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TRANSPORTATION, URBAN DEVELOPMENT, AND GREENHOUSE GASES:

PATTERNS OF CONSUMPTION AND JUSTICE IN PHILADELPHIA, PENNSYLVANIA

A Thesis in

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by

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ABSTRACT

Despite evidence that humans are modifying Earth's climate through greenhouse-gas (GHG) emissions, the United States has no formal GHG mitigation strategy. To fill the gap, many state and municipal governments have adopted plans to bring about GHG reductions. However, by applying global-scale thinking to local-scale problems, these approaches may place undue emphasis on specific policy makers, while ignoring options for mitigation that are outside of these individuals' control. This thesis argues for a more substantive view of GHG emissions that asks detailed questions about the causes of GHG emissions. Nevertheless, the foundation to ask such questions does not yet exist – there is little local information about energy consumption, a proximate cause of GHG emissions.

This thesis presents the idea of *consumptive landscapes* as a lens through which to view GHG emissions. The thesis also presents a method for estimating GHG emissions from transportation in urban areas, using the Philadelphia Metropolitan Area as a test case. A traffic assignment model was applied to commuter origin-destination data, and the results were used to generate GHG emissions maps that were interpreted based on a historical understanding of the region and on contemporary demographic data. The results show that the responsibility for gasoline consumption lies disproportionately with the affluent suburb-to-suburb commuters traveling in automobiles. Conversely, poor populations working in the suburbs use public transport despite the poor quality of service. The results demonstrate that consumption of gasoline is linked to segregation in patterns usually associated with an urban/suburban split. Nonetheless, the results also identify "other" places that are important because their existence suggests alternatives to the urban/suburban dichotomy typically used to describe metropolitan Philadelphia. This "other" category is useful in subverting some of the discursive causes of GHG emissions and in demonstrating that GHG emissions are more than merely economic entities. This conclusion supports the use of a more-substantive view of GHG emissions.

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Chapter 1

INTRODUCTION

There is strengthening evidence that humans are modifying Earth's climate through greenhouse-gas (GHG) emissions (Houghton et al. 2001). On February 16, 2005, the Kyoto Protocol came into force, binding its parties to previously negotiated emissions targets. Among those parties is the United States. Although the United States has not ratified the treaty, it could face international sanctions if it fails to live up to its Kyoto target – a 7 percent reduction below its 1990 GHG emissions by the year 2013. Still, the United States has no active plan to meet its target reduction. This failure to act has led many decision makers at smaller scales, ranging from state governors to college campuses, to adopt emissions reductions targets *and* develop plans to reach them.

These attempts at local mitigation, while laudable, are not unproblematic. Smaller-scale mitigation efforts often apply global thinking to a local problem. At the global scale, the approach to GHG mitigation has been to inventory emissions, adopt an emissions reduction target, and implement a plan to reach that target. Applying this approach at the local scale means selecting the group of decision makers a priori (or in most cases, having those decision makers self-select), then estimating the emissions under their control, and finally developing a plan to mitigate those emissions. Such an approach suffers two flaws. First, just as the consent of key politicians at the national level is required for the ratification of treaties or the implementation of carbon taxes, the consent of local or regional officials is also required to implement GHG mitigation plans at smaller scales. The lack of such consent can kill any mitigation effort, no matter how well conceived. Second, many viable options exist for GHG mitigation that are outside the control of any given decision maker or governing body, particularly at a local level. Thus, rather than focusing on the practices of individuals or entities, I argue that academics interested in GHG mitigation should focus on the processes that result in GHG emissions so that they can identify all possible options for GHG mitigation.

In evaluating existing and potential research approaches in this thesis, I adopt a postmodern approach that rejects the notion that the researcher, or subject, is separate from the object under study. In the case of climate change, I demonstrate how scientists who study climate change and GHG emissions are part of the problem they are studying, and in some cases contribute to the processes that result in GHG emissions through the ways they frame their research. The point of this statement is not to lay blame for climate change on climate scientists, but simply to demonstrate that the ways academics talk about climate change and GHG emissions influence the processes that generate these emissions. Hence, the goal of producing objectively verifiable truth about GHG emissions and the social processes driving them is inappropriate. Instead, I evaluate research based on whether or not it is useful for a given purpose. In this particular case, that purpose is the mitigation of GHG emissions.

Research Goal and Objectives

Thus, the overriding goal of this thesis is to find new approaches to understanding GHG emissions that are more useful in efforts to mitigate those emissions than are current approaches. Ideally, these new approaches would include understandings of the social, political, technical, cultural, ecological, and academic processes that produce GHG emissions at multiple scales in multiple places. However, such an undertaking is too large for any thesis due to the lack of information about many of the proximate causes of GHG emissions.

For instance, little is known about patterns of consumption within metropolitan areas, particularly in the case of transportation, but also in the broader case of the consumption of energy and material goods. These kinds of consumption patterns lead to GHG emissions, and it is well documented that there are spatial differences in incomes, housing type, and consumption of goods, services, and energy within United States metropolitan areas. However, there is little empirical work that documents the details of the spatial differences in consumption, particularly in the context of human-environment issues. Therefore, this thesis concerns itself with addressing this gap and providing a method for beginning to understand the *consumptive landscapes*, or geographies of consumption, of metropolitan areas. Due to the enormity of this task, a single type of consumption is studied here – the consumption of gasoline as the result of the commute to and from work.

The thesis uses three objectives to reach its goal. The first objective is to make the case for process-based approaches to GHG emission studies and to take the necessary first step of a detailed examination of consumptive landscapes. For its second objective, the thesis presents a method for exploring the consumptive landscape in detail, focusing on personal transportation to and from work. This method combines a transportation model with demographic data and other information about the form, function, and character of a metropolitan area and the places therein to generate narratives about the patterns of energy consumption resulting from transportation. The goal of these narratives is not simply to describe these patterns, but also to describe who consumes what and to begin to address questions of how and why various consumptive patterns are created. The third objective is to apply this method to a specific place – the Philadelphia Metropolitan area.

Thesis Structure

Towards those ends, Chapter 2 examines past and present discourses about climate change broadly and GHG emissions specifically, evaluating them through several different geographic perspectives. In doing so, it identifies the advances and shortcomings of existing approaches and suggests evaluation criteria by which modified and new approaches should be measured for comparison. Rather than selecting decision makers a priori and determining how they can best reduce GHG emissions, this chapter makes a case for a substantive view of GHG emissions, modeled after after Yapa's (1996) postmodern approach to studying poverty. Instead of attributing these emissions exclusively to economic forces, these sections of Chapter 2 argue for an approach that asks questions about GHG emissions designed to elucidate the social, political, technical, cultural, ecological, and academic causes of GHG emissions. Finally, this chapter contends that studying consumptive landscapes within metropolitan areas is a necessary foundation for this more substantive approach.

Chapter 3 presents the methods employed in the study. A research approach is described in which local knowledge is blended with demographic data and a traffic model to create a narrative that produces potentially useful descriptions of processes generating GHG emissions. The principal empirical method, which applies a traffic assignment model to origin-destination data, is described in detail. The chapter discusses issues involved in the choices of traffic-assignment heuristic, data structure, analytical procedure, and visualization method.

Chapter 4 describes the study area, including the historical development of the form and function of the Philadelphia metropolitan area's urban landscape. Special attention is paid to the changes in the landscape that have resulted from or have in part facilitated changes to the transportation network. Furthermore, Philadelphia's landscape is often characterized by its stark racial and economic segregation, and I propose that the spatial patterns of that segregation are related to patterns of commuting and gasoline consumption. Chapter 4 therefore lays the foundation for comparisons between segregation and energy consumption patterns by exploring some spatial measures of exclusion and accessibility.

Chapter 5 describes the results of the traffic assignment model and situates them in the local context provided in Chapter 4. First, results for the entire metropolitan area are presented, along with a preliminary examination of the importance of several workplaces within the metropolitan landscape where GHG emissions tend to be concentrated. These places are classified as urban, suburban, or "other," and are presented in three subsections – one for each classification. The spatial commuting and consumptive patterns of each place are examined in detail, along with some basic characteristics of each workplace. The results show that while there are some important similarities among suburban places and among urban places, there also are important differences within these classifications that deserve further study. In addition, the analysis of the "other" category shows that there are important workplaces within the Philadelphia metropolitan area that do not fit into the classic urban/suburban dichotomy.

The apparent conflicts between justice, equity, and current development patterns are explored in Chapter 6. In addition, the role that the urban/suburban dichotomy plays in these conflicts and in the development patterns and decisions that help to shape them is discussed. One of the primary conclusions of this chapter is that to mitigate GHG emissions from commuters, the current patterns of urban and suburban development and growth must change. While the urban/suburban dichotomy that exists in most of the discourses about Philadelphia and other metropolitan areas is only one factor in these decisions, it is an important factor. The chapter closes by offering some preliminary conclusions that help challenge this dichotomy and create critical discursive spaces where alternatives can be conceived and fostered. Specifically, based on Soja's (1996) concept of thirding, I assert that a trichotomy of urban/suburban/"other" is useful in mitigating GHG emissions in at least two ways. First, it suggests that there are alternative modes of living and working in Philadelphia that go beyond the classic urban/suburban dichotomy. Second, these "other" places challenge the notion that GHG emissions are solely economic phenomena by disrupting otherwise robust patterns that link racial and economic segregation (and the economic processes with which they are often associated) to increased gasoline consumption at multiple scales.

The final chapter draws conclusions. First, it places the discussions from Chapters 5 and 6 in a broader context by drawing connections between the patterns of energy consumption in Philadelphia and meta-level discourses regarding climate, environmental justice, and global change. Second, it evaluates the research approach through the evaluation criteria suggested in Chapter 2. Research and data gaps also are identified and discussed. The thesis ends with a brief discussion of potential paths for future research.

Chapter 2

GREENHOUSE GASES AND CONSUMPTION: TOWARD A NEW SCIENTIFIC DISCOURSE

Introduction

I think that scientists have been talking about GHG emissions in the wrong ways. In making this statement, I assume only that these scientists want their work to contribute somehow to a reduction in GHG emissions, thereby minimizing the threats posed by future anthropogenic changes in Earth's climate. Given the concerned tone of most climate scientists, in presentations and in the scientific and popular literatures, this is probably a safe assumption. However, the ways that the results of climate science, particularly those of climate models, have been presented to the public and policy makers have created a discursive knot that is difficult to untie. By showcasing long-term projections of the magnitude and timing of future changes in climate, these scientists have highlighted the weaknesses of their models rather than their strengths.

This dilemma does not make their research any less valid. I believe Oreskes (2004:1686) when she says that, "without substantial disagreement, scientists find human activities are heating the earth." However, the discourse about climate change is much more complex than communicating this simple point. In presenting their work as long-term model projections that can be refined, climate scientists have slowed actions to mitigate GHG emissions because they have encouraged an attitude of wait-and-see while they have continued to refine their models.

The bulk of this chapter explores some of the problems of the current academic discourses about global climate change and GHG estimation and mitigation. In doing so, I do not directly critique the methods or findings of climate scientists, but instead address the way their research has been framed and presented and the resulting impacts on the public discourses that influence GHG mitigation. I then present an alternative way of framing this research, borrowing from postmodern geographic theory. Finally, I present an analytical approach that has the potential to create new kinds of academic discourses about GHG emissions – discourses that I hope will be useful to those who want to reduce the human influence on Earth's climate.

Greenhouse Gas Causes and Solutions: A Discursive Analysis

In this section, I evaluate the prominent scientific discourses on global climate change. My intention here is not to open Pandora's Black Box, in the words of Bruno Latour (1987), by tracking the construction of scientific knowledge about global climate change over time. Rather, I base my discussion on the works of others such as Wynne (1994), Paterson (1996), Sarewitz and Pielke (2000), and Demeritt (2001) who already have presented compelling histories of climate change science and of some political implications of the ways that climate science has been framed. I agree with many of the conclusions of these authors. However, my theoretical approach differs substantially from their approaches.

Demeritt (2000:311), for instance, uses what he calls *heterogeneous constructionism* to describe the scientific discourses about climate change science. In his words, this perspective is "ontologically realist about entities but epistemologically antirealist about theories." He contrasts this viewpoint with other "nominalist" perspectives that contend not only the absence of *objectively knowable* truth about objects under study (epistemologically antirealist), but also the absence of any *essential or inherent* truth about those objects that is not mediated and constructed through our discourses about them (ontologically antirealist). Perhaps he uses this framework because his focus is on the scientific knowledge that has been constructed around the physical systems of Earth and the ways in which those systems are being altered by anthropogenic GHG emissions. That is, Demeritt's constructivist history of climate science focuses almost entirely on the physical sciences and on models of physical systems. To be sure, Earth exists and operates as it does independently of our discourses about it. If we did not talk about the rain, it would still fall; if we did not talk about the radiative properties of carbon dioxide, it would still reradiate long-wave radiation toward Earth's surface; if we did not discuss the changing climate patterns, they would still change. So, perhaps Demeritt's theoretical framework is appropriate given the context of his work. His contention is that an objective reality about Earth and its changing climate exists, even if humans (let alone scientists) cannot ever objectively know it.

However, my focus here is on GHG emissions, or on the causes of climate change, rather than on its physical effects. Elsewhere in this chapter, I demonstrate that these emissions, while they have physical properties, are inherently social. That is, they are the result of human activity. It is also true that the effects of climate change are inherently social. In the end, climate change is a concern not because of an aversion anyone has to an increase in global mean temperature, but because changes in temperature and precipitation will affect human activities and well being. Therefore, the effects of climate change will depend to a great degree on the characteristics of these human activities, including their relationships to environmental systems. However, this is not a point that is explored in any depth by Demeritt (2000). He concerns himself almost exclusively with the construction of science around the prediction of things like changes in temperature and rainfall.

I base my theoretical framework on social theorists such as Michel Foucault (1972, 1978, 1980), Jacques Derrida (1973), and Jean-Francois Lyotard (1979), and geographers such as Edward Soja (1989, 1996), Lakshman Yapa (1996), and David Harvey (1996). Not all of what these individual scholars have written is compatible with the works of the others. Indeed, in some cases they are very much at odds. However, all of these authors have at least one commonality: a fundamental break with the subject/object dichotomy. That is, these authors contend that academics ("subjects") and their discourses are inexorably a part of the ontological entities ("objects") that they study. For instance, extending the discussion above, if we (i.e., humanity) did not talk about race, it would not exist. By creating the categories black, white, yellow, etc. (or alternatively, African-American, Caucasian, Asian, etc.) and ascribing attributes to those categories, we create a thing called race and categorize people based on this social construction.

Foucault (1978) used this concept to show how "normal" (and "abnormal") sexuality has been socially constructed over time, particularly through religious and psychological discourses. Yapa (1996) used this same concept to show how various discourses socially construct poverty. In doing so, he extended the subject/object binary to include other meaningful binaries, including one that I find particularly useful: problem/non-problem, which describes a dichotomy between some sort of social problem under study, such as poverty, and a researcher who is separate from the problem, or is the non-problem.

I argue that the same dichotomy exists in discourses about GHGs – the problem, GHG emissions, is studied by researchers who are assumed to be outside of the problem, or separate from it. In contrast, I show below that the ways that climate change scientists have framed their research has directly influenced the debates regarding GHG emissions and has negatively influenced society's ability to reduce the GHG emissions driving anthropogenic climate change. While recognitions of this problem are appearing in the literature, this thinking has not yet influenced the practices of most academics researching GHG emissions and/or their mitigation. This is troubling because if researchers are part of the object under study, then simply creating accurate knowledge is no longer sufficient for good science. Rather, a more important evaluation criterion is its usefulness for a given purpose. What purpose that is depends on the researcher. As stated in Chapter 1, a goal of this thesis is to produce knowledge that is useful for bringing about GHG mitigation. I therefore use that goal as an evaluation criterion in discussing the perspectives below.

Global Problems and Global Solutions

Sustainable development and its academic cousin sustainability science have become the dominant frameworks through which politicians and academics view global climate change (Turner et al. 2003, Swart et al. 2004). The literature on sustainable development and sustainability science is too voluminous to review here, but one of the defining works in this area is the Bruntland Report (WCED, 1987). According to the report, sustainable energy use requires the reconciliation of four key elements (WCED, 1987:169):

- Sufficient growth of energy supplies to meet human needs (which means accommodating a minimum of 3 per cent per capita income growth in developing countries)
- Energy efficiency and conservation measures, such that waste of primary resources is minimized
- Public health, recognizing the problems of risks to safety inherent in energy resources
- Protection of the biosphere and prevention of more localized forms of pollution

Despite its popularity and political traction, this perspective is not without its critics. Although there are many critiques of sustainable development, I will briefly mention just one, which is its intractability. Take, for instance, the agenda set by the WCED on energy, described above. Critics such as Worster (1993) argue that implementation of such an agenda would require perfect knowledge about the human and environmental systems involved, and that such knowledge cannot be achieved. Protecting the biosphere and preventing more localized forms of pollution, for instance, would require perfect knowledge about the environmental systems involved and their abilities to assimilate and neutralize pollutants and to adapt to human-induced change. Accommodating a minimum of 3 percent per capita income growth in developing countries would require perfect or near-perfect knowledge about the economies of those countries and the response of those economies to different energy policies. Similar arguments could be made for the other objectives listed above. The knowledge requirements of such an undertaking are staggering. Still, there are attempts to generate exactly this kind of perfect knowledge. Perhaps the best known are the numerical Integrated Assessment Models (IAMs) that have been created to study the planetary causes and effects of global climate change simultaneously.

Global Models

Just as global circulation models (GCMs) model global climate, IAMs attempt to model the human systems that contribute to and are influenced by global climate change. These numerical models generally try to simulate social systems and in some cases natural systems through deterministic mathematical equations, although some are based on optimization techniques. These models attempt to model energy use, often using models of economic activity, in order to generate emissions scenarios for input into GCM-style models of the global climate. The outputs of these climate models are used as inputs for economic models, which respond to the stimuli of changing climate. The most complex of these models include feedbacks that permit changes in Earth's climate to affect emissions scenarios.

There are active and contentious discourses about some of the underlying assumptions of these models, including discourses over the appropriate discount rate (Cline 1992, Lind 1995, Manne 1995, Schelling 1995) and the role of technological innovation and diffusion (WCED 1987, Cline 1992, Schipper et al. 1993, Walsh 1993, Grubb et al. 1995, Richels and Edmonds 1995). In general, the literature in these discourses suggests that economic costs of GHG mitigation drop as the discount rate decreases and as technological innovation and diffusion gain speed. However, these are among the most puzzling of issues for modelers, according to Dowlatabadi (1995:293), who presents the following questions as limitations of modelers' knowledge about key dynamics of social systems:

- What brings about demographic transition, and can population changes be predicted for the next century or more?
- What are the roots of technological innovation and diffusion?
- What has led to rapid industrialization in some countries and why have other countries failed to grow?

- How are preferences formed and do they evolve through time?
- Is it possible to manipulate the topics of the above questions through specific initiatives?

Sarewitz and Pielke (2000) argue that social scientists have never been able to answer these questions. In fact, they suggest that even the scientists who produce something as seemingly simple as a demographic projection do not consider those projections reliable. However, this unreliability has not stopped the modelers from producing their models for public consumption. For instance, despite the shortcomings in IAMs and the uncertainty of the results, the 1990 Economic Report of the President quoted a projection by Manne and Richels (1990) that a 20 percent reduction in CO_2 emissions would cost the US economy between $800 billion and $3.6 trillion, thereby resulting in a high perceived cost of abatement. Paterson (1996) argues that this perception may have had a significant impact on the negotiations leading to the United Nations Framework Convention on Climate Change.

However troubling this reliance on questionable model formulations may be, Sarewitz and Pielke (2000) suggest that it is more troubling that GHG mitigation has become discursively coupled with GCMs. Their primary concern is that GCMs produce uncertain results *and will continue to do so in the future*. However, policy makers have come to expect more certain results as these models continue to evolve, in no small part due to the ways that scientists involved with GCM research have presented their findings and plans for future work. Meanwhile, advocates of GHG mitigation have tied their arguments for the need for GHG reductions to the results from GCMs (e.g. Gelbspan 1997). The resulting logic, therefore, is that if GCM results are uncertain, then so is the justification for GHG reduction. Furthermore, since this uncertainty is perceived to be temporary, the logical response is to wait for more definitive studies before acting.

Sarewitz and Pielke (2000), however, argue that along with refined results, tomorrow's GCMs will produce new uncertainties as research uncovers previously unaddressed questions about the way the planet works. In raising this point, they raise a point similar to that made by Lyotard (1979), who contended that scientific inquiry in general creates more uncertainty than it reduces because it is the nature of scientific research to raise more questions than it answers definitively. Figure **2.1** demonstrates that more modeling is not necessarily better. This figure shows the results of more than 2,500 model runs that were performed by climate*prediction*.net[1] on a distributed network of personal computers, similar to the network that the Search for Extraterrestrial Intelligence (SETI; see http://www.seti.org) has used to process radio waves from outer space. It should be noted that the model runs by climate*prediction*.net stopped after 15 years. Had they continued for 30 years, as the Hadley Centre model runs presented in Figure **2.1** do, it is likely that the spread of uncertainty would have increased further.

