteners, syrups, and honey; does not include non-caloric sweeteners (saccharin and aspartame)
Coffee, tea, and cocoa			
Coffee	7.0	377	based on retail weight, not green bean equivalent
Tea	0.8	43	based on dry leaf equivalent
Cocoa	4.1	221	based on chocolate liquor equivalent, not beans
Spices	2.9	156	includes many types of spices, the most significant of which are mustard seed, chile peppers, and black and white pepper
Total	**1,436.4**	**77,281**	

The following sections correspond to food types marked with an asterisk in the 1997 Food Consumption table. These food types use the same USDA report as the other food types but required additional steps to estimate because the total retail weight for the food type is not readily available in the report.

Other dairy products: The total weight for dairy foods given cannot be used because it uses a weight of each type of dairy food converted to the equivalent mass of milk based upon milkfat content. Instead, the product weight of each type of other dairy product must be summed to get a total estimate as has been done in Table B-2 below. Note that butter is left out because it is captured in the estimate for fat and oils.

Table B-2 Other Dairy Products 1997 Per Capita Consumption

Other Dairy Product	Mass (pounds)
Whole and part-skim milk cheese	28.0
Cottage cheese	2.7
Frozen dairy products	28.7
Evaporated and condensed milk	6.6
Dry milk products	4.0
Dried whey	3.4
Total	**73.4**

Fresh Vegetables: In it's tables for fresh vegetables, the USDA report does not show a total retail weight for fresh vegetables, though it does show the primary farm weights and the retail weights for all fresh vegetables except mushrooms, potatoes, and sweet potatoes. Other tables contain farm and retail weights for mushrooms and potatoes, leaving sweet potatoes as the only fresh vegetable without a listed retail weight.

To estimate the weight of sweet potatoes, first estimate their farm weight by subtracting the farm weights for each vegetable type from the total to get 4.6 pounds, as shown in Table B-3. Next assume that sweet potatoes have the same primary to retail weight conversion factor as potatoes (0.96) and multiply this factor by the farm weight to get a retail weight for sweet potatoes of 4.4 pounds. Finally, add all retail weights together including the sweet potato estimate to get a total of 172.8 pounds.

Table B-3 1997 Per Capita Fresh Vegetable Consumption - Sweet Potatoes Calculation

Fresh Vegetable Type	Farm Weight (pounds)	Retail Weight (pounds)
Artichokes	0.5	0.5
Asparagus	0.7	0.6
Bell peppers	7.2	6.7
Broccoli	5.2	4.8
Brussels sprouts	0.3	0.3
Cabbage	10.2	9.5
Carrots	12.5	12.1
Cauliflower	1.6	1.5
Celery	6.0	5.6
Sweet corn	8.1	7.4
Cucumbers	6.3	5.8
Eggplant	0.4	0.4
Escarole/endive	0.2	0.2
Garlic	2.1	1.7
Head lettuce	24.3	22.6
Romain and leaf lettuce	6.1	5.6
Onions	17.9	16.8
Radishes	0.4	0.4
Snap beans	1.4	1.3
Spinach	0.6	0.5
Tomatoes	18.9	16.1
Mushrooms	2.2	2.0
Potatoes	47.9	46.0
Sweet Potatoes	**4.6**	**4.4**
Total	185.6	**172.8**

Canning, freezing, and dehydrated vegetables and chips: The following information is available in the USDA reports (Table B-4):

Table B-4 USDA Tables for Processed Vegetables

Table in USDA Report	Table Contents
Tables 29, 30, and 33	Primary farm weights for each type of processed vegetable, but not their retail weights. Weights for mushrooms and potatoes are shown as "NA."
Table 32	Farm and retail weights for potatoes for each type of processing.
Table 3	Primary to retail conversion factor for potatoes for each type of processing.

To estimate total retail weight:

1. Add the farm weights for each processing type (frozen, canned, and dehydrated) for all vegetables except mushrooms and potatoes. Table B-5 contains these totals.
2. Multiply the potato conversion factor for the appropriate processing type to the total farm weight to get a retail weight estimate. This step assumes that other vegetable types will have the same conversion factor for each type processing as a potato.
3. Finally add the resulting retail weight to the retail weight for potatoes to get a total retail weight.

Table B-5 1997 Per Capita Processed Vegetable Consumption Calculations

Processing Type	Potato Conversion factor	Other Vegetables Farm (pounds)	Other Vegetables Retail (pounds)	Potatoes Retail (pounds)	Total Retail (pounds)
Frozen	0.5	22.5	11.3	29.5	40.8
Canned	0.636	102.5	65.2	1.0	66.2
Dehydrated	0.14	0.9	0.1	2.5	2.6
Chips and shoestrings	0.245			3.9	3.9

Note that dehydrated vegetables (onions and potatoes) and chips and shoestrings (which only have potatoes) have been combined into a single grouping in Table B-1 with a retail weight of 6.5 pounds.

Mushrooms: The USDA provides a retail weight for processed mushrooms, but does not state how these mushrooms have been processed. Mushrooms have therefore been reported separately so as to avoid categorizing them into a particular type of processing (though it is likely that they were canned). Mushroom weights were listed as “NA” in the canning tables, so they are not being double counted with the canned vegetable mass.

Beverages – Inflow Mass

Beverages are also estimated using the USDA report.

Method

1. Convert the per capita gallons consumed for each beverage type to pounds by assuming a density equal to water.

2. Multiply the per capita mass of each beverage by the population of Ann Arbor to estimate total Ann Arbor consumption.
3. Add each Ann Arbor consumption estimate to find total mass.

Calculations

1. Table B-6 below shows the average per capita gallons consumed for each beverage type.
2. Multiply each volume estimate by 8.35 pounds/gallon. This assumes that each beverage type has the same density as water, 1 g/mL.
   Example for carbonated soft drinks:
   53.0 gallons * 8.35 = 442.6 pounds
4. Convert each weight to an Ann Arbor estimate.
   (retail weight in pounds) * (1997 population of 107,604) / 2000 lb/ton
   Example calculation for carbonated soft drinks:
   442.6 pounds * 107,604 / 2000 = 23,810 tons
5. Total mass inflow equals sum of all food type estimates = **49,372 tons**

Table B-6 1997 Beverage Consumption

Beverage	Per Capita (gallons)	Per Capita (pounds)	Ann Arbor (tons)
Bottled Water	13.1	109.4	5,885
Carbonated soft drinks	53.0	442.6	23,810
Selected fruit juices	9.2	76.8	4,133
Fruit drink, cocktails, and ades	8.3	69.3	3,729
Canned iced tea	0.8	6.7	359
Vegetable juices	0.3	2.5	135
Beer	22.0	183.7	9,883
Wine	2.0	16.7	898
Distilled spirits	1.2	10.0	539
Total	**109.9**	**917.7**	**49,372**
Milk	24.0	200.4	10,782
Tea	7.4	61.8	3,324
Coffee	23.5	196.2	10,557
Total w/milk, tea, coffee	164.8	1376.1	74,036

Note that milk is not included in the total because it has already been included in the food estimate as a dairy food. Tea and coffee have not been included because it is assumed that all tea and coffee is made within Ann Arbor using dry tea leaves or dry coffee grounds combined with tap water. The dry content of tea and coffee has been included as food, but the liquid content is not included as a beverage because beverages only include packaged liquids.

Food and Beverages - Inflow Value

The USDA website provides separate estimates for food and alcohol expenditures. Additional detail on the source of funds, expenditures for food at home vs. away from home, and other categories. Some of this detail is presented in the results section for Food and Water and is based upon the same per capita calculations demonstrated below.[184]

Method

1. Add total expenditures for food and alcohol.
2. Subtract retail value assigned for foods "produced at home" through gardening or hunting.
3. Divide by the population of the United States to get a per capita estimate.
4. Multiply by the population of Ann Arbor.

Calculations

1. a. Total 1997 food expenditures (in million $) $730,569
   b. Total 1997 alcohol expenditures (in million $) $88,105
   c. Total 1997 reported "food produced at home" expenditure (in million $) $6,331
   c. Total 1997 US expenditures (in million $)
   $730,569 + $88,105 - $6,331 = $812,343
2. a. 1997 United States population 267.744 million
   b. 1997 Ann Arbor population 107,604
   c. 1997 Ann Arbor expenditures
   $818,674 million / 267.744 million * 107,604 = **$326,473,632**

[184] Food Expenditure Indicators, op. cit.

Food – Outflow Mass

Three different materials types (food scraps in MSW, biosolids, and scum) are included as outflows for food.

Food Scraps in MSW

Method

1. Divide a national estimate of generated food wastes by the population of the United States to get a per capita estimate.
2. Multiply by the population of Ann Arbor to get an Ann Arbor estimate for generated food wastes.
3. Similarly adjust national food composting estimate to get an Ann Arbor estimate using the ratio of U.S. population to Ann Arbor population.
4. Adjust this composting estimate to reflect Ann Arbor's significant home composting programs.
5. Total food scraps in MSW is calculated as the food wastes generated minus food diverted to composting and minus food wastes avoided due to the Food Gatherers food rescue program.

Calculation

1. a. U.S. generation of food wastes.[185]	21,910,000 tons
b. 1997 United States population	267.744 million
c. 1997 Ann Arbor population	107,604
d. Ann Arbor food wastes generated	
21,910,000 / 267.744 million * 107,604 =	8,805 tons
2. a. U.S. composting[186]	285,000 tons
b. Ann Arbor composting[187]	
285,000 / 267.744 million * 107,604 * 2 =	229 tons
3. Food rescued by Food Gatherers in 1997[188] =	640 tons

[185] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update, op. cit.
[186] Ibid.
[187] Ayers, op. cit.
[188] Food Gatherers, op. cit.

4. Total food scraps in MSW

   (food wastes generated) – (diversion to composting) – (food rescued)

   8,805 – 229 – 640 = **7936 tons**

Biosolids and Scum

Method

1. Take reported biosolids and scum processed by the Ann Arbor Wastewater Treatment Plant for 1997.
2. Obtain a per capita average by dividing by the population of the service area, which includes the City of Ann Arbor, Ann Arbor Township, Scio Township, and Pittsfield Township.
3. Multiply this per capita average by the population of Ann Arbor.

Calculations

1. Fiscal year 1997/1998 biosolids[189]	6,524 tons
2. a. 1997 City of Ann Arbor population	107,604
b. 1997 Ann Arbor Township population	3,903
c. 1997 Scio Township population	11,510
d. 1997 Pittsfield Township population	24,995

3. 1997 biosolids for Ann Arbor

   1997 biosolids / (total service area population) * (Ann Arbor population)

   6,524 / (107,604 + 3,903 + 11,510 + 24,995) * 107,604 = **4,743 tons**

Water

The water supply system has a service area of the City of Ann Arbor, Ann Arbor Township, Scio Township, and a small portion of Pittsfield Township. The sewer system has the same service area except that it reaches all of Pittsfield Township.

Method – Inflow Mass

[189] Stauder, Barch & Associates, Inc. Prospectus for City of Ann Arbor Sewage Disposal System and Water Supply System Revenue and Revenue Refunding Bonds. City of Ann Arbor. 17 Dec. 1998.

1. Convert water volume used by Pittsfield Township and subtract from total water consumption.
2. Divide total volume of water used by population of remaining service area (City of Ann Arbor, Ann Arbor Township, and Scio Township)
3. Multiply by the population of Ann Arbor to get an estimate for the city.
4. Convert to tons of water.

Calculations

1. a. 1997 water used by Pittsfield Township[190] 12,432,800 cubic feet

   b. Convert to units of million gallons

   12,432,800 cf * 7.48052 gallons/cf / 1,000,000 = 93 million gallons
2. a. Fiscal year 1997/1998 water used.[191] 6,142 million gallons

   b. Consumption without Pittsfield

   6,142 – 93 = 6049 million gallons
3. a. 1997 City of Ann Arbor population 107,604

   b. 1997 Ann Arbor Township population 3,903

   c. 1997 Scio Township population 11,510
4. Water for Ann Arbor:

   (total water use) / (total service area population) * (Ann Arbor population)

   6,049 million / (107,604 + 3,903 + 11,510) * 107,604 =5,291 million gallons
5. Convert to tons using 8.35 pounds per gallon as the density of water

   5,291 million gallons * 8.35 / 2000 = **22,090,388 tons**

Method – Inflow Value

1. Subtract water charges for Pittsfield Township from the total amount charged for water treatment and distribution.
2. Divide the remaining amount by the population in the rest of the service area (City of Ann Arbor, Ann Arbor Township, and Scio Township).
3. Multiply by the population of Ann Arbor to get an estimate for the City.

[190] Ibid.

[191] Ibid.

Calculations

1. a. Fiscal year 1997/1998 water charges[192] $11,163,851

   b. 1997 Pittsfield Township water charges[193] $109,771

   c. Total charges without Pittsfield

   $11,163,851 - $109,771 = $11,054,080

2. Water for Ann Arbor:

   (total water use) / (total service area population) * (Ann Arbor population)

   $11,054,080 / (107,604 + 3,903 + 11,510) * 107,604 = **$9,669,096**

Note: Fees include charge of $1.60 per 100 cubit feet of water and connection and permit charges. Does not include storm water and sewage fees.

Method – Outflow Mass

1. Divide total volume of sewage water treated by population of service area (City of Ann Arbor, Ann Arbor Township, Scio Township, and Pittsfield Township).
2. Multiply by the population of Ann Arbor to get an estimate for the city.
3. Convert to tons of water.

Calculations

4. Fiscal year 1997/1998 sewage water treated.[194] 6,908 million gallons
5. a. 1997 City of Ann Arbor population 107,604

   b. 1997 Ann Arbor Township population 3,903

   c. 1997 Scio Township population 11,510

   c. 1997 Pittsfield Township population 24,995
6. Sewage water treated for Ann Arbor:

   (total water treated) / (total service area population) * (Ann Arbor population)

   6,908 million gallons / (107,604 + 3,903 + 11,510 + 24,995) * 107,604 =

   5,022 million gallons

[192] Ann Arbor Water Utilities, op. cit.
[193] Stauder, op. cit.
[194] Ann Arbor Water Utilities, op. cit.

- Convert to tons using 8.35 pounds per gallon as the density of water
  5,022 million gallons * 8.35 / 2000 = **20,966,850 tons**

Comments – Data Issues

The most important data issue that may lead to an inaccurate estimate is the frequent use of per capita data throughout the estimation process. This technique ignores any unique characteristics of Ann Arbor that may lead to larger or smaller material flows. However, whether any particular estimate is too high or too low is difficult to determine because arguments can be made for either direction.

For example, students are included in the population estimate for Ann Arbor alongside year-round residents, but many students leave each summer. This seasonal change in population reduces local inflows and outflows for food, a reduction that is not reflected in estimates for the mass and value of food inflows and food scraps in MSW computed using per capita data.

The high levels of disposable income among Ann Arbor residents may lead them to spend more per capita for food than the national average. A recent *Food Review* article studied regional variations in food expenditures and had the following conclusions:[195]

- "… as incomes increase, consumers increase their expenditures on more expensive fresh foods, more processed food, and more meals eaten out."
- "In developed nations like the United States, the total quantity of food consumed is unlikely to increase appreciably with income."
- "Many of the products for which spending is above average…in the high-income markets can be considered high value or discretionary, with the low-income markets showing above-average spending on more basic, staple goods and goods that require additional home preparation. Expenditures on many refrigerated and frozen products are above average in the high-income markets but below average in the low-income markets."

[195] Jekanowski, op. cit.

- "Much of the increase in food spending as income increases likely is not a change in what is eaten but is an improvement—in terms of taste, nutrition, quality, or convenience—in the form in which it is purchased. This sort of increased food spending involves little, if any, increase in use of farm commodities but rather an increase in intermediate inputs and labor."

The take away message of these comments is that the mass estimate for the inflow may be accurate in the aggregate (if not for individual types of food), but the estimate for the economic value of food inflows may be an underestimate due to Ann Arbor's high average incomes.

However, the authors of the article make another point counter to this conclusion. They note that the Midwest region of the United States (of which Ann Arbor is a part) is the most frugal when it comes to food expenditures, and that this regional phenomena cannot be fully explained by regional average income levels.

The per capita estimates for water inflows and outflows, biosolids, and scum are likely to be more accurate because they are based on the per capita average of a much smaller population in which Ann Arbor residents make up a majority. The presence of a particular company or set of companies that use a particularly large amount of water or that introduces biological solids into the sewage system could make the estimates too low (if the businesses are inside Ann Arbor) or too high (if they are outside Ann Arbor but still within the service area).

Food Loss Estimate

A 1997 article estimated the percent of edible food lost by retailers, consumers, and foodservice.[196] Table B-7 applies data from the article to the inflow mass estimates for various food types. The shaded regions in the table show data taken from the article.

[196] Kantor, op. cit.

The percentages for each food type appear in the table among the last columns as the "retail food loss %" and the "foodservice and consumer food loss %." Retail food loss percentages range from 1% to 2%, while foodservice and consumer food loss percentages range from 15% to 32%. These percentages cannot be directly applied to the inflow mass estimates, because they were designed to apply to edible food quantities, whereas the inflow mass estimates in this report include inedible portions of food such as bones, pits, seeds, and peels. The article does not provide a careful accounting of its estimates for the "edible food supply," so there is no direct way to estimate the edible food content in the 1997 Ann Arbor inflow.

Therefore, an indirect method is used. The first column in the table contains an estimate for United States food consumption for 1995 based on retail weight. This estimate was developed using all the assumptions and steps from the 1997 estimate detailed earlier in this appendix, but with 1995 USDA data. The 1995 estimate for each food type is compared to the "1995 US Edible food supply" data given in the article. The "percent edible" is calculated by dividing the edible food supply by the total retail weight for each food type. For example, based on this method of bridging data between this report and the article, 95% of the retail weight of red meat estimated in this report is edible.

Table B-7 Retail, Foodservice, and Consumer Food Losses

Food Type	1995 US estimate (million pounds)	1995 US Edible food supply (million pounds)	Percent edible (%)	1997 Inflow estimate for AA (tons)	1997 Edible inflow for AA (tons)	1997 Inedible inflow for AA (tons)	Retail food loss (%)	Retail food loss (tons)	Foodservice and consumer food loss (%)	Foodservice and consumer food loss (tons)	Total loss (tons)
Meat, poultry, and fish											
Red meat	31,986	30,350	95%	6,316	5,993	323	1%	60	15%	899	959
Poultry	22,069	17,108	78%	4,659	3,612	1,047	1%	36	15%	542	578
Fish and shellfish	3,919	4,008	102%	780	780	-	1%	8	15%	117	125
Eggs	7,970	7,918	99%	1,657	1,646	11	2%	33	29%	477	510
Dairy Products											
Fluid milk and cream	58,675	54,474	93%	11,896	11,044	852	2%	221	30%	3,313	3,534
Other dairy products	19,392	21,802	112%	3,949	3,949	-	2%	79	30%	1,185	1,264
Fats and oils	18,308	20,250	111%	3,669	3,669	-	1%	37	32%	1,174	1,211
Fruits											
Fresh	31,275	22,389	72%	6,827	4,888	1,940	2%	98	30%	1,466	1,564
For processing	5,683	25,949	457%	1,291	1,291	-	1%	13	15%	194	207
Vegetables											
Fresh	42,881	36,830	86%	9,297	7,985	1,312	2%	160	30%	2,396	2,555
For processing	30,171	26,247	87%	6,107	5,312	794	1%	53	15%	797	850
Pulses (beans, peas, lentils)	2,236	2,263	101%	457	457	-	1%	5	15%	69	73
Treenuts and peanuts	2,132	1,861	87%	457	399	58	1%	4	15%	60	64
Flour and cereal products	50,635	45,606	90%	10,766	9,697	1,069	2%	194	30%	2,909	3,103
Caloric Sweeteners	39,430	38,827	98%	8,291	8,164	127	1%	82	30%	2,449	2,531
Total				**76,420**	**68,888**	**7,533**		**1,081**		**18,046**	**19,127**

Most of the percentages calculated are within a reasonable range of 78% to 99%. However, several are over 100%, which should not be possible. The article is either using a different set of USDA food consumption data or is using very different assumptions. The percentage for processed vegetables, 457%, is the most discordant. It is possible that the report based its edible supply estimate on the primary farm weight rather than the processed retail weight of the vegetables. In cases where the percentage was calculated to be over 100%, an edible percentage of 100% was assumed.

The next column in Table B-7 shows the 1997 inflow estimates for Ann Arbor estimated in this report. The edible percentages are applied to estimate the edible portion for each food type, with the remainder categorized as inedible. Finally the retail food loss percentage and the foodservice and consumer food loss percentage are applied to the edible inflow for Ann Arbor.

Table B-8 below shows the conclusions of this analysis.

Table B-8 Mass of Food Inflow, Losses, Recovery, and Consumption in Ann Arbor

Food Flow Type	Mass (tons)	Comments
1997 Inflow estimate	76,420	Does not include beverages, coffee, tea, cocoa, and spices.
Loss because inedible	7,533	Includes parts such as bones, pits, seeds, and peels.
Retail losses	1,081	Losses from perishables discarded at “sell-by” date, damaged packaging, discontinued food products, discard of seasonal items, etc.
Foodservice and consumer losses	18,046	Losses from uneaten perishables, food left on the plate, and scraps from food preparation.
Food Gatherers	640	Food rescued by Food Gatherers that otherwise would have been lost.
Food ingested by Ann Arbor residents in 1997	50,400	Total inflow – food losses + food rescued

Notes:

- All food losses go to one of three fates: food scraps in MSW, compost, or the sewer system (under the assumption that it is not eaten by animals).
- This analysis does not include beverages, coffee, tea, cocoa, and spices.

To be more accurate, additional losses should be added because some of the food rescued by Food Gatherers will be lost when it is finally prepared for a meal, in effect being lost, found, and then lost again.

Food Packaging

A U.S. Environmental Protection Agency study provides data on containers and packaging in MSW.[197] **Table B-9** shows the estimated tons of various types of containers and packaging generated in MSW in the United States in 1997. "Generated" means that the data includes materials that are recycled or discarded. **Table B-9** also shows the estimated tons of containers and packaging generated by Ann Arbor in 1997 on a per capita basis.

[197] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update, op. cit.

Some types of containers and packaging, such as “Beer and Soft Drink Bottles,” are clearly linked to food and beverages. Other types such as “Corrugated Boxes” are used for food and beverages but also used as packaging for other types of materials and other functional uses. **Table B-9** shows which types of containers and packaging are assumed to be primarily used for food and beverages (“in”) or are commonly used for other purposes (“out”).

Table B-9 Containers and Packaging in MSW

Containers and Packaging	1997 U.S. Generated Mass (thousands of tons)	1997 Ann Arbor Generated Mass (tons)	In/Out	Comments
Glass Packaging				
Beer and Soft Drink Bottles	4960	1993	In	
Wine and Liquor Bottles	1820	731	In	
Food and Other Bottles & Jars	3830	1539	In	Non food uses includes cosmetics
Total Glass Packaging	**10610**	**4264**		
Steel Packaging				
Beer and Soft Drink Cans	neg	neg	Out	Less than 5000 tons in 1997
Food and Other Cans	2860	1149	In	
Other Steel Packaging	240	96	Out	Includes steel barrels and drums
Total Steel Packaging	**3100**	**1246**		
Aluminum Packaging				
Beer and Soft Drink Cans	1530	615	In	
Other Cans	50	20	Out	
Foil and Closures	360	145	Out	
Total Aluminum Packaging	**1940**	**780**		
Paper & Paperboard Packaging				
Corrugated Boxes	30160	12121	Out	
Milk Cartons	460	185	In	
Folding Cartons	5420	2178	In	Includes cereal boxes, frozen food boxes, some department store boxes
Other Paperboard Packaging	220	88	Out	
Bags and Sacks	1870	752	Out	
Wrapping Papers	50	20	Out	
Other Paper Packaging	1270	510	Out	
Total Paper & Paperboard Packaging	**39450**	**15855**		
Plastics Packaging				
Soft Drink Bottles	760	305	In	
Milk Bottles	670	269	In	
Other Containers	1540	619	Out	
Bags and Sacks	1520	611	Out	
Wraps	2130	856	Out	
Other Plastics Packaging	2810	1129	Out	
Total Plastics Packaging	**9430**	**3790**		
Wood Packaging	**7030**	**2825**	Out	
Other Miscellaneous Packaging	**190**	**76**	Out	
Total Containers and Packaging	**71750**	**28836**		

Appendix C: Shelter

This appendix provides supplementary information for the study completed on material flows associated with the shelter needs of Ann Arbor, which is presented in Section 2 of Chapter 4.

Data Sources

Obtaining certain pieces of information were critical for the estimation of mass and economic value of material flows into and out of the community. Identified below are the primary data sources used in estimating those flows.

Building-related activity

Construction activities occurring within the City of Ann Arbor were characterized based on building permits issued by the City of Ann Arbor Building Department in 1997. Building-related construction (e.g. carpet replacement, painting, minor repairs) that did not require a permit was not included in this analysis.

Access to the Building Department's electronic database of Building Permits was not granted, so hardcopies of each building permit from 1997 were obtained from the Tax Assessor's Office (Figure C-1). Vital information from each permit was entered into a spreadsheet including Permit Number, Type of Improvement, Subcode, Estimated Cost, Dimensions, and Remarks. Many inconsistencies in the categorization of building activities were discovered, for example, deck construction was placed into both the Residential Alteration and Miscellaneous categories. Roofing of both residential and nonresidential buildings was placed in the Miscellaneous category. When building permits were issued for multiple construction activities, e.g. roofing and siding, the Estimated Cost was allocated to the first activity listed because costs of individual activities were not able to be separated from the total estimated cost and correctly allocated to each activity. Therefore estimated costs may be over or underestimated depending on whether it was listed first or later on a permit.

While the building permits provided some of the vital information, they did not contain all of the information recorded on the Application for Plan Examination and Building Permit (Figure C-2). The application contained information that would have enhanced the quality of the analysis, including more detailed dimensions (number of stories, total square feet of floor area, total land area), type of frame materials (masonry, wood frame, structural steel, reinforced concrete, other) and a more detailed description of the activity. Obtaining the application for each permit was not possible. When copies of the files at the Building Department were searched, very few of the applications could be found in either microfiche or hardcopy. It was suggested that the applications might be in the process of being converted to microfiche, or located in off-site storage.

Characteristics of New Housing - Current Construction Reports[198] provided data on single-family and multifamily housing such as: average and median square feet of floor area, average square feet per unit/building by region for Multifamily Buildings, price per square foot of floor area by location, type of foundation by category of house and location, and principal type of exterior wall material by category of house and location. Data is based on sample surveys so is subject to sampling variability, and errors of response and nonreporting.

Blanchard and Reppe conducted a detailed analysis of the building materials required for construction a 2450 sq. ft residential home[199]. Nearly all building materials were inventoried and weighed. The total mass of materials required for construction, as well as the mass of specific building materials, i.e. windows, cabinets, was calculated and used in this analysis.

Construction and Demolition Debris

Waste assessments conducted at individual building project sites were the source of the EPA's data on the generation of construction and demolition (C&D) debris. In Ann

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[198] United States Bureau of the Census. Current Construction Reports - Characteristics of New Housing: 1997, C25/97-A. U.S. Department of Commerce, 1998. <http:www.census.gov/prod/3/98pubs/c25-97a.pdf> 2 May 2000.

[199] Blanchard, Steven and Peter Reppe. "Life Cycle Analysis of a Residential Home in Michigan." Masters Thesis. University of Michigan. September 1998.

Arbor, very little C&D debris is collected by the City Solid Waste Department so generation of C&D debris is not tracked by the City. Considerable uncertainty exists in the data because studies have been based on very small sample sizes, and a standardized methodology and reporting format for waste assessment data has not been established. In 1998, the EPA took a new approach to characterizing the quantity and composition of building-related C&D debris.[200] This study was a first attempt to characterize C&D debris by using national Census Bureau data on construction industry activities with point source waste assessment data. Data were provided on new construction, renovation, and demolition of both residential and nonresidential structures. Data obtained from waste assessments were based on very small sample sizes and resulted in highly variable waste generation rates. However, variation is inherent in the construction industry because construction practices vary depending on the builder, type of project, and materials used. This report is a first step towards a better characterization of C&D debris.

The National Association of Home Builders (NAHB) Research Center compiled data on waste generation rates for a number of different building-related activities: additions, kitchen, bathroom, roof, deck, and whole house[201].

Each specific renovation activity includes different materials as listed in Table C-1.

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[200] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit.

[201] National Association of Home Builders Research Center, Inc. Waste Management and Recovery: A Field Guide for Residential Remodelers. <http://www.nahbrc.org/builders/green/1hlfguid.pdf> 5 May 2000.

Table C-1 Materials Included in Renovation Projects

Activity	Materials Included:
Basement	Concrete Basement alteration includes finishing of existing basement, replacing walls, installing drain tile, and basement waterproofing.
Bathroom	Not broken down by material type
Cabinets	Cabinets
Decks	Wood outflow data not broken down by material type
Demolition	Concrete, misc. structural materials
Foundation	Concrete
Garage / Carport	Concrete, misc. structural materials
Interior alteration	Not broken down by material type
Kitchen	Not broken down by material type Kitchen appliances are not included.
Porch / Patio	Not broken down by material type
Reroofing	Asphalt shingles Supporting materials are not included: sheathing, underlayment (coated felt, laminated waterproof paper), flashing, drip edge, and nails.
Residential addition	Not broken down by material type Additions were a mix of one-story additions built on a concrete slab foundation, two-story additions with basement, additions combined with other alterations, and numerous permits issued with no indication of the size of the addition or presence/absence or foundation/basement/slab.
Siding	Vinyl siding Supporting materials, i.e. nails, are not included in the analysis.
Windows	Windows, doorwalls, skylights, bay windows
Entryway / Door	Not included in analysis
Fence	Not included in analysis
Insulation	Not included in analysis
Shed / Barn	Not included in analysis
Sign / Awning	Not included in analysis

Assumptions

General

1. Waste generation rates for building-related activities in Ann Arbor are equivalent to national waste assessment data.

Alteration

2. Cost is proportional to square footage
3. Scrap rate equals 5% of materials brought onsite[202]
4. When activity entailed replacement of stock, assumed outflow equals inflow.

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[202] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit.

5. Inflow values can be calculated based on a scrap rate of 5% of total materials brought onsite.
6. For new construction and residential addition, inflow equals stock plus scrap with stock estimated using deconstruction (demolition) mass. Deconstruction mass is used as a substitute for mass of materials brought onsite for construction, because it is assumed that the amount of mass contained in a building following construction, and is approximately equivalent to the material remaining when the building is demolished.
7. Materials required for building a single-family dwelling are proportional to size (square feet).
8. Mass of structure is proportional to structural materials generated in a single-family dwelling demolition.

Demolition

9. Demolition - Assume inflow equals zero because activity entails removal of stock, and no addition.

Detailed Estimation Process

Building Permits from the City of Ann Arbor were obtained for the 1997 calendar year. The following information from each permit was entered into a spreadsheet: permit number, code (type of improvement), sub-code, estimated cost, dimensions of project (width, length, height), and remarks. When a permit listed more than one activity, the permit number was split into multiple parts (i.e. 52000, 52000.5). Since it was not possible to determine the cost allocated to each activity, the entire cost remained with the original permit number. Therefore some of the costs may be over- or under-estimated depending on whether the activity was listed first or later on the permit. Estimated Cost includes the value of materials and labor, even if labor costs were not actually paid, i.e. a "do-it-yourself" job.

Activities were ranked by number of building permits issued and by estimated cost. For each activity, the two ranks were averaged to provide a basis for narrowing the scope of the analysis. Activities with an average rank of 21 or lower were eliminated from the analysis – entry / door, insulation, shed / barn. Next, the nature of the activity and availability of data were considered. Sign / Awning ranked low by cost, 21st was eliminated because the size of the projects and the materials associated with signs and awnings seemed highly variable and difficult to characterize. Fence also ranked low by cost, 22nd, and seemed difficult to characterize because building permit information did not always contain length and height. The Miscellaneous projects were eliminated from the analysis because the types of activities contained within the category were highly variable including replacement of a fire escape, set-up of temporary tents, stair repair, and fire damage repair. Table C-2 lists the rankings, number of permits issued, and estimated cost.

Table C-2 Summary of Number of Building Permits Issued and Estimated Cost

Average Rank	Activity Type	Number of Permits	Percent of Total	Rank By # of Permits	Estimated Cost	Percent of Total	Rank By Cost
2	Nonresidential Renovation	229	7%	3	$ 27,601,090	24%	1
4	Reroofing	751	24%	1	$ 4,432,631	4%	6
5	New Single-Family Dwelling	150	5%	7	$ 18,978,302	16%	3
5	Windows	459	15%	2	$ 2,383,893	2%	8
5	Miscellaneous	183	6%	5	$ 4,437,270	4%	5
10	Decks	196	6%	4	$ 795,626	1%	15
10	Interior Alteration	86	3%	10	$ 2,378,474	2%	9
11	Cabinets	89	3%	9	$ 1,019,340	1%	13
12	Basement	78	2%	12	$ 1,024,777	1%	12
12	Residential Addition	57	2%	17	$ 3,565,985	3%	7
13	New Nonresidential Building	20	1%	23	$ 26,954,018	23%	2
14	Kitchen	59	2%	16	$ 1,218,645	1%	11
14	New Apartment Building / Townhouse	20	1%	24	$ 13,678,236	12%	4
14	Siding	119	4%	8	$ 450,169	0%	20
14	Fence	165	5%	6	$ 295,838	0%	22
15	Porch / Patio	85	3%	11	$ 569,244	0%	19
15	Demolition	64	2%	14	$ 767,300	1%	16
16	Foundation	32	1%	21	$ 1,481,010	1%	10
17	Bathroom	64	2%	15	$ 744,720	1%	18
17	Sign / Awning	70	2%	13	$ 381,442	0%	21
18	Garage / Carport	50	2%	18	$ 748,583	1%	17
20	New Two-Family Dwelling	10	0%	25	$ 993,259	1%	14
21	Entry / Door	47	1%	19	$ 137,745	0%	23
23	Insulation	37	1%	20	$ 27,199	0%	25
23	Shed / Barn	21	1%	22	$ 111,011	0%	24
26	Void	10	0%	26	-	0%	26
	TOTAL	**3151**	**100%**		**$ 115,175,807**	**100%**	

(Shaded) Not included in analysis

NEW CONSTRUCTION:

In order to estimate the flows from new construction, the following building activities were analyzed:

- Multifamily Dwellings (including apartment buildings, townhouses, and two-family dwellings)
- Single Family Dwelling
- Nonresidential (Commercial / Institution)

Multifamily Dwellings

Method:

1. Start with total number of multifamily dwellings, from Ann Arbor Building permits
2. Estimate total sq. ft of construction
3. Calculate waste generation and inflow mass

Calculation - Outflow:

1. Total permits apartments and townhouses reported in 1997, 20

Total units reported in 1997	363
Estimated cost	$ 13,678,236
Total permits two-family dwelling reported in 1997	10
Total units reported in 1997	20
Estimated cost	$ 993,259

2. Estimated waste generation (tons)

   = [Total units x (average sq. ft per unit) x (average waste lbs / sq. ft)] / (lb / ton)

   = (363 + 20 units) x (1095 sq. ft / unit[203]) x (4.0 lbs / sq. ft[204])] / (2000 lb/ton) = 839 tons

Calculation - Inflow:

1. Estimated by summing the mass of materials generated in a multi-family building deconstruction, and average multi-family residential construction debris.

   TOTAL = stock + waste = (129 lbs/sq. ft)[205] + (4.0 lbs/sq. ft)[206] = 133 lb/sq. ft
2. (133 lb/sq. ft) x (383 units) x (1095 sq. ft / unit) / (2000 lb/ton) = 27,889 tons

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[203] United States Bureau of the Census. Current Construction Reports - Characteristics of New Housing: 1997, C25/97-A, op cit.

[204] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit. Table 3, Multi-family average generation values.

[205] Ibid. Table A-12

[206] Ibid. Table 3.

Single Family Dwelling

Method:

1. Start with total number of single-family dwellings, from Ann Arbor Building permits
2. Estimate total sq. ft of construction
3. Calculate waste generation and inflow mass

Calculation - Outflow:

1. Total permits for single-family dwellings in 1997 150

   Estimated cost $ 18,978,302
2. Estimated waste generation (tons)

   = [Total units x (average sq. ft per unit) x (average waste lbs / sq. ft)] / (lb / ton)

   = (150 units) x (1900 sq. ft / unit[207]) x (4.38 lbs/sq. ft)[208]] / (2000 lb/ton)= 624 tons

Calculation - Inflow:

Method 1:

1. Sum of construction materials required for a 2450 sq. ft home in Ann Arbor = 322.5 tons[209]
2. Convert sum to 263.0 lbs/sq. ft
3. (263 lb/sq. ft) x (150 units) x (1900 sq. ft / unit) / (2000 lb/ton) = 37,478 tons

NOTE: Method 1 was chosen because it was based on an actual inventory of building materials required for construction of a single-family residential dwelling.

Method 2:

1. Estimated by summing the mass of materials generated in a single-family building deconstruction, and average single -family residential construction debris.

   TOTAL = stock + waste = (158.2 lbs/sq. ft)[210] + (4.38 lbs/sq. ft)[211] = 163 lb/sq. ft

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[207] Sloan, op. cit.

[208] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit. Table 3.

[209] Blanchard, op. cit.

[210] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit. Table A-3; but based on 30'x30' house with basement 8" thick

2. (162.58 lb/sq. ft) x (150 units) x (1900 sq. ft / unit) / (2000 lb/ton) = 23,168 tons

Method 3:

The ATHENA™ Sustainable Materials Institute conducted a case study of three different types of single-family residential construction, wood design, steel design, and concrete design. However their analysis was limited to the structure and envelope components that *differed* across the three designs. Common elements, e.g. the light frame wood truss system for the roofs, windows, and exterior cladding, were excluded. Functional equivalence was not fully achieved, so a direct comparison between building types will not be completely accurate. Table C-3 shows the weighted resource use for each design as reported by ATHENA [212]:

Table C-3 Resource Use for Single Family Home

	Wood Design	Steel Design	Concrete Design
Weighted Resource Use (tons/2400 sq. ft single-family home)	134.3	152.7	259.0

NOTE: This analysis did not include common elements, so it was not used in this analysis, but is provided as another potential source of data for future research.

Nonresidential (Commercial / Institutional)

Method:

1. Start with total number of new commercial/institutional buildings, from Ann Arbor Building permits
2. Estimate total sq. ft of construction
3. Calculate waste generation and inflow mass

Calculation - Outflow:

1. Total permits for commercial/institutional buildings in 1997 16 [213]

walls,4" thick floor, garage 10'x20' +driveway 10'x45', 4" thick values which are more reflective of the homes built in Ann Arbor.

[211] Ibid. Table 3

[212] Trusty, W.B. and J.K. Meil. "Building Life Cycle Assessment: Residential Case Study." ATHENA Sustainable Materials Institute, Canada. Table 1.

[213] Note: 20 permits were issued, however 4 of these buildings were issued separate permits for construction of the foundation and the building shell

Estimated cost $ 26,954,018

Total square feet[214] 528,596 sq. ft

2. Estimated waste generation (tons)

= [(Total square feet) x (average waste lbs / sq. ft)] / (lb / ton)

= [(528,596 sq. ft) x (3.89 lbs/sq. ft)[215].] / (2000 lb/ton) **1028 tons**

Calculation - Inflow:

Method 1:

1. Estimated by summing the mass of materials generated in a nonresidential deconstruction, and average nonresidential construction debris.

   TOTAL = stock + waste = (151.7 lbs/sq. ft)[216] + (3.89 lbs/sq. ft)[217] = 155.6 lb/sq. ft

2. (155.6 lb/sq. ft) x (528,596 sq. ft) / (2000 lb/ton) = **41,122 tons**

Method 2:

1. The ATHENA™ Sustainable Materials Institute assessed three alternative designs for a typical 50,000 sq. ft three-story office building with one level of underground parking. A summary of the resource use is shown in Table C-4:[218]

Table C-4 Resource Use for 50,000 sq. ft. Office Building

	Steel Design	Wood Design	Concrete Design
Resource Use (tons/50,000 sq. ft office building)	2477	2153	4586

Note: Mass for the Steel Design was chosen as the model for Ann Arbor commercial construction.[219]

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[214] Calculated based on 2 sources: a) City of Ann Arbor Planning Department. New Nonresidential Construction 1980-Present. Ann Arbor: City of Ann Arbor Planning Department, Nov. 1997. b)City of Ann Arbor Building Department. Building Permit. op. cit.
Total square footage (for the 14 buildings that reported sq. footage in above document) is estimated at 528,596 sq. ft. The average size of these 14 buildings was 37,757 sq. ft. The 5 buildings designated for Office use averaged 55,590 square feet.

[215] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit. Table 4

[216] Ibid. Based on waste from 19 Industrial/Commercial Demolition Projects, Table A-18

[217] Ibid. Table 4

[218] Meil, Jamie. ATHENA SMI. Personal interview. 14 Feb. 2000.

[219] JC Beal Construction, op. cit.

2. 2477 tons/50,000 sq. ft = 99.1 lbs/sq. ft
3. TOTAL = stock + waste = (99.1 lbs/sq. ft) + (3.89 lbs/sq. ft)[220] = 103.0 lb/sq. ft
4. (103.0 lbs/sq. ft) x (total new square footage 528,596 sq. ft) / (2000 lb/ton) = 27,223 tons

NOTE: The value for inflow mass determined by this method, 27,223 tons, was found to be much lower than the above method, 41,125 tons. It was acknowledged above that the ATHENA data only accounts for steel, concrete, and wood, whereas C&D reports also include, roofing, brick, scrap iron, asphalt, and landfill debris. The varying inventory of materials appears to account for the difference in inflow mass values.

ALTERATION:

In order to estimate the flows from alterations, the following building activities were analyzed:

- Basement
- Bathroom
- Cabinets
- Deck
- Foundation
- Garage / Carport
- Kitchen
- Nonresidential Renovation
- Porch / Patio
- Residential Addition
- Residential Interior Alteration
- Roofing
- Siding
- Windows

The following activities were not included in analysis:

- Entry/Door
- Fence
- Insulation
- Miscellaneous
- Shed/barn
- Sign / Awning

Basement

Method:

1. Start with total number of basement alterations, from Ann Arbor Building permits
2. Estimate total number of basement walls replaced, other types of alteration
3. Calculate waste generation and inflow mass

[220] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit., Table 4

Calculation - Outflow:

1. Total permits relating to basements in 1997 78

   Estimated cost $ 1,024,777

2. Estimated generation (tons)

   = (Total inflow mass) x (average scrap rate[221])

   = (357 tons) x (5%) **18 tons**

Calculation - Inflow:

1. Categorize permits by size and type of activity

   a. replace all basement walls 5

   b. replace 1 basement wall 6

   c. floor 2

   d. misc. remodeling 65

2. Estimate size and material requirements for each type.[222]

   a. replace all basement walls

      size= (30'Wx8'Hx0.67'thick[223] x4 walls x150lb/cu ft/2000)

      Mass = 48 tons x 5 projects = 240 tons

   b. replace 1 basement wall

      size= (30'Wx8'Hx0.67'thick x 1 wall x150 lb/cu ft /2000)

      Mass = 12 tons x 6 projects = 72 tons

   c. floor

      size=30'x30' x 4/12 x 150 lb/cu ft /2000

      Mass = 22.5 tons x 2 projects = 45 tons

   d. misc. basement remodeling

      =14.25 + 0.75 tons waste/project

      Mass = 15 tons / project[224] x 65 projects = 975 tons

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[221] Ibid.

[222] Ibid. Based on size of residential demolition in Table A-3, basement walls are 30 feet long, 8 feet high, 8 inches thick. Floor is 30 feet by 30 feet, and 4 inches thick.

[223] Note: this is a standard thickness

[224] Note: Inflow (15 tons/project) assumed to be equivalent to inflow for residential interior alteration.

3. Total = 1,332 tons

Bathroom

Method:

1. Start with total number of bathrooms remodeled, from Ann Arbor Building permits
2. Estimate number of major vs. minor remodelings
3. Calculate waste generation and inflow mass

Calculation - Outflow:

1. Total permits citing bathroom remodeling in 1997 64

   Estimated cost $ 744,720
2. Estimated generation (tons)

   Assume minor and major remodelings each equal 50% of all bathroom remodelings

   = [(Total number of bathrooms remodeled – minor) x (average waste per minor bathroom remodeling job)]

   = (32) x (0.25 tons / minor job) 8 tons

   = [(Total number of bathrooms remodeled – major) x (average waste per major bathroom remodeling job)]

   = (32) x (1.0 tons / major job) 32 tons

TOTAL = minor + major = 40 tons

Calculation - Inflow:

1. Assume inflow equals outflow because activity entails replacement of stock
2. Total = 40 tons

Cabinets

Method:

1. Start with total number of cabinet replacements cited on permits, from Ann Arbor Building permits

2. Calculate total pounds of cabinets replaced
3. Calculate waste generation and inflow mass

Calculation - Outflow:

1. Total permits citing cabinet replacement in 1997 89

   Estimated cost $ 1,019,340
2. Estimated generation (tons)

   = [Total number of cabinet replacements x (average waste per minor kitchen remodeling job[225])]

   = (89) x (0.75 tons / job) 67 tons

Calculation - Inflow:

Method 1:

1. Estimated inflow (tons)

   = [Total number of cabinet replacements x (average lb / replacement)] / (lb / ton)

   = (89) x (1,454 lb / kitchen cabinet replacement[226]) / (2000 lb/ton) 65 tons

NOTE: Method 1 was chosen because it is based on an actual inventory of materials required.

Method 2:

1. Assume inflow equals outflow because activity entails replacement of stock
2. Total = 67 tons

Decks

Method:

1. Start with total cost of decks, from Ann Arbor Building permits
2. Estimate total sq. ft of decks built

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225 Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit., Note: Minor kitchen remodeling is defined as cabinet replacement.

226 Blanchard, op. cit., p. 88.

3. Calculate waste generation and inflow mass

Calculation - Outflow:

1. Total permits issued for decks in 1997 196

   Estimated cost $ 795,626

2. Estimated waste generation (tons)

   a. Calculate average sq. ft for permits citing dimensions (121 out of 196) 281 sq. ft

   b. Divide cost by sq. ft and average the values average = $ 13.30 / sq. ft

   c. Use actual dimension when available, otherwise, divide deck cost by average $ / sq. ft to get estimated sq. ft/deck. Average actual and estimated values.

      average = 324 sq. ft

   d. Sum estimated and actual sq. ft to get total sq. ft built 61,636 sq. ft

   Waste = [Total sq. ft x (average waste lbs / sq. ft)] / (lb / ton)

   = (61,636 sq. ft) x (5.5 lb / sq. ft[227]) / (2000 lb/ton) **169 tons**

Calculation - Inflow:

1. Scrap rates are estimated to be approximately 5% of total materials brought onsite.

2. Total materials brought onsite = stock + waste

   (Total)x 0.05 = waste

   (Stock + waste) x 0.05 = waste

   stock + waste = (waste) / 0.05

   stock = (waste) / 0.05 – (waste)

   stock = .95 x (waste) / 0.05

   stock = 19 x (waste)

   stock = 19 x (5.5 lb/sq. ft)

   = 104.5 lb/sq. ft

   TOTAL = stock + waste = 104.5 lb /sq. ft + 5.5 lb/sq. ft = 110 lb/sq. ft

3. (110 lb/sq. ft) x (61,636 sq. ft) / (2000 lb/ton) = **3,390 tons**

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[227] National Association of Home Builders Research Center, Inc. Waste Management and Recovery: A Field Guide for Residential Remodelers, op. cit., Note: Average of 3-8 lb/sq. ft range given.

Foundation

Method:

1. Start with total number and types of foundations constructed, from Ann Arbor Building permits
2. Determine total square feet of foundation added
3. Calculate waste generation and inflow mass

Calculation - Outflow:

1. Total permits foundations, in 1997 — 32

   Estimated cost — $ 1,481,010
2. Estimated waste generation (tons)

   = (Total inflow mass) x (average scrap rate)

   = (4,332 tons) x (5%) — 216 tons

Calculation - Inflow:

1. Categorize foundation permits by size and type of activity
   a. single-family dwelling / basement — 5
   b. apartment bldg / multifamily residential — 7
   c. office / commercial — 5
   d. repair — 6
   e. garage / addition — 5
   f. misc. — 4
2. Estimated size and material requirements for each foundation type
   a. single-family dwelling / basement

      size = (30'x30'x0.67' x4x150lb/cu ft/2000)

      Mass = 180 tons x 5 buildings = 900 tons
   b. apartment bldg / multifamily residential

      size = (30'x30'x0.67' x4x150lb/cu ft/2000)

      Mass = 180 tons x 7 buildings = 1,290 tons
   c. office / commercial

size = (16,667 sq. ft[228] x 4/12 x150lb/cu ft/2000)

Mass = 416 tons x 5 buildings = 2,080 tons

d. repair

Mass = 0.5 tons x 6 projects = 3 tons

e. garage / addition

size = (24'x20' x 5/12x150/2000)[229]

Mass = 15 tons x 5 projects = 75 tons

f. misc.

Mass = 3.5 tons[230] x 4 projects = 14 tons

3. Total 4,332 tons

Garage/carport

Method:

1. Start with total number of garages / carports, from Ann Arbor Building permits
2. Estimate total sq. ft of garages / carports constructed
3. Calculate waste generation and inflow mass

Calculation - Outflow:

1. Total permits issued for garages / carports in 1997 50

   Estimated cost $ 748,583
2. Estimated waste generation (tons)

   = (Total mass of inflow) x (average scrap rate)

   = (886 tons) x (5%) 44 tons

Calculation - Inflow:

1. Calculate average sq. ft for permits citing dimensions (9 out of 50) 466 sq. ft
2. Divide cost by sq. ft and average the values average = $ 21 / sq. ft

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[228] Assume 3 story 50,000 sq. ft building, therefore foundation is 50,000 ÷ 3 = 16,667 sq. ft

[229] 24'x20' based on calculations of actual garages built; 5" thick floor required by City of Ann Arbor Building Department.

[230] Based on 10'x14', 4" thickness.

3. Use actual dimension when available, otherwise, divide garage cost by average $ / sq. ft to get estimated sq. ft/garage. Average actual and estimated values. average = 488 sq. ft
4. Sum estimated and actual sq. ft to get total sq. ft built 21,955 sq. ft[231]
5. Estimate mass contribution of concrete floor.

   Garage Floor Mass = (thickness of concrete slab) x (density of concrete)

   = (5"thick[232]) x (150 lb /cu ft concrete)

   = 62.5 lbs / sq. ft

   Mass of Garage structure = 49.5 lbs/sq. ft[233]
6. TOTAL Mass

   = (square feet of new garages) x [(mass of garage floor) + (mass of garage structure)]

   = (21,955 sq. ft) x [(62.5 lbs / sq. ft) x 0.50[234]+ (49.5 lbs/sq. ft)] / (2000 lbs / ton)

   TOTAL = 886 tons

Kitchen

Method:

1. Start with total number of kitchens remodeled, from Ann Arbor Building permits
2. Estimate number of major vs. minor remodelings
3. Calculate waste generation and inflow mass

Calculation - Outflow:

1. Total permits citing kitchen remodeling in 1997 59

   Estimated cost $ 1,218,645

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[231] Not included in the estimated total square feet are 86 carports and 144 garage ports constructed for permit #55295 because mass associated with this activity has not been estimated. Permit # 53810 has been ignored because the permit includes additions to the residence and therefore using the $100,000 cost of construction results in an extremely high square footage estimate.

[232] City of Ann Arbor Building Department. Private Garage – Requirements. Ann Arbor: City of Ann Arbor Building Department, 2000. Note: Ann Arbor Building Department requires concrete slab to be at least 5 inches thick.

[233] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit., Table A-3, demolition mass of single-family houses without concrete

[234] Estimate that only 50% of the permits entailed constructing a concrete floor.

2. Estimated generation (tons)

   Assume minor and major remodelings each equal 50% of all kitchen remodelings

   = [Total number of kitchens remodeled – minor x (average waste per minor kitchen remodeling job)]

   = (29.5) x (0.75 tons / minor job) 22 tons

   = [Total number of kitchens remodeled – major x (average waste per major kitchen remodeling job)]

   = (29.5) x (4.5 tons / major job) 133 tons

TOTAL = minor + major = **155 tons**

Calculation - Inflow:

1. Assume inflow equals outflow because activity entails replacement of stock
2. Total = **155 tons**

Nonresidential Renovation (Commercial/Institutional)

Method:

1. Start with total cost of nonresidential alteration/addition, from Ann Arbor Building permits
2. Estimate total sq. ft of nonresidential renovation
3. Calculate waste generation and inflow mass

Calculation - Outflow:

1. Total nonresidential alteration/additions in 1997 229

   Estimated cost $27,601,090
2. Total estimated square feet of renovation = $27,601,090 / ($83/sq ft)[235]= 332,543 sq. ft
3. Estimated generation (tons)

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[235] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit., Table A-6. Value confirmed as being a reasonable estimate for Ann Arbor, MI by JC Beal Construction. op. cit.

= [Total Dollars / (Dollars/sq. ft)] x (lb/sq. ft) / (lb / ton)

= [$ 27,601,090 / ($83/sq ft)] x (17.67 lb/sq. ft[236]) / (2000 lb/ton) = 2,938 tons

Note: This method was not deemed accurate by the EPA because the total estimated square feet renovated represented only 1.7 percent of the total floorspace of nonresidential buildings, implying an average of more than 50 years between renovations, which seemed unreasonably low. However, very few waste assessments are available for nonresidential renovation, so until better data is available, this method has been used for this analysis.

Calculation - Inflow:

1. Scrap rates are estimated to be approximately 50% of total materials brought onsite.[237]
2. Total materials brought onsite = stock + waste

   (Total)x 0.50 = waste

   (Stock + waste) x 0.50 = waste

   0.50 stock + 0.50 waste = waste

   0.50 stock = 0.50 waste

   stock = waste

   stock = (17.67 lb/sq. ft)

   TOTAL = stock + waste = 17.67 lb/sq. ft + 17.67 lb/sq. ft = 35 lb/sq. ft
3. (35 lb/sq. ft) x (332,543 sq. ft) / (2000 lb/ton) = 5,820 tons

Porch/patio

Method:

1. Start with total cost of porch/patio alteration, from Ann Arbor Building permits
2. Estimate total sq. ft of alteration
3. Calculate waste generation and inflow mass

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[236] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit., Table A-6; Value confirmed as being a reasonable estimate for Ann Arbor, MI by Dale, JC Beal Construction, Personal Communication, May 18, 2000.

[237] JC Beal Construction, op. cit.

Calculation - Outflow:

1. Total permits issued for porch/patio alteration in 1997 85

   Estimated cost $ 596,244

2. Estimated waste generation (tons)

   a. Calculate average sq. ft for permits citing dimensions (12 out of 85) 142 sq. ft

   b. Divide cost by sq. ft and average the values average = $ 41.60 / sq. ft

   c. Use actual dimension when available, otherwise, divide porch cost by average $ / sq. ft to get estimated sq. ft/ porch. Average actual and estimated values.

      average = 161 sq. ft

   d. Sum estimated and actual sq. ft to get total sq. ft built 1,705 sq. ft

   Waste = [Total sq. ft x (average waste lbs / sq. ft)] / (lb / ton)

   = (1,705 sq. ft) x (5.5 lb / sq. ft[238]) / (2000 lb/ton) **5 tons**

Calculation - Inflow:

1. Scrap rates are estimated to be approximately 5% of total materials brought onsite.

2. Total materials brought onsite = stock + waste

   (Total)x 0.05 = waste

   (Stock + waste) x 0.05 = waste

   stock + waste = (waste) / 0.05

   stock = (waste) / 0.05 – (waste)

   stock = .95 x (waste) / 0.05

   stock = 19 x (waste)

   stock = 19 x (5.5 lb/sq. ft)

   = 104.5 lb/sq. ft

   TOTAL = stock + waste = 104.5 lb /sq. ft + 5.5 lb/sq. ft = 110 lb/sq. ft

3. (110 lb/sq. ft) x (1,705 sq. ft) / (2000 lb/ton) = **94 tons**

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[238] Assume same waste rate as decks.

Residential Addition

- These additions were a mix of one-story additions built on a concrete slab foundation, two-story additions with basement, additions combined with other alterations, and numerous permits issued with no indication of the size of the addition or presence/absence or foundation/basement/slab.
- Only three walls would be constructed with the fourth wall being supplied by the existing foundation.
- Assume ¾ of additions add full basement. Remainder only have slab.

Method:

1. Start with total cost of residential additions, from Ann Arbor Building permits
2. Estimate total square feet of residential additions built
   a. Calculate average sq. ft for permits citing dimensions
   b. Calculate $ / sq. ft for residential additions cited above
   c. Divide addition cost by average $ / sq. ft to get estimated sq. ft/addition; use actual dimension when available
   d. Sum estimated and actual sq. ft to get total sq. ft built
3. Calculate waste generation and inflow mass

Calculation - Outflow:

Method 1:

1. Estimated waste generation (tons)
2. Waste = (Total number of projects) x (average waste tons / project)
   = (57 projects) x (0.75 tons/ job[239]) 43 tons

Method 2:

1. Total permits issued in 1997 57
   Estimated cost $ 3,565,985
2. Estimated waste generation (tons)

239 Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit., Table A-5.

a. Calculate average sq. ft for permits citing dimensions (16 out of 57) 354 sq. ft
b. Divide cost by sq. ft and average the values average = $ 186 / sq. ft
c. Use actual dimension when available, otherwise, divide addition cost by average $ / sq. ft to get estimated sq. ft/addition. Average actual and estimated values.
average = 374 sq. ft (approx. 19'x19')
d. Sum estimated and actual sq. ft to get total sq. ft built 21,319 sq. ft

3. Waste = [Total sq. ft x (average waste in lbs / sq. ft)] / (lb / ton)
= (21,319 sq. ft) x (8 lb / sq. ft[240]) / (2000 lb/ton) 85 tons

NOTE: This method was not used because the size of additions was only reported for 16 out of 57 projects.

Calculation - Inflow:

1. Estimate by summing the mass of materials required for foundation (basement walls and floor), structure, and average residential construction debris for additions.
2. Foundation = walls + floor
Walls = (19' long) x (8' high) x (8" thick)[241] x (concrete density 150 lb/cu ft)
Floor = (19'x19') x (4" thick)[242] x (concrete density 150 lb/cu ft)
= 3 x (7.6 tons / wall) + (9 tons / floor)
= 23 tons + 9 tons = 32 tons
3. Structural mass requirement = the mass of materials generated in a single-family house demolition (49.5 lbs/sq. ft)[243]
4. Average waste generation rate for additions 8 lbs/sq. ft (range=4-12 lbs/sq. ft)[244]
5. TOTAL = foundation + structure + waste

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[240] National Association of Home Builders Research Center, Inc. Waste Management and Recovery: A Field Guide for Residential Remodelers, op. cit., Waste audits estimate that additions generate 4 to 12 lbs/sq. ft of waste.

[241] Standard wall height

[242] Standard foundation thickness

[243] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit., Table A-3 METRO sampling of three single-family houses, does not included concrete

[244] National Association of Home Builders Research Center, Inc. Waste Management and Recovery: A Field Guide for Residential Remodelers, op. cit.