Ironically, climate*prediction*.net has *prediction* italicized in its name to emphasize the focus on prediction rather than mere simulation. To quote the home page, "There is a broad scientific consensus that the Earth will probably warm over the coming century; climate*prediction*.net should, for the first time, tell us what is most likely to happen." The idea is that by using more computing power to produce more model runs, the uncertainty in GCM simulations can be reduced, or at least quantified so that a probabilistic prediction of changes to Earth's climate can be produced. The phrase "for the first time" suggests that all other existing modeling efforts have failed, whereas climate*prediction*.net will succeed. As

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[1] The italics and lack of capitalization are part of the proper name.

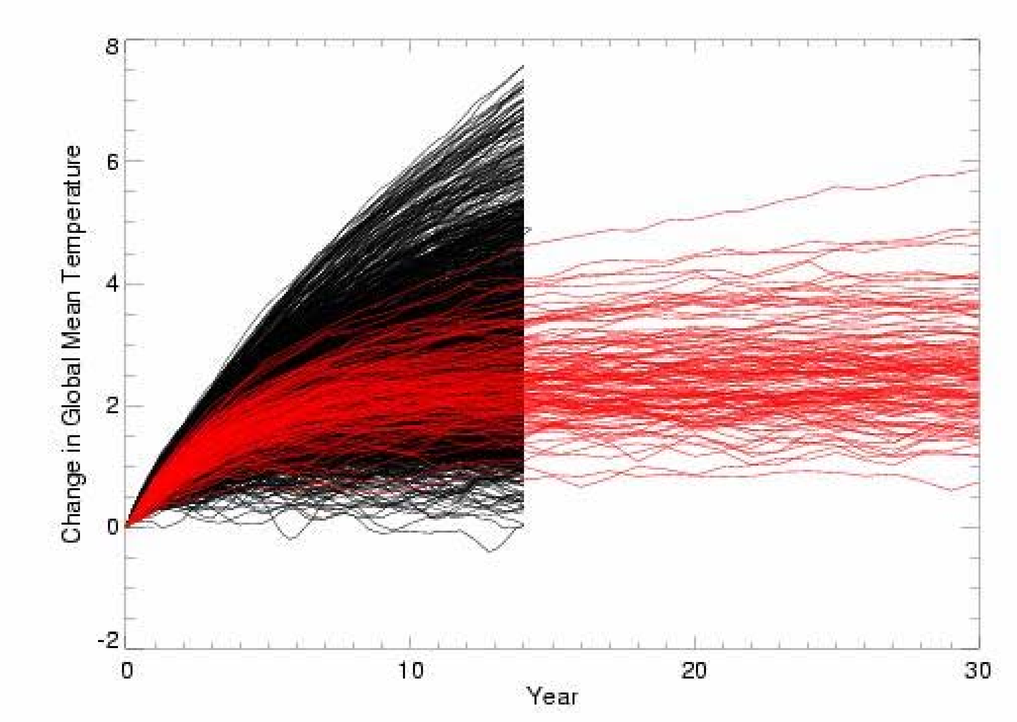

Figure **2.1**: Predictions of global mean temperature after a doubling of atmospheric CO_2. Results in red are the results of 127 model runs by the Hadley Centre. Results in black are the results of 2579 climateprediction.net model runs. Source: climate*prediciton*.net (2005)

Figure **2.1** shows, they have missed the mark. In fact, this project has thus far only served to further highlight uncertainty in GCM projections.

Some modelers (e.g., Oreskes 2003) specifically state that GCMs, and models in general, should not be used for long-term prediction, which is the way their results are most often used. Sarewitz and Pielke (2000) contend that, instead, the best thing scientists can do to address the problem of global climate change is to begin to generate research on the vulnerability of people and places to extreme weather. In doing so, their argument goes, scientists would generate knowledge about how to reduce these vulnerabilities and, since more floods, droughts, and storms are expected with future climate change, they would generate knowledge about how to adapt to the coming impacts. Sarewitz and Pielke (2000:64) further argue that energy-efficiency technologies and other GHG-mitigating options should be freed of entangling GCM discourses and promoted solely on their "intrinsic environmental and economic benefits, and advanced through innovative funding mechanisms."

For the most part, I find these arguments insightful. However, one of the "intrinsic environmental" benefits of energy-efficiency technology is the reduction of GHG emissions that would result from its adoption. Presumably, the authors mean the non-GHG environmental benefits of such options. The problem with this approach is that it may not produce GHG reductions. For instance, focusing on the more immediate environmental impacts of personal transportation might encourage efficiency improvements, which would help to reduce GHG emissions. However, this focus also could promote exhaust-system technologies that capture more volatile organic compounds and particulates. While environmentally beneficial, these technologies do nothing to reduce GHG emissions, and an emphasis on these options may to some degree reduce emphasis on efforts to limit energy consumption. Therefore, while I agree that there is a need to decouple the discourse of GHG mitigation from GCMs (and by extension, IAMs), I must insist that research into options that could bring about GHG mitigation should actively declare such mitigation as one of its goals.

It is not my intention here to issue a blanket indictment of GCMs and climate change scientists. Without GCMs, climate change might not be on the public agenda. However, I am arguing that GCMs often are applied inappropriately; the ways in which they are presented in scientific and policy discourse has hampered efforts to reduce GHG emissions because, as seductive as their global maps and temperature charts of GCMs are, the results are not convincing as long as those people being asked to take action continue to expect (or at least demand) more precise results in the future.

These demands and expectations, whether sincere or intentionally obtuse, have led to what Sarewitz and Pielke (2000) call political gridlock. In addition, Demeritt (2000) claims this focus on modeling has resulted in an inappropriate emphasis on physical systems and processes. Instead, he argues that academics should concern themselves more with the social processes and problems that generated GHG emissions in the first place and, in doing so, recast global climate change as a political, economic, and moral problem rather than simply a global-scale environmental problem. While I do not agree with some of Demerrit's claims or with his theoretical approach, it is difficult to argue with this particular point. I would add that IAMs create further problems by normalizing many economic processes and practices. That is, by linking energy consumption to economic activity, these models ignore many non-economic responses that could reduce GHG emissions. Furthermore, their dominance in political and social discourses places an emphasis on national legislators and regulators, who are the only decision makers capable of implementing market-based approaches such as carbon taxes or tradable emissions permits. This dominance has led to a focus on international diplomacy (e.g., Kyoto Protocol) and national policy options as the primary solutions to global climate change. This focus is problematic for several reasons, which I will now discuss.

Global Treaties and National Options

The most significant international attempt to mitigate GHG emissions is the United Nations Framework Convention on Climate Change (UNFCCC), which formed in 1992 and led to the Kyoto protocol in 1997. This treaty called for differential changes in emissions patterns from the worlds "most developed countries" (MDCs), referred to by the UNFCCC as Annex I countries (see Table **2.1**). The overall goal of these emissions reductions was a 5% reduction in annual Annex I GHG emissions by the year 2013, using 1990 as the benchmark year. While the US has not yet ratified the protocol, it also has not formally withdrawn (UNFCCC 2005), despite frequent news reports to the contrary (e.g., BBC 2005).

The text of the protocol required ratification by no less than 55 parties to the UNFCCC, including Annex I parties accounting for at least 55 percent of 1990 carbon dioxide emissions from all Annex I parties. The protocol came into force on February 16, 2005, 90 days after ratification by The Russian Federation. That ratification brought the total percentage of Annex I emissions from ratifying countries to 61.6 percent. Ratification was

Table **2.1**: Name, dates of signature and ratification, and overall share of emissions for Annex I parties to the Kyoto Protocol. Percentages for countries that have not yet ratified are shown in bold. * indicates share of emissions is less than 0.005% (Source: UNFCCC, 2005)

Country	Date Signed	Date Ratified/ Acceeded/ Accepted	Percentage of Annex I emissions
Australia	29/04/98		**2.10%**
Austria	29/04/98	31/05/02	0.40%
Belgium	29/04/98	31/04/02	0.80%
Bulgaria	18/09/98	15/08/02	0.60%
Canada	29/04/98	17/12/02	3.30%
Croatia	11/03/99		*
Czech Republic	23/11/98	15/11/01	1.20%
Denmark	29/04/98	31/05/02	0.40%
Estonia	12/03/98	14/10/02	0.30%
Finland	29/04/98	31/05/02	0.40%
France	29/04/98	31/05/02	2.70%
Germany	29/04/98	31/05/02	7.40%
Greece	29/04/98	31/05/02	0.60%
Hungary	----	21/08/02	0.50%
Iceland	----	23/05/02	0.00%
Ireland	29/04/98	31/05/02	0.20%
Italy	29/04/98	31/05/02	3.10%
Japan	29/04/98	04/06/02	8.50%
Latvia	14/12/98	05/07/02	0.20%
Liechtenstein	29/06/98	03/12/04	*
Lithuania	21/09/98	03/01/03	0.00%
Luxembourg	29/04/98	31/05/02	0.10%
Monaco	29/04/98		*
Netherlands	29/04/98	31/05/02	1.20%
New Zealand	22/05/98	19/12/02	0.20%
Norway	29/04/98	30/05/02	0.30%
Poland	15/07/98	13/12/02	3.00%
Portugal	29/04/98	31/05/02	0.30%
Romania	05/01/99	19/03/01	1.20%
Russian Federation	11/03/99	18/11/04	**17.40%**
Slovakia	26/02/99	31/05/02	0.40%
Slovenia	21/10/98	02/08/02	*
Spain	29/04/98	31/05/02	1.90%
Sweden	29/04/98	31/05/02	0.40%
Switzerland	16/03/98	09/07/03	0.30%
Ukrane	15/03/99	12/04/04	*
United Kingdom	29/04/98	31/05/02	4.30%
United States of America	12/11/98		**36.10%**
Total Ratified			61.60%

accomplished despite the failure of the United States, which was responsible for 36.1 percent of 1990 Annex I emissions, to ratify the treaty. Thus, even without ratifying the protocol, the United States could face sanctions if it does not reduce its emissions to the agreed-upon national target of 7% below 1990 levels. Despite growing pressure from the international community, the United States still has no formal plan to reduce GHG emissions. As pressure mounts and the international discourses around Kyoto heat up, there will be increasing emphasis on national policies that the United States and other countries could or should enact.

Some of the most commonly discussed and studied options include market-based initiatives. such as tradable emissions permits, and various tax structures (e.g. Dower and Zimmerman 1992, MacKenzie et al. 1992, Reppetto et al. 1992, Mason 1993, Miles-McLean et al. 1993, Pearce and Warford 1993, Walsh 1993). I have shown elsewhere (Neff, 1998) that an increase in the national gasoline tax would reduce gasoline consumption in the personal transportation sector of the United States. However, this solution is problematic for several reasons.

First, if the United States lacks the political will to sign the Kyoto Protocol, it is unlikely to undertake a drastic revision of the tax code to reduce GHG emissions. Second, increasing the price of gasoline has other unintended effects. Figure **2.2** demonstrates that even as the efficiency of personal motor vehicles increased in response to price shocks around 1973 and 1981, miles driven per vehicle increased in the long run. The two dips in the trend line for miles driven per vehicle are short-term responses to these price shocks; over the long term, the aggregate response was to drive more fuel-

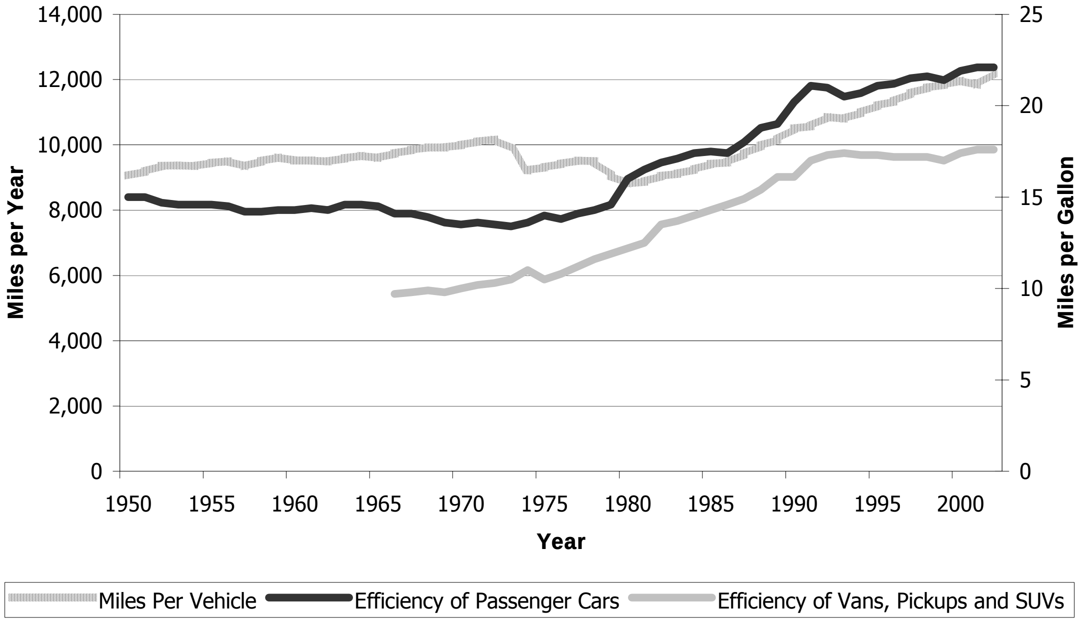

Figure **2.2**: Chart showing the efficiency of passenger cars, the efficiency of other passenger vehicles, and the number of miles driven per vehicle from 1950-2002. Data Source: EIA (2004) efficient vehicles.[2] The overall effect was decreased per-vehicle (and per-capita) consumption of gasoline, but the concomitant increase in vehicle miles traveled (VMT) remained problematic. This increase reflects an increasing dependence on driving, which could be a contributing factor in urban sprawl and might result in future increases in GHG emissions should the efficiency of the motor vehicle fleet continue to drop.[3]

Other problems with an increase in the national gasoline tax have to do with the scale of the analyses supporting such a policy. As a statistical necessity, econometric analyses of the impacts of price increases on the demand for gasoline must be carried out for the nation or at least for mutli-state regions (Neff 1998). These analyses treat people and places in the aggregate. However, personal transportation decisions are made by individuals in response to their local context, and that local context varies greatly across the United States. Therefore, an econometric analysis, while compelling at the national scale, overlooks possible non-economic causes of GHG emissions from transportation such as urban sprawl, lack of public transportation, spatial mismatch, and so on. Thus, econometric analysis treats people and places as averages of the total, as does all regression analysis. However, averages are mathematical calculations – no real person or place might have the characteristics of these averages. For instance, I have shown that in the aggregate, changes to the tax code that returned some of the revenue collected from gasoline taxes through income tax rebates would reduce the overall tax burden of the average United States taxpayer (Neff, 1998). However, there might not be an average United States taxpayer – some taxpayers would

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[2] For clarity, price was left out of the graph in Figure 2.2. For a more detailed analysis, many more graphs, and an econometric analysis, see Neff (1998).

[3] Due to the increased popularity of pickup trucks, vans, and SUVs, the overall efficiency of the personal vehicle fleet in the United States has dropped recently for the first time since 1976, despite improvements in the efficiencies of both vehicle classes shown in Figure 2.2.

benefit less than others, and some would end up paying more taxes. Without intricate tax codes, such a tax structure would probably disproportionately affect lower income families, who tend to spend a greater-than-average percentage of their income on transportation-related expenses. Another way to express this point would be to state that there is a tension between economic efficiency and economic equity.

Thinking Globally and Acting Locally

In response to some of the problems with national-scale initiatives, particularly the political barriers to sweeping environmental laws and regulations, many activists and academics have advocated an approach based on the slogan "Think Globally, Act Locally," a phrase first coined by Hazel Henderson (1978). When Dr. Henderson coined the phrase, she was referring to the notion that, much like the "butterfly effect," local actions could result in global social changes through complex and potentially unforeseen interactions among places and scales. The slogan has since become a rallying cry for activists interested in global issues, particularly global economic and environmental change, and has taken on a life of its own.

In the arena of global climate change, this perspective has in part contributed to countless local initiatives to reduce GHG emissions at scales ranging from multi-state regions, to cities, and to corporate and college campuses. These efforts are not well documented in the literature, but some details can be found in Betsill (2001), Sousky and Schneider (2003), and Betsill and Bulkeley (2004) among other sources. The approaches used in most of these cases are similar and reflect a 5-step approach advocated by The International Council for Local Environmental Initiatives' (ICLEI) Cities for Climate

Protection (CCP) campaign (see Kousky and Schneider 2003). This approach consists of calculating base-year emissions, forecasting emissions growth, adopting an emissions target, completing an action plan, and finally implementing that plan. This approach is comparable to the kinds of thinking behind the UNFCCC and the Kyoto Protocol – emissions estimates for 1990 were calculated, emissions forecasts were generated, and, based on this information, target reductions were agreed on by individual nations. From there, it was each nation's responsibility to develop and implement a mitigation action plan.

Thus, the ICLEI approach being adopted by cities and others is an example of taking global-scale thinking and applying it to local-scale processes. Despite the best intentions of those individuals and entities involved, local initiatives may therefore inherit many of the problems of the global-scale way of thinking. For instance, Kousky and Schneider (2003) show that GHG mitigation using this approach remains a top-down and centralized process, even at the local scale. The commitment to begin the 5-step process and the financial and cooperative support required for gathering the data and developing a mitigation plan necessitate that high-level city officials "buy into the process." While this approach represents a decentering of political power compared to a reliance on national legislators, it could have the same effect at the local scale as it has at the national scale – a lack of political will among officials, which precludes the implementation of mitigation strategies in a city or metropolitan area.

Applying my critique of market-based solutions to the local scale is problematic, but yields some important results. At the national scale, market-based solutions are often suggested for socioeconomic sectors such as transportation that are difficult to control through other means. Power plants are relatively few in number and are stationary sources of

GHGs, whereas automobiles number in the hundreds of millions in the United States alone and are mobile sources of emissions. That is, transportation decisions are made by individuals in response to local circumstances. The thinking, then, is that the only mechanism national decision-makers have for influencing those decisions is to increase the personal costs of each trip. However, local officials are unable to implement similar measures. For instance, in the case of energy use in home heating and cooling, homeowners decide where to set the thermostat by balancing physical comfort with the financial costs of increased energy use. Local officials can influence neither of these factors through taxation. However, there are factors other than energy prices that influence the cost of setting the thermostat at a more comfortable setting, including the amount of insulation in homes and the energy efficiency of furnaces, heat pumps, boilers and air conditioners. Although city officials could mandate that new homes have a certain amount of insulation, they have little influence over most other home-construction decisions. Beyond local government, others, such as community conservation groups or utility companies, can implement energy efficiency programs to help encourage the adoption of energy-efficient technologies and building techniques.

However, the point is that applying "global thinking" to the local scale does not necessarily help bring about efforts like energy efficiency programs. Inheriting the inventory-evaluate-mitigate approach from global-scale perspectives means that researchers working on local-scale GHG mitigation efforts tend to focus their attention on one group of decision makers at a time. While this attention is empowering to those decision makers who receive it, other decision maker and options for GHG mitigation receive little consideration.

This discussion is not meant as a critique of local officials currently engaged in the process of inventorying and mitigating their cities' GHGs – their efforts will surely reduce GHG emissions, at least compared to the emissions that would result if they took no action. Nor is this a critique, per se, of the researchers who help these decision makers navigate the myriad options for GHG mitigation that are within the grasp of city officials, university administrators, or corporate executives. Without academic knowledge about local-scale GHG-emitting practices, these local decision makers probably would not make meaningful reductions in GHG emissions. Still, this brief discussion does demonstrate that the theoretical framework within which these researchers work is problematic for two reasons. First, by first selecting decision makers and then defining the options available to them, they exclude *a priori* other options that might yield greater results. Second, and related to the first point, this perspective focuses on practice rather than process. Rather than viewing GHG emissions as resulting from a set of multi-scale processes that are influenced by multiple actors, emissions are seen as resulting from practices under the control of a specific group of actors.

The next section briefly presents an alternative framework based on postmodern theory that uses theories of *non-sovereign power* to conceptualize the processes producing GHG emissions. The goals of this framework are twofold: to incorporate knowledge about non-economic processes into the scientific discourses about GHG emissions, and to begin to think about the agency of mitigation differently by emphasizing the roles that non-governmental actors play in influencing those processes.