= [(32 tons/ foundation) x (57 projects) x 0.67[245]] + [(9 tons / floor) x (57 projects) x 0.33] + [21,319 sq. ft x (49.5 lbs/sq. ft + 8 lb/sq. ft) / (2000 lb/ton)]

= 1222 + 169 + 613

TOTAL = 2004 tons

Residential Interior alteration

Method:

1. Start with total number of interior alterations, from Ann Arbor Building permits
2. Calculate waste generation and inflow mass

Calculation - Outflow:

1. Total permits issued in 1997 86

   Estimated cost $ 2,378,474
2. Estimated waste generation (tons)

   = (Total number of interiors remodeled) x (average waste per interior remodeling project)

   = (86) x (0.75 tons / project [246]) 65 tons

Calculation - Inflow:

1. Scrap rates are estimated to be approximately 5% of total materials brought onsite.
2. Total materials brought onsite = stock + waste

   (Total) x 0.05 = waste

   (Stock + waste) x 0.05 = waste

   stock + waste = (waste) / 0.05

   stock = (waste) / 0.05 – (waste)

   stock = .95 x (waste) / 0.05

   stock = 19 x (waste)

---

[245] Assume ¾ of additions add full basement. Remainder only have slab.

[246] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit., Table A-5, assume waste generation rate to equal to kitchen remodeling (minor) or additions

stock = 19 x (0.75 tons / project)

= 14.25 tons / project

TOTAL = stock + waste = 14.25 tons / project + 0.75 tons / project = 15 tons / project

3. (15 tons / project) x (86 projects) = **1,290 tons**

Reroofing

Method:

1. Start with total cost of reroofing, from Ann Arbor Building permits
2. Estimate total sq. ft of roofing replaced
3. Calculate waste generation and inflow mass

Calculation - Outflow:

1. Total reroofings in 1997 751

   Estimated cost $ 4,432,631
2. Total estimated square feet of roofing = 751 x (1600 sq. ft/roof[247]) = 1,201,600 sq. ft
3. Estimated generation (tons)

   = [Total sq. ft x (weight of asphalt roof / sq. ft)] / (lb / ton)

   = [1,201,600 sq. ft x (240 lb asphalt roof / 100 sq. ft) [248]] / (2000 lb/ton) = **1,442 tons**

Calculation - Inflow:

1. Assume inflow equals outflow because activity entails replacement of stock
2. Total = **1,442 tons**

Siding

- Assume 100% of residing uses vinyl siding.[249]

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[247] Derman, Asher. "Embodied Energy, Air Pollution, and Materials, Part II." AIA Environmental Resource Guide Apr. 1993: Topic.IV.E 5.

[248] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit., Table A-8

[249] Astro Building Products. op. cit. Estimated that 90% of houses use vinyl vs. aluminum siding.

Method:

1. Start with total number of siding replacement permits, from Ann Arbor Building permits
2. Estimate total sq. ft of siding replaced
3. Calculate waste generation and inflow mass

Calculation - Outflow:

1. Total siding replacement in 1997, 119

   Estimated cost $ 450,169
2. Total estimated square feet of siding

   = 119 houses x (2,325 sq. ft siding/house[250]) = 276,675 sq. ft
3. Estimated generation (tons)

   = [Total sq. ft x (weight of vinyl siding / sq. ft)] / (lb / ton)

   = [276,675 sq. ft x (0.9 lbs/sq. ft)[251]] / (2000 lb/ton) = **125 tons**

Calculation - Inflow:

1. Assume inflow equals outflow because activity entails replacement of stock
2. Total = **125 tons**

Windows

Method:

1. Start with total cost of windows, from Ann Arbor Building permits
2. Estimate total number of windows replaced
3. Calculate waste generation and inflow mass

Calculation - Outflow:

1. Total permits citing window or doorwall replacement in 1997 459

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[250] National Association of Home Builders Research Center, Inc. "Materials Used in Building a 2085-Square-Foot Single-Family." Home Facts & Figures. <http://www.nahb.org/facts/economics/mub.html> 5 May 2000.

[251] 4.5 lbs per 5 sq. ft piece of vinyl siding

Total number of windows / doorwalls replaced 4898 + 124 doorwalls

(Note: Only 88% of permits listed number of windows replaced, so above figure is incomplete)

Estimated cost $ 2,383,893

2. Estimated generation (tons)

= [Total windows and doorwalls x (average weight per window)] / (lb / ton)

= (5,022 windows) x (70.4 lb / window[252]) / (2000 lb/ton) **177 tons**

Calculation - Inflow:

1. Assume inflow equals outflow because activity entails replacement of stock
2. Total = **177 tons**

DEMOLITION:

In order to estimate the flows from demolition, the following building activities were analyzed:

- Residential - Single & Multifamily
- Garage / Storage Building
- Nonresidential (Commercial)
- Interior Demolition
- Misc. / Unknown

Method:

1. Start with total number of demolitions, from Ann Arbor Building permits
2. Categorize demolitions by size and type
3. Calculate waste generation and inflow mass

Calculation - Outflow:

1. Total nonresidential alteration/additions in 1997 64

   Estimated cost $767,300

2. Categorize permits by size and type of activity

   a. residential -single & multifamily 4

[252] Blanchard, op. cit., p. 89

b. garage / storage building 11

c. nonresidential 6

d. interior demolition 34

e. misc. / unknown 9

3. Estimate size and mass of materials for each type

a. residential -single & multifamily

= [Total sq. ft x (weight of building / sq. ft)] / (lb / ton)

= [4 units x 1300 sq. ft[253] x (115 lb / sq. ft)[254]] / (2000 lb/ton) = 299 tons

b. garage / storage building

= Total sq. ft x (weight of building / sq. ft + mass of concrete slab)

= 11 units x 200 sq. ft[255] x (49.5 lb / sq. ft[256] + 4" thick floor x 150lb/cu ft)= 109 tons

c. nonresidential

= [Total sq. ft x (weight of building / sq. ft)] / (lb / ton)

= [6 units x 13,299 sq. ft[257] x (173 lb / sq. ft)[258]] / (2000 lb/ton) = 6,902 tons

d. interior demolition

= [Total projects x (waste generation / project)]

= [34 projects x (0.75 tons / project)[259]] = 25.5 tons

e. misc. / unknown

= [Total projects x (waste generation / project)]

= [9 projects x (0.75 tons / project)[260]] = 7 tons

3. Total = 7,343 tons

Calculation - Inflow:

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[253] Friedman, op. cit.

[254] Franklin Associates. Characterization of Building-Related Construction and Demolition Debris in the United States. EPA530-R-98-010, op. cit., Table 5

[255] Ibid., Based on size of garage in Table A-3

[256] Ibid., Table A-3

[257] Ibid., Table A-4, average size of buildings built between 1920 and 1969

[258] Ibid., Table A-4

[259] Ibid., Table A-5

[260] Ibid., Table A-5

1. Assume inflow equals zero because activity entails removal of stock, and no addition
2. Total = 0 tons

ACTIVITIES NOT INCLUDED IN ANALYSIS

Entry/door

Ranked too low. Count ranking = 19 out of 25, cost ranking = 23 out of 25.

Fence

Ranked too low. Count ranking = 6 out of 25, cost ranking = 22 out of 25.

Insulation

Ranked too low. Count ranking = 20 out of 25, cost ranking = 25 out of 25.

Miscellaneous

Permits that were unable to be categorized into the above groups, were not included in the analysis. The material composition or activities were too varied or difficult to quantify.

Shed/barn

Ranked too low. Count ranking = 22 out of 25, cost ranking = 24 out of 25.

Sign/awning

Ranked too low. Count ranking = 13 out of 25, cost ranking = 21 out of 25.

Summary of Estimates

Table C-5 shows a summary of the building-related activity occurring in Ann Arbor in 1997, and estimates of inflow and outflow mass for each building type.

Table C-5 Summary of Building-Related Construction in Ann Arbor, MI, 1997

Activity	Inflow (tons)	Outflow (tons)	Number of Permits Issued	Estimated Cost
New Residential Construction	**65,000**	**1,500**	**180**	**$ 33.6 million**
New Single-Family Dwelling	37,478	624	150	$ 18,978,302
New Apartment Buildings / Townhouses	26,433	795	20	$ 13,678,236
New Two-Family Dwelling	1,456	44	10	$ 993,259
New Nonresidential Construction	**41,000**	**1,000**	**20**	**$ 27.0 million**
New Commercial/ Institutional Buildings	41,122	1,028	20	$ 26,954,018
Residential Renovation	**15,000**	**2,600**	**2125**	**$ 21.4 million**
Basement	1,332	67	78	$ 1,024,777
Bathroom	40	40	64	$ 744,720
Cabinets	65	67	89	$ 1,019,340
Decks	3,390	169	196	$ 795,626
Foundation	4,332	217	32	$ 1,481,010
Garage / Carport	886	44	50	$ 748,583
Interior alteration	1,290	65	86	$ 2,378,474
Kitchen	155	155	59	$ 1,218,645
Porch / Patio	94	5	85	$ 569,244
Reroofing	1,442	1,442	751	$ 4,432,631
Residential addition	2,004	43	57	$ 3,565,985
Siding	125	125	119	$ 450,169
Windows	177	177	459	$ 2,383,893
Nonresidential Renovation	**5,800**	**2,900**	**229**	**$ 27.6 million**
Nonresidential Renovation	5,800	2,938	229	$ 27,601,090
Demolition	**0**	**7,300**	**64**	**$ 0.8 million**
Nonresidential and Residential Demolition	0	7,343	64	$ 767,300
Activities not included	**-**	**-**	**523**	**$5,390,505**
Entryway / Door	N/A	N/A	47	$ 137,745
Fence	N/A	N/A	165	$ 295,838
Insulation	N/A	N/A	37	$ 27,199
Shed / Barn	N/A	N/A	21	$ 111,011
Sign / Awning	N/A	N/A	70	$ 381,442
Miscellaneous	N/A	N/A	183	$ 4,437,270
TOTAL*	**127,639**	**15,386**	**3151**	**$ 115,175,807**

N/A = category was not analyzed
** = may not sum due to rounding*

Comments

Materials not included

Six building related activities were not analyzed because there were too few projects or the estimated cost was low compared to other projects. These categories include construction of fences, sheds, barns, signs and awnings, addition of insulation, and alteration of entryway/doors. Activities categorized in the miscellaneous category were also not included, with activities ranging from fire escape repairs, temporary tents, and installation of a 160' communications tower. The activities were too varied to be included in the analysis, however comprised only 4 % of the total estimated cost, and represented 6% of the building permits issued.

Data on repair and maintenance were also not included in the analysis. Given that there are over 44,000 housing units in Ann Arbor, routine maintenance materials could have a large impact. These materials were outside of the scope of this analysis, but probably represent a significant economic and mass flow to support the housing stock of Ann Arbor.

Comparisons to Other Data

A study conducted in Germany found the ratio of inflow to outflow for construction materials to be approximately 10:1.[261] This analysis resulted in a 8:1 ratio and so appears consistent with other estimates.

Alternate methods for characterizing flows

An alternate method to characterize the flow of materials into and out of the community would have been to: inventory the total sales of building materials within the city, create an estimate of the amount that remained within the community versus materials transported outside of the community, and add the building materials purchased outside of the city and transported into the city by residents or contractors. This approach would

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[261] Friege, Henning. "Requirement for Policy Relevant Material Flow Accounting – Results of the German Bundestag's Enquête Commission." Regional and National Material Flow Accounting: From Paradigm to Practice of Sustainability, Proceeding of the ConAccount workshop. 21-23 Jan. 1997. Leiden, The Netherlands: Wuppertal Institute for Climate, Environment and Energy, 1997.

have tracked individual materials and not the sum of materials necessary to support the need for shelter.

Figure C-1 Building Permit, City of Ann Arbor, MI, Building Department

CITY OF ANN ARBOR, MI
BUILDING DEPARTMENT
100 N FIFTH AVENUE
(313) 994-2674

BUILDING PERMIT

ASSESSORS COPY
AMOUNT PAID: 1-8-98 Jc 125 — Ryan 46
VALIDATION

DATE 12-31 19 97 PERMIT NO. 55948

APPLICANT Wallside Inc. ADDRESS 313 292-4400 (NO.) (STREET) (CONTR'S LICENSE)

PERMIT TO repair/replacement (TYPE OF IMPROVEMENT) ( ) NO. STORY (PROPOSED USE) NUMBER OF DWELLING UNITS

AT (LOCATION) 2010 Wiltshire Ct. (NO.) (STREET) ZONING DISTRICT R1C

BETWEEN (CROSS STREET) AND (CROSS STREET)

SUBDIVISION 12-06-200-021 LOT BLOCK LOT SIZE

BUILDING IS TO BE FT. WIDE BY FT. LONG BY FT. IN HEIGHT AND SHALL CONFORM IN CONSTRUCTION

TO TYPE USE GROUP BASEMENT WALLS OR FOUNDATION (TYPE)

REMARKS: 08) Replace 5 windows

AREA OR VOLUME (CUBIC/SQUARE FEET) ESTIMATED COST $ 1,575.00 PERMIT FEE $ 35.00

OWNER Dorothy E. Gray
ADDRESS same

BUILDING DEPT. BY Larry Pickel/rf

FORM NO. BOCA - BP 1994

Figure C-2 Application for Plan Examination and Building Permit, City of Ann Arbor, MI Building Department

100 N. FIFTH AVE.
Phone(734) 994-2674
Fax (734)994-8460

CITY OF ANN ARBOR, MI
BUILDING DEPARTMENT
New Construction, Alterations and Additions

APPLICATION FOR PLAN EXAMINATION AND BUILDING PERMIT

IMPORTANT - Applicant to complete all items in Sections I, II, III, IV and IX.

I. LOCATION OF BUILDING

AT (LOCATION) ______ (NO.) ______ (STREET) ZONING DISTRICT ______

BETWEEN ______ (CROSS STREET) AND ______ (CROSS STREET)

SUBDIVISION ______ LOT ______ BLOCK ______ LOT SIZE ______

II. TYPE AND COST OF BUILDING - *All applicants complete Parts A - D*

A. TYPE OF IMPROVEMENT

1 ☐ New building
2 ☐ Addition *(If residential, enter number of new housing units added, if any, in Part D, 13)*
3 ☐ Alteration *(See 2 above)*
4 ☐ Repair, replacement
5 ☐ Wrecking *(If multifamily residential, enter number of units in building in Part D, 13)*
6 ☐ Moving (relocation)
7 ☐ Foundation only

B. OWNERSHIP

8 ☐ Private (individual, corporation, nonprofit institution, etc.)
9 ☐ Public (Federal, State, or local government)

D. PROPOSED USE - *For "Wrecking" most recent use*

Residential
12 ☐ One family
13 ☐ Two or more family - Enter number of units ______
14 ☐ Transient hotel, motel, or dormitory - Enter number of units ______
15 ☐ Garage
16 ☐ Carport
17 ☐ Other - *Specify* ______

Nonresidential
18 ☐ Amusement, recreational
19 ☐ Church, other religious
20 ☐ Industrial
21 ☐ Parking garage
22 ☐ Service station, repair garage
23 ☐ Hospital, institutional
24 ☐ Office, bank, professional
25 ☐ Public utility
26 ☐ Library
27 ☐ Stores, mercantile
28 ☐ Tanks, towers
29 ☐ Other - *Specify* ______

C. COST *(Omit cents)*

10 Cost of improvement	$ ______
To be installed but not included in the above cost	
a. Electrical	$ ______
b. Plumbing	$ ______
c. Heating, air conditioning	$ ______
d. Other (elevator, etc.)	$ ______
11 TOTAL COST OF IMPROVEMENT	$ ______

Nonresidential - Describe in detail proposed use of buildings, e.g., day care center, food processing plant, machine shop, laundry building at hospital, college, parking garage for department store, rental office building, office building at industrial plant. If use of existing building is being changed, enter proposed use.

III. SELECTED CHARACTERISTICS OF BUILDING - *For new buildings and additions, complete Parts E - L, for wrecking, complete only Part J, for all others skip to IV.*

E. PRINCIPAL TYPE OF FRAME

30 ☐ Masonry (wall bearing)
31 ☐ Wood frame
32 ☐ Structural steel
33 ☐ Reinforced concrete
34 ☐ Other - *Specify* ______

F. PRINCIPAL TYPE OF HEATING FUEL

35 ☐ Gas
36 ☐ Oil
37 ☐ Electricity
38 ☐ Coal
39 ☐ Other - *Specify* ______

G. TYPE OF SEWAGE DISPOSAL

40 ☐ Public or private company
41 ☐ Private (septic tank, etc.)

H. TYPE OF WATER SUPPLY

42 ☐ Public or private company
43 ☐ Private (well, cistern)

I. TYPE OF MECHANICAL

Will there be central air conditioning?
44 ☐ Yes 45 ☐ No

Will there be an elevator?
46 ☐ Yes 47 ☐ No

J. DIMENSIONS

48 Number of stories ______
49 Total square feet of floor area, all floors, based on exterior dimensions ______
50 Total land area, sq. ft. ______

K. NUMBER OF OFF-STREET PARKING SPACES

51 Enclosed ______
52 Outdoors ______

L. RESIDENTIAL BUILDINGS ONLY

53 Number of bedrooms ______
54 Number of bathrooms Full ______ Partial ______

Appendix D: Clothing

This appendix provides supplementary information for the study completed on material flows associated with the clothing needs of Ann Arbor, which is presented in Section 3 of Chapter 4.

Data Sources

Obtaining certain pieces of information were critical for the estimation of mass and economic value of material flows into and out of the community. Identified below are the primary data sources used in estimating those flows.

Sales of clothing

New Clothing

The 1997 Economic Census[262] publishes sales data for retail trade categorized by NAICS code. Sales data on clothing and apparel was obtained from the following subsectors:

- NAICS code 448: Clothing & clothing accessories stores - includes new clothing and clothing accessories from fixed point-of-sale locations; men's, women's, and children's clothing; shoe stores; jewelry, luggage, and leather goods stores.
- NAICS code 452: General merchandise stores - includes Conventional, Discount or Mass Merchandising, and National Chain Department stores, other General Merchandise Stores, Warehouse Clubs, and superstores.
- NAICS code 4533: Used merchandise stores includes used merchandise, antiques, secondhand goods (except motor vehicles, motor vehicle parts, tires and mobile homes).

Use of the Economic Census of Retail Trade for the U.S. violates the definition of the inflows as based on consumption by Ann Arbor residents. Sales by Ann Arbor stores to non-Ann Arbor residents should not be included in the inflow value, however sales data

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[262] United States Bureau of the Census. United States 1997 Economic Census, Retail Trade – Geographic Area Series., op. cit.

United States Bureau of the Census. Michigan 1997 Economic Census, Retail Trade - Geographic Area Series. op. cit.

cannot be adjusted to account for residence of the purchaser. In addition, it is known how much Ann Arbor residents spend on clothing and footwear at non-Ann Arbor stores and through mail-order.

The U.S. Census Bureau publishes Current Industrial Reports for various manufacturing sectors including apparel and footwear. Data are reported on quantity and value of manufacturer's shipments, exports, imports, and U.S. apparent consumption. Apparent consumption represents new domestic supply and is derived from subtracting exports from the sum of manufacturers' shipments plus imports.

Other sources of data on new clothing and footwear include the American Apparel Manufacturers Association Marketing Committee, with data on apparel sales in the U.S., broken down by apparel type, type of retail establishment, and year.[263] The National Income and Product Accounts Tables[264], published by the U.S. Department of Commerce, report Gross Domestic Product, National Income, Personal Income, and Personal Consumption Expenditures. Applicable data included personal consumption expenditures on clothing and shoes.

The American Fiber Manufacturers Association and the Fiber Economics Bureau publish data on fiber production and consumption in the United States.[265] However, fibers are converted into products in addition to apparel, such as curtains, towels, sheets, and fabrics used by other manufacturers such as seat padding for the automotive industry.

Information was also obtained from interviews with individual stores located in Ann Arbor such as Kmart, Jacobson's, and local thrift shops.

Reuse / Resale of clothing

National data on sales of used merchandise have only recently become available. The recent reclassification of the Standard Industrial Codes (SIC) resulted in a new category

[263] American Apparel Manufacturers Association, op. cit.
[264] Bureau of Economic Analysis, op. cit.

titled Used Merchandise Stores (NAICS code 4533). However, as mentioned above, this category includes many material types, and the portion of sales attributable strictly to apparel cannot be isolated. Statistics on the reuse rate of clothing were not found. However reports indicate that sales by secondhand stores and donations to resale shops are increasing.

Clothing Outflows

The EPA Characterization of Municipal Solid Waste in the U.S.[266] calculated generation of clothing and footwear in municipal solid waste using sales data from the Department of Commerce and data on average weights for each type of product included. Adjustments were made for net imports of the products based on Department of Commerce data. However, the EPA assumes that reused textiles re-enter the waste stream the same year that they are first discarded, and so considers reuse a diversion rather than recovery.[267]

Trans-America Trading Co.[268] and Council for Textile Recycling [269] provide information on generation and destination of recovered textiles on a national basis.

The City of Ann Arbor Solid Waste Department collects textiles as part of the curbside recycling program and lists mass data in their annual report.[270]

Assumptions

- Purchases made in Ann Arbor by non-Ann Arbor residents are approximately equal to the non-Ann Arbor purchases made by Ann Arbor residents.
- No used clothing enters Ann Arbor.
- All used clothing is purchased at Ann Arbor thrift stores and remains within Ann Arbor.

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[265] Horn, Frank. Fiber Economics Bureau. Personal interview. 25 Aug. 1999.
[266] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update, op. cit.
[267] Ibid.
[268] Trans-America Trading Co., op. cit.
[269] Information: Don't Overlook Textiles, op. cit.
[270] City of Ann Arbor Department of Solid Waste, op. cit.

- Clothing not sold by Ann Arbor thrift stores is donated or sold to organizations located outside of Ann Arbor.
- All of the clothing and footwear available for consumption in the U.S., is evenly distributed among the entire U.S. population.
- Generation of clothing and footwear in the Ann Arbor waste stream was assumed to be equal to the national generation rate.

Detailed Estimation Process

Method:

No data source reports a complete picture of sales, consumption, and reuse/resale of clothing in either economic or mass values. Percent of Ann Arbor retail sales data attributable to Ann Arbor residents cannot be determined. Department of Commerce data on personal consumption of clothing and footwear are not reflective of the buying power of Ann Arbor residents. In order to take into consideration the many different ways of accounting for clothing flows, several estimates have been made using different data sources (Table D-1). These individual estimations have been analyzed for gaps and limitations in order to create the most accurate estimation for the inflow and outflows occurring in Ann Arbor.

Table D-1 Estimates of Clothing Inflow Value, Inflow Mass, and Outflow Mass

Data Source	Inflow - $	Inflow - mass	Outflow - mass	Comments
1997 Economic Census, Retail Trade National Sales of new and used clothing	$168,836,996			▪ Ann Arbor is home to a large mall, so sales may be higher ▪ Buying power of Ann Arbor residents is higher than the national average.[271] ▪ Does not include mail order
1997 Economic Census, Retail Trade Ann Arbor Sales of new and used clothing	$241,222,000			▪ Sales from Merchandise Stores estimated from Washtenaw County Stores ▪ Does not include mail order ▪ Includes purchases by non-Ann Arbor residents. ▪ Does not include purchases made outside of Ann Arbor by residents.
American Apparel Manufacturers Association National New Apparel Sales	$67,955,109			▪ Sales numbers tend to be underestimated as compared to other estimation processes such as Consumer Expenditure Surveys[272] ▪ Includes mail order.
U.S. Department of Commerce. National Income and Product Accounts Tables Per capita spending on clothing and shoes	$111,726,000			▪ Buying power of Ann Arbor residents is higher than the national average.[273]
Current Industrial Reports, 1997 Apparent consumption of Apparel and Footwear		2,928 tons		▪ Mass was based on weight conversions factors for specific clothing types, based on data from Franklin & Associates ▪ Quantity data on 4 apparel types was withheld to protect individual companies
Fiber Economics Bureau, national fiber consumption		1,520 tons		▪ Percentage of fiber made into apparel is estimated. ▪ Does not included non-fiber apparel, i.e. rubber on shoes, leather handbags

[271] Strich, op. cit.

[272] Simon, op. cit.

[273] Strich, op. cit.

Table D-1, continued

Data Source	Inflow - $	Inflow - mass	Outflow - mass	Comments
EPA Characterization of MSW, generation of clothing and footwear in MSW stream			2,315 tons 301 tons recovered 2,011 tons disposed	▪ Reuse is included in generation
1994 Current Industrial Reports Apparent consumption of Apparel and Footwear			2,667 tons	▪ Data and method used by Franklin & Associates for calculating 1997 generation. ▪ Assumes all clothing and footwear produced/imported in 1994 has 3 year residence time, and then is disposed in 1997.
Ann Arbor Solid Waste Department, textile recovery and disposal			68.1 tons recovered ~386 tons disposed	▪ Does not include donations to reuse stores ▪ Textiles include linens and other non-apparel items
Mass donated to thrift stores in Ann Arbor				▪ Total donations = 315 tons ▪ Resale = 80.5 tons
Donations from thrift stores to charitable organizations outside of Ann Arbor			234.5 tons	▪ Mass based on number of bags of clothing donated ▪ Mass per bag assumed to weigh 22 lbs
Trans-America Trading Company, textile recycling			502 tons	▪ Based on national average ▪ Does not include donations to reuse stores ▪ Textiles include materials other than clothing i.e. sheets, towels

Clothing Sales

Estimation 1: National Sales of new and used clothing, scaled to population of Ann Arbor

4. Calculate sales per Clothing and Clothing Accessory establishment

   Sales ÷ Number of Establishments = Sales per establishment

   \$136,397,645,000[274] ÷ 156,601[275] = \$870,988 per establishment

5. Number of establishments in Ann Arbor = 153
6. Multiply Sales per establishment x number of Establishments

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[274] United States Bureau of the Census. United States 1997 Economic Census, Retail Trade – Geographic Area Series, op. cit., NAICS Code 448: Clothing & clothing accessories stores.

$ 870,988 x 153[276] = $133,261,216

7. Calculate Sales per General Merchandise Store

   Sales ÷ Number of Establishments = Sales per establishment

   $330,444,460,000[277] ÷ 36,171[278] = $9,135,618 per establishment

8. Multiply Sales per establishment x number of Establishments

   $9,135,618 x 9[279] = $82,220,562

9. Multiply total sales in Ann Arbor x fraction of sales composed of clothing & apparel

   $82,220,562 x 40%[280] [281] = $32,888,224

10. Calculate Sales per Used Merchandise Store

    Sales[282] ÷ Number of Establishments[283] = Sales per establishment

    $6,043,642,000 ÷ 17,990 = $335,944 per establishment

11. Multiply Sales per establishment x number of Establishments

    $335,944 x 16[284] = $5,375,112

12. Multiply total sales in Ann Arbor x fraction of sales composed of clothing & apparel

    $5,375,112 x 50%[285] = $2,687,556

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[275] Ibid., NAICS Code 448: Clothing & clothing accessories stores.

[276] United States Bureau of the Census. Michigan 1997 Economic Census, Retail Trade - Geographic Area Series, op. cit., Table 4 Summary Statistics for Places: 1997. Ann Arbor, MI.

[277] United States Bureau of the Census. United States 1997 Economic Census, Retail Trade – Geographic Area Series, op. cit., NAICS Code 452: General Merchandise Stores.

[278] Ibid., NAICS Code 452: General Merchandise stores.

[279] United States Bureau of the Census. Michigan 1997 Economic Census, Retail Trade - Geographic Area Series, op. cit., Table 4 Summary Statistics for Places: 1997. Ann Arbor, MI.

[280] Investor Relations. Kmart. <http://www.kmart.com/corp/investor/fact/factbk_1997/16stm> 5 May 2000.

[281] Clark, op. cit., Note: Clothing represents approximately 70% of their total sales. Jacobson's considers themselves to be a specialty department store, differing from a typical department store in that they have a smaller volume of sales and they have a smaller home store.

[282] United States Bureau of the Census. United States 1997 Economic Census, Retail Trade – Geographic Area Series, op. cit., NAICS Code 4533: Used Merchandise Stores.

[283] Ibid., NAICS Code 4533: Used Merchandise Store.

[284] United States Bureau of the Census. Michigan 1997 Economic Census, Retail Trade - Geographic Area Series, op. cit., Table 4 Summary Statistics for Places: 1997. Ann Arbor, MI.

[285] Note: Assumption made by researcher.

13. Total: Clothing & Clothing Accessory + General Merchandise + Used Merchandise
    Total: $133,261,216 + $32,888,224 + $2,687,556= $168,836,996

Estimation 2: Ann Arbor Sales of new and used clothing

1. Total Sales from 153 Clothing & clothing accessories stores[286] = $164,738,000

2. Total Sales from 9 General Merchandise stores[287] = data were withheld to avoid disclosing data on individual companies. Use data from Washtenaw County, MI.
3. Calculate Sales per General Merchandise Store, Washtenaw County
   Sales ÷ Number of Establishments = Sales per establishment
   $493,609,000[288] ÷ 24[289] = $20,567,000 per establishment
4. Multiply Sales per establishment x number of Establishments in Ann Arbor
   $20,567,000 x 9[290] = $185,103,000
5. Multiply total sales in Ann Arbor x fraction of sales composed of clothing & apparel
   $185,103,000 x 40%[291] [292] = $74,041,000

6. Total Sales from 16 Used Merchandise stores[293] = $4,886,000
7. Multiply Total Sales from Used Merchandise stores x fraction of sales composed of clothing & apparel
   $4,886,000 x 50%[294] = $2,443,000

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[286] United States Bureau of the Census. Michigan 1997 Economic Census, Retail Trade - Geographic Area Series, op. cit., Table 4 Summary Statistics for Places: 1997. Ann Arbor, MI. Clothing & clothing accessories stores.

[287] Ibid. Table 4 Summary Statistics for Places: 1997. Ann Arbor, MI. General Merchandise stores.

[288] Ibid. Table 3 Summary Statistics for Counties: 1997. Washtenaw County, MI., NAICS Code 452: General Merchandise stores.

[289] Ibid., Table 3 Summary Statistics for Counties: 1997. Washtenaw County, MI., NAICS Code 452: General Merchandise stores.

[290] Ibid., Table 4 Summary Statistics for Places: 1997. Ann Arbor, MI.

[291] Investor Relations, op. cit.

[292] Clark, op. cit., Note: Clothing represents approximately 70% of their total sales. Jacobson's considers themselves to be a specialty department store, differing from a typical department store in that they have a smaller volume of sales and they have a smaller home store.

8. Total: Clothing & Clothing Accessory + General Merchandise + Used Merchandise
   Total: $164,738,000 + $74,041,000 + $2,443,000= $241,222,000

Estimation 3: National New Apparel Sales

3. Annual Sales 1997[295] = $169,088,000,000
4. Annual Sales ÷ US Population
   $169,088,000,000 ÷ 267,743,595 = $631 per capita
5. Expenditures per capita x Population of Ann Arbor
   $631 per capita x 107,604 = $ 67,955,109

Estimation 4: Per capita spending on clothing and shoes

1. Personal Consumption Expenditures for clothing and shoes ÷ US population,
   $278 billion[296] ÷ 267,743,595 = $1,038 per capita.
2. Multiply by the population of AA
   $1,038 per capita x 107,604[297] = $111,726,000

Inflow Mass:

Estimation 1: National apparel and footwear apparent consumption, 1997

1. Apparent consumption of apparel[298] and footwear[299] in the U.S., 1997
2. For each apparel type, multiply quantity x weight conversion factor (lbs per unit) (Table D-2)

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293 United States Bureau of the Census. Michigan 1997 Economic Census, Retail Trade - Geographic Area Series, op. cit., Table 4 Summary Statistics for Places: 1997. Ann Arbor, MI. Used Merchandise stores

294 Note: Assumption made by researcher.

295 American Apparel Manufacturers Association, op. cit.

296 Bureau of Economic Analysis, op. cit.

297 Nutting, op. cit.

298 United States Bureau of the Census. Current Industrial Reports - Table 5. Shipments, Exports, Imports, and Apparent Consumption of Selected Apparel Items: 1997 and 1996 (MQ23A97). U.S. Department of Commerce <http:www.census.gov/ftp/pub/industry/1/mq23a975.pdf> 29 May 2000.

299 United States Bureau of the Census. Current Industrial Reports - Footwear Production 1997 (MA31A) U.S. Department of Commerce <http://www.census.gov/pub/industry/1/ma31a97.pdf> 29 May 2000.

Table D-2 1997 Current Industrial Reports. Apparel and Footwear

Apparel Type	Quantity	Value (in millions)	Weight Conversion Factor (lbs per unit)[300]	Total mass (tons)
Men's & boy's apparel				
Sweaters	5,011,000	$ 592	1.40[301]	3,508
Tops (except sweaters)	(D)	(D)	0.66	
	1,018,089,000[302]		0.66	839,923
Bottoms	1,018,089,000	$ 11,324	1.40	712,662
Coats				
Suit type, dress and sport	19,968,000	$ 1,164	5.00	49,920
Other coats	185,215,000	$ 3,882	5.00	463,038
Suits	89,468,000	$ 1,334	4.00	178,936
Swimwear	44,672,000	$ 179	0.11	2,457
Women's & girl's apparel				
Sweaters	246,689,000	$ 2,785	1.40[303]	172,682
Dresses	350,542,000	$ 6,174	1.70	297,961
Tops (except sweaters)	(D)	(D)	0.70	
	2,871,318,000[304]		0.70	1,004,961
Skirts	189,639,000	$ 2,045	1.10 [305]	104,301
Coats and jackets	185,521,000	$ 4,463	3.20	296,834
Bottoms (except skirts)	957,106,000	$ 9,109	1.10	526,408
Suits	(D)	(D)	4.00[306]	
	189,639,000[307]		4.00[308]	379,278
Swimwear	85,030,000	$ 1,119	0.21[309]	8,928

300 Franklin Associates. Working paper: Methodology for Characterization of Municipal Solid Waste in the United States, Table G-04 Unit Weight Conversion Factors for Apparel.

301 Assume equal to bottoms

302 Assume 2.5 tops per bottom

303 Assume same as men's

304 Assume 3 tops per bottom

305 Assume same as bottoms

306 Assume same as men's

307 Assume same as skirts

308 Assume same as men's

309 Assume same as nightwear & underwear

Table D-2, continued

Apparel Type	Quantity	Value (in millions)	Weight Conversion Factor (lbs per unit)[310]	Total mass (tons)
Other apparel (men's/women's)				
Playsuits	(D)	(D)		
	81,246,000[311]		1.20[312]	48,748
Coveralls, etc	81,246,000	$ 1,055	1.20[313]	48,748
Robes and dressing gowns	56,416,000	$ 637	1.20[314]	33,850
Pajamas and other nightwear	212,804,000	$ 1,443	0.21	22,344
Underwear (except foundation garments)	3,284,255,000	$ 4,276	0.21	344,847
Foundations garments	430,125,000	$ 2,448	0.21	45,163
Infants' apparel	524,526,000	$ 1,788	0.30	78,679
Shoes (pairs)	1,620,439,000	N/A	2.0[315]	1,620,439
TOTAL:	**9,586,761,000 (actual) 15,274,186,500 (with estimated quantities)**	**$ 55,816 (actual)**		**7,284,615**

(D) withheld to avoid disclosing data for individual companies
Italics = quantity estimated

3. Total mass ÷ US Population

   7,284,615 tons ÷ 267,743,595 = 0.027 tons per capita

4. Tons per capita x Population of Ann Arbor

   0.027 tons per capita x 107,604 = 2,928 tons

Estimation 2: National fiber consumption

1. 1998 US per capita fiber consumption, at the consumer level[316] = 85.7 lbs per capita
2. Per capita fiber consumption x percent of fiber converted to apparel

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[310] Franklin Associates. Working paper: Methodology for Characterization of Municipal Solid Waste in the United States, Table G-04 Unit Weight Conversion Factors for Apparel.
[311] Assume same as coveralls
[312] Assume same as other garments
[313] Assume same as other garments
[314] Assume same as other garments
[315] Estimated based mass of leather boots = 3 lb/pair, running shoes = 1.4 lb/pair, sandals = 0.7 lb/pair
[316] Horn, op. cit.

85.7 lbs per capita x 33%[317] = 28.3 lbs per capita

3. U.S. fiber consumption per capita x population of Ann Arbor

   28.3 lbs per capita x 107,604 ÷ 2000 lbs/ton = 1520 tons

Reuse:

Estimation 1: Mass donated to, from, and sold by Ann Arbor thrift stores

Assumptions:

- One garbage bag of clothing weighs 22 lbs.

1. St. Vincent De Paul Society: 85% of the clothing they receive is passed on to other organizations including Salvation Army, a church in Ypsilanti, and a mission in Africa, all located outside of Ann Arbor. St. Vincent De Paul donates clothing to other organizations at a higher rate than most thrift stores because they sort incoming clothing well. In general, other thrift stores pass on 25-50% of the clothing received through donations.[318]
2. In 1997, St. Vincent De Paul gave away 6540 bags of clothing.

   6540 bags x 22 lbs/bag ÷ 2000 lbs/ton = 72 tons given away
3. Total mass donated to St. Vincent De Paul = mass given away by St. Vincent De Paul ÷ their donation rate

   72 tons ÷ 85%= 84 tons received
4. Total mass sold = total mass donated to St. Vincent De Paul - mass given away

   84 tons - 72 tons = 12 tons sold
5. 1997 Total Sales = $85,000 (=$3.50/pound)

6. Ann Arbor PTO Thrift Store: 75 % of the clothing they receive is donated to organizations located outside of Ann Arbor.[319]
7. Ann Arbor PTO Thrift Store gives away 150 bags of clothing per week.

   150 bags/wk x 50 weeks x 22 lbs/bag ÷ 2000 lbs/ton = 82.5 tons given away

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317 Metzger, Michael R., et al. The Regional Welfare Effects of U.S. Import Restraints on Apparel, Petroleum, Steel and Textiles. Brookfield: Avebury. 1996.

318 Norman, Barb. St. Vincent De Paul Society, Ann Arbor. Personal interview. 27 April 2000.

319 Ann Arbor PTO Thrift Store. op. cit.

8. Total mass donated to Ann Arbor PTO Thrift Store = mass given away by Ann Arbor PTO Thrift Store ÷ their donation rate

   82.5 tons ÷ 75%= 110 tons received

9. Total mass sold = total mass donated to Ann Arbor PTO Thrift Store - mass given away

   110 tons - 82.5 tons = 27.5 tons sold

10. Kiwanis Club: 66 % of the clothing they receive is donated to organizations located outside of Ann Arbor.[320]

11. Kiwanis Club gives away 800 lbs of clothing per truckload per week.

    800 lbs/week x 50 weeks x 4 truckloads/wk ÷ 2000 lbs/ton = 80 tons given away

12. Total mass donated to Kiwanis Club = mass given away by Kiwanis ÷ their donation rate

    80 tons ÷ 66%= 121 tons received

13. Total mass sold = total mass donated to Kiwanis Club - mass given away

    121 tons - 80 tons = 41 tons sold

14. Total mass donated to Ann Arbor thrift stores = St. Vincent DePaul + PTO + Kiwanis

    = 84 tons + 110 tons + 121 tons 315 tons received by thrift stores

15. Total mass sold by Ann Arbor thrift stores

    = 12 tons + 27.5 tons + 41 tons 80.5 tons sold by thrift stores

16. Total mass donated from Ann Arbor thrift stores to organizations outside of Ann Arbor

    = 72 tons + 82.5 tons + 80 tons 234.5 tons given to non-Ann Arbor organizations

Estimation 2: National recovery of textiles

Source: Eric Stubin, Trans-America Trading Company

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[320] Fry, Will. Kiwanis Club. Personal interview. 9 May 2000.

1. Mr. Stubin estimates that 2.5 billion pounds of textile waste are recycled annually, representing 20% of all textile waste.
2. Textiles recycled per capita = total textile waste recycled ÷ US Population
   2.5 billion lbs ÷ 267,743,595 = 9 lbs per capita
3. Pounds per capita x Population of Ann Arbor
   9 lbs per capita x 107,604 ÷ 2000 lbs/ton = 502 tons recovered for recycling

Mass of Clothing and Footwear Outflows in Ann Arbor

Estimation 1: U.S. Generation, Recovery, and Disposal of clothing and footwear

1. Generation of Clothing and Footwear in MSW stream ÷ US Population
   5,760,000 tons[321] ÷ 267,743,595 = 0.022 tons per capita
2. Pounds per capita x Population of Ann Arbor
   0.022 tons per capita x 107,604 = 2,315 tons
3. Recovery of Clothing and Footwear in MSW stream[322] ÷ US Population
   760,000 tons[323] ÷ 267,743,595 = 0.0028 tons per capita
4. Pounds per capita x Population of Ann Arbor
   0.0028 tons per capita x 107,604 = 301 tons[324]
5. Disposal = generation - recovery
   2,315 tons - 301 tons = 2,014 tons

Estimation 2: U.S. Generation of clothing and footwear based on 1994 Current Industrial Reports[325] (use same calculation method as Inflow Mass-Estimation 1).

1. Apparent consumption of apparel[326] and footwear[327] in the U.S., 1994

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321 Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update, op. cit. Table 15 Characterization of MSW by Weight, Nondurable Goods, Clothing and Footwear.

322 Ibid. Note: The EPA assumes that reused textiles re-enter the waste stream the same year that they are first discarded, and so considers re-use as a diversion rather than recovery.

323 Ibid. Table 16 Characterization of MSW by Weight, Nondurable Goods, Clothing and Footwear.

324 Assume that recovered clothing is either exported or recycled outside of AA.

2. For each apparel type, multiply quantity x weight conversion factor (lbs per unit) (Table D-3)

Table D-3 1994 Current Industrial Reports. Apparel and Footwear

Apparel Type	Quantity (in thousand dozen)	Assumptions to account for missing data[328]	Value (in millions)	Weight Conversion Factor (lbs per unit)[329]	Total mass (tons)
Men's & boy's apparel					
Sweaters	1,893	1,893	$ 737	1.4	15,901
Tops (except sweaters)	(D)	176,323	(D)	0.66	698,238
Bottoms	70,529	70,529	$ 10,737	1.4	592,444
Coats					
Suit type, dress and sport	1,354	1,354	$ 1,149	5	40,630
Other coats	12,459	12,459	$3,028	5	373,773
Suits	1,103	1,103	$ 1,464	4	26,464
Swimwear	3,981	3,981	$ 190	0.11	2,627
Women's & girl's apparel					
Sweaters	16,031	16,031	$2,283	1.4	134,660
Dresses	24,961	24,961	$ 6,174	1.7	254,599
Tops (except sweaters)	128,110	128,110	$ 10,378	0.7	538,062
Skirts	16,623	16,623	$2,243	1.1	109,713
Coats and jackets	13,839	13,839	$ 4,126	3.2	265,706
Bottoms (except skirts)	82,063	82,063	$8,529	1.1	541,619
Suits	(D)	16,623	(D)	4	398,958
Swimwear	5,764	5,764	$ 802	0.21	7,263

[325] Franklin, Marge, op. cit., Estimates for generation of clothing and footwear in 1997 are based on 1994 Current Industrial Reports, because 3 year lag from year produced/imported is assumed. Therefore 1994 data is used to predict generation for 1997.

[326] United States Bureau of the Census. Current Industrial Reports - Table 4B. Apparel Quantity of Production by Type of Fabric: 1993 (MQ23A). U.S. Department of Commerce, 1994. <http://www.census.gov/ftp/pub/industry/mq23a94b.txt> 29 May 2000.

[327] United States Bureau of the Census. Current Industrial Reports - Footwear Production 1994 (MA31A) U.S. Department of Commerce <http://www.census.gov/ftp/pub/industry/ma31a94.txt> 29 May 2000.

[328] same assumptions as found in data for 1997

[329] Franklin Associates. Working paper: Methodology for Characterization of Municipal Solid Waste in the United States: Table G-04 Unit Weight Conversion Factors for Apparel.

[329] Assume equal to bottoms

Table D-3, continued

Apparel Type	Quantity (in thousand dozen)	Assumptions to account for missing data[330]	Value (in millions)	Weight Conversion Factor (lbs per unit)[331]	Total mass (tons)
Other apparel (men's/women's)					
Playsuits	(D)	4,048	(D)	1.2	29,146
Coveralls, etc	(D)	4,048	(D)	1.2	29,146
Robes and dressing gowns	(D)	4,048	(D)	1.2	29,146
Pajamas and other nightwear	19,962	19,962	$ 1,679	0.21	25,152
Underwear (except foundation garments)	229,176	229,176	$3,453	0.21	288,762
Foundations garments	34,243	34,243	$2,268	0.21	288,762
Infants' apparel	36,211	36,211	$ 1,485	0.3	61,637
Shoes (pairs)	1,654,506	1,654,506	$ 87	2.0	1,654,506
TOTAL	**2,352,808**	**2,557,898**	**$60,811**		**6,406,913**

3. Total mass ÷ US Population

   6,406,913 tons ÷ 260,289,237[332]= 0.025 tons per capita

4. Tons per capita x Population of Ann Arbor

   0.025 tons per capita x 108,368[333] = 2,667 tons

Estimation 2: Textile Recovery by Ann Arbor Solid Waste Department

1. Textile waste generated = tons textiles recovered ÷ 15%[334]

   68.1 tons[335] ÷ 15% = 454 tons waste generated

2. Textile waste disposed = textile waste generated –textile waste recovered

   454 tons generated – 68.1 tons recovered = 386 tons textile waste disposed

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330 same assumptions as found in data for 1997

331 Franklin Associates. Working paper: Methodology for Characterization of Municipal Solid Waste in the United States: Table G-04 Unit Weight Conversion Factors for Apparel.

331 Assume equal to bottoms

332 Estimated Resident Population for States and Regions of the U.S., 1990-1998. op. cit.

333 Nutting, op. cit. Note: Population estimate for 1994 was not available, data so based on estimated population for 1995.

334 Ann Arbor Solid Waste Department estimates that only 15% of total textile waste in MSW stream is recovered.

335 City of Ann Arbor Department of Solid Waste, op. cit.

3. Percent of textiles in Ann Arbor MSW = tons textile waste ÷ total Ann Arbor waste disposed

   385.9 tons textile waste ÷ 39,775 tons Ann Arbor waste disposed[336] = 0.97% of Ann Arbor MSW is textile waste

Note: Based on the estimate that 15% of Ann Arbor textile waste is disposed, the percent of textile waste in MSW is much lower than EPA's estimate that textiles represent 4.4% of the waste stream. This may be due to a large diversion rate prior to MSW such as donations of clothing to secondhand stores, or the estimate of percent of textiles recovered from waste stream is too high.

Estimation 3: Characterization of mass of outflows

1. Outflow = generation - clothing resold within Ann Arbor

   = 2,315 tons - 80.5 tons 2,234 tons in outflow

2. Mass of clothing in MSW = outflow - given away by thrift stores - recovered for recycling

   = 2,234 tons - 234.5 tons - 68.1 tons = 1921 tons in MSW

[336] Ibid.

Appendix E: Transportation

This appendix provides supplementary information for the study completed on material flows associated with the transportation needs of Ann Arbor, which is presented in Section 4 of Chapter 4.

Data Sources

Michigan Department of State TR/9050 Reports

These reports are used as the primary source for data to estimate the stock, inflow, and outflow of vehicles.[337] Five TR/9050 reports were sent to the project team by the Michigan Department of State, each showing the number of vehicle registrations as of a particular date:

- October 1, 1996
- October 1, 1997
- October 1, 1998
- November 28, 1999
- April 7, 2000

The computer program used to generate the reports changed for both the 1999 and 2000 reports, so these reports cannot be used to accurately portray a time series with the 1996-1998 reports. The 1999 report is considered by the Michigan Department of State to contain errors and is therefore not used. The 2000 report is considered to be correct.

The TR/9050 reports show vehicle registrations for all individually owned vehicles and most corporate fleets. As will be discussed later, other types of vehicles such as those owned by government organizations are not included.

[337] All correspondence with the Michigan Department of State occurred through Liz Coin in the Office of Policy and Planning over the period July 1999 to April 2000.

The TR/9050 reports show counts of Michigan vehicle registrations grouped in several different ways:

- By model year (Example: Model Year 1998 Vehicles)
- By body style (Example: motor homes)
- By county (Example: Washtenaw County) - Total vehicle counts for each county are available in all five reports. The 1999 and 2000 reports also contain subtotals for each body type for each county.
- Registration type (Example: Blue Passenger registrations) - Totals vehicle counts for each registration type are shown in four ways: total Michigan registrations, grouped by model year, grouped by body type, and grouped by county.

The reports do not contain the following

- Changes in ownership: Vehicle registrations indicate the stock of vehicles in Michigan, but they do not show activity such as the transfer of ownership of used vehicles, new vehicle purchases, or vehicle retirement.
- Ann Arbor registrations: The Department of State has no way to view registration totals by any geographic level smaller than counties.
- Other model year groupings: Registrations grouped by model year are not available for each body type, nor are they available for Washtenaw County. This deficiency will become important in the estimating process used in this report.

Table E-1 shows notes provided by the Michigan Department of State on which vehicles are included in each body style.

Table E-1 TR/9050 Body Style Notes

Body Style	Includes
Ambulance	
Bus	Motor vehicle designed for carrying more than 15 passengers.
Convertible	
Dump	Dumpster-hoist, dump box, gravel truck, garbage
Hearse	
Motorcycle	Motor vehicle with not more than 3 wheels in contact with the ground which is not a moped.
Motor home	Vehicle constructed or altered to provide living quarters including permanently installed cooking and sleeping facilities and used for recreation, camping, or other non-commercial use.
Mixer	Cement truck, feed grinder, transit mixer
Panel	Sedan delivery
Pickup	A light duty truck with a low-sided open body
Roadster	Dune buggy
Stake	Box, grain, tilt bed, glass rack, cattle rack, flat bed, rack, pallet, platform, canopy, log bunk
Station wagon	Vehicle which has one or more seats behind the driver and 2 or more windows on each side.
Trailer coach	Coach, camper, travel trailer, tent camper, pop-up camper, camping trailer
Tank	Water spreader, tank fire truck, sprayer, bulk bumper, asphalt spreader, sludge truck, oiler, gas truck
Trailer	All trailers except "trailer coach"
Tractor	Truck tractor, road tractor, semi tractor
Utility	Boom truck, journeyman, tool, cable reel, service, tire body, camera, gas service, tree mover, winch, line, hi-ranger, crane, tree trimmer, splicer, armored car, trouble rig, tower truck, well driller, ladder truck
Van	Bakery, walk in, beverage, milk, cargo, step van, refrigerator, package, delivery, parcel delivery
Wrecker	Tow truck, flatbed wrecker, platform wrecker
Two door	Hardtop, 2-door jeep, coupe
Four door	Sedan, limousine, hardtop sedan
Unknown	

Table E-2 shows the registration types that appear in each TR/9050 report. The registration types for 1997 and 1998 are the ones used throughout this report's analysis. Great Lakes Splendor Graphic registrations were not yet available in 1996. Vanity and Commemorative registrations were split into subcategories in 1999 and 2000, but these subcategories are not used in this analysis.

Table E-2 TR/9050 Vehicle Registration Types

Registration Type	1996	1997 and 1998	1999 and 2000
Passenger	X	X	X
Commercial	X	X	X
Trailer	X	X	X
5Yr. Trailer	X	X	X
Motorcycle	X	X	X
Handicap	X	X	X
Vanity	X	X	
- V. Commercial			X
- V. Trailers			X
- V. Motorcycles			X
- V. Miscellaneous			X
ARO	X	X	X
Veteran	X	X	X
Organization	X	X	X
Historical	X	X	X
Commemorative	X	X	
- Passenger Commemorative			X
- Commercial Commemorative			X
Olympic	X	X	X
Great Lakes Splendor Graphic			
- GLSG Passenger		X	X
- GLSG Commercial		X	X
- GLSG Trailer		X	X
- GLSG Motorcycle		X	X

Other Vehicle Fleets

The TR/9040 includes personal vehicles and corporate fleets. Table E-3 shows comments provided by the Michigan Department of State to describe categories of vehicles that are not included in the TR/9050 reports.

Table E-3 Vehicles Not Included in TR/9050

Vehicles Not Included
▪ Municipal: includes vehicles owned by state, state institution, municipality, nonpublic, nonprofit college or university ▪ Non-Profit organization ▪ Manufacturer: issued to persons, firms, corporations, or associations which manufacture new motor vehicles, and is used for vehicles being transported or tested ▪ In-Transit: used by individual or association to move a vehicle for repair, service or to deliver a vehicle ▪ Repossession: used by the secured party only to move a repossessed vehicle to a place of impoundment or sale ▪ Special Farm: truck or road tractor used to transport farm crops, fertilizer, seed, etc., from the farm to the fields ▪ Special Mobil: examples - road construction or maintenance machinery, log splitters, mobile tool shed trailers ▪ Transporter: used to transport from a manufacturing, assembling, or distributing, plant to a dealer or sales agent.

Inflow and outflow estimates are included for the fleets listed below. Data were collected by interviews by phone and in person and by obtaining copies of internal reports from the fleet organization. These fleets were chosen as having a potentially large size and an identifiable point of contact for data collection.

- Ann Arbor Municipal City Government: All vehicles owned by the municipal city government, but not by county, state, or federal government agencies.
- Ann Arbor Transportation Authority (AATA): the local public transit organization serving Ann Arbor and Ypsilanti, a nearby city. AATA maintains a fleet of transit busses.
- University of Michigan: This University maintains a large fleet of vehicles for a variety of purposes.
- Huron Valley Ambulance (HVA): This organization maintains a fleet of ambulances to serve Ann Arbor and surrounding areas. All ambulances in the area are operated by HVA.
- School Busses: All school busses in Ann Arbor are operated by the Ann Arbor School District.

Other data such as the mass and economic value of various body types of vehicles were collected from a wide variety of sources listed later during the description of the estimation process.

Mass and Value Estimates

No single data source contains average mass and price for all vehicle types, so these data were collected from a variety of interviews and reports.

Maintenance Materials

Data on the mass of maintenance materials used during throughout the 11 year lifespan of a typical four door automobile were used as the basis for estimates for inflows and outflows of maintenance materials.[338] Price quotes for maintenance material prices were gathered through website of an online autoparts store.[339]

Assumptions

General Assumptions

- Ann Arbor residents never buy used vehicles from sources outside the community. Similarly, used vehicles are never sold to buyers outside the community. Another way to interpret this assumption is that the mass and economic value of used vehicles purchased from outside the community is roughly equal to the mass and economic value of used vehicles sold to other communities. Under this assumption there is no net effect on the stock of vehicles in Ann Arbor. An exception to this assumption is that the City of Ann Arbor purchases many of its vehicles used, and the lowered price for used vehicles paid by the City is used in this report.
- It is assumed that there are no immigrants or emigrants moving into or out of the community who are bringing in or removing vehicles. This assumption also implies that the population does not experience seasonal changes that would reduce the stock of vehicles. Given that many students leave Ann Arbor during the summer, it is likely that the stock of vehicles is reduced during these months. The most significant impact of this assumption is that the estimates of the use of maintenance materials is based upon the stock of vehicles in the community, so these estimates may be overstated.

TR/9050

- The proportion of model years for a particular registration type will remain constant for all body types under that registration type.
- All new vehicles purchased in 1997 had a model year of either 1997 or 1998, and all scrapped vehicles were from pre-1997 model years.
- The proportion of new and retired vehicles to the ending stock for a particular body type is the same for Michigan, Washtenaw County, and Ann Arbor.

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[338] Keoleian Gregory A., et al. LCI Modeling Challenges and Solutions for a Complex Product System: A Mid-Sized Automobile. Warrendale: Society of Automotive Engineers, Inc. 1998.

[339] Country Autoparts. County Lincoln Mercury Mazda Auto Parts. <http://www.countryautoparts.com/> 8 Mar. 2000.

- The number of vehicles of each body type per capita is the same in Washtenaw County and Ann Arbor.
- The ratio of Washtenaw to Michigan vehicles is the same in 1997 and 2000, even though the methods used to create the TR/9050 changed between the 1997 report and the 2000 report.

Other Vehicle Fleets

- The size of the fleet owned and operated by the City of Ann Arbor is the same in 2000 as it was in 1997.
- Half of all municipal vehicles sold at auction remain in the community, while the other half are sold to individuals and organizations outside of Ann Arbor.

Mass and Value Estimates

- For many body styles, the mass and retail price has not changed significantly between 1997 and 2000.

Maintenance Materials

- All vehicle body styles require the same average amount of maintenance materials per year as a four door automobile. For example, a vehicle with a shorter lifespan requires more maintenance materials during its lifespan so that the average per year remains constant.
- No unexpected accidents or breakdowns occur that would require replacement parts beyond normal maintenance. Parts such as engines, transmissions, alternators, and body panels never need to be replaced.
- Stocks of maintenance materials remain constant. Parts are brought into the community as they are needed, so the inflow of maintenance materials equals their use. When these maintenance materials are installed in a vehicle, they replace used materials that are removed from the vehicle and from the community as wastes or to be recycled. Therefore, the mass of outflows equals the mass of inflows for maintenance materials in any given year.

Detailed Estimation Process

The following sections each describe part of the process of estimating the mass and value of inflows and outflows related to mobility:

- TR/9050 Reports - Estimates the number of inflow vehicles and the number of outflow vehicles.
- Other Vehicle Fleets - Estimates the number of inflow vehicles and the number of outflow vehicles owned by organizations whose registrations do not appear in the TR/9050 reports (Ann Arbor City Government, University of Michigan, AATA, HVA, and Ann Arbor School District).
- Mass and Value Estimates - Applies unit mass and price for vehicles to estimate mass and value of inflows and outflows of vehicles.
- Maintenance Materials - Estimates the mass and value of inflows and outflows for maintenance materials based on the stock of vehicles in 1997.

TR/9050 Reports

Most vehicles in Michigan are represented in the TR/9050 reports. Data from these reports and further calculations are included in a series of ten tables (Table E-4 through Table E-13) to arrive at estimates for the inflow and outflow of vehicles. The estimation process will be described in detail below by stepping through each table in order. The data tables appear at the end of this section.

Overall Process

The goal of this process is to estimate the number of purchased vehicles and the number of retired vehicles in Ann Arbor in 1997. We have assumed that no used vehicles move in or out of Ann Arbor through immigration, emigration, or used car sales and purchases. Transferring ownership between individuals and organizations within Ann Arbor does not change the stock of vehicles in the community and do not count as inflows or outflows. Therefore, we estimate the inflow of vehicles based the purchase of new vehicles and estimate the outflow of vehicles based on the retiring of vehicles after they have completed their useful life.

Patterns of purchases and retirement can be different for each body style, so inflow and outflow vehicles will be estimated separately for each body style. The number of vehicles purchased and retired will be estimated based on the changes in the number of different model year vehicles from year to year. Model year totals for each body style are not available, so the first eight tables described below transform model year data grouped by registration type into estimates for each body style. These new and retired vehicle estimates for Michigan are adjusted to create an estimate for Washtenaw County and then for Ann Arbor.

Table E-4 1996 Registrations by Body Style and Registration Type
Table E-5 1997 Registrations by Body Style and Registration Type

Table E-4 and Table E-5 collect data from various parts of the TR/9050 reports. Specifically, they show the number of registrations of each body type for each registration type in 1996 and 1997.

Examples of TR/9050 Data in Table E-5

1.	Vans registered as handicap vehicles in 1997:	1,143
2.	Total vans registered in 1997:	159,136
3.	Total vehicles with handicap registrations in 1997:	63,677

Table E-6 Registrations by Model Year and Registration Type

Table E-1 shows the number of registrations for vehicles in 1996 and 1997 of various model years for each type of registration. In 1996, vehicles were of model year 1997 or of earlier years (called "pre-1997"). In 1996, vehicles were of model year 1998, 1997, or pre-1997.