A Postmodern View of Climate Change

The postmodern view of climate change presented here is heavily influenced by the postmodern view of poverty presented by Yapa (1996). This postmodern view begins with a critique of the subject/object dichotomy in modern science, which sees the researcher, or subject, as separate from the object being studied. In contrast, a postmodern view would place the academic and his discourses squarely within the object under study. An example can be taken from the analysis above, which demonstrates that academic discourses about the role GCM results should play in policy decisions have contributed to a political gridlock regarding GHG mitigation. Setting aside, for the moment, the moral and ethical implications of this conclusion, these academic discourses are therefore part of the process that helps to perpetuate GHG emissions. The point of this statement is not to cast blame on any particular scientist or scientific community. Rather, the purpose here is simply to demonstrate that academic discourses play a role in shaping the social processes that they study. Of course, there are other factors at work. The availability of different technologies, for instance, influences energy efficiency, which influences energy use and ultimately GHG emissions from the burning of fossil fuels.

Applying Foucault's (e.g., 1976, 1980) view of non-sovereign power, Yapa (1996) argues that there an infinite number of sites at which various entities exert power of some sort over the creation of poverty. He presents what he calls a "nexus of the production relations of poverty" in which he categorizes this infinite number of sites into six categories: academic, ecological, technical, political, social, and cultural. These are not discrete analytical categories, but bundles of discursive-material entities. These bundles, or nodes, "act and react upon each other constantly to maintain a dynamic system of mutually constituted elements." In other words, to say that political elements of poverty are influenced by the five others misses the point. Rather than being separate entities, these nodes are *mutually constituted*, or made up of each other. In the example of poverty, then, the technical causes of poverty are constituted of academic, ecological, technical, political and cultural entities, just as poverty is constituted of academic, ecological, technical, political and cultural entities.

It is this last point that differentiates a postmodern view of climate change from one proposed by the NRC (1992:75), which suggests examination of five types of social variables that they say are "known to affect the environmental systems implicated in global change:" 1) population change, 2) economic growth, 3) technological change, 4) political-economic institutions, and 5) attitudes and beliefs (Figure 1). The NRC (1992) are quick to point out that these "variables" do not act independently, but rather interact in a complex web of relations. Rather than simply claiming that these variables interact in a complex web of relations, I argue that they are mutually constituted.

An example that I have adapted for climate change is presented in Figure **2.3**. For this example, I have opted to keep the same nodes that Yapa (1996) used, although I could have just as easily used others. Because these nodes are mutually constitutive, some could be removed and others added without altering the network's fundamental properties. That is, these nodes can and should be rearranged to meet the needs of different researchers. However, my purpose here is not to create a network of nodes specific to climate change – it is simply to point out that this approach works for climate change. For instance, energy use could be thought of as having academic, ecological, technical, political, social, and cultural elements. This is a different way of thinking about energy use than the perspectives

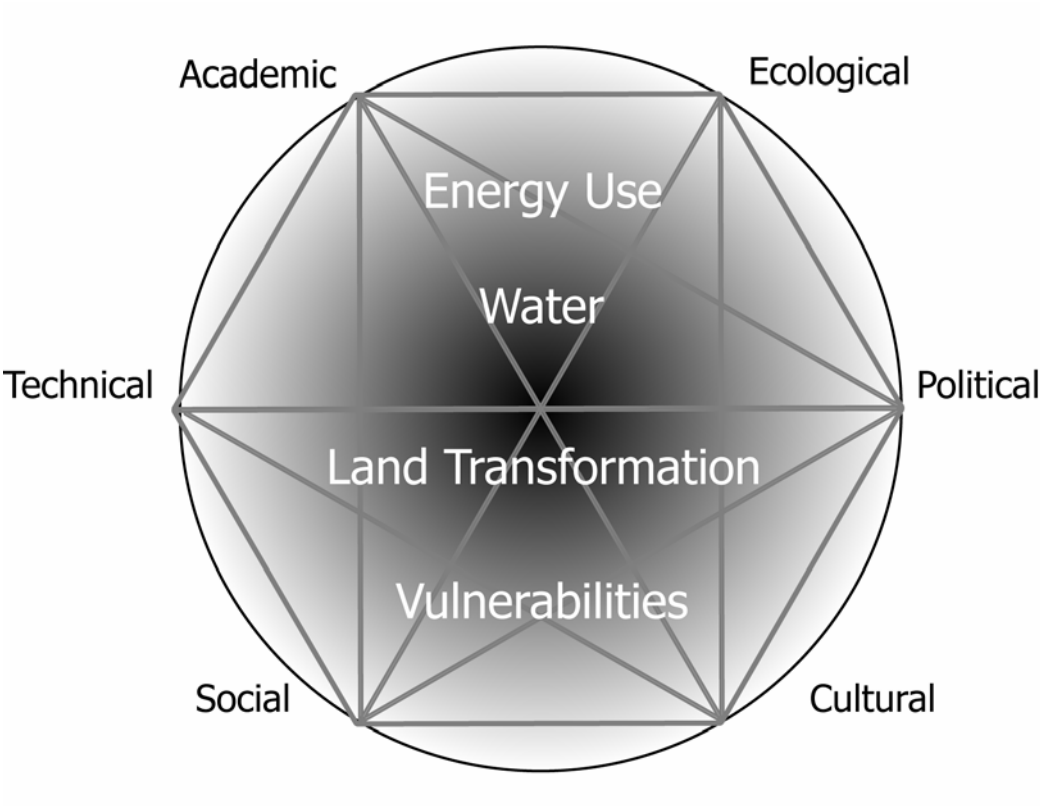

Figure **2.3**: A nexus of relations for global climate change, after Yapa (1996).

described earlier in this chapter, which view energy use – and the resulting emissions – as primarily economic activities.

For example, some technical elements of GHG emissions are presented in Figure **2.4**. In this example, I start with GHG emissions and divide them into technical components, such as transportation, electricity, home heating, etc. I then ask the question, "How are GHG emissions generated from transportation?" Viewing the answers through the nexus of relations presented in Figure **2.3** presents a different view of GHG emissions than the approaches previously discussed. For instance, some of the technical elements of transportation include the transportation network, automobile efficiency, and so on. Alternatively, I could explore the cultural components of automobile efficiency (e.g., the popularity of SUVs) or social elements of land-use change (e.g., suburban sprawl and urban decay). The point is that with this approach, the process of GHG production in the case of transportation is no longer seen as only an economic or political process, but rather a process that is made up of a variety of aspects of transportation (or home heating, or electricity …). Thus, rather than simply working with city officials to reduce emissions within its boundaries, someone interested in reducing GHG emissions from transportation may work to reduce urban sprawl or subvert the discourses that make SUVs popular. In doing so, they would work with a different collection of agents previously excluded from GHG mitigation discourses.

Thus, I use this postmodern approach to think about the production of GHG emissions in a way that includes a larger number and more diverse group of agents than are included by the approaches that appear in the literature. More important, I use a different

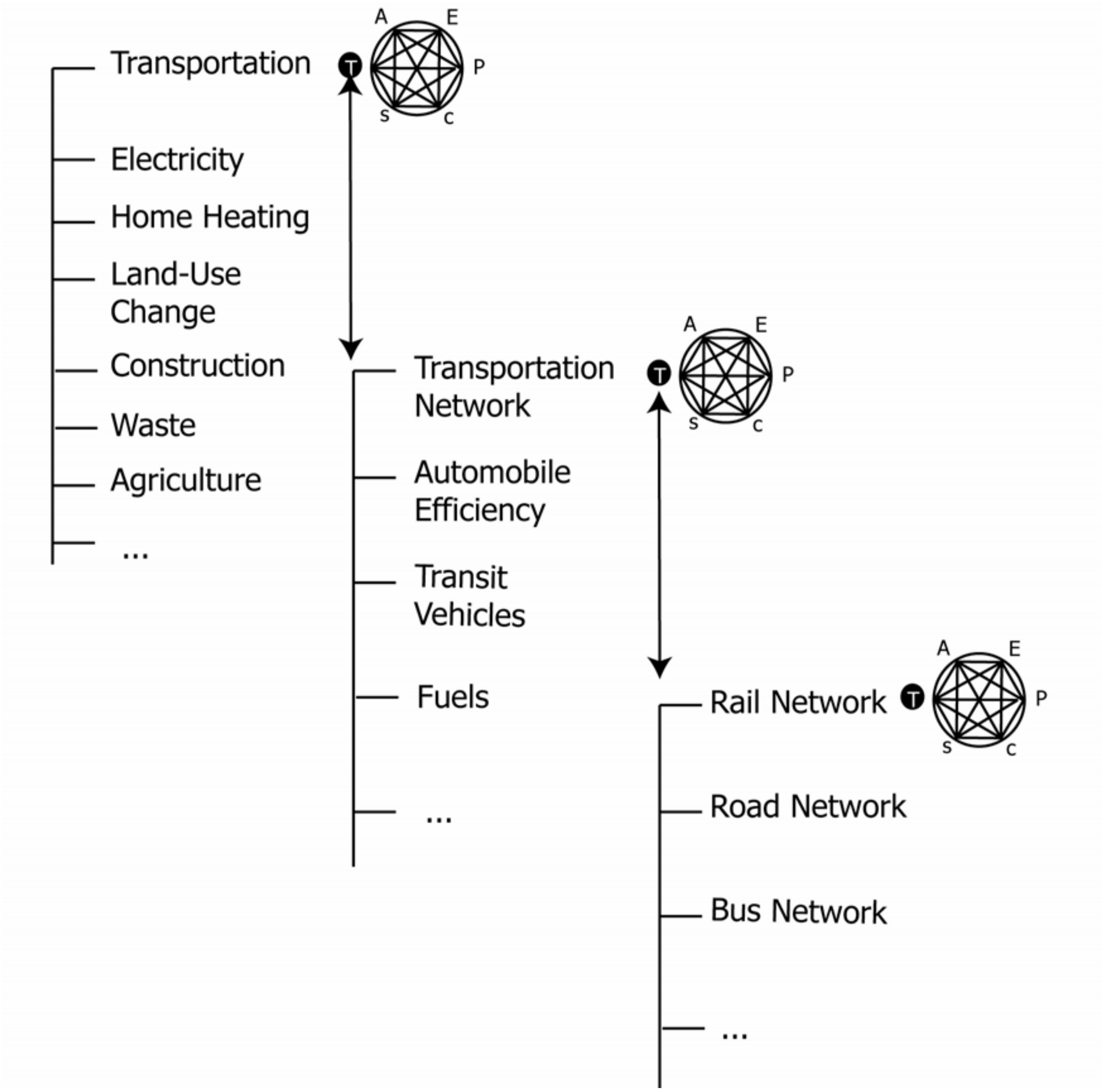

Figure **2.4**: A substantive view of GHG emissions as an alternative to an inventory-based approach, after Yapa (1996).

evaluation criterion for evaluating the resulting research. Rather than simply asking whether or not I have accurately reflected the GHG emission profile for a specific place, I ask whether or not a particular representation is useful for reducing GHG emissions. Because I have situated academic knowledge as part of the processes that generate GHG emissions, and since there are multiple, indeed infinite, ways to represent these processes, it is not enough simply to "get the numbers right." If academic knowledge can be a discursive cause of GHG emissions, then it also can be a discursive cause of GHG reductions. The goal of a postmodern view of GHG emissions, then, becomes the creation of such knowledge.

Consumptive Landscapes: Linking Place and Space with Consumption

Towards that end, I advocate the study of what I call *consumptive landscapes*. Consumptive landscapes are not a kind of landscape that can be found "out there" in the field. Rather, a consumptive landscape is a kind of spatial knowledge about consumption that occurs within a given place. A consumptive landscape differs from what other geographers have called *landscapes of consumption* in that consumptive landscapes seek to describe, quantify, and contextualize the consumption that occurs across space and within place, while landscapes of consumption are places and spaces that particularly enable and/or are socially constructed through consumption, typically of retail goods (e.g., Sack 1988, 1992). Thus, geographers interested in landscapes of consumption are interested in the ways that commodities are presented by retailers or with the ways that commodities are used to create spaces within the home. They also may be interested in the intersections between consumption and other kinds of space and place studied by geographers, including gendered space. Ultimately, geographers who study landscapes of consumption focus on the places that produce and are produced by consumption – these landscapes exist in a concrete sense. They can be visited and photographed; their inhabitants can be interviewed. The same is true of the consumptive landscapes of Leichenko and Solecki (2005), which are suburban developments where population densities are low and consumption levels are high.

My consumptive landscapes, on the other hand, are *representations* of real places and spaces. They consist of maps, charts, data tables, and narratives that describe the consumption of energy, goods, and/or services within a specific geographic area. Consumptive landscapes are both quantitative and qualitative. A consumptive landscape cannot be viewed from the Sears Tower or the Empire State Building. Rather, it is a way of seeing a particular landscape, such as metropolitan Chicago or New York, through the lens of consumption. Consumptive landscapes are constructed by answering questions like "how does the consumption of electricity vary across the cityscape," or "which commuters use the most gasoline to get to and from work."

Consumptive landscapes are concerned with process. As such, they may contain descriptions of landscapes of consumption insofar as descriptions of those landscapes help to explain spatial patterns of consumption and their effects on the landscape. Consumptive landscapes are concerned with the history of places and changes in their consumption patterns over time. They relate spatial patterns of consumption to other patterns, such as racial, economic, or gendered segregation and exclusion. Fundamentally, consumptive landscapes are concerned with answering questions about who consumes what; where, how and why that consumption occurs; and what the consequences of that consumption are.

While they need not necessarily include analyses of GHG emissions, consumptive landscapes are a useful way of thinking about GHG emissions at a local scale. These emissions cannot be measured directly – they must be estimated based on activity data such as gasoline combustion or solid waste production. Most of those activity data involve some kind of consumption. Electricity is consumed in homes and businesses. That electricity can be measured, and GHG estimates can be calculated based on the fuel mix at nearby power plants and other conversion coefficients. Gasoline is burned as a result of transportation, and estimates of the amount of gasoline consumed during a given trip can be used to yield estimates of that trip's GHG emissions. Solid waste, a byproduct of consumption, produces GHG emissions when it decomposes in a landfill and also can easily be measured.

Using consumptive landscapes as a perspective for studying GHG emissions avoids the trap of focusing on a single kind of decision maker, such as a city official, and instead provides a spatially specific estimate of GHG emissions in a cityscape. As already mentioned, consumptive landscapes are rich with contextual and historical information about the places within the landscape. As such, carefully constructed consumptive landscapes have something to say about the processes that contribute to various kinds of consumption. While this approach does not necessarily elucidate pathways to emissions reduction in and of itself, it can provide the basis upon which more substantive questions like the questions suggested in the previous section can be asked. Furthermore, the consumptive landscape perspective does not get bogged down in assigning GHG emissions to any particular person or group of persons. The intent is not to lay blame or responsibility, but instead to move toward a collective responsibility for altering behavior that leads to GHG emissions.

Consumptive landscapes take considerable time and expertise to construct. Furthermore, to keep their focus on process, they must focus on a particular kind of consumption. The remainder of this thesis serves as an example of a consumptive landscape for metropolitan Philadelphia, focusing on the consumption of gasoline by commuters who drove alone to work. Chapter 3 presents a new method for estimating and spatially representing gasoline consumption and the resulting GHG emissions from transportation in cases where origin-destination data are available. Chapter 4 provides some regional context for Philadelphia, focusing on racial and economic segregation. Chapter 5, then, presents a series of maps, charts, and tables that describe the patterns of gasoline consumption within fourteen places in the Philadelphia metropolitan area. Region-wide patterns of energy consumption, and the relationships between those patterns and the patterns of segregation presented in Chapter 4, are discussed in Chapter 6. Together, Chapters 4, 5, and 6 constitute an example of what I call a consumptive landscape for Philadelphia.

Chapter 3

RE-PRESENTING THE CONSUMPTIVE LANDSCAPE

Introduction

This chapter presents an approach that uses a transportation model to describe patterns of gasoline consumption (and thereby GHG emissions) resulting from the commute to work. This approach not only estimates GHG emissions from transportation in the Philadelphia Metropolitan area, but also identifies the people and places producing the emissions by mapping the emissions according to commuters' destinations and origins in conjunction with demographic and other spatially referenced data.

There are some studies that have been developed in parallel with the development of this thesis that demonstrate the power of mapping consumptive landscapes, even if they do not use this terminology. Most notably, the Transportation Research Board (TRB) of the National Research Council (Feigon et al. 2003; see also http://www.travelmatters.org), provides transportation emissions maps similar to those produced here. The TRB report presents maps for Chicago, Los Angeles, and San Francisco that show emissions from automobiles by residence that are normalized both by area and by number of households. However, there are several differences between the TRB study and this thesis.[4]

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[4] The foremost difference between the TRB study and this thesis is the sources and character of data. The TRB study is based on Vehicle Miles Traveled (VMT) data provided by the location efficiency model (LEM; see Feigon et al., 2003 and http://www.locationefficiency.com). Herein lies the most significant flaw in the TRB's approach: the VMT data generated by the LEM are based on regression models using residential density, transit access, and indicators of local amenities and pedestrian friendliness. Although it is unclear what data were used to calibrate the regression model, it appears to be drawn from a national county-level dataset of VMT provided by the Office of Highway Policy Information (formerly Office of Highway Information Management, or OHIM; see http://www.fhwa.dot.gov/policy/ohpi/index.htm). Thus, the local-scale

The method used in this study estimates VMT by origin and destination based on the Census Transportation Planning Package (CTPP; BTS 1990)[5]. This approach does not take into account emissions from trips other than the commute to and from work, nor does it include emissions from side trips during the commute. Even so, it bases the VMT estimates on directly observed data and accounts for a significant portion of a household's daily intra-metropolitan travel. It also accounts for the portion of trips most likely to be addressed by planners responsible for shaping the transportation network. Basing emissions estimates on origin-destination pairs also allows the investigator to tabulate and display emissions by either origin or destination, or both. This added detail in the data provides the opportunity

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assessments are likely based on national average travel behavior and are subject to many of the critiques of such approaches presented earlier in this thesis.

Even if they are based on more regionally or locally specific data, the VMT data are suspect because they are not being used for the purpose originally intended. The LEM was originally developed as part of an assisted mortgage program designed to offer an incentive for people to live in location-efficient neighborhoods. Eligibility for these special mortgages is based on the location efficiency of the neighborhood, as determined by the LEM. Thus, in the original context, predicting VMT based on location attributes, such as density and access to transit, is appropriate because it is not the prediction of VMT itself that is important. Rather, in this context, the predicted VMT is important only as an indicator of the efficiency (or more accurately the desirability) of a location, based on criteria set by the program officers.

Still, the efficiency of a place, as defined by the LEM, and the behavior of those living in these "efficient" locations are not necessarily linked. For instance, commuters may decide not to use the public transportation routes available for several reasons. The transit system may not provide speedy and affordable service to their particular workplace, or the commuters may simply prefer to drive instead of taking the train or bus. While a relationship between automobile ownership and VMT was confirmed using neighborhood data, there is no mention in any report linked to this work of an effort to confirm the VMT estimates for any of the cities in the study. In sum, the researchers all but assured that emissions would be linked to location attributes such as residential density by basing their emissions calculations on VMT estimates that are themselves based on location attributes. Perhaps this approach seemed reasonable in the face of the difficulties involved in finding reliable neighborhood-level data on VMT, particularly for trips tied to a specific household address. Nonetheless, the use of data that was never really meant as an accurate portrayal of local residents' behavior leaves their findings suspect, at best.

[5] Some may think there is a tension between my advocacy of non-sovereign power in Chapter 2 and my use of government-collected census data, which could be construed as an exercise in sovereign power. However, I do not believe a tension exists. Lyotard (1979) argued that those using a postmodern framework need not discard all of modernity, but instead should apply those aspects of modernity that they find useful. In the same way, I argue that sovereign data may prove useful to promoting non-sovereign power. The data are not automatically contaminated simply because they were collected by the government. In this case, census data are clearly useful in producing a detailed geography of energy consumption from which more substantive questions can be asked that might lead to non-sovereign empowerment.

to explore the processes involved in GHG emission generation more deeply. Furthermore, these data are available at a neighborhood scale for every metropolitan area in the United States. Basing a research approach on such widely available data makes it possible to apply the approach across socially and environmentally diverse cities. For example, the model created for this thesis has already been used to estimate emissions from the commute to Penn State University (Stueur, 2004).

The remainder of this chapter describes the data and methods used to convert the CTPP data into VMT and, by extension, estimates of gasoline consumption and emissions for commuters in the Philadelphia metropolitan area. Methods for visualizing the results also are discussed.