Method

1. The registrations for 1997 and 1998 model year registrations and for the totals across all model years were taken directly from the TR/9050 reports.
2. Registrations for the pre-1997 model years were computed by subtracting 1997 and 1998 model year registrations from the total.

Calculation Example

1. Vehicles registered as handicap in 1997:

a. Model year 1997 vehicles:	4,286
b. Model year 1998 vehicles:	436
c. Total vehicles:	63,677

2. Vehicles registered as handicap in 1997 with model years before 1997:

   (total vehicles) – (model year 1997 vehicles) – (model year 1998 vehicles)

   63,677 – 4,286 – 436 = **58,955**

Table E-7 1996 Reg's for Pre-1997 Model Year Vehicles by Body Style & Reg Type
Table E-8 1996 Reg's for 1997 Model Year Vehicles by Body Style & Reg Type
Table E-9 1997 Reg's for Pre-1997 Model Year Vehicles by Body Style & Reg Type
Table E-10 1997 Reg's for 1997 Model Year Vehicles by Body Style & Reg Type
Table E-11 1997 Reg's for 1998 Model Year Vehicles by Body Style & Reg Type

These five tables combine the data from Table E-4, Table E-5, and Table E-6 to estimate registrations in 1997 and 1998 broken out by model year, body style, and registration type. These estimates assume that the proportion of model years for a particular registration type will be the same for all body styles. These detailed estimates are then totaled for each body style to get an estimate of registrations in a particular year (1996 or 1997) for a particular model year (Pre-1997, 1997, or 1998) for each body style.

Method for each Data Point

1. Find the appropriate number of registrations in Table E-6 (registrations for a particular model year and registration type).
2. Divide the number of vehicles of the specific body style in Table E-4 or Table E-5 by the total across all body styles for that registration type.
3. Multiply the ratio from step 2 by the registrations from step 1.

Calculation Example

To estimate Pre-1997 model year vans registered as handicap vehicles in 1997 as shown in Table E-9:

1. Pre-1997 model year handicap registrations in 1997 (Table E-6): 58,955
2. a. Vans registered as handicap vehicles in 1997 (Table E-5): 1,143

   b. Total handicap vehicles in 1997 (Table E-5): 63,677
3. Pre-1997 model year vans registered as handicap vehicles in 1997

   (Pre-1997 handicap regs in 1997) * (ratio of vans to total handicap regs in 1997)

   58,955 * (1,143 / 63,677) = **1,058**

Method for Total Registrations by Body Style

1. Repeat the method described above for all registrations for the particular body style.
2. Total these estimates to get an estimate for total registrations for that body style for the given calendar year and model year.

Calculation Example

To estimate pre-1997 model year van registrations in 1997 as shown in Table E-9:

1. Repeat the method describe above for all registration types:

a. Commercial registration type	119,758
b. Handicap registration type	1,058
c. Vanity registration type	674
d. ARO registration type	53
e. Veteran registration type	499
f. Organization registration type	67
g. Historical registration type	65
h. Commemorative registration type	11,098
i. Olympic registration type	72
j. GLSG Commercial registration type	9,991

2. Pre-1997 model year vans registered in 1997 equals the sum of pre-1997 model year vans in 1997 for each registration type.

   119,758 + 1,058 + 674 + 53 + 499 + 67 + 65 + 11,098 + 72 + 9,991 = **143,334**

Table E-12 1997 New and Retired Vehicle Estimates for Michigan by Body Style

The first two sections of this report, "Model Year Stocks in 1996" and "Model Year Stocks in 1997" are simply a summary of totals taken from Table E-7 through Table E-11. The inflow (new) and outflow (retired) vehicles for 1997 are then estimated using two assumptions; all new vehicles purchased in 1997 had a model year of either 1997 or 1998, and all retired vehicles were from pre-1997 model years. The calculation for scrapped vehicles is also based on the observation that the total registrations in 1997 equal the registrations in 1996 plus new vehicles in 1997 minus scrapped vehicles in 1997.

Method

1. Estimates for the number of new vehicles for each body style:

   new = 1998 model year vehicles registered in 1997
   + 1997 model year vehicles registered in 1997
   - 1997 model year vehicles registered in 1996

2. Estimates for the number of retired vehicles for each body style:

   retired = 1996 total vehicles
   + new vehicles in 1997 (estimated above)
   - 1997 total vehicles

3. "1997 Stock Ratios" are calculated by dividing the new and retired vehicle estimates for each body style by the estimates for total new and retired vehicles. These are calculated for later use in Table E-13.

Calculation Examples

To estimate new and retired vans in 1997:

1. a. Pre-1997 model year vans in 1996 (Table E-7)	154,448
b. 1997 model year vans in 1996 (Table E-8)	2,560
c. Total vans registered in 1996 (Table E-4)	157,008
2. a. Pre-1997 model year vans in 1997 (Table E-9)	143,334
b. 1997 model year vans in 1997 (Table E-10)	14,134
c. 1998 model year vans in 1997 (Table E-11)	1,668
d. Total vans registered in 1997 (Table E-5)	159,136

3. New vans in 1997

   (1998 model year vans in 1997) + (1997 model year vans in 1997) – (1997 model year vans in 1996)

1,668 + 14,134 – 2,560 = **13,241.5**

4. Retired vans in 1997

   (total vans in 1996) + (new vans in 1997) – (1997 total vans)

   157,008 + 13,241.5 – 159,136 = **11,113.5**

5. Total new and retired vehicles are calculated by summing individual estimates for new and retired vehicles for each body style:

   a. Total new vehicles in 1997 (summed in Table E-12) 755,444

   b. Total retired vehicles in 1997 (summed in Table E-12) 643,365

6. New 1997 stock ratio for vans

   (new vans in 1997) / (total new vehicles in 1997)

   13,241.5 / 755,444 = **.083**

7. Retired 1997 stock ratio for vans

   (retired vans in 1997) / (total retired vehicles in 1997)

   11,113.5 / 643,365 = **.070**

Note that two of the retired estimates in Table E-12 are negative. For utility vehicles, this probably means that more used (pre-1997) utility vehicles were purchased than were retired, violating our assumption that no used vehicles are purchased from outside the community. For unknown vehicles, this probably just means that several vehicles were registered as unknown that previously had been registered under another body type. In all future calculations, these negative retired vehicles are counted as additional new vehicles and added to the new vehicle estimates. This makes sense because a negative retired vehicle means that a vehicle with an older model year was registered for the first time in Michigan and is essentially a new vehicle. Because the negative retired vehicles have been reclassified as new vehicles, the retired vehicle estimates are adjusted to zero for these two body types in future calculations.

Table E-13 1997 Washtenaw and Ann Arbor New and Retired Vehicle Estimates

This table estimates the number of vehicles of each body style registered in Ann Arbor in 1997 and the number of vehicles of each body style purchased and retired in Ann Arbor in 1997.

Method

1. The first section of this report shows Michigan and Washtenaw County registrations for each body type as shown in the TR/9050 report for April 7, 2000.
2. The "% of State" computes the proportion of Michigan vehicles in Washtenaw County for each body type.
3. In the next section, the "Michigan" column shows the total Michigan registrations in 1997 for each body type as reported in the TR/9050.
4. The "Washtenaw" column multiplies each Michigan registration number by the "% of State" for that body type to estimate the registrations in Washtenaw County in 1997 for each body type.
5. To estimate the number of new and scrapped vehicles in Washtenaw County, the Washtenaw stock estimates are multiplied by the 1997 stock ratios for Michigan calculated in Table E-12.
6. Finally, the "Ann Arbor" section estimates the stock, new, and scrapped vehicles for Ann Arbor in 1997 by dividing each Washtenaw County estimate by the population of the county and multiplying by the population of the City of Ann Arbor.

Calculation Example

To estimate stock, new, and retired vans in 1997 in Ann Arbor:

1. a. Vans registered in Michigan in 2000 (from TR/9050) 154,236

   b. Vans registered in Washtenaw County in 2000 (from TR/9050) 3,406
2. Percent of state = Washtenaw vans in 2000 / Michigan vans in 2000

   3,406 / 154,236 = 2.2%
3. Vans registered in Michigan in 1997 (from TR/9050) 159,136

4. Vans registered in Washtenaw County in 1997

   Michigan vans in 1997 * % of state for vans

   159,136 * 2.2% = 3,514.2

5. New vans in Washtenaw County in 1997

   1997 Washtenaw County vans * New 1997 Stock Ratio (from Table E-12)

   159,136 * .083 = 292.4

6. Retired vans in Washtenaw County in 1997

   1997 Washtenaw County vans * Retired 1997 Stock Ratio (from Table E-12)

   159,136 * .070 = 245.4

7. a. Washtenaw County 1997 population 300,805

   b. City of Ann Arbor 1997 population 107,604

8. 1997 stock of vans in Ann Arbor

   1997 stock of vans in Washtenaw * Ann Arbor population / Washtenaw population

   3,514.2 *107,604 / 300,805 = **1,257.10**

9. 1997 new vans in Ann Arbor

   1997 new vans in Washtenaw * Ann Arbor population / Washtenaw population

   292.4 *107,604 / 300,805 = **104.60**

10. 1997 retired vans in Ann Arbor

    1997 retired vans in Washtenaw * Ann Arbor population / Washtenaw population

    245.4 *107,604 / 300,805 = **87.79**

Table E-4 1996 Registrations by Body Style and Registration Type

Body Style	Passenger	Commercial	Trailer	5Yr. Trailer	Motorcycle	Handicap	Vanity	ARO	Veteran	Organization	Historical	Commemorative	Olympic	Total
Ambulance		369									8			377
Bus	536	2,379				22	11				22	60		3,030
Convertible	36,811	81				155	2,808	22	204	70	1,649	14,673	72	56,545
Dump		20,883									18			20,901
Hearse		592					5				3			600
Motorcycle					118,709		1,719				267			120,695
Motor Home	40,792	82				525	318	48	426	71	44	11,172	19	53,497
Mixer		2,510												2,510
Panel		334									25			359
Pickup		931,172				5,526	6,767	1,169	10,617	1,768	948	250,784	617	1,209,368
Roadster	2,528	16				9	225	2	10	1	318	834		3,943
Stake		35,762									139			35,901
Station Wagon	899,429	8,529				11,745	9,509	1,502	8,193	1,585	151	313,707	1,521	1,255,871
Trailer Coach			157,419				43				8			157,470
Tank		3,800									97			3,897
Trailer			792,529	18,095			48				2			810,674
Tractor		46,163									21			46,184
Utility		14,881									63			14,944
Van		138,336				988	597	66	459	74	27	16,385	76	157,008
Wrecker		6,361									9			6,370
Two Door	1,147,418	1,794				5,929	22,204	724	5,924	989	5,056	380,289	1,338	1,571,665
Four Door	1,990,778	6,735				27,051	18,868	2,276	13,905	1,932	2,024	663,107	2,399	2,729,075
Unknown	9	31	3	1	4							15		63
Total	4,118,301	1,220,810	949,951	18,096	118,713	51,950	63,122	5,809	39,738	6,490	10,899	1,651,026	6,042	8,260,947

Table E-5 1997 Registrations by Body Style and Registration Type

Body Style	Passenger	Commercial	Trailer	5Yr. Trailer	Motorcycle	Handicap	Vanity	ARO	Veteran	Organization	Historical	Commemorative	Olympic	GLSG Passenger	GLSG Commercial	GLSG Trailer	GLSG Motorcycle	Total
Ambulance		364									7				10			381
Bus	491	2,455				29	18				31	40		39	53			3,156
Convertible	32,653	72				231	3,437	22	275	74	3,391	10,827	80	10,801	26			61,889
Dump		21,515									42				38			21,595
Hearse		520					7				6				69			602
Motorcycle					104,655		2,330				612						18,885	126,482
Motor Home	34,927	62				622	431	46	544	74	150	8,167	15	7,668	13			52,719
Mixer		2,635									1							2,636
Panel		321									36				15			372
Pickup		850,204				7,088	9,498	1,217	13,154	1,966	2,102	202,723	581		167,785			1,256,318
Roadster	2,180	14				12	267	2	11	3	526	553		570				4,138
Stake		35,368									287				315			35,970
Station Wagon	802,024	8,469				14,842	13,755	1,571	10,454	1,818	324	262,180	1,568	228,904	1,405			1,347,314
Trailer Coach			149,441				81				18					11,838		161,378
Tank		3,800									193				2			3,995
Trailer			787,052	11,148			97				8					2,444		800,749
Tractor		46,493									32				1			46,526
Utility		16,492									116				74			16,682
Van		132,426				1,143	772	59	551	77	65	12,204	82		11,757			159,136
Wrecker		6,455									19							6,474
Two Door	919,469	1,518				6,773	26,346	687	6,684	1,003	10,772	263,178	1,199	252,895	384			1,490,908
Four Door	1,710,021	6,096				32,929	24,412	2,243	17,432	2,027	3,625	534,729	2,334	436,575	986			2,773,409
Unknown	11	33	6			8						2		135		1	1	197
Total	3,501,776	1,135,312	936,499	11,148	104,655	63,677	81,451	5,847	49,105	7,042	22,363	1,294,603	5,859	937,587	182,933	14,283	18,886	8,373,026

Table E-6 Registrations by Model Year and Registration Type

	Model Year	Passenger	Commercial	Trailer	5Yr. Trailer	Motorcycle	Handicap	Vanity	ARO	Veteran	Organization	Historical	Commemorative	Olympic	GLSG Passenger	GLSG Commercial	GLSG Trailer	GLSG Motorcycle	Total
In 1996	Pre-1997	4,054,377	1,200,830	944,774	18,096	117,750	51,493	62,208	5,739	39,229	6,362	10,899	1,623,872	5,937					8,141,566
	1997	63,924	19,980	5,177	-	963	457	914	70	509	128	-	27,154	105					119,381
	Total	4,118,301	1,220,810	949,951	18,096	118,713	51,950	63,122	5,809	39,738	6,490	10,899	1,651,026	6,042					8,260,947
In 1997	Pre-1997	3,097,977	1,026,709	877,032	10,627	97,439	58,955	71,093	5,296	44,431	6,088	22,363	1,177,263	5,119	811,788	155,453	12,818	17,750	7,498,201
	1997	349,831	96,968	53,882	443	6,405	4,286	9,334	489	4,223	846	-	102,447	658	112,426	25,228	1,239	984	769,689
	1998	53,968	11,635	5,585	78	811	436	1,024	62	451	108	-	14,893	82	13,373	2,252	226	152	105,136
	Total	3,501,776	1,135,312	936,499	11,148	104,655	63,677	81,451	5,847	49,105	7,042	22,363	1,294,603	5,859	937,587	182,933	14,283	18,886	8,373,026

Table E-7 1996 Registrations for Pre-1997 Model Year Vehicles by Body Style and Registration Type

Body Style	Passenger	Commercial	Trailer	5Yr. Trailer	Motorcycle	Handicap	Vanity	ARO	Veteran	Organization	Historical	Commemorative	Olympic	Total
Ambulance	-	363	-	-	-	-	-	-	-	-	8	-	-	371
Bus	528	2,340	-	-	-	22	11	-	-	-	22	59	-	2,981
Convertible	36,240	80	-	-	-	154	2,767	22	201	69	1,649	14,432	71	55,683
Dump	-	20,541	-	-	-	-	-	-	-	-	18	-	-	20,559
Hearse	-	582	-	-	-	-	5	-	-	-	3	-	-	590
Motorcycle	-	-	-	-	117,746	-	1,694	-	-	-	267	-	-	119,707
Motor Home	40,159	81	-	-	-	520	313	47	421	70	44	10,988	19	52,662
Mixer	-	2,469	-	-	-	-	-	-	-	-	-	-	-	2,469
Panel	-	329	-	-	-	-	-	-	-	-	25	-	-	354
Pickup	-	915,932	-	-	-	5,477	6,669	1,155	10,481	1,733	948	246,659	606	1,189,661
Roadster	2,489	16	-	-	-	9	222	2	10	1	318	820	-	3,886
Stake	-	35,177	-	-	-	-	-	-	-	-	139	-	-	35,316
Station Wagon	885,468	8,389	-	-	-	11,642	9,371	1,484	8,088	1,554	151	308,548	1,495	1,236,189
Trailer Coach	-	-	156,561	-	-	-	42	-	-	-	8	-	-	156,611
Tank	-	3,738	-	-	-	-	-	-	-	-	97	-	-	3,835
Trailer	-	-	788,210	18,095	-	-	47	-	-	-	2	-	-	806,354
Tractor	-	45,407	-	-	-	-	-	-	-	-	21	-	-	45,428
Utility	-	14,637	-	-	-	-	-	-	-	-	63	-	-	14,700
Van	-	136,072	-	-	-	979	588	65	453	73	27	16,116	75	154,448
Wrecker	-	6,257	-	-	-	-	-	-	-	-	9	-	-	6,266
Two Door	1,129,608	1,765	-	-	-	5,877	21,882	715	5,848	969	5,056	374,034	1,315	1,547,070
Four Door	1,959,877	6,625	-	-	-	26,813	18,595	2,249	13,727	1,894	2,024	652,201	2,357	2,686,362
Unknown	9	30	3	1	4	-	-	-	-	-	-	15	-	62
Total	4,054,377	1,200,830	944,774	18,096	117,750	51,493	62,208	5,739	39,229	6,362	10,899	1,623,872	5,937	8,141,566

Table E-8 1996 Registrations for 1997 Model Year Vehicles by Body Style and Registration Type

Body Style	Passenger	Commercial	Trailer	5Yr. Trailer	Motorcycle	Handicap	Vanity	ARO	Veteran	Organization	Historical	Commemorative	Olympic	Total
Ambulance	-	6	-	-	-	-	-	-	-	-	-	-	-	6
Bus	8	39	-	-	-	0	0	-	-	-	-	1	-	49
Convertible	571	1	-	-	-	1	41	0	3	1	-	241	1	862
Dump	-	342	-	-	-	-	-	-	-	-	-	-	-	342
Hearse	-	10	-	-	-	-	0	-	-	-	-	-	-	10
Motorcycle	-	-	-	-	963	-	25	-	-	-	-	-	-	988
Motor Home	633	1	-	-	-	5	5	1	5	1	-	184	0	835
Mixer	-	41	-	-	-	-	-	-	-	-	-	-	-	41
Panel	-	5	-	-	-	-	-	-	-	-	-	-	-	5
Pickup	-	15,240	-	-	-	49	98	14	136	35	-	4,125	11	19,707
Roadster	39	0	-	-	-	0	3	0	0	0	-	14	-	57
Stake	-	585	-	-	-	-	-	-	-	-	-	-	-	585
Station Wagon	13,961	140	-	-	-	103	138	18	105	31	-	5,159	26	19,682
Trailer Coach	-	-	858	-	-	-	1	-	-	-	-	-	-	859
Tank	-	62	-	-	-	-	-	-	-	-	-	-	-	62
Trailer	-	-	4,319	-	-	-	1	-	-	-	-	-	-	4,320
Tractor	-	756	-	-	-	-	-	-	-	-	-	-	-	756
Utility	-	244	-	-	-	-	-	-	-	-	-	-	-	244
Van	-	2,264	-	-	-	9	9	1	6	1	-	269	1	2,560
Wrecker	-	104	-	-	-	-	-	-	-	-	-	-	-	104
Two Door	17,810	29	-	-	-	52	322	9	76	20	-	6,255	23	24,595
Four Door	30,901	110	-	-	-	238	273	27	178	38	-	10,906	42	42,713
Unknown	0	1	0	-	0	-	-	-	-	-	-	0	-	1
Total	63,924	19,980	5,177	-	963	457	914	70	509	128	-	27,154	105	119,381

Table E-9 1997 Registrations for Pre-1997 Model Year Vehicles by Body Style and Registrations Type

Body Style	Passenger	Commercial	Trailer	5Yr. Trailer	Motorcycle	Handicap	Vanity	ARO	Veteran	Organization	Historical	Commemorative	Olympic	GLSG Passenger	GLSG Commercial	GLSG Trailer	GLSG Motorcycle	Total
Ambulance	-	329	-	-	-	-	-	-	-	-	7	-	-	-	8	-	-	345
Bus	434	2,220	-	-	-	27	16	-	-	-	31	36	-	34	45	-	-	2,843
Convertible	28,888	65	-	-	-	214	3,000	20	249	64	3,391	9,846	70	9,352	22	-	-	55,180
Dump	-	19,457	-	-	-	-	-	-	-	-	42	-	-	-	32	-	-	19,531
Hearse	-	470	-	-	-	-	6	-	-	-	6	-	-	-	59	-	-	541
Motorcycle	-	-	-	-	97,439	-	2,034	-	-	-	612	-	-	-	-	-	17,749	117,834
Motor Home	30,899	56	-	-	-	576	376	42	492	64	150	7,427	13	6,639	11	-	-	46,746
Mixer	-	2,383	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	2,384
Panel	-	290	-	-	-	-	-	-	-	-	36	-	-	-	13	-	-	339
Pickup	-	768,874	-	-	-	6,562	8,290	1,102	11,902	1,700	2,102	184,349	508	-	142,581	-	-	1,127,969
Roadster	1,929	13	-	-	-	11	233	2	10	3	526	503	-	494	-	-	-	3,722
Stake	-	31,985	-	-	-	-	-	-	-	-	287	-	-	-	268	-	-	32,539
Station Wagon	709,541	7,659	-	-	-	13,741	12,006	1,423	9,459	1,572	324	238,417	1,370	198,191	1,194	-	-	1,194,896
Trailer Coach	-	-	139,952	-	-	-	71	-	-	-	18	-	-	-	-	10,624	-	150,664
Tank	-	3,436	-	-	-	-	-	-	-	-	193	-	-	-	2	-	-	3,631
Trailer	-	-	737,075	10,627	-	-	85	-	-	-	8	-	-	-	-	2,193	-	749,988
Tractor	-	42,046	-	-	-	-	-	-	-	-	32	-	-	-	1	-	-	42,078
Utility	-	14,914	-	-	-	-	-	-	-	-	116	-	-	-	63	-	-	15,093
Van	-	119,758	-	-	-	1,058	674	53	499	67	65	11,098	72	-	9,991	-	-	143,334
Wrecker	-	5,838	-	-	-	-	-	-	-	-	19	-	-	-	-	-	-	5,857
Two Door	813,443	1,373	-	-	-	6,271	22,996	622	6,048	867	10,772	239,324	1,048	218,963	326	-	-	1,322,052
Four Door	1,512,834	5,513	-	-	-	30,487	21,308	2,032	15,773	1,752	3,625	486,262	2,039	377,998	838	-	-	2,460,461
Unknown	10	30	6	-	-	7	-	-	-	-	-	2	-	117	-	1	1	173
Total	3,097,977	1,026,709	877,032	10,627	97,439	58,955	71,093	5,296	44,431	6,088	22,363	1,177,263	5,119	811,788	155,453	12,818	17,750	7,498,201

Table E-10 1997 Registrations for 1997 Model Year Vehicles by Body Style and Registration Type

Body Style	Passenger	Commercial	Trailer	5Yr. Trailer	Motorcycle	Handicap	Vanity	ARO	Veteran	Organization	Historical	Commemorative	Olympic	GLSG Passenger	GLSG Commercial	GLSG Trailer	GLSG Motorcycle	Total
Ambulance	-	31	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	32
Bus	49	210	-	-	-	2	2	-	-	-	-	3	-	5	7	-	-	278
Convertible	3,262	6	-	-	-	16	394	2	24	9	-	857	9	1,295	4	-	-	5,877
Dump	-	1,838	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	1,843
Hearse	-	44	-	-	-	-	1	-	-	-	-	-	-	-	10	-	-	55
Motorcycle	-	-	-	-	6,405	-	267	-	-	-	-	-	-	-	-	-	984	7,656
Motor Home	3,489	5	-	-	-	42	49	4	47	9	-	646	2	919	2	-	-	5,215
Mixer	-	225	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	225
Panel	-	27	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	29
Pickup	-	72,617	-	-	-	477	1,088	102	1,131	236	-	16,042	65	-	23,139	-	-	114,898
Roadster	218	1	-	-	-	1	31	0	1	0	-	44	-	68	-	-	-	364
Stake	-	3,021	-	-	-	-	-	-	-	-	-	-	-	-	43	-	-	3,064
Station Wagon	80,123	723	-	-	-	999	1,576	131	899	218	-	20,747	176	27,448	194	-	-	133,236
Trailer Coach	-	-	8,598	-	-	-	9	-	-	-	-	-	-	-	-	1,027	-	9,634
Tank	-	325	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	325
Trailer	-	-	45,283	443	-	-	11	-	-	-	-	-	-	-	-	212	-	45,950
Tractor	-	3,971	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	3,971
Utility	-	1,409	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	1,419
Van	-	11,311	-	-	-	77	88	5	47	9	-	966	9	-	1,621	-	-	14,134
Wrecker	-	551	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	551
Two Door	91,856	130	-	-	-	456	3,019	57	575	120	-	20,826	135	30,325	53	-	-	147,552
Four Door	170,833	521	-	-	-	2,216	2,798	188	1,499	244	-	42,315	262	52,350	136	-	-	273,361
Unknown	1	3	0	-	-	1	-	-	-	-	-	0	-	16	-	0	0	21
Total	349,831	96,968	53,882	443	6,405	4,286	9,334	489	4,223	846	-	102,447	658	112,426	25,228	1,239	984	769,689

Table E-11 1997 Registrations for 1998 Model Year Vehicle by Body Style and Registration Type

Body Style	Passenger	Commercial	Trailer	5Yr. Trailer	Motorcycle	Handicap	Vanity	ARO	Veteran	Organization	Historical	Commemorative	Olympic	GLSG Passenger	GLSG Commercial	GLSG Trailer	GLSG Motorcycle	Total
Ambulance	-	4	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	4
Bus	8	25	-	-	-	0	0	-	-	-	-	0	-	1	1	-	-	35
Convertible	503	1	-	-	-	2	43	0	3	1	-	125	1	154	0	-	-	833
Dump	-	220	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	221
Hearse	-	5	-	-	-	-	0	-	-	-	-	-	-	-	1	-	-	6
Motorcycle	-	-	-	-	811	-	29	-	-	-	-	-	-	-	-	-	152	992
Motor Home	538	1	-	-	-	4	5	0	5	1	-	94	0	109	0	-	-	759
Mixer	-	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27
Panel	-	3	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	3
Pickup	-	8,713	-	-	-	49	119	13	121	30	-	2,332	8	-	2,066	-	-	13,451
Roadster	34	0	-	-	-	0	3	0	0	0	-	6	-	8	-	-	-	52
Stake	-	362	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	366
Station Wagon	12,360	87	-	-	-	102	173	17	96	28	-	3,016	22	3,265	17	-	-	19,183
Trailer Coach	-	-	891	-	-	-	1	-	-	-	-	-	-	-	-	187	-	1,080
Tank	-	39	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	39
Trailer	-	-	4,694	78	-	-	1	-	-	-	-	-	-	-	-	39	-	4,812
Tractor	-	476	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	476
Utility	-	169	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	170
Van	-	1,357	-	-	-	8	10	1	5	1	-	140	1	-	145	-	-	1,668
Wrecker	-	66	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	66
Two Door	14,170	16	-	-	-	46	331	7	61	15	-	3,028	17	3,607	5	-	-	21,304
Four Door	26,354	62	-	-	-	225	307	24	160	31	-	6,151	33	6,227	12	-	-	39,587
Unknown	0	0	0	-	-	0	-	-	-	-	-	0	-	2	-	0	0	3
Total	53,968	11,635	5,585	78	811	436	1,024	62	451	108	-	14,893	82	13,373	2,252	226	152	105,136

Table E-12 1997 New and Retired Vehicle Estimates for Michigan by Body Style

	Model Year Stocks In 1996			Model Year Stocks in 1997				1997 Inflow and Outflow		1997 Stock Ratios	
Body Style	Pre-1997	1997	Total	Pre-1997	1997	1998	Total	New	Retired	New	Retired
Ambulance	371.0	6.0	377	344.7	32.5	3.9	381	30.3	26.3	0.079	0.069
Bus	2,981.4	48.6	3,030	2,843.3	277.9	34.8	3,156	264.1	138.1	0.084	0.044
Convertible	55,683.4	861.6	56,545	55,179.8	5,876.5	832.7	61,889	5,847.7	503.7	0.094	0.008
Dump	20,559.2	341.8	20,901	19,531.2	1,842.9	221.0	21,595	1,722.0	1,028.0	0.080	0.048
Hearse	590.2	9.8	600	541.0	54.7	6.3	602	51.2	49.2	0.085	0.082
Motorcycle	119,707.1	987.9	120,695	117,833.8	7,656.0	992.3	126,482	7,660.4	1,873.4	0.061	0.015
Motor Home	52,661.8	835.2	53,497	46,745.5	5,214.5	758.9	52,719	5,138.2	5,916.2	0.097	0.112
Mixer	2,468.9	41.1	2,510	2,383.9	225.1	27.0	2,636	211.0	85.0	0.080	0.032
Panel	353.5	5.5	359	339.0	29.5	3.5	372	27.5	14.5	0.074	0.039
Pickup	1,189,661.4	19,706.6	1,209,368	1,127,969.4	114,897.9	13,450.7	1,256,318	108,642.0	61,692.0	0.086	0.049
Roadster	3,886.3	56.7	3,943	3,722.2	364.0	51.8	4,138	359.1	164.1	0.087	0.040
Stake	35,315.7	585.3	35,901	32,539.4	3,064.3	366.3	35,970	2,845.3	2,776.3	0.079	0.077
Station Wagon	1,236,189.3	19,681.7	1,255,871	1,194,895.9	133,235.5	19,182.6	1,347,314	132,736.5	41,293.5	0.099	0.031
Trailer Coach	156,611.5	858.5	157,470	150,664.1	9,634.4	1,079.6	161,378	9,855.4	5,947.4	0.061	0.037
Tank	3,834.8	62.2	3,897	3,631.2	324.8	39.0	3,995	301.6	203.6	0.075	0.051
Trailer	806,354.2	4,319.8	810,674	749,987.8	45,949.6	4,811.6	800,749	46,441.5	56,366.5	0.058	0.070
Tractor	45,428.5	755.5	46,184	42,078.4	3,971.1	476.5	46,526	3,692.1	3,350.1	0.079	0.072
Utility	14,700.5	243.5	14,944	15,093.3	1,418.8	169.9	16,682	1,345.2	(392.8)	0.081	(0.024)
Van	154,447.7	2,560.3	157,008	143,334.2	14,133.9	1,667.8	159,136	13,241.5	11,113.5	0.083	0.070
Wrecker	6,265.9	104.1	6,370	5,856.5	551.3	66.2	6,474	513.4	409.4	0.079	0.063
Two Door	1,547,069.9	24,595.1	1,571,665	1,322,052.2	147,551.9	21,303.9	1,490,908	144,260.7	225,017.7	0.097	0.151
Four Door	2,686,361.6	42,713.4	2,729,075	2,460,461.1	273,360.7	39,587.2	2,773,409	270,234.5	225,900.5	0.097	0.081
Unknown	62.1	0.9	63	173.1	21.3	2.6	197	22.9	(111.1)	0.116	(0.564)
Total	8,141,566.0	119,381.0	8,260,947	7,498,201.0	769,689.0	105,136.0	8,373,026	755,444.0	643,365.0	0.090	0.077

Table E-13 1997 Washtenaw and Ann Arbor New and Retired Vehicle Estimates

	2000			1997				Ann Arbor		
Body Style	Michigan	Wastenaw	% of State	Michigan	Wastenaw	New	Retired	Stock	New	Retired
Ambulance	354	1	0.3%	381	1.1	0.1	0.1	0.39	0.03	0.03
Bus	3,111	55	1.8%	3,156	55.8	4.7	2.4	19.96	1.67	0.87
Convertible	64,308	1,963	3.1%	61,889	1,889.2	178.5	15.4	675.79	63.85	5.50
Dump	18,177	549	3.0%	21,595	652.2	52.0	31.0	233.32	18.61	11.11
Hearse	561	11	2.0%	602	11.8	1.0	1.0	4.22	0.36	0.35
Motorcycle	86,247	2,691	3.1%	126,482	3,946.4	239.0	58.5	1,411.70	85.50	20.91
Motor Home	43,631	1,024	2.3%	52,719	1,237.3	120.6	138.9	442.60	43.14	49.67
Mixer	2,454	31	1.3%	2,636	33.3	2.7	1.1	11.91	0.95	0.38
Panel	374	8	2.1%	372	8.0	0.6	0.3	2.85	0.21	0.11
Pickup	1,402,887	32,125	2.3%	1,256,318	28,768.7	2,487.8	1,412.7	10,291.14	889.94	505.35
Roadster	3,543	156	4.4%	4,138	182.2	15.8	7.2	65.18	5.66	2.58
Stake	29,359	716	2.4%	35,970	877.2	69.4	67.7	313.80	24.82	24.22
Station Wagon	1,573,020	48,309	3.1%	1,347,314	41,377.3	4,076.5	1,268.2	14,801.51	1,458.23	453.65
Trailer Coach	143,324	2,678	1.9%	161,378	3,015.3	184.1	111.1	1,078.65	65.87	39.75
Tank	3,721	92	2.5%	3,995	98.8	7.5	5.0	35.33	2.67	1.80
Trailer	725,836	15,087	2.1%	800,749	16,644.1	965.3	1,171.6	5,953.94	345.31	419.11
Tractor	46,757	675	1.4%	46,526	671.7	53.3	48.4	240.27	19.07	17.30
Utility	17,112	226	1.3%	16,682	220.3	23.0	-	78.81	8.21	-
Van	154,236	3,406	2.2%	159,136	3,514.2	292.4	245.4	1,257.10	104.60	87.79
Wrecker	5,717	157	2.7%	6,474	177.8	14.1	11.2	63.60	5.04	4.02
Two Door	1,256,630	40,093	3.2%	1,490,908	47,567.7	4,602.7	7,179.2	17,015.92	1,646.47	2,568.15
Four Door	2,833,890	89,257	3.1%	2,773,409	87,352.1	8,511.4	7,115.0	31,247.59	3,044.69	2,545.19
Unknown	73	2	2.7%	197	5.4	3.7	-	1.93	1.31	-
Total	8,415,322	239,312		8,373,026	238,307.8	21,906.0	18,891.4	85,247.5	7,836.2	6,757.8

Other Vehicle Fleets

In this section, estimates are developed for vehicle fleets not included in the TR/9050 reports.

Ann Arbor City Government

Inflow – New Purchases

The Water Utilities Department and Parks and Recreation Department of the City of Ann Arbor municipal government purchase their own vehicles. The Fleet Services Division of the Public Services Department purchases vehicles for all other departments. 1997 vehicle purchases data for Fleet Services purchases were available, but not for the Utilities and Parks Departments.

Method for Fleet Services Inflow

1. Group purchased vehicles by their unit price and count the number of vehicles purchased for each grouping.
2. Multiply the unit price by the number of vehicles to estimate total expenditures for purchased vehicles.
3. Assign each vehicle to one of the body styles used by the TR/9050 report and count total vehicles for each body style.

Calculations

1. Table E-14 shows the vehicles purchased by Fleet Services in 1997.[340]
2. The vehicles have been grouped into nine groups because the vehicles in each group share a common price per vehicle.
3. Calculate the total budgeted for each grouping. For example, for the total budgeted for vans is (# vans purchased) * (unit price for vans).

   2 * $17,500 =$35,000

4. Add together the total budgeted for each grouping to estimate total budgeted for all vehicles as shown in the table.

[340] Fleet Services Equipment Purchases 1996-97. Ann Arbor Public Services Department. Fleet Services Division. 4 May 2000.

5. These vehicles have also been grouped by the TR/9050 body styles with total vehicles purchased for each listed in Table E-14 under "Total Purchased."

Table E-14 Ann Arbor Fleet Services 1997 Vehicle Purchases

Vehicle Description	# Purch.	Unit Price	Total Budgeted	Body Style	Total Purchased
Ford Dump	1	$ 58,000	$ 58,000	Dump	2
Ford 1-Ton Dump	1	$ 26,800	$ 26,800		
GMC/Ford Pickup	4	$ 14,500	$ 58,000	Pickup	4
General Tractor	1	$ 87,000	$ 87,000	Tractor	1
GMC Aerial Truck	1	$ 80,000	$ 80,000	Utility	1
Ford Van	2	$ 17,500	$ 35,000	Van	2
Patrol Car	12	$ 21,000	$ 252,000	Four Door	20
Detective Car	4	$ 16,000	$ 64,000		
Dodge Omni	4	$ 12,500	$ 50,000		
Total			**$ 710,800**	**Total**	**30**

Method for Water Utilities and Parks and Recreation Inflow

1. Categorize the stock of Fleet Services, Utilities, and Parks vehicles into the TR/9050 body styles.
2. Using the relationship between the number of Fleet Services stock vehicles and purchased for each body style as a guide, estimate the number of Utilities and Parks vehicles purchased. This is a subjective process made necessary by the lack of data for the Utilities and Parks services purchased vehicles.

Calculations

1. Table E-15 shows the stock of vehicles of each body style for the Fleet Services fleet and the Utilities and Parks fleets.[341]
2. The shaded numbers in Table E-15 are subjective estimates of purchased vehicles. The numbers shown were chosen to create a reasonable overall ratio of purchased to stock vehicles for each body style and especially for the total number of purchased and stock vehicles.

[341] Ann Arbor Current Vehicles. Ann Arbor Public Services Department. Fleet Services Division. 4 May 2000.

Table E-15 1997 Ann Arbor Government Vehicle Stock and Purchases

	Fleet Services		Utilities & Parks		Total	
Body Style	Stock	Purch.	Stock	Purch.	Stock	Purch.
Ambulance						
Bus	2				2	
Convertible						
Dump	74	2	24	1	98	3
Hearse						
Motorcycle	6		2		8	
Motor Home						
Mixer						
Panel						
Pickup	53	4	58	5	111	9
Roadster						
Stake	1		2		3	
Station Wagon	1		5		6	
Trailer Coach						
Tank						
Trailer	2		2		4	
Tractor	5	1			5	1
Utility	33	1	21	1	54	2
Van	46	2	17	1	63	3
Wrecker	1				1	
Two Door	25		4		29	
Four Door	122	20	11	3	133	23
Total	371	30	146	11	**517**	**41**

Outflow – Retired Vehicles

Except in rare circumstances, Ann Arbor city government auctions off its vehicles as its method of vehicle retirement. These annual auctions sell vehicles from all divisions (including Parks and Recreation and Water Utilities) to individuals and businesses in Ann Arbor and from throughout the state of Michigan. Records are not kept on how many vehicles are sold to local residents, but the Fleet Services division roughly estimates that about half of all vehicles are sold to individuals from outside the local community.[342]

Method for Outflows

1. Assign each auctioned vehicle to a body style from the TR/9050 reports.
2. Count the total vehicles sold for each body style.

[342] Gibbons, Tom. Ann Arbor Public Services Department. Fleet Services Division. Personal interview. 4 May 2000.

3. Divide the total for each body style by two to estimate the number sold to individuals and organizations outside of Ann Arbor.

Calculations

1. Table E-16 shows the count of vehicles auctioned by Fleet Services on June 4, 1997 grouped by body styles from the TR/9050 reports.[343]
2. Each count has been divided by two to estimate the total number of vehicles leaving the community.

Table E-16 1997 Ann Arbor Government Auctioned Vehicles

Body Type	# Sold	Estimated # Leaving Community
Four Door	23	11.5
Pickup	15	7.5
Van	5	2.5
Stake	3	1.5
Dump	2	1

The total amount raised from the 1997 auction was $128,000.[344]

University of Michigan

Stock data in 2000 is available for the University of Michigan fleet, but not 1997 stocks, inflows, and outflows. Keith Johnson of Garage Services for the University said that stocks have not substantially changed, so the 2000 stocks can be used as 1997 stocks. He also suggested that the number of purchased and retired vehicles be based upon a rate of turnover for the fleet ranging from five years for light passenger vehicles to seven years for trucks.[345]

Method for Inflows and Outflows

1. Categorize vehicles in the current University of Michigan fleet into the TR/9050 body styles.
2. For each body style, assign an average retirement age.

[343] Auction of June 4, 1997. Ann Arbor Public Services Department. Fleet Services Division. 4 May 2000.
[344] Ibid.
[345] Johnson, Keith. Garage Services, University of Michigan. Personal interview. 9 May 2000.

3. Divide the stock by the average retirement age for each body style to estimate both new and retired vehicles. This method assumes that an even distribution of ages exists for each body style and that each vehicle is replaced as soon as it is retired.

Calculation

1. Table E-17 shows the stock of University of Michigan vehicles.[346]
2. A retirement age of five years was assigned to station wagons, vans, and four door automobiles. A retirement age of seven years was assigned to buses, dump trucks, stake trucks, utility trucks, and wreckers. A retirement age of six years was assigned to pickup trucks because they have characteristics in common with both groups of vehicles.
3. The column titled "# Replaced" shows the results of dividing the stock count by the replacement age for each body style. This result is used as both the inflow and outflow number of vehicles.

Table E-17 University of Michigan Vehicle Stock and Replacements

Body Type	# in Stock	Replacement Age	# Replaced
Ambulance			
Bus			
Transit Coach	38	7	5.4
Other Busses	17	7	2.4
Convertible			
Dump	24	7	3.4
Hearse			
Motorcycle			
Motor Home			
Mixer			
Panel			
Pickup	118	6	19.7
Roadster			
Stake	6	7	0.9
Station Wagon	88	5	17.6
Trailer Coach			
Tank			
Trailer			
Tractor			
Utility	14	7	2.0
Van	452	5	90.4
Wrecker	1	7	0.1
Two Door			
Four Door	249	5	49.8
Total	1007		191.8

[346] Ibid.

School District

All school busses used to transport students to Ann Arbor area public schools are owned and operated by the Ann Arbor Public School District.

Table E-18 contains data taken from school district records:[347]

Table E-18 Ann Arbor School District School Busses

New	Retired	Stock	Unit Price	Unit Mass
15	22	126	$51,251	17,500 pounds

Ann Arbor Transportation Authority

The AATA is an independent non-profit organization that operates a fleet of transit busses that provide public transportation services to Ann Arbor and Ypsilanti.

The following data were all gathered through an interview with the AATA.[348] Table E-19 shows the size of the AATA contingency and active fleets in 1997 and 2000. The size of the contingency fleet in 1997 is actually unknown, but an estimate of 10 vehicles is used based on the proportion between fleets in 2000, creating a total fleet of 81 buses.

Table E-19 Ann Arbor Transit Authority Fleets

AATA Fleet	1997	2000
Contingency fleet	10	11
Active fleet	71	73

About 14 buses were purchased in 1997. An outflow of 13 buses is assumed as a reasonable estimate that matches the slow growth seen between 1997 and 2000.

The approximate cost was $227,797 with a curb weight of 27,200 pounds.

Huron Valley Ambulance

The HVA owns and operates all ambulances in Washtenaw County.

[347] Williams, op. cit.

Method

1. Report information on new, retired, and stock ambulances from HVA.
2. Create reasonable estimates for missing information based upon available data.

Calculations

1. Table E-20 contains estimates for several pieces of information about HVA's fleet of ambulances.[349]

Table E-20 HVA Ambulance Fleet Information

Ambulance Type	1997 New and "Re-Chassised"	Stock in 2000	Unit Price	Unit Mass (pounds)
ALS	9	26	$73,000	11,000
BLS	1	6	$50,000	8,000

- Ambulance Type: The HVA uses two types of ambulances, Advanced Life Support (ALS) and Basic Life Support (BLS).
- New and "Re-Chassised": The HVA satisfies most of its need for new ambulances by refurbishing its existing fleet, a process called a "re-chassis." This process saves $25,000-$30,000 off the price of a new ambulance.
- Unit Price: The prices lists are for new ambulances, not "re-chassised" ones.

2. The HVA also provided the following information: [350]

   a. Total stock was 30 ambulances in 1997.

   b. There was definitely one new BLS in 1997, but the total number of new ambulances was "probably 2 or 3". This does not include "re-chassised" ambulances.

   c. The number of retired ambulances was "probably 2 or 3" in 1997.

3. The number of new, retired, and stock vehicles for ALS and BLS ambulances shown in Table E-21 were chosen as a good fit with the available data described above.

Table E-21 HVA Ambulance Fleet Estimates

Ambulance Type	1997 New	1997 Retired	1997 Stock
ALS	2	1	24
BLS	1	1	6

Mass and Value Estimates

In order to convert the quantity of vehicles estimated above into values of mass and economic value, we need an average unit mass and price for each body style.

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[348] Smith, Jean. Ann Arbor Transportation Authority. Personal interview. 3 May 2000.

[349] Simpson, Roger. Huron Valley Authority. Personal interview. 3 May 2000.

[350] Ibid.

- Unit Price: Prices used are the retail price for new vehicles with the exception of Ann Arbor city government vehicles that are purchased used.
- Unit Mass: Curb weight is used as the unit mass for each type of vehicle. Curb weight is defined as "the weight of a motor vehicle with all permanently mounted equipment and maximum capacity of engine fuel, oil and coolant. Same as Tare Weight."[351] The curb weight is different from the gross vehicle weight of a vehicle, which includes its maximum load of cargo and passengers.

Table E-22 contains prices and curb weights for each body style collected from a wide variety of sources. Where "sampling" is mentioned for a body type, and estimate for the prices and/or curb weights was created by looking up prices and weights for multiple models within each body type in the Auto Channel's New Car Buyer's Guide.[352]

[351] National Truck Equipment Association. <http://www.ntea.com/tech/byterm.asp> 8 May 2000.
[352] New Car Buyer's Guide. op. cit.

Table E-22 Body Style Unit Mass and Price

Body Style	Mass (pounds)	Source Notes	Price (dollars)	Source Notes
Ambulance		Note that the single ambulance in Washtenaw County reported on the TR/9050 will be assumed to be a BLS.		
- ALS	11,000	See HVA section above.	$73,000	See HVA section above.
- BLS	8,000	See HVA section above.	$50,000	See HVA section above.
Bus	17,500	Assumed same as smaller bus, UM other buses	$62,839	assumed same as smaller bus, UM other buses.
- UM Transit Coach	27,200	Assumed to be the same as an AATA transit bus.	$198,633	[353]
- UM Other Buses	17,500	Assumed to be the same as a school bus.	$62,839	Same source as UM transit coaches.
- AATA Transit Bus	27,200	See AATA section above.	$227,797	See AATA section above.
- School Bus	17,500	See the School District section above.	$51,251	See the School District section above.
Convertible	3,300	Based on a sampling of 2000 model year convertible curb weights.	$37,000	Based on sampling of 2000 model year convertible retail prices.
Dump	24,000	Simple dump trunks range from 15,000 to 28,000 pounds. Garbage trucks weigh more.[354]	$95,000	Range for simple dump trucks is $80,000 to $115,000. Same source as mass.
Hearse	5,300	[355]	$60,000	Same source as mass.
Motorcycle	400	Based on a sampling of 1998 model year motorcycle curb weights.	$8,000	Based on sampling of 1998 model year motorcycle retail prices.
Motor home	13,000	Based on sampling of six motor homes.[356]	$50,000	Based on average motor home prices in 2000.[357]
Mixer	24,000	[358]	$70,000	Same source as mass.
Panel	7,200	[359]	$38,000	Same source as mass.
Pickup	2,500	Based on sampling of 2000 model year pickup truck curb weights.	$21,000	Based on sampling of 2000 model year pickup truck retail prices.
Roadster	3,000	Based on a sampling of 2000 model year motorcycle curb weights.	$42,000	Based on sampling of 2000 model year pickup truck retail prices.

353 Garage Services, University of Michigan. Personal interview. 22 May 2000.
354 Chesley Truck Sales. Personal interview. 5 May 2000.
355 W.R. Bennett Funeral Coaches. Personal interview. 5 May 2000.
356 A.C. Nelsen Sales. A.C. Nelsen. <http://www.acnrv.com/sales.html> 20 May 2000
357 RV Family. Recreation Vehicle Industry Association. <http://www.rvia.org/consumers/recreationvehicles/types.htm> 4 Jun. 2000.
358 Mays International Trucks. Personal interview. 5 May 2000.
359 Churneys Truck Center. Personal interview. 5 May 2000.

Body Style	Mass (pounds)	Source Notes	Price (dollars)	Source Notes
Stake	18,000	[360]	$65,000	2000 prices were $65,000-$70,000. Same source as mass.
Station wagon	3,800	Based on sampling of 2000 model year sport utility curb weights.	$27,000	Based on sampling of 2000 model year sport utility retail prices.
Trailer coach	4,000	Based on sampling of six trailer coaches.[361]	$14,000	Based on average trailer coach prices in 2000.[362]
Tank	21,000	Same source as stake body style.	$90,000	2000 price. Same source as stake body style.
Trailer	8,010	[363]	$20,000	2000 prices range from $15,000 to $25,000. Same source as stake body style.
Tractor	13,115	Same source as trailer body style.	$60,000	2000 prices range from $55,000 to $70,000. Same source as stake body style.
Utility	15,000	A simple utility truck is 6,900 pounds, while a high-ranger is 25,000 pounds.[364]	$100,000	A simple utility truck costs $24,000-$75,000 in 2000, while a high-ranger costs $140,000. Same source as mass.
Van	3,968	Based on curb weight of 1,800 kg for a minivan in 1987.[365] The minivan curb weight was used instead of the van curb weight because the lower weight was closer to the observed curb weight of 3,200 pounds from sampling.[366]	$25,000	Based on sampling of 2000 model year van retail prices.
Wrecker	12,000	Based on gross vehicle weight, which should be same as curb weight for this body style.[367]	$68,000	2000 price. Same source as mass.
Two door	2,737	1997 average for new compact cars.[368]	$20,444	Average price for new car in 1997.[369]
Four door	3,241	1997 average for new midsize cars[370]	$20,444	Same source as two door.

[360] La Pine Truck Sales and Equipment Co. Personal interview. 5 May 2000.

[361] Terry's RV Sales. <http://www.terrysrv.com/> 2 Jun. 2000.

[362] RV Family, op. cit.

[363] Gaines, op. cit.

[364] Work Truck Sales and Leasing. Personal interview. 5 May 2000.

[365] Shaw, Greg. "Wheelchair rider risk in motor vehicles: A technical note." Journal of Rehabilitation Research and Development. 37:1 Jan/Feb 2000. <http://www.vard.org/jour/00/37/1/conte371.htm> 20 May 2000.

[366] New Car Buyer's Guide, op. cit.

[367] Fox's Towing. Personal interview. 5 May 2000.

[368] Davis, Stacy, ed. Transportation Energy Data Book: Edition 18, op. cit.

[369] Ibid.

We now have all the data we need to estimate the mass and economic value of the inflow and outflow of vehicles for Ann Arbor in 1997.

Methods

1. Inflow mass: For each data source, multiply the number of vehicles for each body style purchased by the unit mass for that body style.
2. Inflow value: For each data source, multiply the number of vehicles for each body style purchased by the unit price for that body style. Note that different unit prices apply for the Ann Arbor government purchases than for other data sources.
3. Outflow mass: For each data source, multiply the number of vehicles for each body style retired by the unit mass for that body style.

Calculations

1. Table E-23 summarizes the relevant data estimates in previous sections of this report: unit mass, unit price, new vehicles, and retired vehicles.

The calculation results for the following steps can be found in the tables, "1997 Inflow Mass," "1997 Inflow Value," and "1997 Outflow Mass."

2. Inflow mass in tons (for each data source and for each body style)
   (# of new vehicles) * (unit mass in pounds) / 2000
   Example: Inflow mass of government dump trucks
   3 * 24,000 / 2000 = 36 tons
3. Total inflow mass in tons
   Total across all data sources and body styles **14,850 tons**
4. Inflow value (for each data source and for each body style)
   (# of new vehicles) * (unit mass)
   Example: Inflow value of government dump trucks
   (2 * $58,000) + (1 * $26,8002) = $142,800
5. Total inflow value across all data sources and body styles **$187,127,644**

[370] Ibid.

6. Outflow mass in tons (for each data source and for each body style)

   (# of new vehicles) * (unit mass in pounds) / 2000

   Example: Outflow mass of government dump trucks

   1 * 24,000 / 2000 = 12 tons

7. Total outflow mass in tons

   Total across all data sources and body styles **12,826 tons**

Table E-23 Summary of New and Retired Vehicle Data

Body Style	Mass (pounds)	New Vehicle Price	Ann Arbor Government Price	TR/9050		Ann Arbor City Government		University of Michigan		School District, AATA, and HVA	
				New	Retired	New	Retired	New	Retired	New	Retired
Ambulance											
ALS	11,000	$ 73,000								2	1
BLS	8,000	$ 50,000		0.03	0.03					1	1
Bus											
UM Transit Coach	27,200	$ 198,633						5.4	5.4		
Other UM Busses	17,500	$ 62,839		1.7	0.9			2.4	2.4		
AATA Transit Bus	27,200	$ 227,797								14	13
School Bus	17,500	$ 51,251								15	22
Convertible	3,300	$ 37,000		63.9	5.5						
Dump	24,000	$ 95,000		18.6	11.1		1	3.4	3.4		
Ford Dump			$ 58,000			2					
Ford 1-Ton Dump			$ 26,800			1					
Hearse	5,300	$ 60,000		0.4	0.3						
Motorcycle	400	$ 8,000		85.5	20.9						
Motor Home	13,000	$ 50,000		43.1	49.7						
Mixer	24,000	$ 70,000		1.0	0.4						
Panel	7,200	$ 38,000		0.2	0.1						
Pickup	2,500	$ 21,000	$ 14,500	889.9	505.4	9	7.5	19.7	19.7		
Roadster	3,000	$ 42,000		5.7	2.6						
Stake	18,000	$ 65,000		24.8	24.2		1.5	0.9	0.9		
Station Wagon	3,800	$ 27,000		1,458.2	453.6			17.6	17.6		
Trailer Coach	4,000	$ 14,000		65.9	39.8						
Tank	21,000	$ 90,000		2.7	1.8						
Trailer	8,010	$ 20,000		345.3	419.1						
Tractor	13,115	$ 60,000	$ 87,000	19.1	17.3	1					
Utility	15,000	$ 100,000	$ 80,000	8.2		2		2.0	2.0		
Van	3,968	$ 25,000	$ 17,500	104.6	87.8	3	2.5	90.4	90.4		
Wrecker	12,000	$ 68,000		5.0	4.0			0.1	0.1		
Two Door	2,737	$ 20,444		1,646.5	2,568.2						
Four Door	3,241	$ 20,444		3,044.7	2,545.2		11.5	49.8	49.8		
Patrol/Utilities Car			$ 21,000			15					
Detective Car			$ 16,000			4					
Dodge Omni			$ 12,500			4					
Unknown				1.3							
Total				**7,836.2**	**6,757.8**	**41**	**24**	**191.8**	**191.8**	**32**	**37**

Table E-24 1997 Ground Motor Vehicles Inflow Mass

Body Style	TR/9050 (tons)	Ann Arbor City Government (tons)	University of Michigan (tons)	School District, AATA, HVA (tons)	Total (tons)
Ambulance	0.12			15	15
Bus	14.62		95.08	321.65	431
Convertible	105.36				105
Dump	223.26	36.00	41.14		300
Hearse	0.95				1
Motorcycle	17.10				17
Motor Home	280.40				280
Mixer	11.44				11
Panel	0.76				1
Pickup	1,112.43	11.25	24.58		1,148
Roadster	8.48				8
Stake	223.40		7.71		231
Station Wagon	2,770.65		33.44		2,804
Trailer Coach	131.75				132
Tank	28.01				28
Trailer	1,382.98				1,383
Tractor	125.03	6.56			132
Utility	61.58	15.00	15.00		92
Van	207.53	5.95	179.35		393
Wrecker	30.26		0.86		31
Two Door	2,253.19				2,253
Four Door	4,933.92	37.27	80.70		5,052
Total	13,923	112	478	337	**14,850**

Table E-25 1997 Ground Motor Vehicles Inflow Value

Body Type	TR/9050	Ann Arbor City Government	University of Michigan	School District, AATA, HVA	Total
Ambulance	$ 1,530			$ 196,000	$ 197,530
Bus	$ 104,966		$ 1,230,902	$ 3,957,923	$ 5,293,791
Convertible	$ 2,362,559				$ 2,362,559
Dump	$ 1,767,504	$ 142,800	$ 325,714		$ 2,236,018
Hearse	$ 21,563				$ 21,563
Motorcycle	$ 683,996				$ 683,996
Motor Home	$ 2,156,900				$ 2,156,900
Mixer	$ 66,738				$ 66,738
Panel	$ 7,994				$ 7,994
Pickup	$ 18,688,775	$ 130,500	$ 413,000		$ 19,232,275
Roadster	$ 237,541				$ 237,541
Stake	$ 1,613,457		$ 55,714		$ 1,669,171
Station Wagon	$ 39,372,335		$ 475,200		$ 39,847,535
Trailer Coach	$ 922,225				$ 922,225
Tank	$ 240,085				$ 240,085
Trailer	$ 6,906,270				$ 6,906,270
Tractor	$ 1,144,004	$ 87,000			$ 1,231,004
Utility	$ 821,109	$ 160,000	$ 200,000		$ 1,181,109
Van	$ 2,615,038	$ 52,500	$ 2,260,000		$ 4,927,538
Wrecker	$ 342,940		$ 9,714		$ 352,654
Two Door	$ 33,660,339				$ 33,660,339
Four Door	$ 62,245,695	$ 429,000	$ 1,018,111		$ 63,692,806
Total	$ 175,983,565	$ 1,001,800	$ 5,988,356	$ 4,153,923	**$ 187,127,644**

Table E-26 1997 Ground Motor Vehicles Outflow Mass

Body Style	TR/9050 (tons)	Ann Arbor City Government (tons)	University of Michigan (tons)	School District, AATA, HVA (tons)	Total (tons)
Ambulance	0.11			9.50	10
Bus	7.64		95.08	369.30	472
Convertible	9.07				9
Dump	133.29	12.00	41.14		186
Hearse	0.92				1
Motorcycle	4.18				4
Motor Home	322.85				323
Mixer	4.61				5
Panel	0.40				0
Pickup	631.69	9.38	24.58		666
Roadster	3.88				4
Stake	217.98	13.50	7.71		239
Station Wagon	861.93		33.44		895
Trailer Coach	79.50				80
Tank	18.91				19
Trailer	1,678.54				1,679
Tractor	113.45				113
Utility			15.00		
Van	174.18	4.96	179.35		358
Wrecker	24.13		0.86		25
Two Door	3,514.52				3,515
Four Door	4,124.48	18.64	80.70		4,224
Total	11,926	58	478	379	**12,826**

Maintenance Materials

Maintenance materials are estimated based on applying data on the typical maintenance needs of an automobile to the stock of all vehicles in Ann Arbor.

Method

1. Estimate the number of units of various maintenance materials (parts and liquids) used over a vehicle's life.
2. Divide these units by the number of miles assumed traveled during the vehicle's lifespan to estimate the units per mile and multiply by the average annual mileage for an automobile to estimate the units of maintenance materials used in one year for one vehicle.
3. Multiply these units by the unit mass and unit price for each type of maintenance material to estimate the total mass and value of maintenance materials used for a vehicle in one year.

4. Estimate the total stock of vehicles in Ann Arbor.
5. Multiply the mass and value of annual maintenance materials used per vehicles by the total stock to estimate total maintenance materials used in Ann Arbor.
6. Assume that stocks of maintenance materials remain constant so that the mass of maintenance materials used is equal to the inflow and outflow mass of maintenance materials.