Traffic Assignment and Analysis

The VMT and emissions estimates, and in turn the maps visualizing these emissions, are based on an All-Or-Nothing (AON) traffic assignment model that is loosely coupled with the ArcView interface (see Appendix A for a discussion of AON traffic assignment). Traffic assignment is a problem for which there is no single optimal solution when viewed through the eyes of individuals traveling on the network trying to minimize their travel costs. That is, there are no algorithms for assigning traffic such that each traveler successfully minimizes his travel cost. Instead, there are many heuristics that approach optimality. AON traffic assignment finds the shortest-distance path for each travel and assigns them to that path. An incremental assignment heuristic requires data describing the additional travel time imposed on an arc by the addition of commuters. In other words, this approach accounts for congestion effects that AON assignment ignores. There are still other approaches, such as stochastic or agent-based approaches, which also take into account congestion effects and other factors including traffic lights, cross traffic, left turns, etc., when calculating travel time. The base assumption of all of these approaches is that each traveler attempts to minimize his or her travel time in the context of the actions of everyone else.

These complex approaches are unnecessary for the scope and scale of this thesis. Estimating commuter travel time is not of primary importance. Because absolute emissions estimates are less important in this thesis than understanding estimates for a place relative to other places, the use of a simple AON model is not problematic. Only the network of major highways and roads is used, eliminating the possibility of the AON model assigning massive amounts of traffic to neighborhood streets, which would result in lower than realistic estimates of emissions. It is possible that using an AON assignment on a sparse graph (see below and Appendix A) would result in overestimates of emissions, but this approach would only increase each individual trip by a few hundred meters in the worst case. In short, I have a high degree of confidence in the *relative* emissions estimates for each place.

Figure **3.1 describes the data involved in each step of the analytical process**. Tabular data describing the locations and lengths of road segments and the locations of places of work and residence were exported from ArcView and imported into a program coded in C called TARN (Traffic Assigner by Rob Neff; see Appendix B for the code). TARN, in turn, builds a network that connects all origins and destinations with the road network and uses origin-destination data from the CTPP to assign commuters to their shortest path routes between their home and workplace. Results are initially exported into a series of origin-destination matrices that provide the total number of commuters, total number of drivers, and total miles traveled for each origin-destination pair. These tables are then summarized for all origins, all destinations, and specific combinations of destination points that make up definable workplaces in the metropolitan area. Finally, the results are mapped using Avenue scripts (see Appendix C) to produce surfaces that show total emissions by workplace and by residence. Furthermore, the place-specific tables generated for each workplace result in maps of commuters, drivers, and emissions by neighborhood of origin for each workplace (i.e., the work-shed, car-shed, and emission-shed for each place of work).

Figures **3.2** and **3.3**, **respectively,** describe the generation of the spatial data and the exporting of them to tabular form for input to TARN. The CTPP tabulates data by traffic analysis zone (TAZ), a special aggregation unit designed specifically for the 1990 CTPP that is approximately the same size as a Census block group. In fact, a TAZ is compiled using Census blocks in much the same way that Census block groups are formed, but TAZs do not have a direct one-to-one correspondence to block groups. Shapefiles defining the TAZs are now available online, but the shapefiles are of questionable quality and were not available when the study was first conducted. Instead, an ArcInfo coverage of the TAZs for the Philadelphia metropolitan area was constructed based on a coverage of Census blocks. As described in Figure **3.2**, this coverage was joined with a table assigning each block to a TAZ, then dissolved based on the TAZ field. This strategy resulted in a polygon coverage of the TAZs, which was then converted to a point shapefile by defining the centroids of each

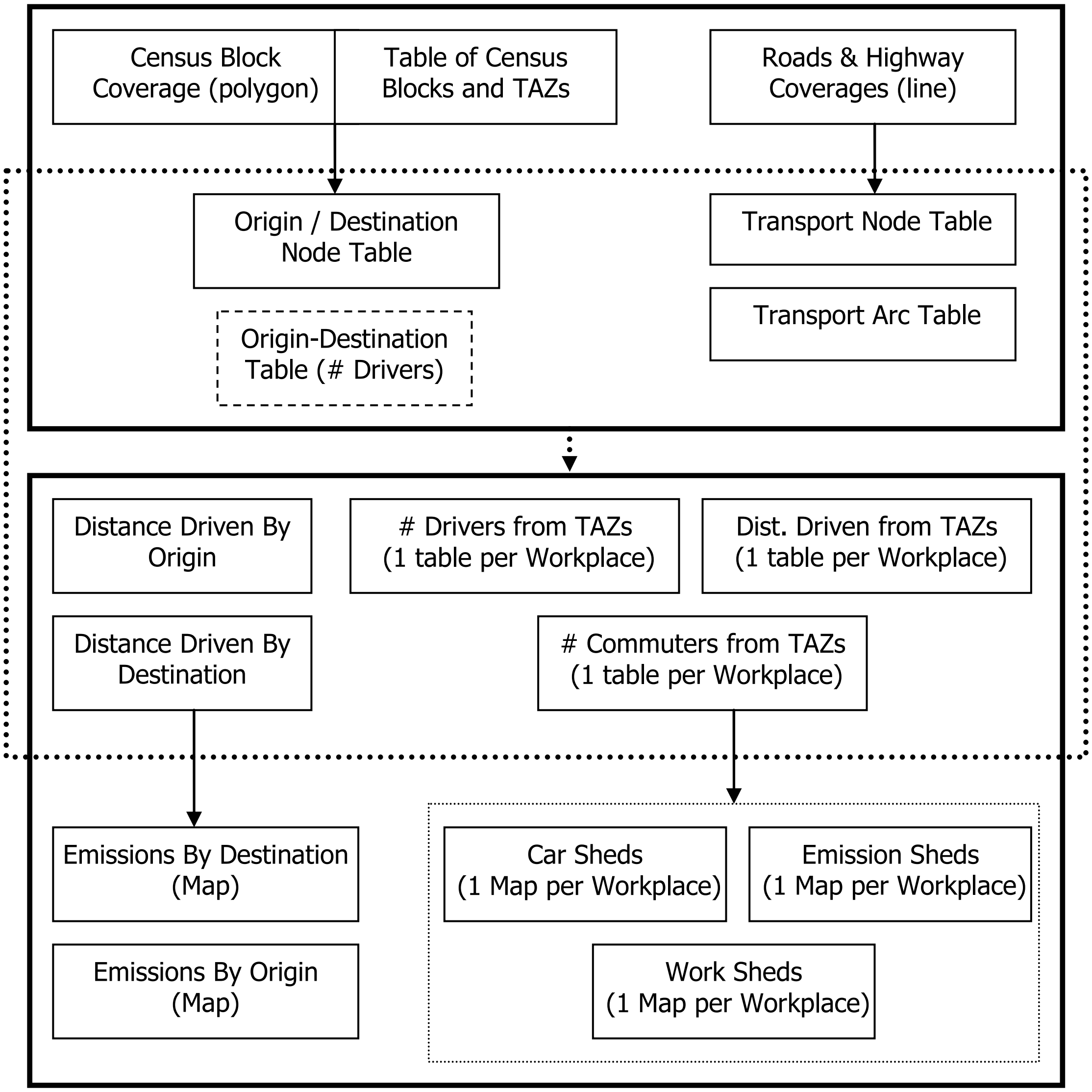
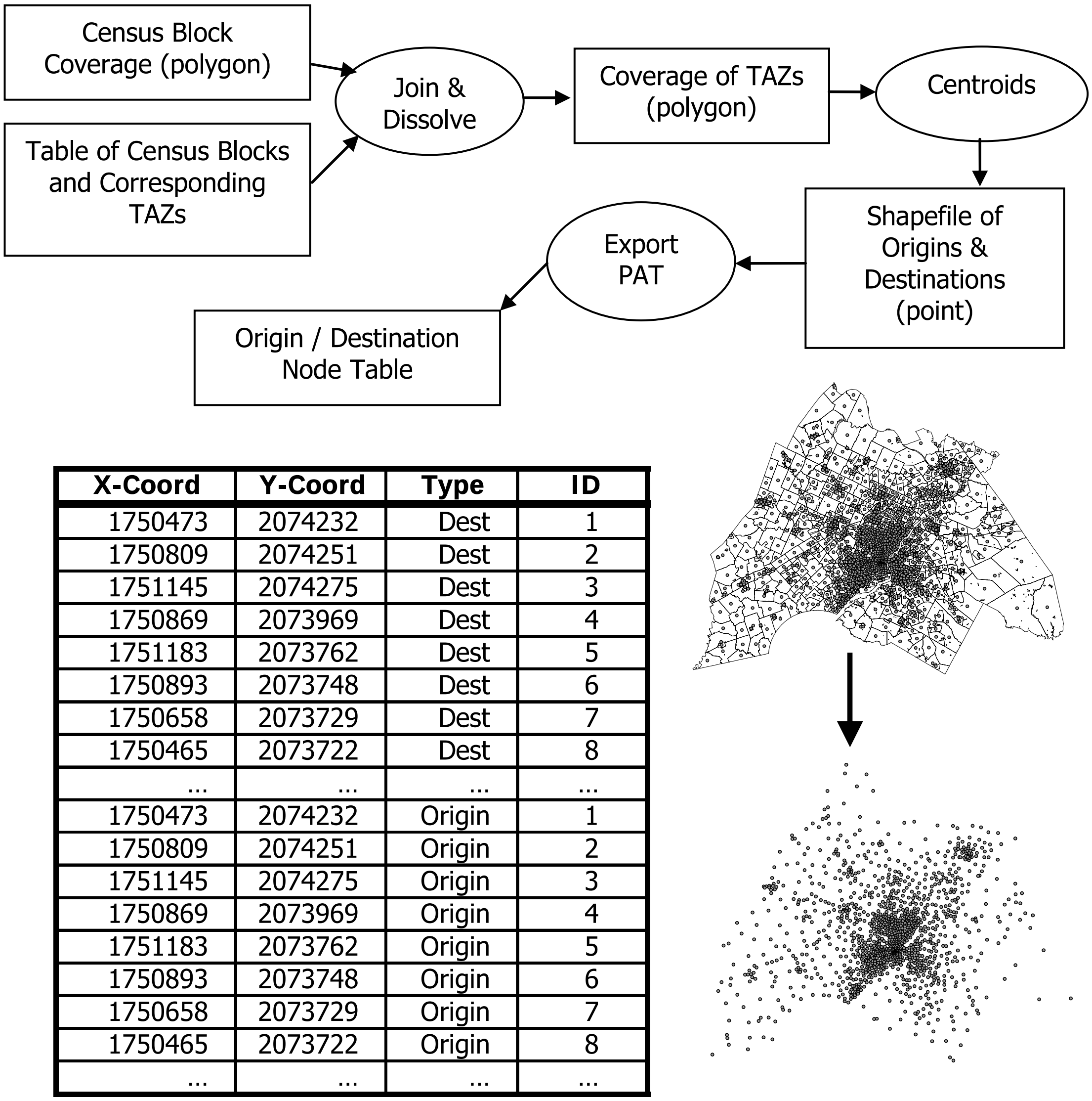
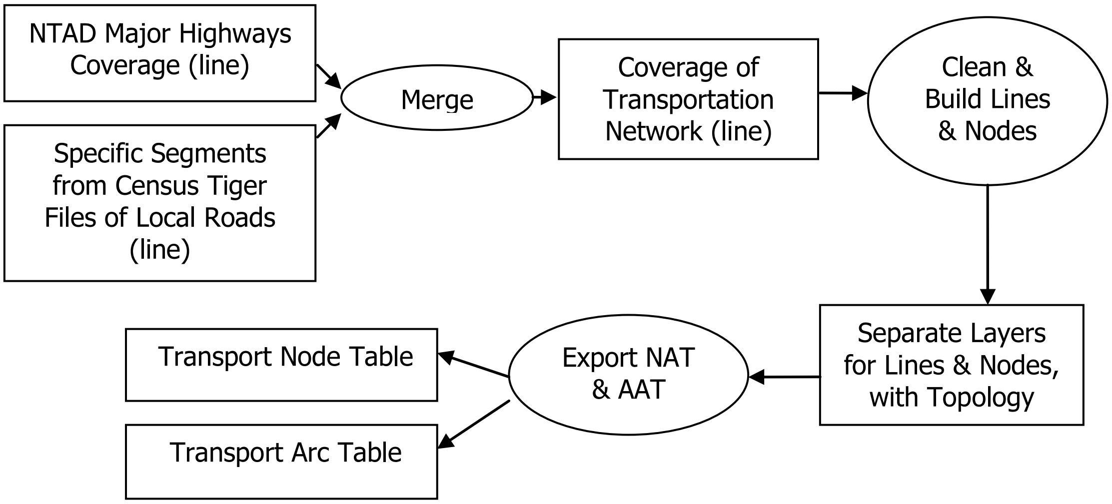


Figure **3.1**: Basic analysis plan, showing the data used in the GIS in bold boxes and the data used in TARN in the dotted box. Similarly, data transformations performed in the GIS are shown using bold arrows, while the transformation performed in TARN are indicated with the dotted arrow. A dashed data box indicates data incorporated from outside both the GIS and TARN.

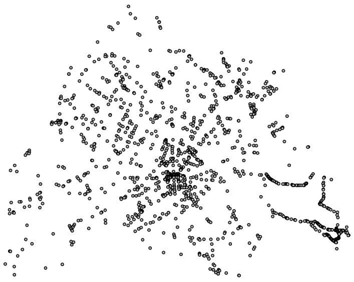


X-Coord	Y-Coord	Type	ID
1750473	2074232	Dest	1
1750809	2074251	Dest	2
1751145	2074275	Dest	3
1750869	2073969	Dest	4
1751183	2073762	Dest	5
1750893	2073748	Dest	6
1750658	2073729	Dest	7
1750465	2073722	Dest	8
...	...	...	...
1750473	2074232	Origin	1
1750809	2074251	Origin	2
1751145	2074275	Origin	3
1750869	2073969	Origin	4
1751183	2073762	Origin	5
1750893	2073748	Origin	6
1750658	2073729	Origin	7
1750465	2073722	Origin	8
...	...	...	...

Figure **3.2**: Data analysis diagram showing preparation of the spatial attributes of origins and destinations from Census data, graphic representation of the origins and destinations, and a sample from the resulting table. Note that each point is used to create both a destination and an origin.



X-Coord	Y-Coord	Type	ID
1731465	2145230	Road	1
1732260	2142171	Road	2
1743304	2140499	Road	3
1734296	2140292	Road	4
1744221	2138765	Road	5
1744305	2138692	Road	6
1744251	2138653	Road	7
1727092	2138332	Road	8
1723387	2136719	Road	9
1744601	2136717	Road	10
...	...	...	...



To-Node	From-Node	Length	ID
1	2	3310	1
2	4	2872	3
4	3	10561	2
4	15	8324	12
5	7	116	5
7	6	67	4
7	10	2003	7
8	2	6952	6
8	14	10185	11
9	11	774	9
...	...	...	...

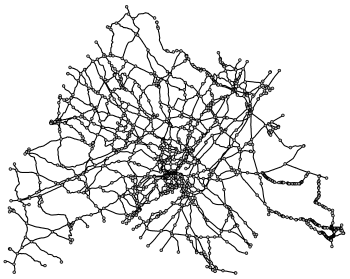


Figure **3.3**: Data analysis diagram showing preparation of the spatial attributes of roads, graphic representation of the roads, and a sample from the tables produced. Note that the data were exported from arc/info coverages, and therefore contain topologic information.

polygon. Finally, the point attribute table, complete with x and y coordinates, was exported to a text file that was readable in TARN. Note that the x and y coordinate data are not expressed in degrees, but in meters because all data were projected using a Lambert equal-distance projection using meters to minimize the effects of projection distortions on distance calculations. This strategy also made model output much easier to interpret without additional conversions – an important consideration when performing multiple model runs for debugging and data verification.

Figure **3.3** shows the data preparation process for the road network. As described in Appendix A, the road network came mostly from the National Transportation Atlas Database (BTS 1992) and consisted of state and national highways. However, not all portions of the metropolitan area are accessible via major highways. In those cases, some road segments were merged from the Census TIGER files, which provide spatial data for nearly every road in the study area (see the discussion regarding AON traffic assignment in Appendix A for an explanation of the effects that these data decisions had on the model results). Using tight tolerances, the resulting ArcInfo coverage was cleaned and the topology for the nodes and lines was built, which resulted in layers that could be read separately as point and line layers representing the nodes and arcs of the road network. The attribute tables were exported and cleaned to generate tables resembling the tables shown in Figure **3.3**. Note that the tables retain the topology of the original ArcInfo coverage (i.e., the arcs refer to the nodes, which in turn contain the spatial information). Had the tables been created using shapefiles, this topology would not be available, thus making subsequent analyses difficult or impossible.

Figure **3.4** shows the details of the analysis based on these tables, in conjunction with the origin-destination tables for all commuters and specifically for those commuters who drove alone. First, the network is imported by TARN, then additional links are created between the origins and destinations and the road network. A few links are added to the road network to represent bridges and other connections not represented in the spatial data. Finally, the origin-destination tables are loaded, the data are run through the AON traffic assignment routine, and the results are dumped to multiple text files. As shown in Figure **3.4**, the program generates separate tables for (1) distance driven by origin, (2) distance driven by destination, (3) traffic loads for both roads and links, and (4) origin-destination matrices that show the number of commuters, number of drivers, and total distance driven for each origin-destination pair. Finally, after places are identified based on emissions maps, the origin-destination matrices are summarized to create tables representing the number of commuters, number of drivers, and distance driven from every residential TAZ to each workplace of interest (with one set of tables for each workplace).

These steps are not performed automatically. TARN works using an interactive command-line system that prompts the user and executes the entered commands. Table **3.1** lists all the commands recognized by TARN with their functions, and their syntaxes. This list demonstrates the datasets required for each command and the flexibility of the interface. This flexibility comes at a cost – using the interface requires a degree of skill and expertise beyond that required to operate a GIS. Work is underway to integrate this model with the new ArcGIS interface more tightly using Visual C++, but such integration is outside the scope of this thesis. Until then, the tables, figures, and text in this chapter should provide

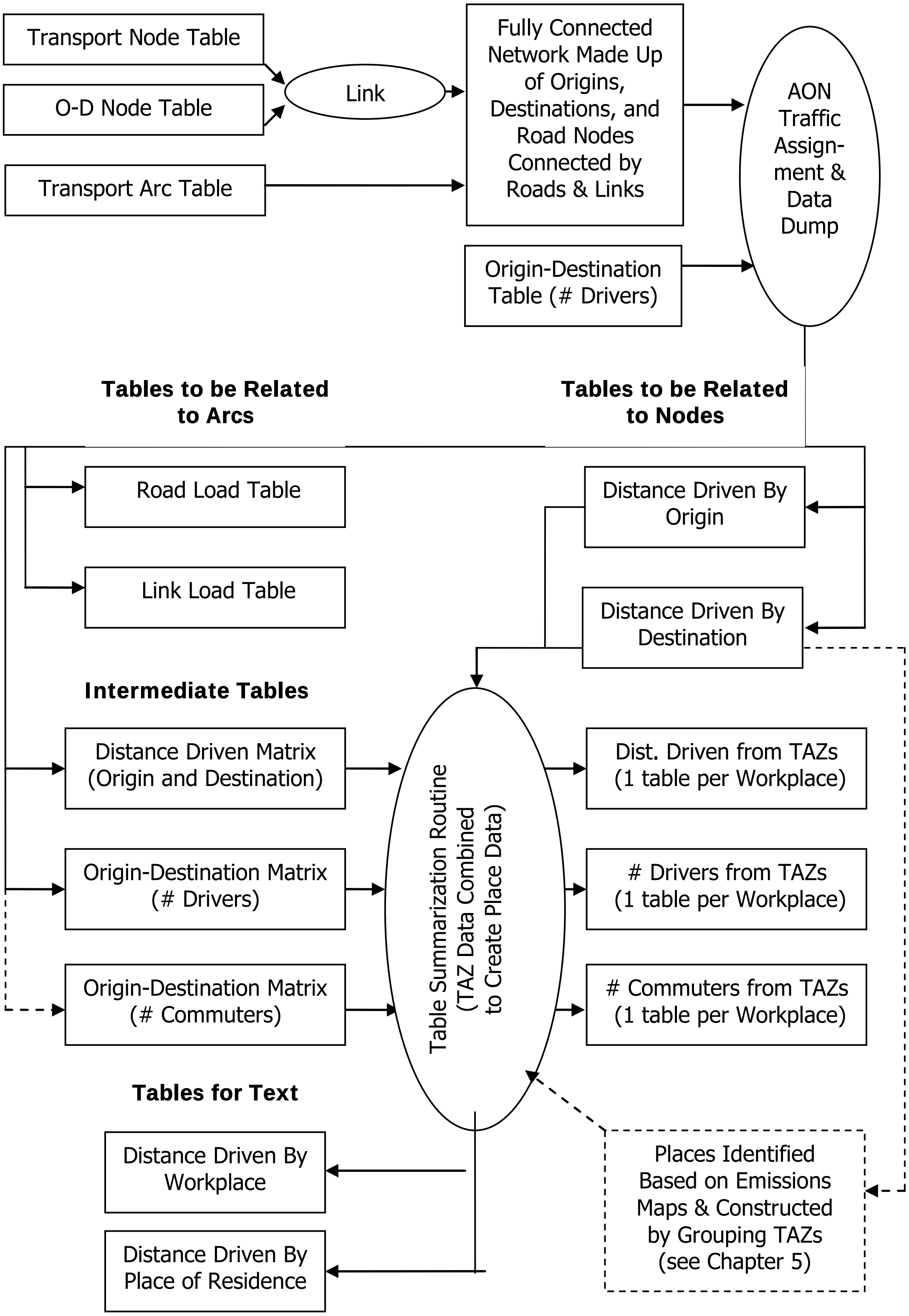


Figure **3.4**: Details of data analysis in TARN. Steps in dashed lines are performed in the GIS (see Figure **3.5**).