Calculation - Parts

1. Table E-28 shows the quantity of different parts used as maintenance materials throughout 120,000 miles in the lifespan of a generic automobile.[371]
2. The number of units used over the vehicle lifespan is divided by 120,000 and multiplied by 11,400 miles (average annual mileage[372]) to get an annual estimate.
3. The "Unit Mass" shows mass in kilograms for one unit for each type of part.
4. The unit mass is multiplied by the units used per year to estimate total mass of that part type used in one year.
5. The same is done with unit prices for each maintenance part to estimate the economic value of maintenance parts.[373]

Calculation - Liquids

1. Table E-28 shows the volume of different liquids used for maintenance throughout 120,000 miles in the lifespan of a generic automobile.[374]
2. The liters used over the vehicle lifespan is divided by 120,000 and multiplied by 11,400 miles to get an annual estimate.
3. The "kg per Liter" shows the mass of one liter for each liquid.
4. The liters used per year is multiplied by the kg per liter to estimate total mass of that liquid used in one year.
5. The same is done with the unit price per gallon to estimate total value for each liquid.

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[371] Keoleian Gregory A., et al. LCI Modeling Challenges and Solutions for a Complex Product System: A Mid-Sized Automobile, op. cit.

[372] Davis, Stacy, ed. Transportation Energy Data Book: Edition 18, op. cit.

[373] AutoZone Auto Parts, op. cit.

[374] Keoleian Gregory A., et al. LCI Modeling Challenges and Solutions for a Complex Product System: A Mid-Sized Automobile, op. cit.

6. Table E-27 below shows the number of vehicles in Ann Arbor in 1997, estimated in previous sections of this Appendix.

Table E-27 Vehicles in 1997 Stock

Vehicle Fleet	# of vehicles
TR/9050	85,248
Ann Arbor Government	517
University of Michigan	1007
School District	126
AATA	81
HVA	30
Total	**87,009**

7. Total maintenance materials used in 1997

   Total stock vehicles * (mass of parts per vehicle + mass of liquids per vehicle)

   87,009 * (17.97 + 12.66) = 2,665,085 kg

8. Convert to tons

   2,665,085 kg * (2.2046 lb/kg) / (2000 lb/ton) = **2,938 tons**

9. This mass of maintenance is used as both the inflow and outflow mass of maintenance materials.

10. Total maintenance materials used in 1997

    Total stock vehicles * (value of parts per vehicle + value of liquids per vehicle)

    87,009 * ($135.07 + $17.94) = **$13,313,247**

Table E-28 Maintenance Materials Per Vehicle

Parts	Units Used over Lifetime	Units Used per Year	Unit Mass (kg)	Mass Used per Year (kg)	Ann Arbor Use in 1997 (tons)		Unit Price	Cost per Year	Ann Arbor Value in 1997
Air filter	4.3	0.409	0.233148	0.10	9.1		$ 6.19	$ 2.53	$ 220,011
Battery	1.7	0.162	14.5152	2.34	224.8		$ 49.99	$ 8.07	$ 702,453
Brake pad (front and rear)	1	0.095	1.7201	0.16	15.7		$ 29.99	$ 2.85	$ 247,892
Drive belt	2	0.190	0.15	0.03	2.7		$ 31.98	$ 6.08	$ 528,681
Lump bulb	3.5	0.333	0.2242	0.07	7.1		$ 3.99	$ 1.33	$ 115,432
Exhaust system	1	0.095	17.7936	1.69	162.1		$ 79.98	$ 7.60	$ 661,099
Oil filter	15.7	1.492	0.524	0.78	75.0		$ 4.99	$ 7.44	$ 647,568
PCV valve	2	0.190	0.1	0.02	1.8		$ 2.29	$ 0.44	$ 37,857
Shock absorbers (1 set)	1	0.095	33.0582	3.14	301.2		$ 61.99	$ 5.89	$ 512,397
Spark plugs	16	1.520	0.03665	0.06	5.3		$ 1.79	$ 2.72	$ 236,733
Tires (1 set)	2	0.190	41.2	7.83	750.8		$ 200.00	$ 38.00	$ 3,306,323
Transaxle fluid filter	1	0.095	0.067	0.01	0.6		$ 20.00	$ 1.90	$ 165,316
Windshield	1	0.095	14.2792	1.36	130.1		$ 416.76	$ 39.59	$ 3,444,858
Windshield wiper blades	18.7	1.777	0.217727	0.39	37.1		$ 5.99	$ 10.64	$ 925,878
Total Parts		**6.736**		**17.97**	**1,723.6**			**$ 135.07**	**$ 11,752,499**
Fluids	**Liters Used over Life Time**	**Liters Used per Year**	**kg per Liter**	**Mass Used per Year (kg)**	**Ann Arbor Use in 1997 (tons)**	**Gallons Used per Year**	**Price Per Gallon**	**Price Per Year**	**Ann Arbor 1997 Value**
Engine oil	78.1	7.42	0.91	6.75	647.6	1.96	$ 5.00	$ 9.80	$ 852,687
Engine coolant	22.2	2.11	1.15	2.42	231.7	0.56	$ 5.30	$ 2.95	$ 256,920
Windshield cleaner	44	4.18	0.20	0.84	80.2	1.10	$ 1.19	$ 1.31	$ 114,332
Brake fluid	3	0.29	1.11	0.32	30.4	0.08	$ 7.76	$ 0.58	$ 50,834
Transaxle fluid	28	2.66	0.88	2.34	224.5	0.70	$ 4.68	$ 3.29	$ 286,136
Total Fluids				**12.66**	**1,214.4**			**$ 17.94**	**$ 1,560,909**
Total Maintenance Materials per Vehicle (kg)				**30.63**	**2,938.0**			**$ 153.01**	**$ 13,313,408**

Comments – Data Issues

Major Data Issues

Ann Arbor Specific Data

Probably the most significant source of error in the inflow and outflow estimates comes from the lack of TR/9050 data specific to Ann Arbor. The methods used in this report assume that for each body style the ratio of new and retired vehicles to the total stock is the same in Ann Arbor as for all of Michigan. This report also assumes that the number of vehicles per capita in Ann Arbor is the same as the number per capita in Washtenaw County for each body style. In other words, the stock of vehicles in Ann Arbor is set by County level data, and changes to that stock are set by State level trends.

Ann Arbor is very different from the rest of the State and even the County, however, in that it is more urban with a higher density and also has a large student population. For example, the City may have a different trends in new and retired vehicles than the State for each body style. Also, Ann Arbor is likely to have fewer vehicles per capita than the County due to increased reliance on walking, biking, and busses. Ann Arbor may also have a different proportion of body styles with the stock of vehicles. For example, Ann Arbor is likely to have fewer pickup trucks than more rural areas.

However, using Washtenaw County data creates a more accurate estimate of stock vehicles than using only Michigan-level data would have because most of the state of Michigan is more rural than Washtenaw County and therefore different from Ann Arbor. For example, in 2000 Washtenaw had fewer registered tractors and pickup trucks and more registered station wagons, two door cars, and four door cars.

Average Mass and Price

Average unit mass and prices were difficult to obtain for most body styles. Each body style may contain vehicles with a wide variety of curb weights and prices. The most extreme case may be the utility body style, which contains vehicles whose prices range from $24,000 to over $300,000. Errors in choosing average masses and prices could have made the estimates in the report either too low or too high.

However, it should be noted that the unit mass and price used for the two most common body styles are probably the most accurate of all the unit mass and price values used. The unit mass and prices for two door and four door cars came from a U.S. Department of Energy Study that estimated average curb weights and prices in 1997.[375] Two and four door cars make up 51% of all vehicles in Michigan and about half of the inflow and outflow estimates in this report (45% of inflow mass, 55% of inflow value, and 52% of outflow mass).

Maintenance Schedules

This report assumes that all vehicles have the same maintenance requirements as a four door automobile. However, some vehicles may require significantly more maintenance such as the AATA busses which are typically in year-round daily use in stop and go traffic. For this reason, the estimates for maintenance materials should be assumed to be too low.

Minor Data Issues

Examples of other data issues are described below. None of these issues should have a large impact on the total inflow and outflow estimates.

- Changes in unit mass and price: The unit mass and price estimates are assumed to remain constant. Several of the unit prices may be slightly high because they were based on vehicle prices in 2000. Between June of 1997 and February of 2000, the Consumer Price Index for transportation for urban customers increased from 144.0 to 149.7 .[376] Also, the mass of retired vehicles is assumed to be the same as new vehicles even though the average weight of vehicles has changed over time. For example, the average fleet weight for automobiles in 1997 was 3,000 pounds, decreased to a low of 2,675 pounds in 1986, and rose back up to 2,977 pounds by 1997.[377] It is not clear whether the different in weight of retired vehicles has the effect of raising or lowering estimates.

[375] Davis, Stacy, ed. Transportation Energy Data Book: Edition 18, op. cit.

[376] Consumer Price Index – All Urban Consumers. Bureau of Labor Statistics. <http://stats.bls.gov/cpihome.htm> 7 March 2000.

[377] Davis, Stacy, ed. Transportation Energy Data Book: Edition 18, op. cit.

- "Unknown" vehicle body style: Vehicles whose body style were unknown in the TR/9050 reports were left out of the inflow and outflow estimates. However, unknown vehicles were only .002% of all registered vehicles in 1997.
- Missing fleets: Other vehicles exist which do not appear in the TR/9050 reports and are not owned by the organizations included in this report. Examples might include cars with manufacturer plates driven by Ford employees who live in Ann Arbor, farm vehicles, church vans, and state and federal government vehicles. However, it is unlikely that any of these groups of vehicles would be so large as to materially change the inflow and outflow estimates.
- Maintenance schedules: This report assumes that all vehicles have the same maintenance requirements as a four door automobile. However, some vehicles may require significantly more maintenance such as the AATA busses which are typically in year-round daily use in stop and go traffic. For this reason, the estimates for maintenance materials should be assumed to be too low.
- Municipal vehicle categorization: Ann Arbor municipal vehicles were categorized in the TR/9050 body styles based upon their description in various municipal reports. This categorization process was highly subjective, and it is probably that several of the vehicles were placed into categories with an average unit mass very different from that of the municipal vehicle. However, a handful of errors of this type would not have a noticeable impact on the final total estimates.

Indirect Material Estimates

Road Infrastructure

The City of Ann Arbor's Public Services Department has catalogued a subset of materials used for transportation infrastructure in 1997 as shown in Table E-29.[378]

[378] City of Ann Arbor Public Services Department, op. cit.

Table E-29 Ann Arbor 1997 Transportation Infrastructure Materials Used

City Materials	Inflow Mass (tons)	Inflow Value	Outflow Mass
Hot Asphalt	5,071	$110,000	2,000 tons (millings returned to asphalt supplier)
Road Salt	5,807	$194,481	none (not including runoff)
Cold Patch (Sylvax)	359	$22,000	none

Other 1997 projects not included above are shown in Table E-30.

Table E-30 Other 1997 Ann Arbor Construction Projects

Construction Projects	Asphalt Inflow (tons)
Annual resurfacing project	31,951
Huron Parkway resurfacing	2,875
S. Main St. Phase III roadway construction	2,780
Wall St. reconstruction	2,724
Dhu Varren Road improvements	5,702

This data does not include materials used by the Field Services Division of the Utilities Department, by the State of Michigan who resurfaced four miles of roads, or by contractors who built roads in subdivisions in 1997 that did were not officially accepted by the City until later. Other transportation infrastructure materials could include materials related to the Ann Arbor Airport and local railways.

Despite these gaps, the use of over 50,000 tons of asphalt has been catalogued, over three times the mass of new vehicles in the same year. If the full use of asphalt and all other transportation infrastructure materials were included, the total would be yet higher.

A connection between the mass of vehicle inflows and outflows and that of transportation infrastructure exists in that as the stock of vehicles grows in the community, more roads and other infrastructure are required to support them.

Fuel

The mass and value estimate for gasoline uses the following pieces of data:

- Average annual mileage for a vehicle is 11,400 miles.
- Average fuel economy in 1997 is 28.6 mpg.
- 87,009 vehicles were in Ann Arbor in 1997.

- In 1997, gasoline cost at $1.29 per gallon

By assuming that all vehicles in Ann Arbor have the same average mileage and mpg as an automobile, rough estimates for the mass and value of fuel used to power vehicles can be created.

1. # of vehicles * annual miles traveled / mpg

   = 87009 * 11,400 / 28.6 = 34,681,510 gallons

2. 34,681,510 gallons * $1.29 per gallon = **$44,739,148**.
3. 34,681,510 gallons * 6.2 pounds per gallon / 2000 = **107,513 tons**

Appendix F: Communication

This appendix provides supplementary information for the study completed on material flows associated with the communication needs of Ann Arbor, which is presented in Section 5 of Chapter 4. For the purpose of data retrieval and analysis, printed material, and mail were broken down as shown below in Table F-1.

This study examines inflows and outflows of material in 1997. Specifically, examined are inflows of printed material and mail delivered to Ann Arbor in 1997, and the outflows of MSW associated with these materials, as well as the mail sent out of the community. Table F-1 lists all the materials included in the analysis.

Table F-1 Materials Included in the Communication Category

Communication Category	Components
Printed Material	• Books • Magazines • Office Paper • Directories • Other Commercial Print • Newspaper (Newsprint and Newspaper Inserts)
Mail	• First-Class Mail • Priority Mail • Express Mail • Standard Mail (A) • International Mail • US Postal Service Mail • Free Mail Service For the Blind

Data Sources

Obtaining certain pieces of information was critical for the estimation of mass and economic value of material flows into and out of the community. Identified below are the primary data sources used in estimating those flows.

Outflows:

Municipal Solid Waste Stream

The flow of printed material and mail out of the community as part of the MSW stream is included in this study. This data was obtained from the EPA's *Characterization of Municipal Solid Waste in the United States: 1998 Update*[379]. This report, published in July 1999, was prepared by Franklin Associates on behalf of the Municipal and Industrial Solid Waste Division of the U.S. Environmental Protection Agency. The authors of the EPA report used a materials flow methodology to estimates of the mass of MSW generation in the United States based on information compiled on domestic production of materials and products from the U.S. Department of Commerce and various trade organizations. Adjustments are made to the domestic production numbers to account for converting scrap, which is generated in the production processes utilized to fabricate the various products being considered. Examples cited by the EPA report include clippings from plants that make boxes from paperboard, glass scrap or cullet generated in a glass bottle plant, or plastic scrap from a fabricator of plastic consumer products. Because converting scrap is usually clean and easily extracted from the process it is valuable material, almost always recovered and recycled within the industry that it is generated.

Additional adjustments are also made to account for diversions from MSW to account for when products are either permanently or temporarily diverted from the municipal waste stream because of the way they are used. For example, some office paper is diverted from the MSW stream when it is filed away for future use. The EPA report provides estimates for the MSW generated as a result of paper products including newspapers, newspaper inserts, books, magazines, office papers, directories and what is classified as "other" commercial printing. The report also provides estimates for MSW generation associated with Standard (A) mail. Though data is not provided for other classes of mail in the report, some results relevant to Standard (A) mail have been assumed to be pertinent to the other classes of mail under consideration in this study. Data provided includes the mass of MSW generated, the percentage of material discarded versus that

[379] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update, op. cit.

which is recovered and relative percentages attributable to commercial and residential sources.

Mail Generated

Data on the mail that is generated by the community is derived from the United States Postal Service's 1998 Annual Report.[380] This document, provided by the United States Postal Service provides details on the operating activities of the postal service, including the mass associated with mail processed and delivered in the United States.

Inflows:

Printed Material Supplied

It was not possible to gain access to production data for 1997 by the time this study was completed. However, Franklin Associates made available a series of notes that were released to the EPA in 1995 as a supplement to the EPA's waste characterization study of 1993. The document provides details of the underlying data and methodology used in estimating the generation of MSW in 1993. These working papers provided a method for estimating the entire material flow without having access to production data for 1997.

The main contribution of this working paper was a basis for making assumptions about the relationship between inflows and outflows of materials based on the amount of material that is withheld from municipal solid waste. There is no definitive study accounting for how much paper is stored away by individuals, businesses and institutions, but this study makes an estimate for each material or product type of the net annual accumulation. Therefore the assumptions used by Franklin Associates were used without adjustment.

Mail Delivered

A staff member at the Detroit postal operations center provided information about local mail delivery. Though mass data was not available an estimate was provided for the number of letters that were delivered in 1999. In the absence of 1997, the 1999 data has

[380] United States Postal Service, op. cit.

been adjusted based on national statistics for changes in the quantity of mail processed between 1999 and 19997. Based on pieces of mail, a mass has been calculated using an estimated mass per piece of mail.

Assumptions

Table F-2 provides a complete listing of the assumptions made in estimating material flows for the communication category.

Table F-2 Assumptions Made in the Estimation of Mass and Economic Value Calculations

General Assumptions	
• Ann Arbor consumption patterns per capita are equivalent to the national average per capita • Ann Arbor patterns of MSW generation are equivalent to the national average per capita • Seasonal fluctuations in the population of Ann Arbor do not significantly impact the estimates • The difference between inflows and outflows contributes to the community stock	
Category Specific Assumptions	
Books	• The new supply of books to the community is 104% of the MSW reported for the community*
Magazines	• The new supply of magazines to the community is 104% of the MSW reported for the community*
Office Papers	• The new supply of office paper to the community is 115% of the MSW reported for the community*
Directories	• The new supply of directories to the community is 103% of the MSW reported for the community*
Other Commercial Print	• The new supply of other commercial print to the community is 104% of the MSW reported for the community*
Newspaper: newsprint and newspaper inserts	• The new supply of newsprint and newspaper inserts to the community is 107% of the MSW reported for the community* • 6% of new supply of newsprint and newspaper inserts to Ann Arbor is overissue that is recovered*
Mail, all	• Generation of MSW associated with Standard mail (A) as a percentage of mail processed by USPS is 96% • Generation of MSW associated with all classes of mail as a percentage of mail processed by USPS is consistent with data for Standard mail (A) • Generation of MSW as a percentage of mail processed by USPS is consistent in 1993 and 1997 • The number of pieces of mail lost or destroyed in the US postal system prior to delivery is negligible • The average weight of a piece of mail is 0.09 pounds**

* Source: Franklin Associates. Working paper for EPA report on Characterization of Municipal Solid Waste in the United States. April 1995

** Source: USPS 1998 Annual Report

Detailed Estimation Process

Details describing the estimation process used for quantifying material flows associated with communication are provide in the text that follows in the following order: printed material, newspapers and mail. Calculations pertaining to newspapers are separated from the remainder of printed materials.

Printed Material

The estimation of data for the flow of printed material is based on available data estimating MSW generation for the U.S. population for the year 1997. Population is used to scale this data in order to estimate the MSW generation by the City of Ann Arbor. Based on these figures and the detailed notes of the methodology used by Franklin Associates to generate the 1993 waste characterization report, estimates were made of the entire flow of materials from the outflow of MSW leaving the community back to the new supply of materials into the community. Figure F-1 illustrates the flow of materials as it was modeled for the calculations that follow. The direction of arrows is indicative of how calculations were made rather than the actual flow of material. The numbers in each box may be used to refer to calculations contained in the next section. Printed material examined for this study was divided into five classifications taken from the EPA's report MSW. The classifications are books, magazines, office paper, directories, and other commercial print. Figure F-1 illustrates how these flows have been modeled, and the results of these calculations.

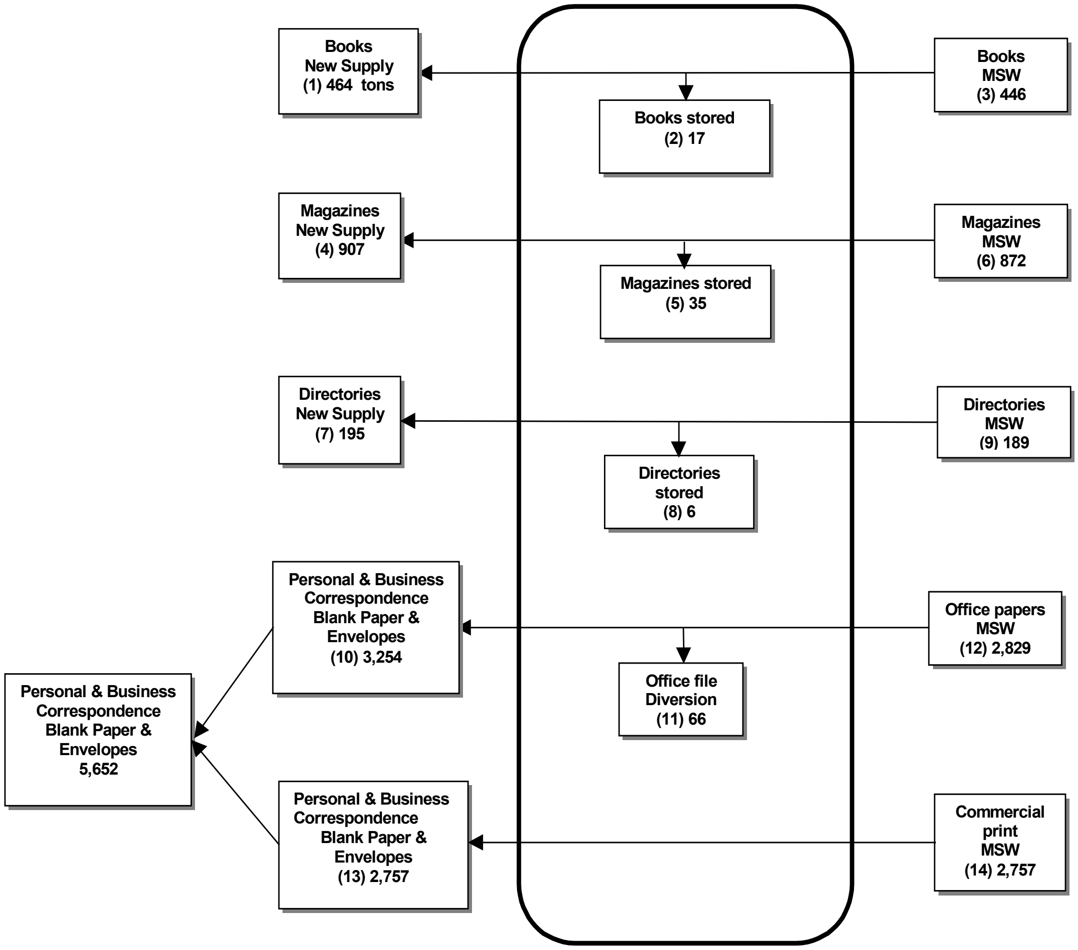

Figure F-1 Flow Diagram for Printed Material

There are three basic steps followed in the calculations that follow.

1. Outflow calculation: Multiply 1997 national per capita MSW generation associated with each material by the City of Ann Arbor population in 1997 to estimate MSW stream, attributable to books, that is generated by the Ann Arbor population.
2. Inflow calculation: Estimate of the inflow into the community is made based on a mass balance calculation subtracting a percentage estimated to account for material added to community stocks. Economic value calculations are estimated from retail sales in Ann Arbor.
3. Addition to stock calculation: Assumption made based on Franklin Associates research.

All Printed Material, including newspaper

Inflow- Economic Value:

1. Total retail sales of printed material at bookstores and newspaper outlets in Ann Arbor, 1997[381] $74,493,000

2. Total purchases by the University of Michigan library system, 1997 $13,015,355

3. Total retail value of blank paper and envelopes used to generate office paper, personal and business correspondence, and other commercial print, 1997

   Assuming retail $1000 per ton for paper

   Total mass of blank paper and envelopes calculated 8,904 tons

   See Inflows: mail generated *3,252 tons*

   See Inflows: other commercial print *2,757 tons*

   See Inflows: office paper *2,895 tons*

   Total retail value

   8,904 tons * $1,000 / ton = $8,904,000

4. Total economic value of inflows (expended by Ann Arbor population)
   $74,493,000 + $13,015,355 + $8,904,000 = $96,412,355

Books:

Calculation - Outflow - Mass:

1. Total MSW generated from books in the U.S., 1997[382] 1,110 thousand tons

2. U.S. population, 1997 267,743.0 thousand

3. Per capita MSW generated from books, 1997
   1,110 thousand tons / 267,743.0 thousand = 0.004 tons

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[381] United States Bureau of the Census. Michigan 1997 Economic Census, Retail Trade - Geographic Area Series, op. cit.

[382] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update, op. cit.

4. Ann Arbor population, 1997 — 107.6 thousand

5. Total Ann Arbor MSW generated from books, 1997
   .004 tons * 107.6 thousand = **446 tons**

   Figure F-1, Box 3

Calculation - Inflow - Mass:

1. Total inflow of books into Ann Arbor

Assume inflow is 104% of outflow[383]

446 tons * 1.04 = **463.8 tons**

Figure F-1, Box 1

Calculation - Addition to stocks:

1. Inflow – Outflow

463 tons – 446 tons = **17 tons**

Figure F-1, Box 2

Magazines:

Calculation - Outflow - Mass:

1. Total MSW generated from magazines in the U.S., 1997
   2,170 thousand tons

2. U.S. population, 1997 — 267,743.0 thousand

3. Per capita MSW generated from magazines, 1997
   2,170 thousand tons / 267,743.0 thousand = 0.008 tons

4. Ann Arbor population, 1997 — 107.6 thousand

5. Total Ann Arbor MSW generated from magazines, 1997
   .008 tons * 107.6 thousand = **872 tons**

   Figure F-1, Box 6

[383] Franklin Associates. Working paper: Methodology for Characterization of Municipal Solid Waste in the United States: Paper and Paperboard, op. cit.

Calculation - Inflow - Mass:

1. Total inflow of magazines into Ann Arbor

   Assume inflow is 104% of outflow[384]

   872 tons * 1.04 = **906.9 tons**

   Figure F-1, Box 4

Calculation - Addition to stocks:

1. Inflow – Outflow

   907 tons - 872 = **35 tons**

   Figure F-1, Box 5

Directories:

Calculation - Outflow - Mass:

1. Total MSW generated from directories in the U.S., 1997

   470 thousand tons

2. U.S. population, 1997 267,743.0 thousand

3. Per capita MSW generated from directories, 1997

   470 thousand tons / 267,743.0 thousand = 0.002 tons

4. Ann Arbor population, 1997 107.6 thousand

5. Total Ann Arbor MSW generated from directories, 1997

.002 tons * 107.6 thousand = **188.9 tons**

Figure F-1, Box 9

Calculation - Inflow - Mass:

1. Total inflow of directories into Ann Arbor

Assume inflow is 103% of outflow[385]

---

[384] Ibid.

188.9 tons * 1.03 = 194.6 tons

Figure F-1, Box 7

Calculation - Addition to stocks:

1. Inflow - Outflow

195 tons – 189 tons = 6 tons

Figure F-1, Box 8

Office Papers:

Calculation - Outflow - Mass:

1. Total MSW generated from office papers in the U.S., 1997

   7,040 thousand tons

2. U.S. population, 1997 267,743.0 thousand

3. Per capita MSW generated from office papers, 1997

   7,040 thousand tons / 267,743.0 thousand = 0.026 tons

4. Ann Arbor population, 1997 107.6 thousand

5. Total Ann Arbor MSW generated from office papers, 1997

   .026 tons * 107.6 thousand = 2,829.2 tons

   Figure F-1, Box 12

Calculation - Inflow - Mass:

1. Total inflow of material

Assume inflow is 115% of outflow

2829.2 tons * 115 = 3,253.6 tons

Figure F-1, Box 10

Calculation - Addition to stocks:

1. Inflow – Outflow

[385] Ibid.

3254 tons - 2829 tons = 65.8 tons

Figure F-1, Box 11

Other Commercial Print:

Calculation - Outflow - Mass:

1. Total MSW generated from other commercial print in the U.S., 1997
   6,860 thousand tons

2. U.S. population, 1997 267,743.0 thousand

3. Per capita MSW generated from other commercial print, 1997
   6,860 thousand tons / 267,743.0 thousand = 0.026 tons

4. Ann Arbor population, 1997 107.6 thousand

5. Total Ann Arbor MSW generated from other commercial print, 1997
   .026 tons * 107.6 thousand = 2,756.9 tons

   Figure F-1, Box 14

Calculation - Inflow - Mass:

1. Total inflow of material contributing to commercial print into Ann Arbor
   Assume inflow is equal to outflow 2756.9 tons

   Figure F-1, Box 13

Calculation - Addition to stocks:

1. Inflow – Outflow
   2756 tons – 2757 tons = 0 tons

Newspaper

The estimates made of material flows associated with newspapers is based on the EPA's 1998 MSW Characterization report[386] which provides estimates of MSW generation in the United States attributable to newspapers in 1997. This data is scaled using population to provide estimated Ann Arbor mass flows. This data, in conjunction with working papers from Franklin Associates[387] that detail the methodology for deriving MSW estimates from new supply of material provide a method for estimating the corresponding inflows of newspapers and additions to stocks for the Ann Arbor population in 1997.

Newspaper is divided into to newsprint and newspaper inserts as designated by the EPA's classification system. Newsprint refers to the material on which most newspapers are printed. Inserts are those materials inserted in, or accompanying newspapers for the purpose of advertising, consumer coupons or television guides.

There are three basic steps followed in the calculations that follow.

1. Outflow calculation: Multiply 1997 national per capita MSW generation attributable to newspapers by the city of Ann Arbor population in 1997 to estimate MSW generated by the Ann Arbor population. Assume that 6% of new supply is overissue that is recovered.[388]
2. Inflow calculation: Estimates of the inflows into the community are made based on a mass balance calculation, assuming that MSW generated from newsprint and newspaper inserts is a given percentage of the new supply of newspaper.
3. Addition to stock calculation: Assumption made based on Franklin Associates research.

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[386] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update, op. cit.

[387] Franklin Associates. Working paper: Methodology for Characterization of Municipal Solid Waste in the United States: Paper and Paperboard, op. cit.

[388] Ibid.

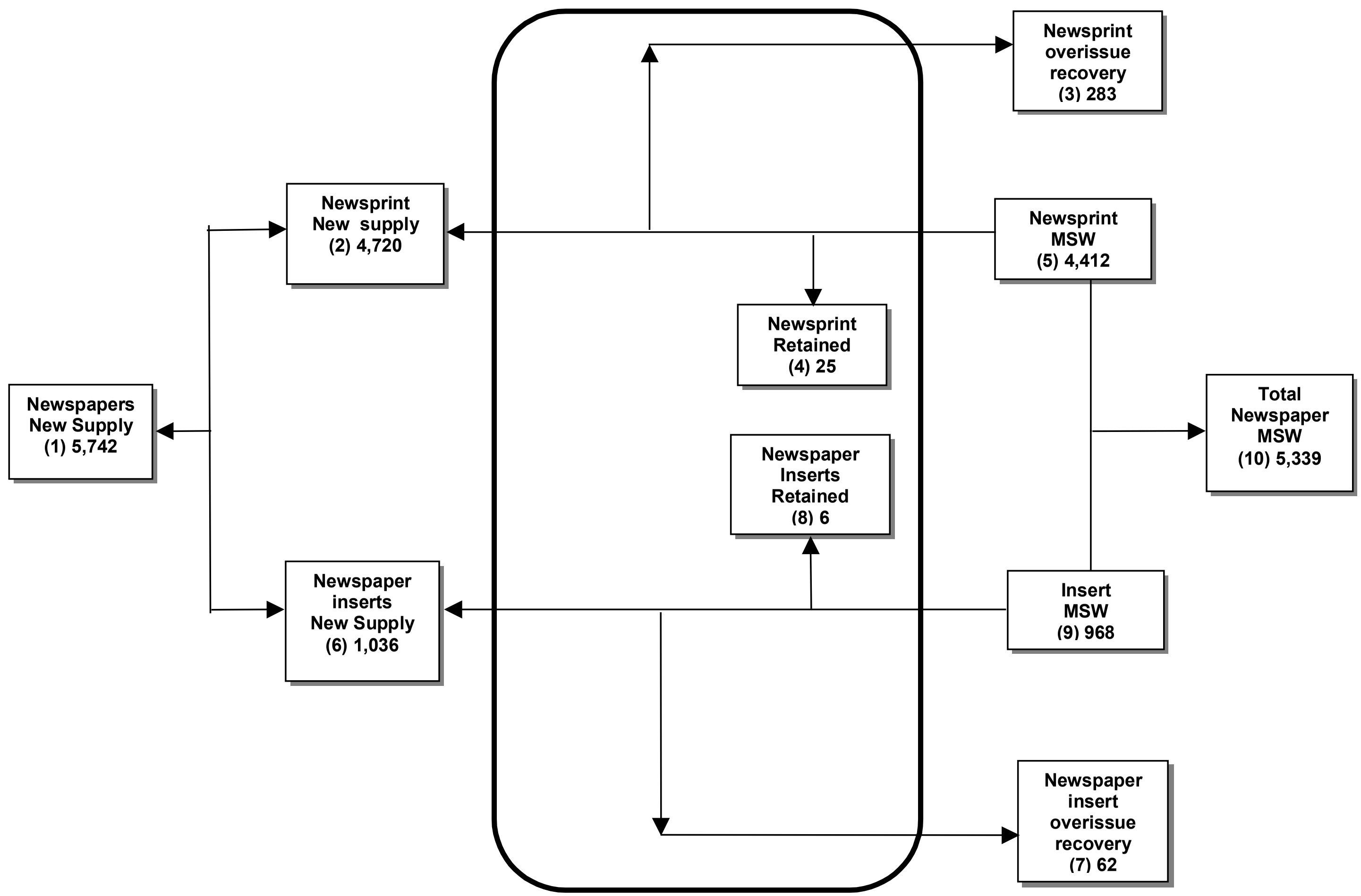

Figure F-2 Flow Diagram for Newspapers

Newsprint

Calculation - Outflow - Mass:

1. Total MSW generated from newsprint in the U.S., 1997[389]

   10,960 thousand tons

2. U.S. population, 1997 267,743.0 thousand

3. Per capita MSW generated from newsprint, 1997

   10,960 thousand tons / 267,743.0 thousand = 0.041 tons

4. Ann Arbor population, 1997 107.6 thousand

5. Total Ann Arbor MSW generated from newsprint, 1997

   .041 tons * 107.6 thousand = 4,411.6 tons

   Figure F-2, Box 5

6. Total Ann Arbor recovery of newsprint overissue, 1997

   Assume 6% of new supply of newsprint[390]

   See *Inflow* calculation for new supply

   5017.0 tons * .06 = 283.2 tons

   Figure F-2, Box 3

7. Total outflow of material associated with newsprint

   MSW generated + recovery of overissue =

   4,404.6 tons + 301.0 tons = 4,694.8 tons

Calculation - Inflow - Mass:

1. Total inflow of newsprint into Ann Arbor,

Assume inflow is 107% of MSW outflow[391]

4,688.8 tons * 1.07 = 4,720.4 tons

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[389] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update, op. cit.

[390] Franklin Associates. Working paper: Methodology for Characterization of Municipal Solid Waste in the United States: Paper and Paperboard, op. cit.

Figure F-2, Box 2

Calculation - Addition to stocks:

1. Inflow – Overissue – MSW Outflow

   4,720 tons – 4,412 tons – 283 tons = 25 tons

   Figure F-2, Box 4

Newspaper Inserts

Calculation - Outflow - Mass:

1. Total MSW generated from newspaper inserts in the U.S., 1997

   2,327 thousand tons

2. U.S. population, 1997 267,743 thousand

3. Per capita MSW generated from newspaper inserts, 1997

   2,327 thousand tons / 267,743 thousand = 0.009 tons

4. Ann Arbor population, 1997 107.6 thousand

5. Total Ann Arbor MSW generated from newspaper inserts, 1997

   .009 tons * 107.6 thousand = 968.4 tons

   Figure F-2, Box 9

6. Total Ann Arbor recovery of newspaper insert overissue, 1997

   Assume 6% of new supply of newspaper inserts[392]

   See *Inflow* calculation for new supply

   1,000.7 tons * .06 = 62.2 tons

   Figure F-2, Box 7

7. Total outflow of material associated with newspaper inserts

   MSW generated + recovery of overissue =

---

[391] Ibid.

935.2 tons + 60.0 tons = 1,030.6 tons

Calculation - Inflow - Mass:

1. Total inflow of newspaper inserts into Ann Arbor

Assume inflow is 107% of MSW outflow[393]

935.2 tons * 107% = 1,036.2 tons

Figure F-2, Box 6

Calculation - Addition to stocks:

1. Inflow – Overissue – MSW Outflow

1,036 tons – 62 tons - 968 tons = 6 tons

Figure F-2, Box 8

Mail

The estimates of the flow of mail into and out of the community is based on published data obtained from the United States Postal Service, as well as personal communications with local staff in the Detroit area offices. The EPA's MSW characterization report provides the basis for estimates of MSW generated by this flow of mail, as well as estimates of the mass of mail that is retained in homes, businesses and institutions in the community and results in a net addition to stocks.

Six classes of mail are included in this study, for which definitions are presented below.[394]

- First-class mail: A class of mail including letters, postcards, and postal cards, all matter wholly or partially in writing or typewriting, and all matter sealed or otherwise closed against inspection.
- Priority mail: Priority mail provides two- to three-day delivery service of documents and parcels

[392] Ibid.
[393] Ibid.
[394] United States Postal Service, op. cit.

- Express mail: Express mail provides overnight delivery for documents and packages weighing up to 70 pounds.
- Standard mail (A): This class of mail includes advertising letters, flats and small parcels. This class of mail is predominantly made up of presorted mail, or bulk mail.
- International mail: This is mail originating in the United States and having a destination in any foreign location.
- US Postal Service mail: mail generated by the US postal system
- Free Postal Service for the Blind: still need definition

The following is a basic description of the process by which estimates for mail are made.

1. Outflow calculation: There are two outflows associated with mail.
   Mail generated: Multiply 1997 national per capita mail generation by the City of Ann Arbor population in 1997 to estimate mail generated by the Ann Arbor population
   MSW generated from mail delivered: Estimate of the outflow from the community is made based on a mass balance calculation subtracting a percentage estimated to account for material added to community stocks from mail delivered.
2. Inflow calculation: There are two inflows associated with mail.
   Mail delivered: Multiply estimated number of pieces of mail delivered to Ann Arbor by the calculated average mass per piece of mail.
   Inflow of a supply of blank paper and envelopes into the city of Ann Arbor that contribute to the mail generated by the community.
3. Addition to stock calculation: Assumptions made based on Franklin associates research

Figure F-3 is an illustration of the model used to calculate material flows associated with mail into and out of Ann Arbor. The direction of arrows is representative of how estimates were calculated rather than the actual direction of flow of materials.

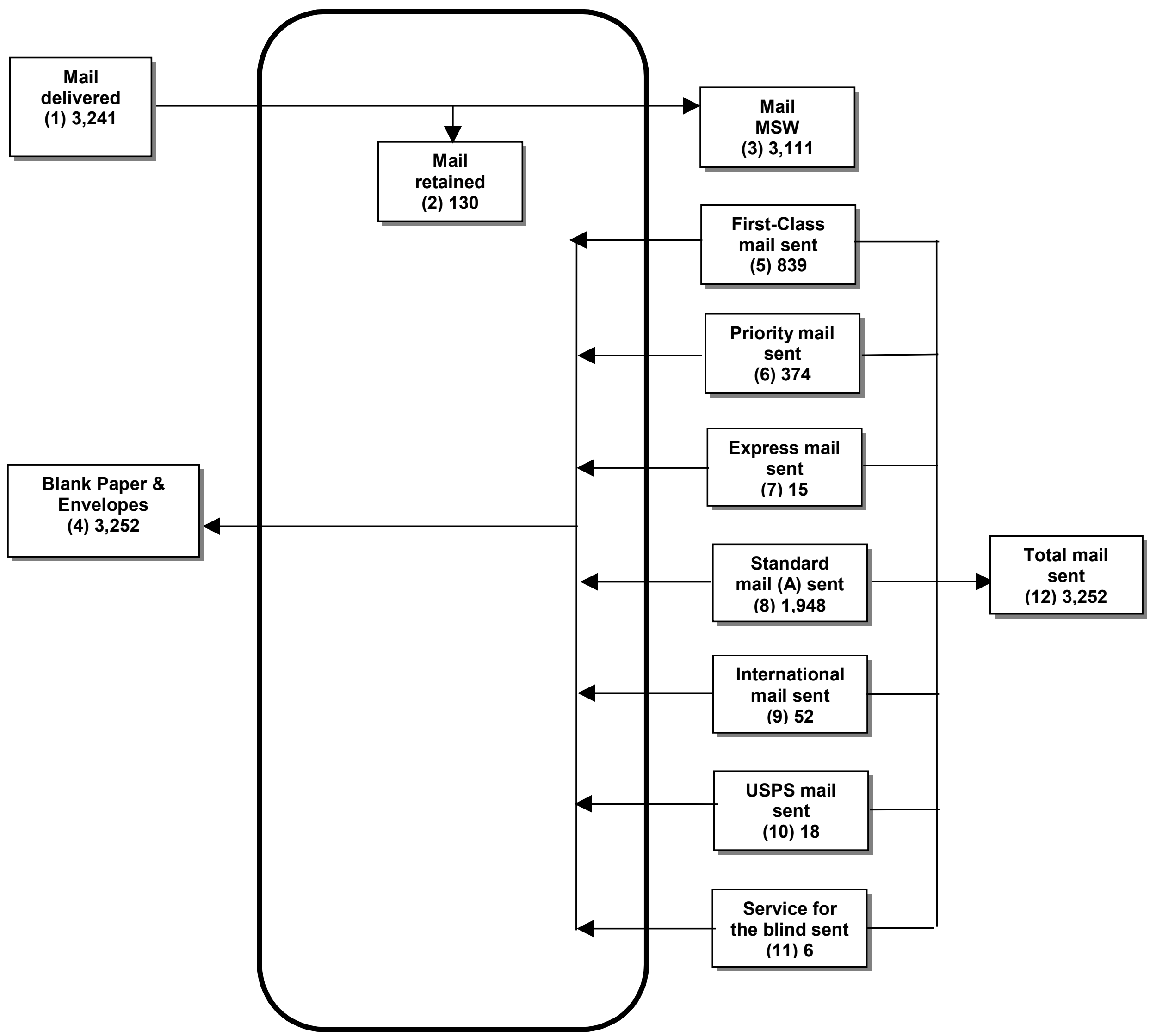

Figure F-3 Flow Diagram for Mail Handled by the United States Postal Service

Mail Delivered:

Calculation - Inflow - Mass:

1. Total number of letters delivered to the City of Ann Arbor, 1999[395]

   73,632,000 pieces

2. Total number of letters delivered, 1997

   1999 figure reduced 2.2% based on national trend in first-class mail processed[396]

73,632,000 pieces * 97.8% = 72,012,096 pieces

3. Average mass per piece of mail[397] .09 lb/piece

4. Total mass of letters delivered to Ann Arbor, 1997

72,012,096 pieces * (0.090 pounds/piece) = 6,481,089 pounds

6,481,089 pounds / (2,000 pounds/ton) = 3,240.5 tons

Figure F-3, Box 1

Calculation - Outflow - Mass:

1. Generation of MSW from Standard mail (A) as a percentage of Standard mail (A) processed in 1993[398]

4,011 thousand tons / 4,178 thousand tons = 96%

2. Assume percentage generation of MSW from all mail is the same as Standard mail (A) in 1993 and assume this is the same for 1997 in Ann Arbor.

See *Inflow* calculation for total inflow of mail to Ann Arbor

3,240.5 tons * .96 = 3,110.9 tons

Figure F-3, Box 3

Calculation - Addition to stocks:

1. Inflow – MSW Outflow

3,241 tons – 3111 tons = 130 tons

Figure F-3, Box 2

Mail Generated (First-Class mail):

Calculation - Outflow - Mass:

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[395] Torrence, op. cit.

[396] United States Postal Service, op. cit.

[397] Calculated based on data in United States Postal Service, op. cit. Note: 16,124.1 million pounds / 179,482.8 million pieces = .090 pounds per piece

[398] Franklin Associates. Working paper: Methodology for Characterization of Municipal Solid Waste in the United States: Paper and Paperboard, op. cit.

1. Total U.S. First-Class Mail generated, 1997[399]

   4,115.1 million pounds / (2000 pounds/ton) =

   2.1 million tons

2. U.S. population, 1997 — 267,743.0 thousand

3. Per capita First-Class Mail generated, 1997

   2.1 million tons / 267,743.0 thousand = 7.8 thousand tons

4. Ann Arbor population, 1997 — 107.6 thousand

5. Total Ann Arbor First-Class Mail generated, 1997

   7.8 thousand tons * 107.6 thousand = **839.3 tons**

   Figure F-3, Box 5

Mail Generated (Priority mail):

Calculation - Outflow - Mass:

1. Total U.S. Priority Mail generated, 1997[400]

   1,860.6 million pounds / (2000 pounds/ton) =

   0.93 million tons

2. U.S. population, 1997 — 267,743.0 thousand

3. Per capita Priority Mail generated, 1997

   0.93 million tons / 267,743.0 thousand = 0.003 thousand tons

4. Ann Arbor population, 1997 — 107.6 thousand

5. Total Ann Arbor Priority Mail generated, 1997

   0.003 thousand tons * 107.6 thousand = **373.9 tons**

   Figure F-3, Box 6

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[399] United States Postal Service, op. cit.

[400] Ibid.

Mail Generated (Express mail):

Calculation - Outflow - Mass:

1. Total U.S. Priority Mail generated, 1997[401]

    76.3 million pounds / (2000 pounds/ton) = 0.038 million tons

2. U.S. population, 1997 267,743.0 thousand

3. Per capita Priority Mail generated, 1997

    0.038 million tons / 267,743.0 thousand = 0.0001 thousand tons

4. Ann Arbor population, 1997 107.6 thousand

5. Total Ann Arbor Priority Mail generated, 1997

    0.0001 thousand tons * 107.6 thousand = 15.3 tons

    Figure F-3, Box 7

Mail Generated (Standard Mail (A)):

Calculation - Outflow - Mass:

1. Total U.S. Priority Mail generated, 1997[402]

    9,693.9 million pounds / (2000 pounds/ton) = 4.85 million tons

2. U.S. population, 1997 267,743.0 thousand

3. Per capita Standard Mail (A) generated, 1997

    4.85 million tons / 267,743.0 thousand = 0.018 thousand tons

4. Ann Arbor population, 1997 107.6 thousand

[401] Ibid.

[402] Ibid.

5. Total Ann Arbor Standard Mail (A) generated, 1997

    0.018 thousand tons * 107.6 thousand = **1,947.9 tons**

    Figure F-3, Box 8

Mail Generated (International mail):

Calculation - Outflow - Mass:

1. Total U.S. International Mail generated, 1997[403]

    International surface + International air =

    102.0 million pounds + 157.2 million pounds =

    259.2 million pounds

    259.2 million pounds / (2000 pounds/ton) =

    0.13 million tons

2. U.S. population, 1997 267,743.0 thousand

3. Per capita International Mail generated, 1997

    0.13 million tons / 267,743.0 thousand = 0.0005 thousand tons

4. Ann Arbor population, 1997 107.6 thousand

5. Total Ann Arbor International Mail generated, 1997

    0.0005 thousand tons * 107.6 thousand = **52.1 tons**

    Figure F-3, Box 9

Mail Generated (U.S. Postal Service mail):

Calculation - Outflow - Mass:

1. Total U.S. Postal service mail generated, 1997[404]

    88.4 million pounds / (2000 pounds/ton) =

    0.04 million tons

---

[403] Ibid.

2. U.S. population, 1997 267,743.0 thousand

3. Per capita U.S. Postal service mail generated, 1997

   0.04 million tons / 267,743.0 thousand = 0.0002 thousand tons

4. Ann Arbor population, 1997 107.6 thousand

5. Total Ann Arbor U.S. Postal service mail generated, 1997

   0.0002 thousand tons * 107.6 thousand = **17.8 tons**

   Figure F-3, Box 10

Mail Generated (Free for the Blind mail):

Calculation - Outflow - Mass:

1. Total U.S. mail provided free for the blind generated, 1997[405]

   30.6 million pounds / (2000 pounds/ton) =

   0.015 million tons

2. U.S. population, 1997 267,743.0 thousand

3. Per capita mail provided free for the blind generated, 1997

   0.015 million tons / 267,743.0 thousand = 0.000 thousand tons

4. Ann Arbor population, 1997 107.6 thousand

5. Total Ann Arbor mail provided free for the blind generated, 1997

   0.000 thousand tons * 107.6 thousand = **6.1 tons**

   Figure F-3, Box 11

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[404] Ibid.

[405] Ibid.

Total Mail Generated (All classes):

Calculation - Outflow - Mass:

Totaled from above calculations | 3,252.4 tons

Figure F-3, Box 12

Calculation - Inflow - Mass:

1. Total inflow of paper and envelopes used to generate the outflow of mail from Ann Arbor,

Assume inflow equal to outflow | 3,252.4 tons

Figure F-3, Box 13

Appendix G: Frequently Cited Data

Table G-1 lists source and value of commonly cited data.

Table G-1 Frequently cited data

Data	Value	Source
Ann Arbor - Estimated Population July 1997	107,604	Nutting, Jeffrey. Population and Households in Southeast Michigan 1995-1998. Southeast Michigan Council of Governments. Nov. 1998. <http://www.semcog.org/data/popocc/popocc98.pdf> 3 Jun. 2000.
Ann Arbor - Estimated Households July 1997	43,381	Nutting, Jeffrey. Population and Households in Southeast Michigan 1995-1998. Southeast Michigan Council of Governments. Nov. 1998. <http://www.semcog.org/data/popocc/popocc98.pdf> 3 Jun. 2000.
Washtenaw County- Estimated Population July 1997	300,805	Nutting, Jeffrey. Population and Households in Southeast Michigan 1995-1998. Southeast Michigan Council of Governments. Nov. 1998. <http://www.semcog.org/data/popocc/popocc98.pdf> 3 Jun. 2000.
U.S. Population, 1997	267,743,595	Estimated Resident Population for States and Regions of the U.S., 1990-1998. Michigan Information Center. <http://www.state.mi.us/dmb/mic/census/demo/pop_est/st9098.htm> 7 Feb. 2000

Appendix H: Total Solid Material Outflows

This appendix provides supplementary information for creating the mass estimates for total solid waste outflows presented in Chapter 5.

Data Sources

The prevalence of data regarding solid waste enables a detailed comparison of the material outflows modeled in this study with the total community outflows. Estimates for the total community outflows have been developed using the following data sources:

- Characterization of Municipal Solid Waste[406]: This report contains estimates of national municipal solid waste (MSW) for 1997.
- Ann Arbor Solid Waste Report[407]: This report contains mass data for municipal solid waste managed by the City of Ann Arbor, which includes MSW from residents and small businesses but not the University of Michigan or other large businesses.
- University of Michigan Solid Waste Data[408]: Data collected from an interview with the Plant Operations Department includes the University's solid waste except for yard trimmings, which are composted on University land.

Detailed Estimation Process

The Resource Conservation and Recovery Act (RCRA) regulates the management of non-hazardous and hazardous solid wastes generated by industrial, commercial, agricultural, and mining operations and from community activities. Table H-1 shows the different solid waste types, as defined by RCRA, used to characterize total material outflows.

[406] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update. op. cit.
[407] City of Ann Arbor Department of Solid Waste. op. cit. "Waste Reduction Report for the Period of July 1993-1998"
[408] Plant Operations, op. cit.

The steps used to develop mass estimates for total outflows are described below.

1. The estimates generated in Chapter 4 are categorized according to their solid waste type. Materials within each solid waste type still not accounted for are identified.
2. An estimate is created for total municipal solid waste (MSW) associated with Ann Arbor residents, small businesses, and the University of Michigan.
3. The mass for subcategories of MSW not accounted for in step 1 are estimated.
4. An additional estimate is created for MSW from large businesses.
5. All remaining waste categories without an estimate are marked as “unknown”.

The estimates created include all solid wastes for Ann Arbor and do not distinguish between their fate of landfill disposal, recycling, or reuse. Solid wastes are the only form of wastes included; gaseous wastes and wastewater are excluded.

Table H-1 Total Solid Waste Outflows Based on RCRA Solid Waste Categories

Waste Category	Materials Included	Total Solid Outflow Mass (in tons)	Data Sources
▪ **Municipal Solid Waste**	MSW from Ann Arbor residents, small businesses, and the University of Michigan	74,348	Sum of Ann Arbor and U of M data
Durable Goods	Major appliances, small appliances, furniture and furnishings, carpets and rugs, miscellaneous durables	7,650	Characterization of MSW
Nondurable Goods			
Communication	Outgoing USPS mail Disposed and recycled paper	19,000	Communication outflow estimates
Clothing	Disposed and recycled clothing Thrift store donations to outside organizations	2,200	Clothing outflow estimates
Other Nondurable Goods	Tissue paper and towels, paper and plastic plates and cups, trash bags, disposable diapers, other nonpackaging paper, towels, sheets, pillowcases, other miscellaneous nondurables	4,882	Characterization of MSW
Containers and Packaging	Glass, steel, aluminum, paper, plastic, and wood; bottles, jars, cans, foil, boxes, cartons, bags, wraps, and pallets	20,188	Characterization of MSW
Food Scraps	Food scraps disposed in landfill; does not include composted food	8,000	Food and Water outflow estimates
Yard Trimmings	Grass, leaves, and tree and brush trimmings in municipal compost; does not include University of Michigan or residential backyard composting	11,514	Ann Arbor data
Miscellaneous Inorganic Wastes	Soil, bits of concrete, stones	914	Characterization of MSW
Other Large Commercial MSW	Durable goods, other nondurable goods, containers and packaging, and misc. inorganic wastes from large corporations who hire independent waste haulers. Does not include materials associated with Communication, Clothing, or food scraps	12,850	Comparison of Characterization of MSW with Ann Arbor of University of Michigan MSW data
▪ **Automotive**			
Ground Motor Vehicles and Maintenance Materials	Retired ground motor vehicles Maintenance materials	16,000	Transportation outflow estimates
Other Vehicles	Bicycles, trains, airplanes, boats	Unknown	
▪ **Municipal Sludge**	Biosolids and scum	5,000	Food and Water outflow estimates
Construction and Demolition Debris			
Building-related C&D	Most building-related C&D debris	15,000	Shelter outflow estimates
Other C&D	Roadway and bridge construction waste, land clearing and inert debris waste, misc. building-related C&D (from 8% of building permits not estimated in this study)	Unknown	
▪ **Industrial Waste**	Wastes from manufacturing or other industrial processes	Unknown	
▪ **Other Hazardous Waste**	All hazardous wastes except for automotive wastes	Unknown	

Categorization of Materials into Solid Waste Categories

Outflow estimates developed in Chapter 4 of this report are classified into the solid waste types defined by RCRA.[409]

- The MSW category includes the estimates for paper-based Communication, Clothing, and food scraps (Food and Water).
- Automotive includes all Transportation outflows.
- Municipal Sludge includes biosolids and scum (Food and Water).
- Building-related Construction and Demolition (C&D) Debris includes Shelter outflows.

The following waste categories are not included in the Chapter 4 materials. The details of materials included in each of these waste categories can be found in Table H-1.

- Municipal Solid Waste – The subcategories defined by Franklin Associates are used to define waste categories[410].
  - Durable Goods
  - "Other Nondurable Goods": The materials included in the estimates for Communication and Clothing are nondurables within MSW. This subcategory of nondurables includes all nondurable materials not in Communication and Clothing.
  - Containers and Packaging
  - Yard Trimmings
  - Miscellaneous Inorganics
- Automotive Waste - "Other Vehicles": Although the name of this waste category focuses on automotive wastes, other types of retired vehicles including bicycles, trains, airplanes, and boats are classified here to ensure their inclusion.
- C&D Debris – "Other C&D": This waste subcategory contains all construction and demolition debris not associated with buildings.

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[409] National Archives and Records Administration. Code of Federal Regulations, Title 40, Volume 17, Part 258.2. U.S. Government Printing Office, Jul 1999 <http://frwebgate.access.gpo.gov/cgi-bin/get-cfr.cgi> 14 Jun 2000.

[410] Franklin Associates. Characterization of Municipal Solid Waste: 1998 Update. op. cit.

- Industrial Waste – This category includes all non-hazardous wastes from manufacturing and other industrial processes.
- "Other Hazardous Waste" – This category includes all hazardous wastes, with the exception of hazardous automotive wastes.

Mining, Oil and Gas Processing, and Agricultural wastes are either negligible or not present within Ann Arbor so are excluded from the above analysis.

Total MSW Estimate

Total MSW from all sources except for large businesses is estimated based upon the City of Ann Arbor and University of Michigan data sources described above.

64,084 tons City of Ann Arbor MSW + 10,264 tons University of Michigan MSW
= 74,348 tons

Estimates for MSW Subcategories

Yard trimmings are based solely on City of Ann Arbor data. The State of Michigan bans all landfilling of yard wastes, so it is assumed that all yard trimmings are composted. Residential yard trimmings are collected by the city for composting. The University of Michigan's yard trimmings are composted on University property and are not included in the estimate. It is assumed that large businesses also compost their yard trimmings onsite. The reported yard trimmings for Ann Arbor is 11,514 tons.

The total MSW mass still unaccounted for can be calculated as follows:

Total Ann Arbor MSW - yard trimmings - Clothing - Communication - Food scraps

= 74,348 total MSW - 11,514 tons yard trimmings - 2,200 tons Clothing - 19,000 tons Communication - 8,000 tons Food Scraps

= 33,634 tons

This mass is allocated to the remaining MSW subcategories, including durable goods, other nondurable goods, containers and packaging, and miscellaneous inorganic wastes. The mass is allocated to the four categories based upon their relative size in the national MSW stream, as calculated in Table H-2.

Table H-2 National Generation (in thousand tons)

Material Type	Total Mass Generated in U.S. MSW (in thousands of tons)	Relative Percent (%)	Applied to Ann Arbor - multiplied by 33,634 tons (in tons)
Durable goods	3,610	23	7,650
Other nondurable goods	17,350	15	4,882
Containers & packaging	71,750	60	20,188
Misc. inorganic wastes	3,250	3	914
TOTAL	**119,540**	**100%**	**33,634**

Values may not sum due to rounding

Estimate for MSW from Large Businesses

Finally, an estimate is created for the MSW from large companies that hire waste haulers independent of the City. This estimate is highly uncertain because commercial MSW is highly variable depending upon the specific local businesses involved, and local commercial MSW data is unavailable.

The Ann Arbor and University of Michigan MSW totals are subtracted from an estimate of total MSW based on the per capita national characterization of MSW. Yard trimmings are excluded from all MSW data for this estimate.

Total MSW = U.S. Total MSW ÷ U.S. Population x Ann Arbor population
= 216,970,000 tons ÷ 267,744,000 x 107,604
= 87,198 tons

Large commercial MSW = Total MSW (based on U.S. per capita) - City of Ann Arbor - University of Michigan MSW
= 87,198 tons - 64,084 tons - 10,264 tons
= 12,850 tons

Also note that the previous estimates for communication, clothing, and food scraps include all sources, including residential, University of Michigan, and small and large commercial sources. Therefore, this separate estimate for large commercial MSW only includes durable goods, other nondurable goods, containers and packaging, and miscellaneous inorganic materials. It is assumed that large companies perform their own composting and disposal of yard trimmings, and this outflow is not included.

Remaining Waste Categories

Data are unavailable for the following waste subcategories, whose mass is marked as unknown.

- Automotive Waste - “Other Vehicles”
- C&D Debris – “Other C&D”
- Industrial Waste
- “Other Hazardous Waste”