Table **3.1**: Commands recognized by TARN, with their functions and their syntaxes.

Command	Function	Syntax
wd	Change working directory	wd <path>
run	Execute a script	run <filename>
createnet	Create a new network	createnet <net_name>
loadnodes	Imports nodes from text file	loadnodes <net> <filename>
loadarcs	Imports arcs from text file	loadarcs <net> <type> <filename>
loadod	Imports origin-destination table	loadod <net> <type> <filename>
addlink	Link specified node pair	addlink <net> <type1> <id1> <type2> <id2>
linknodes	Link specified groups of nodes automatically	linknodes <net> <type1> <type2> {distance}
aon	Perform AON traffic assignment	aon <net>
sum	Dump results to text tables	sum <net>
sumtab	Sum columns or rows of existing tables	sumtab filename <rows|cols> <headname1,headname2,…,headnameX> <outfile> {outcols|outrows}
quit	Quit the program	quit

enough information for someone with GIS and programming training to operate the model.[6]

Finally, the tabular model results are imported back into the GIS and mapped (see Figure **3.5**). The table showing the number of commuters traveling on each road is joined with the roads coverage and then mapped using a graduated symbol scheme that shows more heavily traveled road segments in thicker lines and less heavily traveled segments in thinner lines. While this step is not directly useful for estimating greenhouse gases, it is useful for confirming that the model is working properly and the data were properly prepared and formatted.

Emissions surfaces by origin and destination are created by joining the appropriate tables to the original centroids shapefile, normalizing the data by area, and interpolating a raster surface using a standard nearest neighbor method. While this approach results in some distortion around the edge of the study area, this problem is unavoidable given the lack of data points outside the study area. In the case of Philadelphia, there are more than 1000 data points within the study area, so the distortion is minimal. The resulting maps will be shown in Chapter 5. There, the emissions map for destinations will be used to identify "hotspots," or places with above-average emissions. When multiple adjacent TAZs are selected as hotspots, they are merged to create a *workplace*. As discussed previously, these TAZ

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[6] The coding environment in ArcView 3, the GIS used at the start of this project, did not allow for tight integration between TARN and the GIS. ArcView has since evolved into the ArcGIS 8 (and even more recently, 9). During this evolution, Avenue, the old rigid coding environment, was abandoned in favor of Visual Basic and Visual C++. This environment allows new data structures and classes to be created by the programmer, and permits complex functions to be embedded into the user interface using dynamically linked libraries (dlls). While this makes tighter integration of the TARN and ArcGIS interfaces is possible, it requires a significant amount of time and expertise and is better left to a future research project with more human and financial resources.

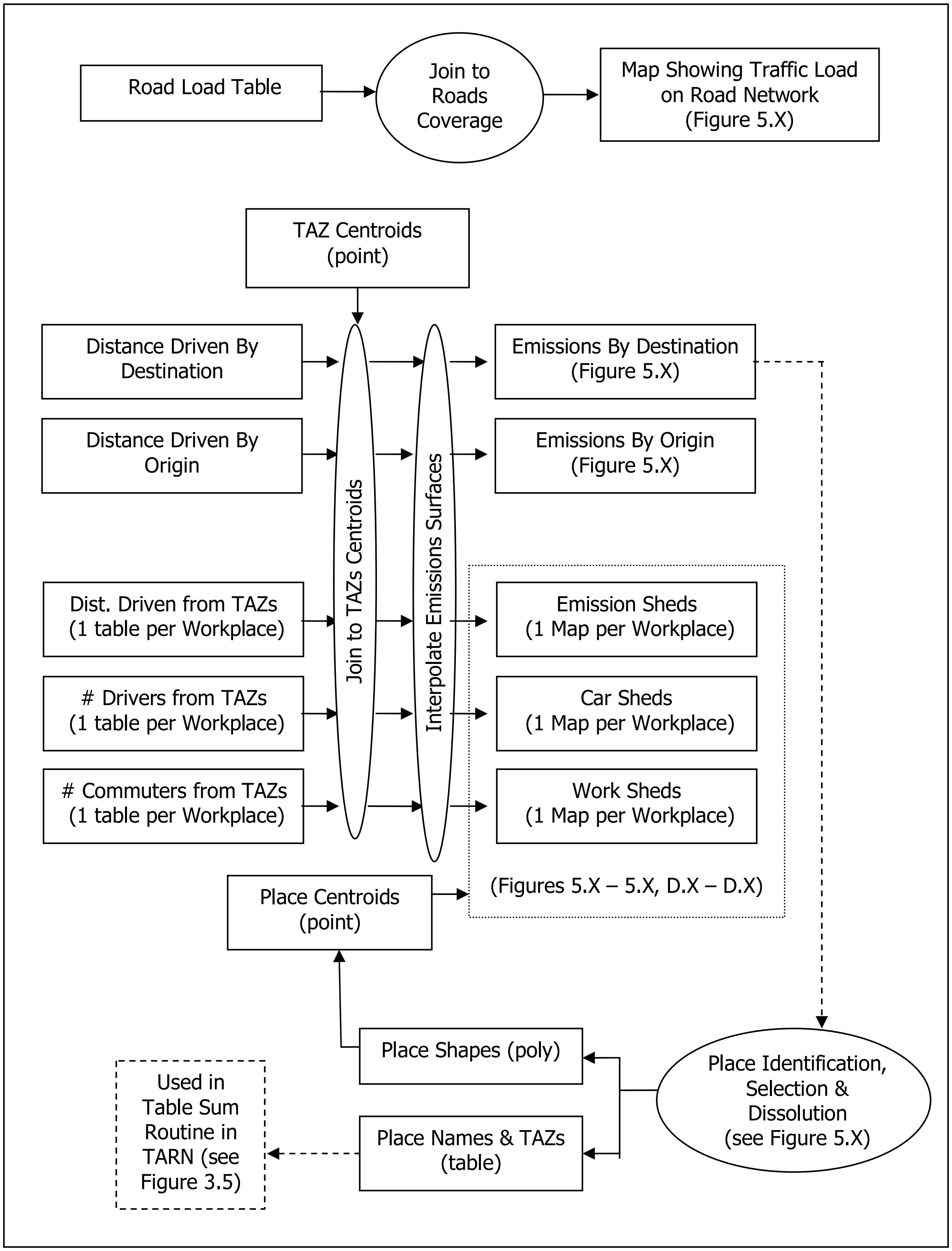

Figure **3.5**: Details of data analysis and visualization in the GIS. Operations in dashed boxes and arrows are performed in TARN (see Figure **3.4**).

combinations are used to create tables showing distance driven, number of drivers, and number of commuters for each workplace. These tables, in turn, are joined to the TAZ centroids and interpolated to surfaces (after normalizing the results by area).[7]

For the Philadelphia metropolitan area, 33 hotspots were identified. Interpolating three surfaces and creating three finished maps for 33 hotspots would be prohibitively labor intensive. Depending on the computer speed and the persistence of the computer operator, it would take many days to complete the required operations by hand, even if they were only performed once per hotspot.

Consequently, several scripts were written to automate the repetitive tasks involved in interpolating the surfaces and generating finished maps. The scripts are provided in Appendix C. Information on these scripts and their functions is provided in Table **3.2**.

Conclusions

This chapter presented an analytical approach to mapping a portion of the consumptive landscape of urban areas — specifically, the consumption of gasoline by commuters driving alone — and the tools used to perform the required analyses. In this approach, emissions maps are created by using both commuter origin and destination data.

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[7] A certain amount of data degradation may occur as a result of the transformation of the census data – which are area data – to point data (centroids), to arc data (traffic assignment to roads), to point data (residence and workplace centroids), and back to area data (interpolated statistical surfaces). However, this degradation is unavoidable given the necessity of each step. Furthermore, as previously stated, the goal of this thesis is not to provide the most accurate estimates of GHG emissions possible, but rather to provide reasonable estimates of emissions by residence and workplace. The assignment of emissions to these points allows the analyses in subsequent chapters. Had the emissions estimates been attributed solely to the roads over which they are emitted physically, the detailed geography of emissions presented in Chapters 5 and 6 would have been lost.

Table **3.2**: Avenue scripts used to analyze and visualize the traffic model results and their functions.

Script Name	**Function**
Splinter Theme	Creates a new theme for each feature in the original theme, thereby "splintering" the original theme into many smaller themes
Rename Themes	Renames a group of themes quickly. The new names appear in the legend.
QuickGrids	Interpolates multiple grids from a single point theme and multiple tables that are joinded to the point theme. An existing grid theme is used to provide some basic paramaters for the new grids.
LinkLegends	Links multiple legends so that a change to the master legend changes the rest of the legends.
Modify Layout	Changes the specified layout to contain three view windows and corresponding legends. This prepares a layout to be used with the 3View family of scripts
3View script family	Calls a dialog box that allows the user to select the views to be displayed in a 3-view layout, and within the selected views, provides the ability to quickly reorder themes and change which themes are displayed. Also provides a means to export the layout to an image file quickly and automatically.

By identifying the places where the people most responsible for GHG emissions from commuting trips work and live, these maps allow a more thorough reading of the transportation-related consumption patterns in the landscape than other approaches do. In addition, maps are generated showing the work-shed, car-shed, and emission-shed for each workplace identified as a hotspot. These sheds are statistical surfaces showing which residential areas contribute the most to the total number of commuters, drivers, and distance driven for each workplace.

This analytical approach, while novel, is insufficient to inform a GHG inventory that is truly agent-based. Identifying those consuming the most gasoline (and therefore generating the most emissions) during their commute is an important step towards this goal, but a truly agent-based approach requires a deep understanding and analysis of all possible actors who can alter these consumption patterns. An agent-based approach would require a complex analysis of the role of urban form and function in consumption patterns and, in turn, a detailed analysis of the processes by which urban form and function are constructed in a given place. Finally, an analysis of the decisions that individuals can and do make within existing urban forms would be part of an agent-based approach.

Such an analysis would be too ambitious for this thesis, but the next chapter attempts to provide a broad understanding of some of the major historical moments and processes that have shaped Philadelphia's transportation network and the urban landscape in which it functions. Contemporary demographic data also are presented to provide local context to the subsequent analysis of the maps of Philadelphia's consumptive landscapes, which is presented in Chapter 5.

Chapter 4

PHILADELPHIA: FORM, FUNCTION, AND CHARACTER

Introduction

Any researcher concerned with the study of consumptive landscapes of a place must, by definition, concern himself with some of the defining characteristics and activities of that place and, where possible, draw linkages to larger-scale processes influencing local processes and transformations. Nonetheless, the intent of this chapter is not to present a comprehensive summary of Philadelphia's past or present physical, economic or social states. Rather, the purpose of this chapter is to set the stage for later chapters, which describe the spatial patterns of energy consumption during the commute to work and the relationship between those patterns and the spatial patterns of social exclusion in today's Philadelphia metropolitan area.

As its title suggests, this chapter is concerned with three characteristics of Philadelphia: its physical form, its socioeconomic function, and its social character. Form and function are closely related and are discussed in a single section, followed by a section on the social character of the metro area. The discussion of physical form focuses primarily on the transportation network, although it also pays some attention to housing stock and other physical characteristics of the built environment. The accompanying account of the socioeconomic functioning of Philadelphia focuses on transformations in the ways that Philadelphians have earned their living. It also discusses the city's social character and reports patterns of segregation in Philadelphia. The social character of Philadelphia is presented separately from form and function not because it is unrelated to form and function, but for emphasis.

Form and Function: The Transportation Network and Economic Activity

Like all American cities, Philadelphia has undergone several transformations, many of them influenced by the type of transportation available to its inhabitants and the extent of transit systems' coverage. The city was originally designed to be a city of green space, large lots, and spacious single-family homes, with development driven by real estate speculation aided by the grid system. In fact, the grid system did lead to rapid and intense real estate speculation and development. As the city industrialized and immigrants from the United States and abroad flocked to the economic opportunities of urban life, the value of land skyrocketed in and around what is now the central business district. However, a lack of any substantial public transportation system – combined with the complicated economic networks holding the city together – led to a dense hodgepodge of residential and commercial development. During the time leading up to (and to some degree during) the industrial revolution, the middle-class skilled workers lived in row houses in the same neighborhoods with the poor, who lived in alleyway shacks (Warner, 1968). This social (and racial) integration was not the result of altruism on the part of the business owners and other members of the upper classes, nor was it particularly harmonious.

Rather, Warner argues, the parties involved had little choice but to live together due to the traffic congestion caused by the grid system. In fact, from its inception through the middle of the 19th Century, Philadelphia was not only a heterogeneous landscape with regard to residence, but also to workplace. Merchants and tradesmen located their shops in a hodge-podge arrangement with little or no industry-specific agglomeration that is common in today's landscape. That was changing in the 1850s with large factories and mills beginning to form industry-specific neighborhoods. Similar types of businesses clustered together to reach economies of scale and the workers in those industries moved closer to work. However, even within those residential clusters, there was income heterogeneity.

While the very rich settled in exclusive communities such as Germantown and Mantua, the development of these places did not begin in earnest until the transportation network made them accessible to the middle-class skilled workers of Philadelphia. Mantua, for instance, was originally settled as a village in 1809 and, although the 1812 completion of the Spring Garden Bridge led to increased real estate activity (Rosenthal 1963), it really began to boom when public transportation made living in Mantua more convenient for middle-class workers earning their living in the city. In 1831, the first omnibuses began running in the city and, by 1852, there was a bus running from Central Philadelphia to West Philadelphia every 12 minutes (Jackson 1931). The first horse-drawn rail cars appeared in the city in 1857 (Jackson 1931) and, by 1859, service connected Mantua with both Central Philadelphia and the Northern Liberties (Rosenthal 1963). Even though Mantua and Germantown were officially annexed by Philadelphia during the consolidation of 1854 (see below), this pattern of development was driven by increased mobility – first by horse drawn street car, and later by electric street car – and resulted in these places being termed "streetcar suburbs" by researchers like Adams et al. (1991).

By 1930, this phenomenon already had resulted in a "core city of poverty, low skills, and low status surrounded by a ring of working-class and middle-class homes" (Warner

1968:171). The improved mobility afforded by the electric streetcar and other technologies, such as the telephone, and by the reorganization of many industries into large offices, mills, and factories allowed skilled workers to use criteria other than location to select their homes. These criteria included yard size, reduced air pollution, new schools, and income homogeneity. Warner (1968) found that between 1860 and 1930, clustering decreased dramatically in the housing of skilled workers in every industry but the textile industry. He speculated that the seasonality of the work and irregular work schedules held that industry together spatially. All other residential clustering in the city during this period occurred as new immigrants, low-skill and low-income workers, and marginalized ethnic and racial groups clustered in sections of the city with cheap, old housing. Thus, one of the legacies of the industrial revolution on the social landscape of Philadelphia was economic segregation and exclusion and, consequently, some of the first American slums.

Warner argues that while this segregation has, in the long term, had a negative effect on the metropolitan region as a whole, it had a supportive effect for those living in the suburbs. The homogeneity of the suburbs relaxed many demands of middle-class life, including the intense child-care requirements of urban living and the necessary security of strong police, strong locks and walls, and civilian vigilance in mixed-class urban districts. It is not surprising, then, that the process of suburbanization continued in the post-war era, this time fueled by the increased mobility afforded by the automobile.

For example, Northeast Philadelphia, often described as Philadelphia's first automobile suburb, was largely undeveloped until the post-war construction boom in the 1940s and 1950s. Northeast Philadelphia, along with several suburban communities just past the city boundary, were rapidly developed during this time as the result of mortgage programs run by the Federal Housing Authority (FHA) and the Department of Veterans Affairs (VA) loan programs, both of which largely limited the availability of loans to new housing stock (Adams et al. 1991).

Even more recently, the creation of edge cities and spatially dispersed suburban employment has again changed the physical form of the Philadelphia metropolitan area. As more and more of the city's workforce moved to the suburbs, so did many of the retailers, followed by many of the industrial and managerial jobs. This transformation is part of a national trend towards a new urban form characterized by an economic decline in the city center and regional decentralization of much of industrial and service-based employment. This regional decentralization is coupled with the intensification and local agglomeration of economic activity in the suburbs, including many forms of employment and amenities such as retail shopping and various consumer services. This new urban form has been discussed extensively in both the popular and academic literature with little consensus about the causes or effects of this latest metropolitan transformation. One of the undeniable effects, however, has been a shift in commuting patterns away from more traditional suburb-to-city commuting to an increase in suburb-to-suburb commuting, as well as city-to-suburb commuting, also known as "reverse commuting." Chapters 5 and 6 specifically measure these patterns for the Philadelphia metro area, but it should be noted here that suburb-to-suburb commuting has become the dominant form of commuting in the Philadelphia area.

This new urban form is not always cast in a negative light. For instance, Joel Garreau (1991) in his *Edge City: Life on the New Frontier,* lists King of Prussia, home of the world's largest shopping complex, as one of the "great" American edge cities. Garreau describes edge cities as places of new economic and social hope, a view not always shared by academics concerned with racialized landscapes and issues of equitable development. While Garreau and others are hopeful that the opportunities provided by edge cities will lead to a new sort of urban renewal, others point to the fact that many of society's most underprivileged continue to be left behind in the old central cities, increasingly disconnected from the economic opportunities in the new cities at the fringe. Perhaps one of Garreau's sharpest critics is Soja, who writes in *Postmetropolis*:

> Los Angeles looms large in Garreau's *Edge City*, and vice versa. Garreau has become well connected to a local network of journalists and others who are similarly spin-doctoring optimistic pictures of paradigmatic Los Angeles and life on its "new frontier" in local and national newspapers … [*Edge City* is] filled with allusions to the original Garden City concept of Ebenezer Howard … where one can obtain the best of both worlds, city and countryside wedded together by the electronic possibilities of the new Information Age and a radically optimistic vision of the coming together of gender, race, and class divisions. (2000:245)

Soja goes on to paint a much less rosy picture of Los Angeles – one of racial and economic segregation, where divisions are growing rather than shrinking, and where those left behind in the older parts of the city are increasingly cut off from the economic opportunities of what he calls the *Exopolis*, the new part of the city at the fringe. In making his case, he quotes others, such as Thomas Bender, who lament the lack of culture or diversity in these vast landscapes of consumption. Nonetheless, Soja points out that Bender and other detractors of the Exopolis are perhaps as guilty of engaging in hyperbole as Garreau and his colleagues, in this case romanticizing an urban past that may not have been quite as utopian as it appears when compared to a hypercritical view of modern-day suburbia.

Character: A Landscape of Exclusion and Separation

Cultural critiques notwithstanding, Adams et al. (1991) and Warner (1968) effectively show that racial and economic segregation have been increasing in the Philadelphia metropolitan area since the city's inception. There is no need to reproduce their analyses here, but it is helpful to produce a snapshot of current racial segregation, because – as I will demonstrate later in this thesis – patterns of energy consumption from transportation and patterns of racial segregation appear to be closely related. This finding is not entirely surprising. The literature suggests that the development of the transportation network and the resulting changes in development patterns away from the city have been driven, at least in part, by a desire of affluent Philadelphians to separate themselves from less desirable residents of the metro area – particularly those left behind in the inner city and former streetcar suburbs.

Figures **4.1** and **4.2** show the percentages of blacks residing in and working in each census transportation analysis zone (TAZ), respectively, in 1990. On each map, the regional rail system appears not only to provide reference, but also to begin to draw connections between racial exclusion and the accessibility afforded by the public transportation network. For each figure, the index of dissimilarity is shown. The index is best interpreted as the percentage of a particular group that would need to relocate in order to create an even distribution. In other words, nearly 75 percent of all African Americans would need to move to a new place of residence in order to be evenly distributed throughout the Philadelphia metropolitan area. The city's workplaces were less segregated than residences, with a dissimilarity score of only .3521, but were still highly segregated – 35 percent of all black

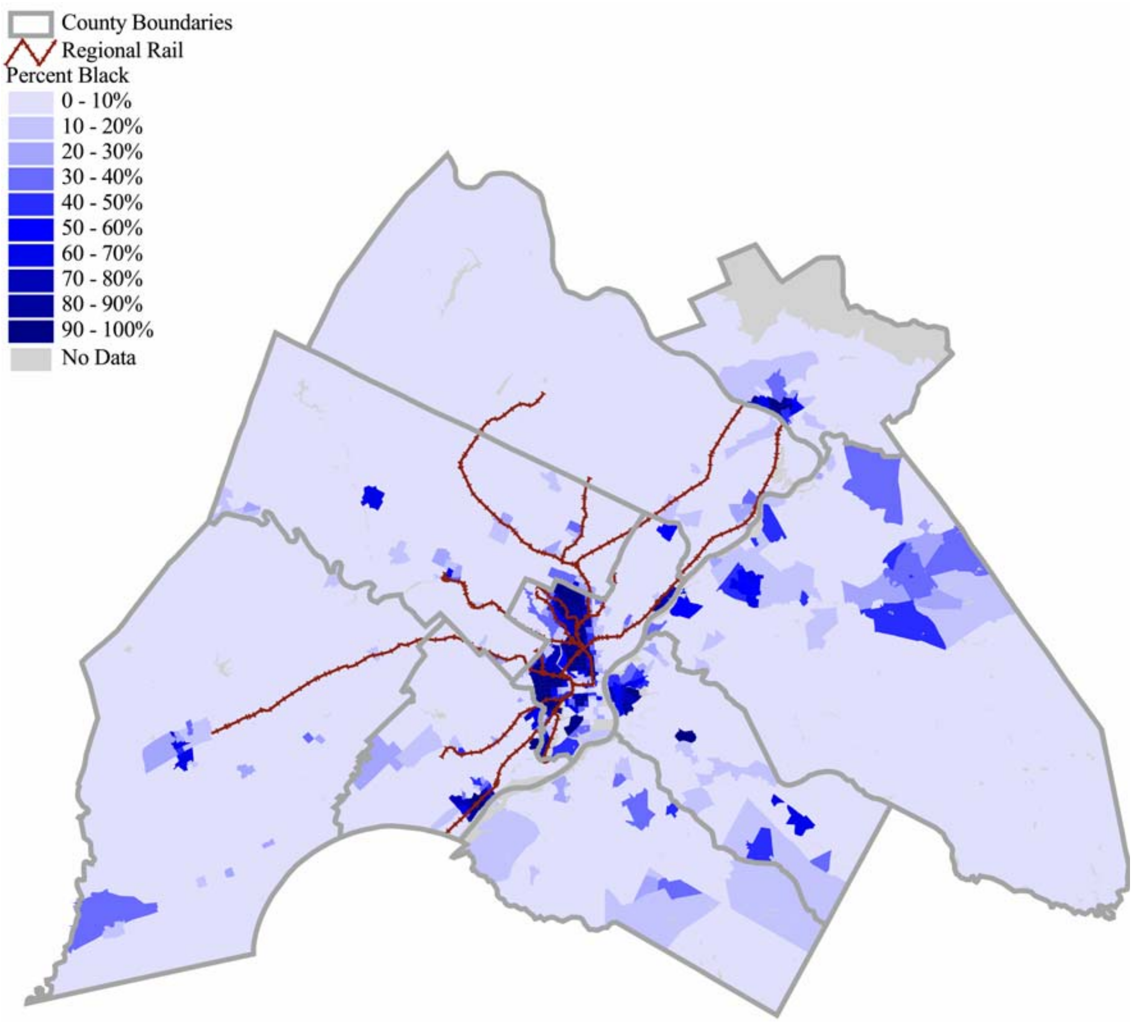

Figure **4.1**: Percentage of residents who were black in each TAZ. Data source: BTS (1990). Index of dissimilarity = .7465

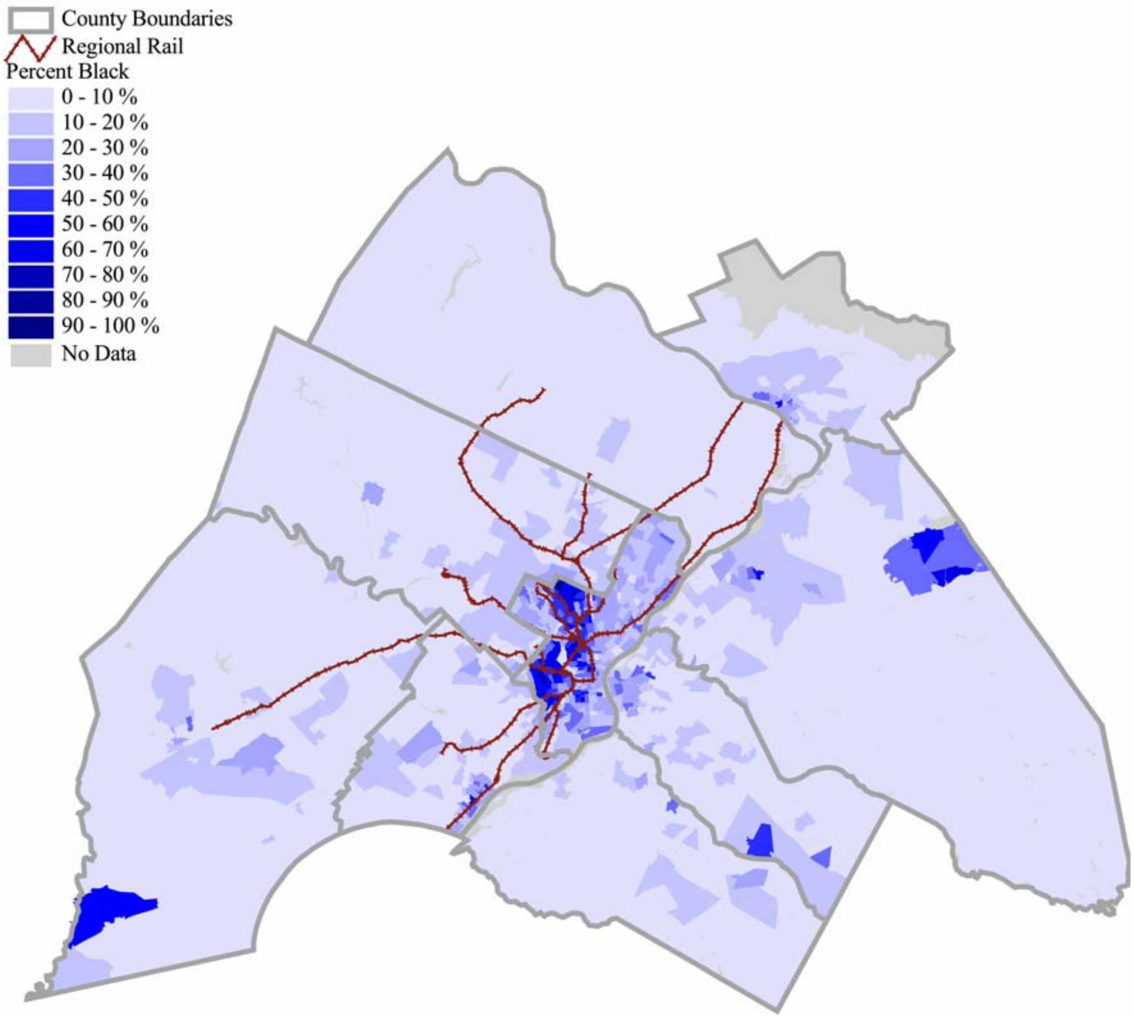

Figure **4.2**: Percentage of workers who were black in each TAZ. Data source: BTS (1990). Index of dissimilarity = .3521 workers would need to change workplace in order to be evenly distributed.

These patterns of racial segregation are related to patterns of economic segregation, as demonstrated by Figures **4.3** and **4.4**. The spatial homogeneity of earnings in residential areas shown in Figure **4.3** reveals a similar pattern to that shown in Figure **4.1** for percentage of residents who were black. Residents of the inner city and former streetcar suburbs, who are predominantly black, have a markedly lower median earning than the rest of the city. Furthermore, these workers are precluded from many of the financial opportunities of the metropolitan area, which are disproportionately located outside the city and beyond the reach of the regional rail system (Figure **4.4**). In short, working in the suburbs requires an automobile, something that is financially beyond many of the city's lowest earners. Supporting that point, Figure **4.5** shows that the residents in the poorest, blackest parts of the city are the least likely to own enough automobiles to support single-car commuters, whereas residents of the richest, whitest areas of the metro area own more than one car per worker. To be sure, this picture may have something to do with the availability of public transportation in the city, but the lack of automobiles and of public transit from the city to the suburbs does mean that the black, poor inhabitants of Philadelphia have less access to suburban economic opportunities.

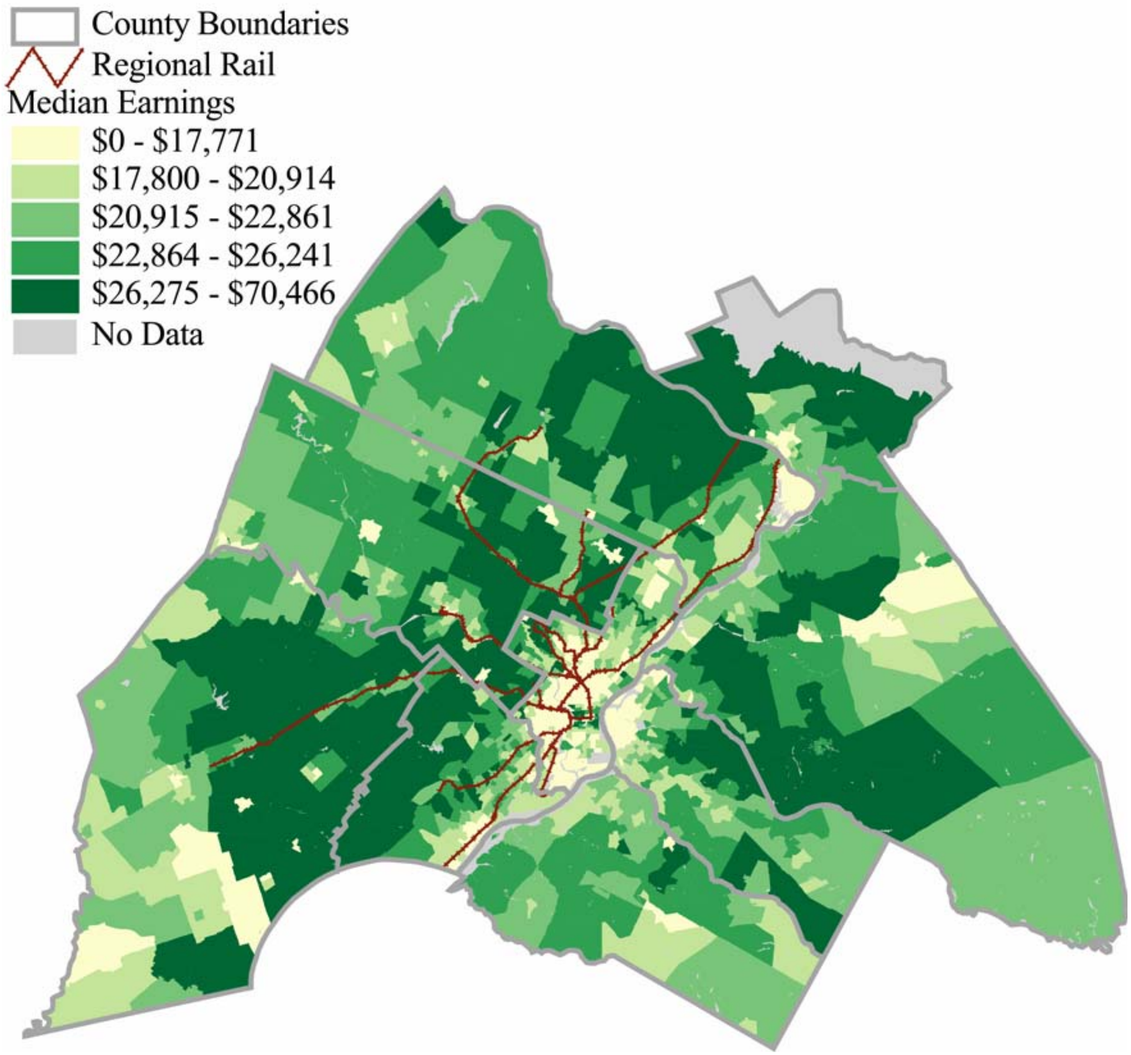

Figure **4.3**: Median earnings, by place of residence. Each TAZ was classified using quantiles. Data Source: BTS (1990) Color ramp by Brewer (2005).

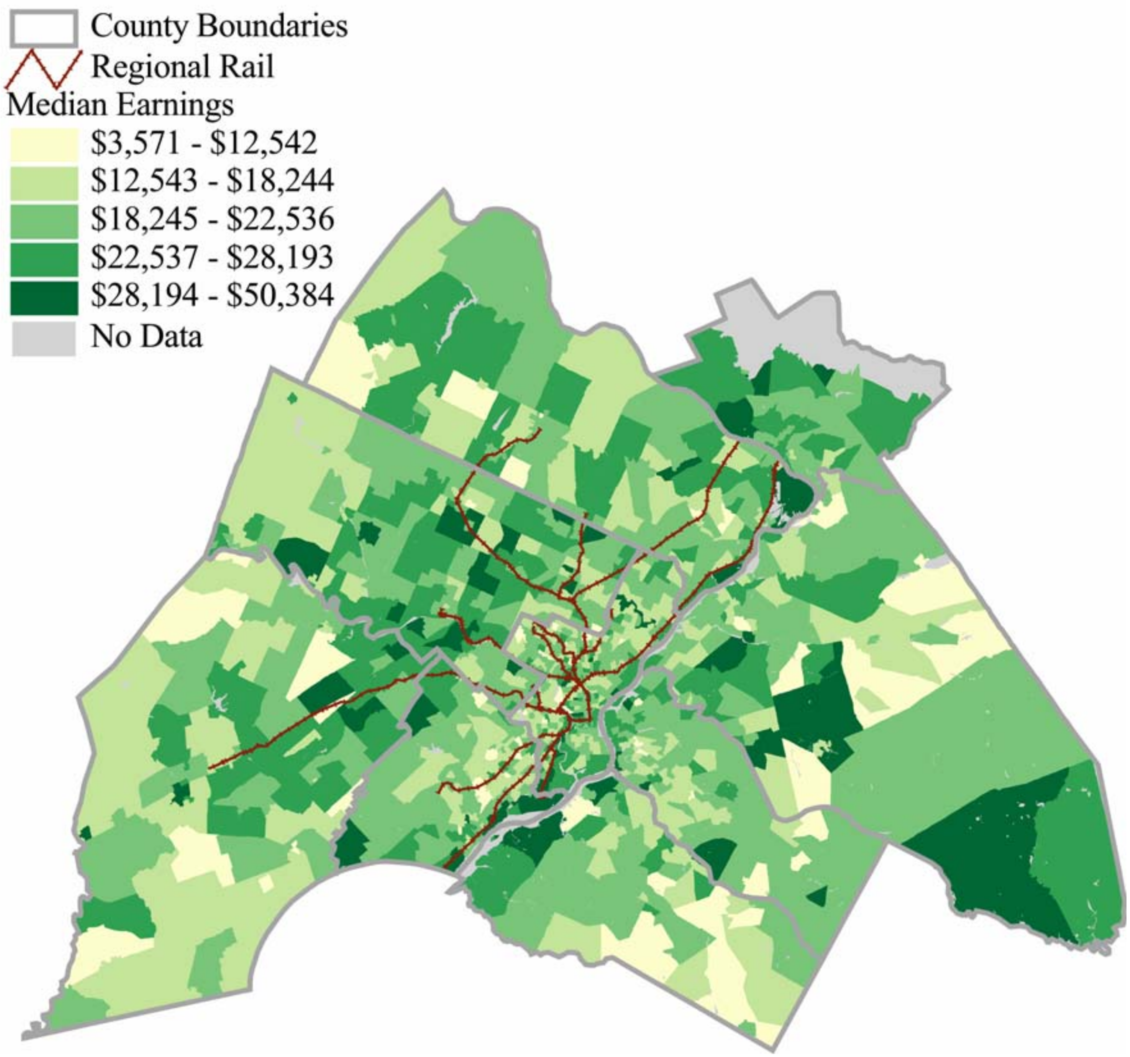

Figure **4.4**: Median earnings, by workplace. Each TAZ was classified using quantiles. Data source: BTS (1990). Color ramp by Brewer (2005).

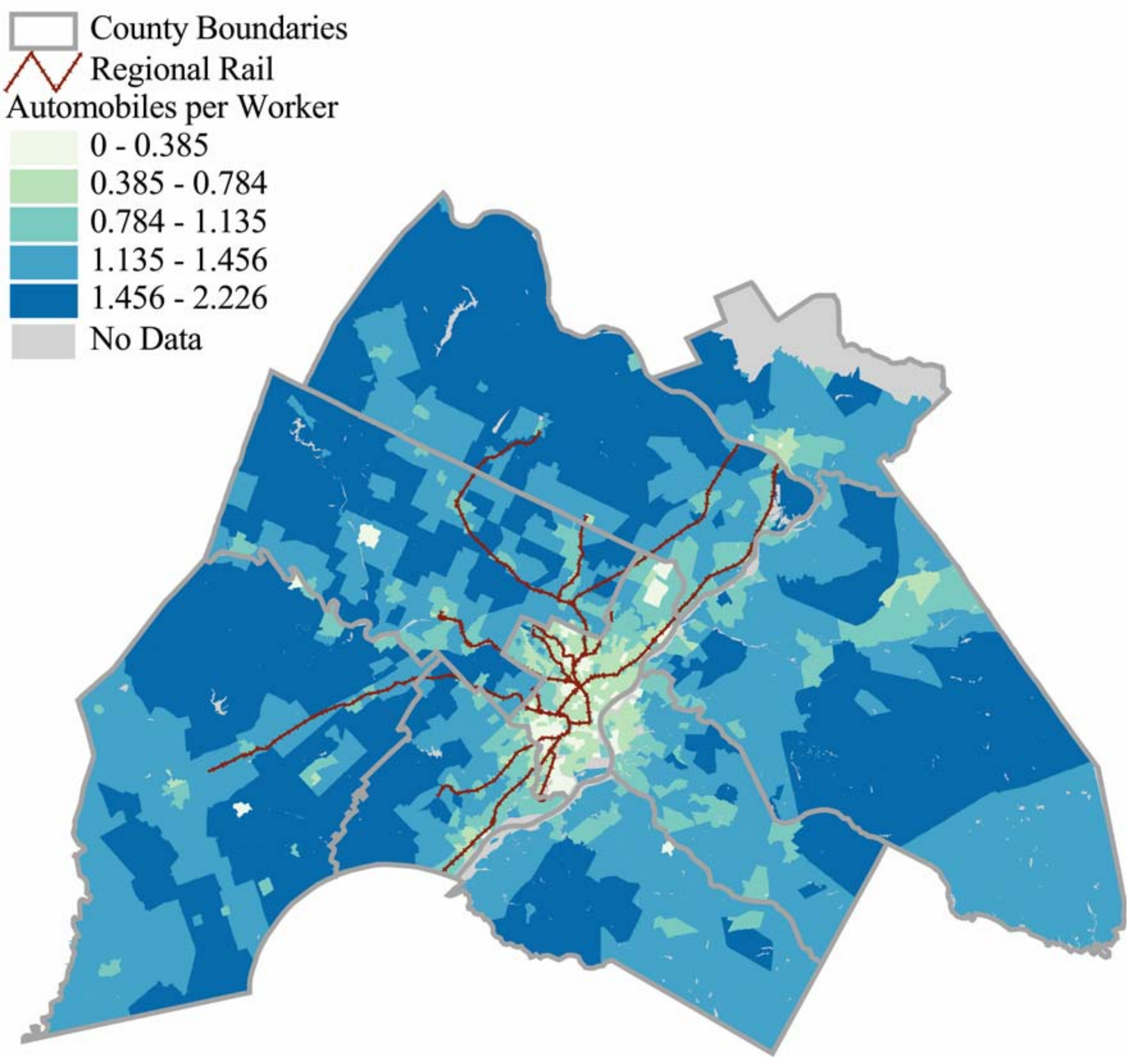

Figure **4.5**: Automobiles per worker, by place of residence for 1990. Each TAZ was classified using quantiles. Data source: BTS (1990). Color ramp by Brewer (2005).

Conclusions

Philadelphia has undergone two periods of outward migration from the city to the suburbs, first as part of the industrial revolution, and second during the postwar building boom driven by government policies. During this second period of rapid suburbanization, there was a massive out-migration from many of the old streetcar suburbs to newer suburbs. As the housing market began to collapse in the older neighborhoods, federal agencies helped their demise by identifying streetcar neighborhoods near the city center as high-risk areas for mortgages. Many argue that fear of racial violence fueled the massive migration of whites from the city to the surrounding suburbs, a process known as "white flight." Adams et al. (1991) argue, however, that this process was not so much driven by the whites running from the city as it was driven by whites moving towards the financial and social opportunities that residential suburbia offered, aided by the increased mobility afforded by new roads and more affordable automobiles. Those left behind, so they argue, remained because they were unable to take advantage of the same financial opportunities available to the affluent, predominantly white, new suburbanites.

Whether it was through push or pull effects, or a combination of both, neighborhoods like Mantua and many others in West and North Philadelphia underwent a dramatic social and economic transformation between 1950 and 1975. Furthermore, there was a strong relationship between the collapsing housing markets in these former streetcar suburbs and the new development in automobile suburbs. As the suburbs prospered, the residential neighborhoods in Philadelphia declined by nearly every measure, including property value, the number of new mortgages, the median income of residents, and racial and ethnic diversity (Adams et al. 1991). In contrast, crime rates soared. As these neighborhoods became less and less desirable, the residents who remained were increasingly poor and members of marginalized racial groups. In Philadelphia, as in much of America, this meant that they were black. Although the transportation network did not cause suburbanization, the increased mobility afforded to the middle class by streetcars and automobiles certainly enabled it.

Today's Philadelphia remains segregated, both racially and economically. As more economic opportunities are found outside the borders of Philadelphia and outside the reach of public transportation, the plight of many of those left behind in the old city deepens. The next chapter examines the patterns of energy consumption from transportation in the Philadelphia metro area. Chapter 6 will then draw linkages between the energy consumption patterns revealed in Chapter 5 and the patterns of racial and economic segregation revealed here.

Chapter 5

EXPLORING PHILADELPHIA'S CONSUMPTIVE LANDSCAPE: TRANSPORTATION, GREENHOUSE GASES, SPACE, AND PLACE

Introduction

The primary purpose of this chapter is to present the modeling results in both the regional context of the Philadelphia metropolitan area and the local context of each workplace. Using a metropolitan area map of emissions generated by workplace, I select workplaces that generated higher than average emissions. Once I identify these "hotspots," I consider their general characteristics and then talk about several important hotspots in detail. As part of these discussions, I cover other characteristics of each workplace, including the history of local development, and the nature of the workforce employed there. The goal of these discussions is not to explain why the patterns of emissions exist as they do in the landscape, but to explore those patterns and describe them so that they can be interpreted in a later chapter.

In general, the findings presented here show that there are distinct differences between urban and suburban places, both in terms of their consumption of energy and resulting GHG emissions and in terms of character of the place and the nature of its workforce. There also are considerable differences within these broad categories, and several workplaces in each category are explored and discussed to demonstrate the diversity of development and employment patterns within the Philadelphia metropolitan area. This examination also leads to the interesting discovery that there are several places in Philadelphia's consumptive landscape that do not fit neatly into either the urban or suburban categories.

Hotspots in the Consumptive Landscape

Hotspots can be thought of as problem areas or workplaces where commuters cause a disproportionate amount of GHG emissions. It is important to note that the processes driving GHG emissions are not necessarily located in the hotspots themselves, at least not entirely. Rather, these hotspots should be viewed as places where the processes driving emissions are manifest. Thus, the goal of this chapter is to identify and analyze these hotspots and the patterns of consumption and employment within and among these places in the hope of understanding the processes driving GHG emissions.

The first step is identifying these hotspots. Metropolitan areas are so large that treating each origin and destination point individually would be intractable and would not lead to results useful for understanding the processes that drive GHG emissions. For instance, the Philadelphia metro area has about 1350 transportation analysis zones (TAZs), which means that the origin-destination matrix contains roughly 1.8 million cells. Thus, it is imperative that any detailed analyses be performed on a small subset of the origin-destination table, whether the table cells contain estimates of commuters, drivers, or emissions.

Once those hotspots are identified, they need to be characterized and analyzed. One goal of this analysis is to describe the attributes, history, and employment patterns of each place in relation to its consumptive patterns. Another equally important goal is to describe and explore the relationships between these hotspots and other places, including places of residence and other hotspots. The section on Philadelphia's hotspots first describes the hotspots in relation to each other, both geographically and in terms of some basic measures of consumption and efficiency. Then, fourteen specific hotspots are explored in the search for related patterns of history, employment, transportation and consumption. Most of these workplaces are divided into urban and suburban hotspots as a result of these explorations, and the differences between urban and suburban workplaces are discussed.

However, there are a few places that do not fit into this binary classification system. These places serve as counterpoints to the classic dichotomy of urban/suburban place that scholars and others often use as a lens through which to view American metropolitan areas. As discussed in Chapter 6, these counterpoints could open critical spaces in our discourses about cities, thereby altering some of the discursive processes that help to drive development and consumption patterns. I discuss the historical, employment, transportation and consumptive patterns for these "other" places separately from the urban and suburban workplaces. While I leave the full implications of this third category for the next chapter, I briefly address the theoretical basis for treating them as separate from urban and suburban places. In doing so, I also provide some guidelines for distinguishing between urban and suburban places. The subsequent sections describe selected urban, suburban and "other" hotspots, which are categorized based on these guidelines.

Philadelphia's Hotspots: Workplace and its Role in Emissions Generation

Figure **5.1** shows an emissions surface with hotspot boundaries and centroids identified. The emissions surface is based on a total emissions normalized by the area of each TAZ. Normalizing in this manner eliminates the skew towards larger polygons that might occur due to larger emissions estimates being assigned to TAZs with larger areas (see Monmonier 1996). In identifying hotspot boundaries, care was taken to include only those TAZs that contained an emission-surface value greater than one standard deviation above the mean. Nonetheless, due to some irregularly shaped TAZ boundaries, some hotspot boundaries do contain areas with lower emissions than the 1 standard deviation cutoff value, and some portions may even be below average. Still, on average, the hotspots identified are the workplaces that are responsible for above-average emissions, normalized by area.

Table **5.1** presents the emissions, number of commuters, and number of drivers for each hotspot, sorted in descending order by emissions. The table includes percentages (based on total emissions for all places, including non-hotspots) to show the relative importance of each place. The hotspots accounted for more than 41 percent of all commuters, but only 36 percent of all emissions from commuters in the metropolitan area. Even though these hotspots were important places, they were not necessarily the most important; they were places where emissions were concentrated in a small area. Emissions resulting from commutes to workplaces that were not in these concentrated areas accounted for more than 63 percent of the total. These workplaces primarily were in the suburbs and their typical commuting pattern was suburb-to-suburb (see Chapter 6).

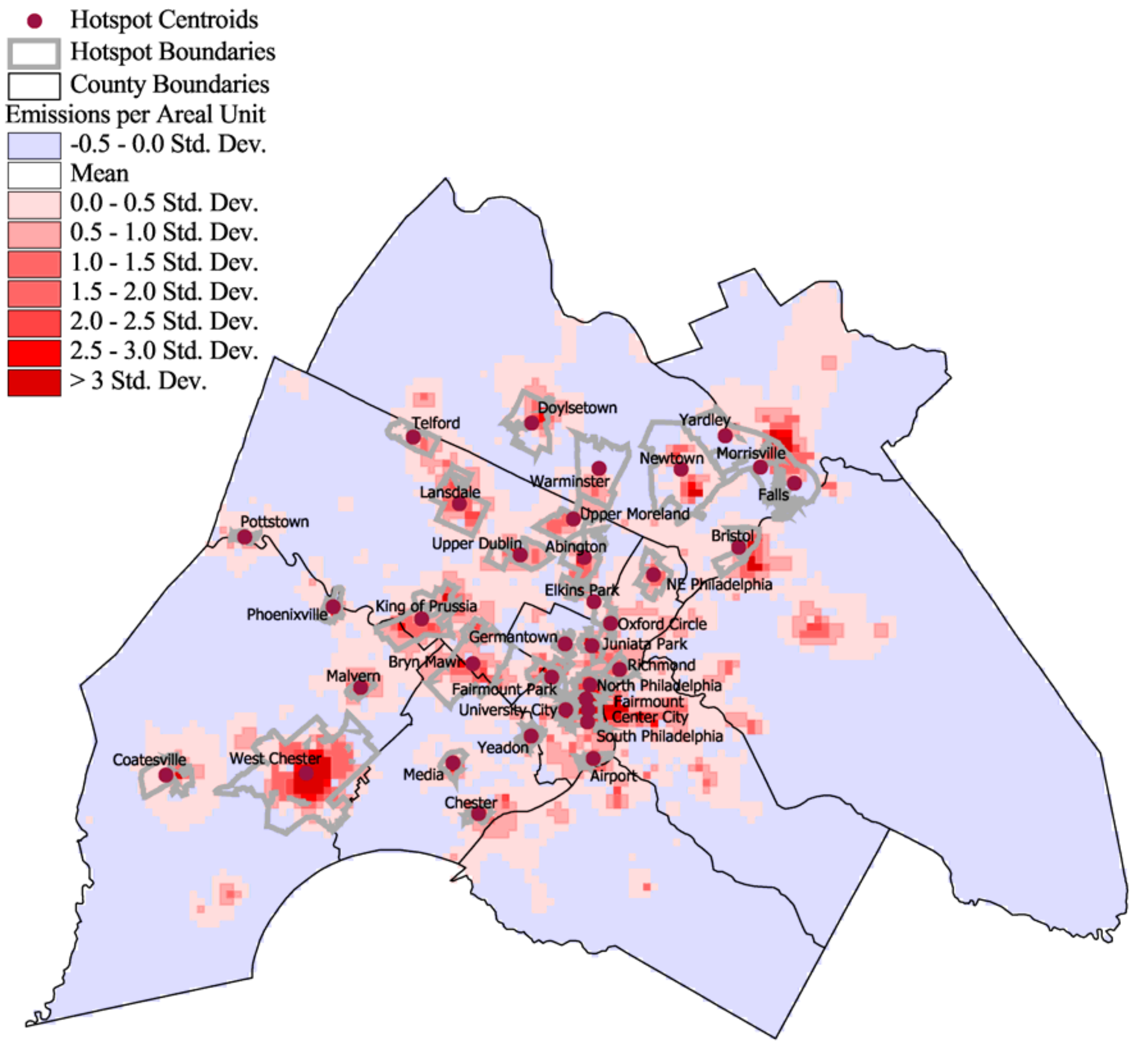

Figure **5.1**: Emissions surface from Figure **5.2**.a with hotspot boundaries and centroids identified.

Table **5.1**: Emissions, commuters, and drivers per hotspot destination

Workplace	Emissions (MTCE)	Percent of Total	Drivers	Percent of Total	Commuters	Percent of Total
Center City	24.81	6.19%	84,937	5.88%	239,746	11.40%
King of Prussia	14.11	3.52%	44,849	3.11%	53,897	2.56%
Brynmawr	8.36	2.08%	27,651	1.92%	35,896	1.71%
University City	7.53	1.88%	25,523	1.77%	57,210	2.72%
West Chester	6.82	1.70%	23,800	1.65%	30,905	1.47%
Upper Moreland	6.78	1.69%	24,148	1.67%	28,367	1.35%
Lansdale	5.68	1.42%	20,594	1.43%	24,417	1.16%
North Philadelphia	5.32	1.33%	19,130	1.33%	37,735	1.79%
Abington	5.27	1.31%	19,858	1.38%	25,442	1.21%
Upper Dublin	5.13	1.28%	16,283	1.13%	19,223	0.91%
NE Philadelphia	5.03	1.26%	17,157	1.19%	27,618	1.31%
Fairmount Park	4.46	1.11%	17,424	1.21%	25,395	1.21%
Newton	3.96	0.99%	15,635	1.08%	18,640	0.89%
Fairmount	3.93	0.98%	14,295	0.99%	28,490	1.36%
Airport	3.53	0.88%	10,354	0.72%	19,319	0.92%
Doylestown	3.16	0.79%	11,585	0.80%	13,488	0.64%
Warminster	3.12	0.78%	10,432	0.72%	13,481	0.64%
Malvern	2.86	0.71%	8,244	0.57%	9,549	0.45%
Bristol	2.65	0.66%	9,753	0.68%	12,695	0.60%
Juniata Park	2.38	0.59%	9,564	0.66%	16,812	0.80%
South Philadelphia	2.15	0.54%	6,826	0.47%	14,603	0.69%
Elkins Park	2.07	0.52%	9,102	0.63%	12,035	0.57%
Oxford Circle	1.93	0.48%	8,295	0.57%	13,821	0.66%
Richmond	1.85	0.46%	7,587	0.53%	14,852	0.71%
Media	1.61	0.40%	8,748	0.61%	10,782	0.51%
Pottstown	1.54	0.39%	4,935	0.34%	6,224	0.30%
Chester	1.53	0.38%	7,006	0.49%	9,630	0.46%
Germantown	1.47	0.37%	5,829	0.40%	10,978	0.52%
Coatsville	1.42	0.35%	4,326	0.30%	5,509	0.26%
Yeadon	1.14	0.28%	5,854	0.41%	8,247	0.39%
Morrisville	1.13	0.28%	4,426	0.31%	5,477	0.26%
Yardley	1.00	0.25%	3,024	0.21%	3,660	0.17%
Phoenixville	0.93	0.23%	3,834	0.27%	4,859	0.23%
Telford	0.83	0.21%	3,679	0.25%	4,215	0.20%
Falls	0.22	0.05%	698	0.05%	828	0.04%
All Hotspots	146	36.35%	515,385	35.71%	864,045	41.10%
Other	255	63.65%	927,933	64.29%	1,238,428	58.90%
All Places	401	100.00%	1,443,318	100.00%	2,102,473	100.00%

Nonetheless, the hotspots identified here accounted for the most significant concentrations of GHG emissions in the metropolitan area – while they accounted for about 41 percent of the commuters, collectively they only made up about 8.55 percent of the total surface area of the metro area. As such, these places were important drivers of 1990 GHG emissions. In addition, they are a remarkably diverse collection of places, both statistically and in character. For instance, there was considerable variation in efficiency measures for the hotspots (Table **5.2**). Kilograms of carbon equivalent (KgCE) GHG emissions per driver ranged from .18 for Media to .35 for Malvern. KgCE GHG emissions per commuter showed even more variation: .10 for Center City to .30, again for Malvern. This second efficiency measure divides the emissions for each place by its total number of commuters, regardless of the mode of transportation they used to commute to work, thus demonstrating the overall carbon efficiency of each place. Finally, the percentage of commuters who drove alone ranged from 35 percent for Center City to 87 percent for Telford.

Table **5.3** displays the percentage of commuters, drivers, and emissions that came from urban, suburban and "other" residences for each hotspot workplace. The percentage of commuters who were urban dwellers varied from almost 0 percent in Pottstown, a distant independent suburb, to 70 percent for the Richmond area, an urban workplace with a significant amount of heavy industry. Similarly, there was significant variation on the origin of those driving to work – about 1 percent of all drivers commuting to Pottstown lived in urban places, but nearly 55 percent of all drivers commuting to Richmond had urban residences. With regard to emissions, Pottstown again had the lowest percentage of

Table **5.2**: Efficiency of each place using three metrics: Kilograms of Carbon Equivalent (KgCE) of emissions per driver, KgCE per commuter, and percent of commuters driving.

Place	KgCE / Driver	KgCE / Commuter	Commuters Driving (%)
Center City	0.29	0.10	35.43%
King of Prussia	0.31	0.26	83.21%
Brynmawr	0.30	0.23	77.03%
University City	0.29	0.13	44.61%
West Chester	0.29	0.22	77.01%
Upper Moreland	0.28	0.24	85.13%
Lansdale	0.28	0.23	84.34%
North Philadelphia	0.28	0.14	50.70%
Abington	0.27	0.21	78.05%
Upper Dublin	0.31	0.27	84.71%
NE Philadelphia	0.29	0.18	62.12%
Fairmount Park	0.26	0.18	68.61%
Newton	0.25	0.21	83.88%
Fairmount	0.28	0.14	50.18%
Airport	0.34	0.18	53.59%
Doylestown	0.27	0.23	85.89%
Warminster	0.30	0.23	77.38%
Malvern	0.35	0.30	86.33%
Bristol	0.27	0.21	76.83%
Juniata Park	0.25	0.14	56.89%
South Philadelphia	0.31	0.15	46.74%
Elkins Park	0.23	0.17	75.63%
Oxford Circle	0.23	0.14	60.02%
Richmond	0.24	0.12	51.08%
Media	0.18	0.15	81.14%
Pottstown	0.31	0.25	79.29%
Chester	0.22	0.16	72.75%
Germantown	0.25	0.13	53.10%
Coatsville	0.33	0.26	78.53%
Yeadon	0.19	0.14	70.98%
Morrisville	0.26	0.21	80.81%
Yardley	0.33	0.27	82.62%
Phoenixville	0.24	0.19	78.91%
Telford	0.22	0.20	87.28%
Falls	0.31	0.26	84.30%
All Hotspots	0.28	0.17	59.65%
Other	0.27	0.21	74.93%
All Places	0.28	0.19	68.65%

Table **5.3**: Percentage of commuters, drivers, and emissions for each place that are suburban residents, urban residents, or residents of "other" areas. In the case of emissions, this table shows the percentage attributable to each classification of residents. See text later in this chapter for the justification and description of the "other" category.

	Commuters			Drivers			Emissions		
Workplace	Percent Suburban	Percent Urban	Percent Other	Percent Suburban	Percent Urban	Percent Other	Percent Suburban	Percent Urban	Percent Other
Center City	35%	59%	6%	43%	48%	8%	62%	28%	10%
King of Prussia	91%	8%	1%	93%	6%	1%	89%	8%	2%
Brynmawr	87%	11%	2%	89%	9%	2%	88%	9%	3%
University City	35%	60%	5%	48%	45%	7%	65%	28%	8%
West Chester	97%	3%	0%	98%	2%	0%	95%	4%	1%
Upper Moreland	89%	8%	3%	90%	7%	3%	87%	9%	4%
Lansdale	93%	6%	1%	95%	4%	1%	91%	8%	1%
North Philadelphia	34%	60%	6%	47%	44%	9%	66%	25%	9%
Abington	76%	19%	5%	80%	15%	5%	80%	15%	5%
Upper Dublin	82%	15%	3%	85%	12%	3%	84%	11%	4%
NE Philadelphia	29%	49%	21%	38%	39%	23%	55%	35%	10%
Fairmount Park	46%	44%	10%	57%	35%	8%	73%	21%	6%
Newton	91%	6%	3%	91%	5%	4%	87%	9%	4%
Fairmount	30%	62%	8%	40%	49%	11%	58%	29%	13%
Airport	39%	51%	10%	47%	45%	9%	58%	34%	8%
Doylestown	96%	3%	1%	97%	2%	1%	94%	4%	2%
Warminster	82%	11%	7%	89%	7%	4%	85%	11%	4%
Malvern	96%	3%	1%	96%	3%	1%	94%	4%	1%
Bristol	87%	8%	5%	89%	6%	5%	85%	10%	5%
Juniata Park	28%	64%	8%	39%	51%	10%	61%	29%	10%
South Philadelphia	29%	65%	5%	44%	47%	9%	61%	28%	10%
Elkins Park	63%	30%	7%	69%	23%	8%	75%	17%	9%
Oxford Circle	27%	61%	11%	35%	51%	14%	55%	31%	13%
Richmond	21%	70%	9%	31%	55%	14%	54%	33%	14%
Media	97%	3%	0%	98%	2%	0%	96%	4%	0%
Pottstown	99%	1%	0%	99%	1%	1%	97%	1%	2%
Chester	93%	6%	1%	93%	6%	1%	87%	11%	2%
Germantown	29%	65%	6%	38%	54%	8%	61%	30%	9%
Coatsville	97%	2%	0%	97%	2%	0%	93%	7%	1%
Yeadon	86%	12%	1%	87%	11%	1%	87%	11%	2%
Morrisville	96%	2%	2%	96%	2%	2%	92%	4%	3%
Yardley	95%	1%	4%	95%	2%	3%	92%	3%	5%
Phoenixville	97%	3%	0%	98%	1%	0%	95%	4%	1%
Telford	98%	1%	0%	98%	1%	0%	95%	4%	1%
Falls	95%	3%	2%	96%	1%	3%	94%	3%	4%

emissions attributable to urban residents, but Northeast Philadelphia narrowly beat out Richmond as the place with the greatest percentage of emissions coming from urban residents. Between these extremes, there are many patterns to be explored, some of which are more relevant than others to the processes driving emissions.

As shown in the discussion below and in Chapter 6, many of these differences among places can be explained by dividing each place into urban or suburban categories. Yet there remains significant diversity among places within each of these categories. As such, the analysis and contextualization of the results for this thesis are divided into two chapters. The remainder of this chapter focuses on the role that individual workplaces have in generating GHG emissions. While the discussion about interactions between suburban and urban places is deferred to Chapter 6, the individual workplaces covered in this chapter are organized and presented in groups of similar places. Specifically, urban places are presented together, as are suburban places. Before proceeding, it is important to take a moment and reflect on the act of categorizing these places, because through this categorization, assertions are made about each place and its role in generating GHG emissions from the commute to work.

A note on the categorization of place

Historically, Philadelphians have referred to places within the Philadelphia border as urban areas, with suburban areas lying outside the legal boundaries of the city (Warner 1968, Lapsansky 1994). Nonetheless, there are substantial portions of Philadelphia proper that are considered by many scholars and inhabitants to be more suburban than urban, most notably

Northeast Philadelphia. For instance, Adams et al. (1991) describe the northeastern portion of the city as one of the first automobile suburbs to emerge in the period after World War II, despite the fact that this area legally had been part of the city since the Consolidation Act of 1854 (see Chapter 4). Some residents and politicians have echoed this sentiment, noting that the development patterns are much more like the surrounding suburban areas than the rest of the city, and perhaps more importantly, the attitudes of the citizens toward city hall are more suburban than urban (see, for example, Infield 1985). There even have been repeated, albeit unsuccessful, bids in the state senate to allow Northeast Philadelphia to secede from the rest of the city and create a new county called Liberty County (for a partial account of these failed attempts, see Roche 1983, Infield 1985, Meyers 1987, Miller 1988, Zausner, 1991, and Infield 2000).

In light of these facts, treating the entire city as urban based solely on its political boundaries does not make sense, particularly when the purpose of such a distinction is to aid an analysis of commuters' behavior. Nonetheless, as is shown elsewhere in this thesis, classification of places within the metropolitan area as urban or suburban is a useful distinction because it helps to explain some of the differences in commuting behaviors from place to place. The question remaining, then, is what criteria should be used in determining the urban-ness or suburban-ness of a place. The treatment of Adams et al. (1991) of the Far Northeast as an automobile suburb and other neighborhoods such as Mantua as streetcar suburbs suggests that, to some degree, places can be classified as suburban based on the history of their formation and their primary function within the city.

Adams et al. describe both the Far Northeast and Mantua as suburban bedroom communities serving Central Philadelphia, at least during the periods in which they were created. Nonetheless, it is unlikely that present-day residents, politicians or researchers would classify contemporary Mantua as a suburb. While the area is largely residential with the exception of businesses along Lancaster Avenue and other main throughways, it is today largely considered one of the quintessential Philadelphia urban slums, not a residential suburb. Thus, while the Northeast always has been considered suburban, the Mantua area and/or its context have changed over time, resulting in its transformation from a suburban place to an urban place.

One major difference between Northeast Philadelphia and Mantua is when and how they were created. As discussed in Chapter 4, the Village of Mantua, later to become part of the district of West Philadelphia, was founded about 140 years before Northeast Philadelphia was developed. While development in Mantua and the rest of West Philadelphia was driven, first, by the omnibus, then, by horse-drawn streetcar, the Far Northeast remained undeveloped until government-sponsored programs connected it with the rest of the city with new road construction during the World War II era. As Northeast Philadelphia and other automobile suburbs boomed in the period from 1950-1970, Mantua and other neighborhoods in West and North Philadelphia declined. So, one difference between Northeast Philadelphia and the rest of the city is indeed that Northeast Philadelphia was not developed until much later, prospering while much of the rest of the city declined as part of the process of early suburbanization.

Without minimizing this important distinction between some urban and suburban places in Philadelphia, the contemporary characteristics of these places also must play a role in their classification. Numerous authors have attempted to identify some of the defining characteristics of both urban and suburban places. For instance, Jacobs (1961) suggests that urban places are places with a diversity of land uses within the same area, places that are accessible and inviting to pedestrians and places that contain dense development, including residential development. Soja (2000) suggests that urban places are places where *skynekism*, or synergisms that arise from the purposeful clustering and collective cohabitation of people in space, is most intensively, but not necessarily exclusively, concentrated. Like Jacobs, Soja suggests that urban areas are places with a certain degree of density. Further, both Jacobs and Soja talk at some length about synergies, both positive and negative, that occur in urban environments. These are synergies of process, and Harvey (1989) argues that urban space is fixed only to the degree that urban processes are confined within fixed spaces. To the degree these processes are in flux, so too are the urban spaces containing them. I find no fault with this argument, and to some degree, much of this chapter is a struggle to define, categorize and characterize places based on the processes that govern the transportation of their workers.

Suburban place, on the other hand, is often treated as the "other" in discourses about urban and metropolitan place. That is, suburbia is what urban place is not. Extending Jacobs (1961), suburban places are places with homogeneous land uses, inaccessible to pedestrians due to their spatially dispersed development patterns and a reliance on the automobile. Traditionally, suburbs have been residential areas outside the city that serve as bedroom communities for those working in the city. However, recent decades have seen a transformation in the structure of the metropolitan landscape such that suburbs have become more than just an intermediate step between rural and urban place. Soja (2000) actively avoids the term suburban in *Postmetropolis*, referring instead to what he calls *Exopolis*, a new form of city at the fringe, sometimes taking the form of what Garreau (1991) calls an edge city, sometimes taking the form of a more dispersed development pattern focused on providing consumer goods and services to its residents, in what Thomas Bender (1996) would call *City Lite*, a place that does not age, but rather "is consumed and replaced" and "devotes itself to consumption, not creativity …" These descriptions and critiques of suburban place and life are not unproblematic and it is not the purpose of this thesis to delve into a cultural critique of the suburbs. For the purposes of this thesis, the term suburb is used simply to describe the portions of a metropolitan area that are not urban, where dependence on the automobile has shaped the landscape into distinct homogeneous land uses.

Yet, as Malpas (1998) so elegantly argues, place is more than a location in space, or a passive container with some unique characteristics. Similarly, place is much more than a location in which processes occur; it is more than mere context. Returning to Harvey's assertions about the nature of urban place and process, it would be a mistake to claim that urban space can be characterized simply as the container of urban process, or defined by the processes at work in that space. Malpas argues that subjectivity, thought, and experience can be thought of as essentially a function of place or locale. If he is correct, then understanding place, and the manner in which places are formed and transformed, is to understand the human identities (and by extension, human processes) that are constructed in part by the places in which they dwell.

This discussion is best saved for the next chapter, but an important point can be drawn from these preliminary excursions into geographic theories of place and space: places and their processes are inexorably intertwined – it is as pointless to discuss place in the absence of process as it is to discuss process in the absence of place. Thus, to define a priori the characteristics of urban and suburban place in order to study later the process of commuting within urban and suburban places is to a large degree putting the cart before the horse. However, rearranging the cart and horse in this particular case does nothing to improve the mobility of the metaphorical vehicle. That is to say, reversing the order and studying the process of commuting within places to define them as urban or suburban is not an improvement. Instead, the two must be treated in unison.

Such treatment is easier said than done. While the analytical process is often nonlinear, particularly in exploratory research, the reporting of that process is not. Words, sentences and paragraphs are read one after the other. Nonetheless, what follows is an attempt to describe both the characteristics of urban and suburban places and their classification as urban or suburban based on their characteristics.

The following two subsections present urban and suburban hotspots. The hotspots were classified into urban and suburban workplaces primarily using the Philadelphia County boundary – workplaces inside the boundary were considered urban, and workplaces outside the boundary were considered suburban. While this rule was applied to nearly every place, there were three places within the Philadelphia County Boundary that have attributes of both urban-ness and suburban-ness. They are discussed in a third section following the sections on urban and suburban hotspots, and are classified as neither urban nor suburban. Instead, they are placed in an "other" category that has considerable significance for the way metropolitan areas are described and understood. The location and extent of the urban, suburban and "other" places in and around Philadelphia are displayed in Figure **5.2**. It should be noted that in the cases of Northeast Philadelphia and Fairmount Park, the hotspots were smaller than the surrounding "other" subregions. This is because the "other" subregions were defined based on both workplace and residential characteristics, while hotspots were defined based solely on workplace characteristics.

In the following discussion, maps representing the emission-shed, car-shed, and work-shed are displayed for each hotspot. In addition, graphs based on census data show the occupations, by gender, and the median earnings, by mode of transportation, of the workers employed in each hotspot. Additional analyses on the racial identity of the workers are discussed, but not represented graphically due to space considerations. As it turns out, racialized identity stands above gender in this quantitative analysis as a factor differentiating places with high emissions from those with low emissions and differentiating urban areas from suburban areas. Thus, it is easy to argue that it makes more sense to display occupation by racial identity than by gender, but the data required for this analysis are not provided by the census. Still, there does appear to be a gendered component to some of the workplaces examined here, and it is possible that this component plays a role in the emissions and commuting patterns of each place. Within the discussion of each place, some of its history is also considered, but the primary focus in this chapter is simply on describing the emissions and commuting patterns of each workplace in the context of some of the demographic and spatial characteristics of its workers. Conclusions about the relevance of these patterns and characteristics are left for later chapters.

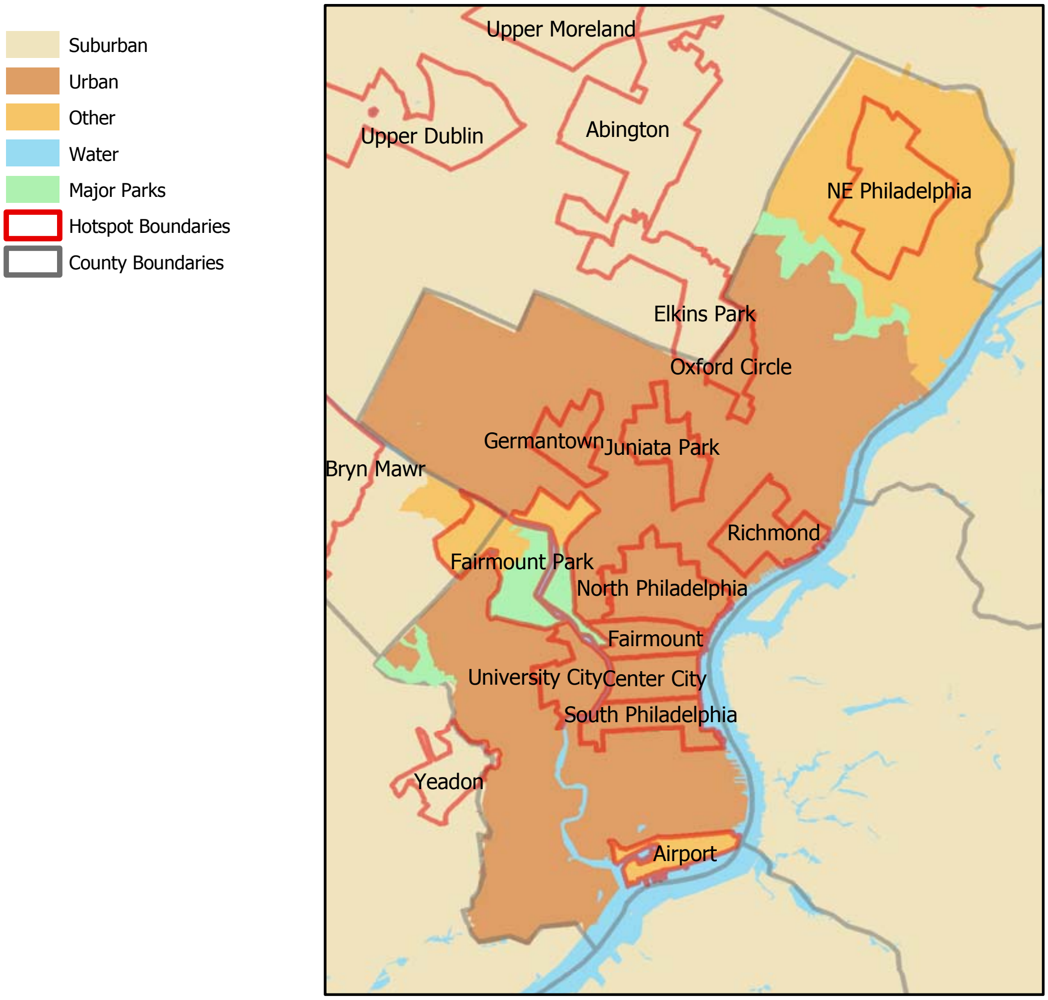

Figure **5.2**: Urban, suburban, and other places in Philadelphia County and the surrounding area. All areas in the metropolitan area not shown on this map were classified as suburban. Note that in the cases of Northeast Philadelphia and Fairmount Park, the areas classified as "other" are larger than the size of the hotspots. Parks and waterways are shown for reference.

Urban Hotspots

As previously stated, hotspots generally were considered urban if they were located within the political boundaries of the city of Philadelphia. There were, however, three places identified as hotspots where this classification was questionable – Northeast Philadelphia, Fairmount Park, and the area surrounding the airport (see Figure **5.2**). What made these locations stand apart from the other places within the city were the behaviors and attributes of their commuters, which will be discussed later. For now, I will focus on the commuting attributes common to most urban places. Typically, urban places drew less than 35 percent of their commuters from the suburbs and had a smaller than average percentage of their commuters driving to work. Commuters who drove tended to be disproportionately suburbanites, and the responsibility for emissions also tended to lay with those residing in suburban locations. There were other characteristics that these places shared in common, but there were also significant differences among urban areas.

This section describes five hotspots that were readily identified as urban places – Center City, North Philadelphia, University City, South Philadelphia, and Germantown. These five places were chosen because of their importance to GHG emissions and their unique characteristics. The discussion of each place contains a brief history of its development and a short description of its current character. The commuting, driving, and emissions patterns for each place are then displayed and described. Finally, census data is used to address the nature of employment and transportation in each place. At the end of this section, a short summary is provided. This summary draws some common themes from the detailed discussions of each place, and also highlights some significant differences among these urban places.

Center City

For the purposes of this analysis, Center City is defined as the area bounded by Vine and South streets from north to south and the Delaware and Schuylkill rivers from east to west. As it expanded east towards the Schuylkill River during the 18th, 19th, and early 20th centuries, the center of the city was always the commercial heart of the region, in no small part to William Penn's original vision for the city. Despite deviations from his original vision of the *function* of grid development, particularly during expansive growth of the mid 19th century, development continued to follow the physical form of a grid pattern. While development in the city core was much denser than William Penn had envisioned and led to considerable traffic problems that to some extent persist today (see, for instance, Adams et al. 1991 and Lapsansky 1994), the grid system in the city's center certainly contributed to successful real estate speculation and continues to serve as a focal point of urban agglomeration.[8] Still, many parts of Center City are less built-up than might be expected due to historical building practices. Until the mid 1980s, no buildings in the downtown area were taller than 548 feet because of an unwritten agreement among the city's developers not to build any structure taller than the top of the statue of William Penn atop City Hall. As a result, the city center grew outward while other cities grew upward. Still, there are now many skyscrapers in the downtown area taller than the statue and the density of development

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[8] It was William Penn's intention that the grid's design would facilitate real estate speculation and lead to sparse development, with single-family homes surrounded by individual yards. Instead, development during the mid 1800s divided and re-divided lots into the dense collection of town homes and storefronts that today is one of Philadelphia's defining characteristics (Warner 1968).

along Market Street rivals the density of other city centers, even if the spatial extent is smaller.[9]

While there have been considerable growing pains along the way, Center City is today a vibrant and viable area in the city, and in 1990 employed more than 11 percent of all the workers in the metropolitan area (Table **5.1**). Typical of many American cities, Center City is the hub of the regional and urban transit network, with various points along Market Street serving as the end of the line for most transit lines (see Chapter 4).

Figure **5.3** presents the 1990 work-shed, car-shed and emission-shed for the workers of Center City. The largest concentrations of commuters working in Center City lived within the boundaries of the city (Figure **5.3**.c). In fact, 59 percent of all commuters working in Center City lived in urban places. However, this pattern did not hold when examined for drivers and emissions. While only 35 percent of all commuters lived in suburban places, 53 percent of all commuters driving to Center County were suburban, and 62 percent of all GHG emissions from commuters driving alone were a result of suburbanites driving to Center City (see Table **5.3**). These patterns can be seen in Figure **5.3**.b and Figure **5.3**.a, respectively. The increase between percentage of drivers and percentage of emissions for suburban-dwelling commuters was due to the added distance traveled by suburban drivers, in comparison to urban drivers. Overall, the progression from Figure 5.3.a to 5.3.b to 5.3.c is centrifugal or away from the center. That is, the places producing the most emissions are further away from Center City than the places from which the most drivers originated, which

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[9] Remarkably, the statue remains a prominent feature despite this new development, due to the central location of City Hall and the heavy traffic that circles the building every day.

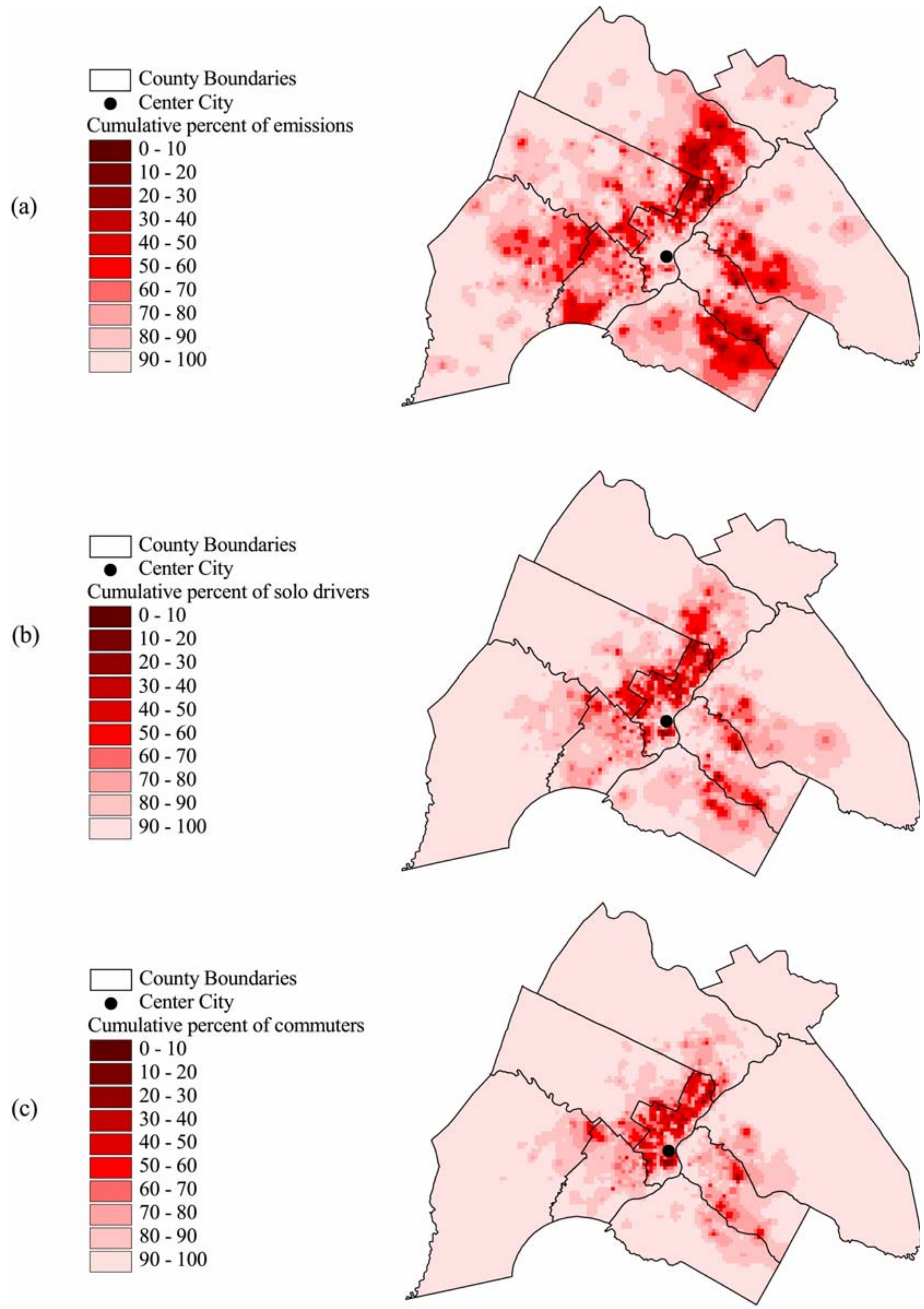

Figure **5.3**: GHG emissions resulting from the commute to Center City (a), and drivers (b) and commuters (c) destined for Center City

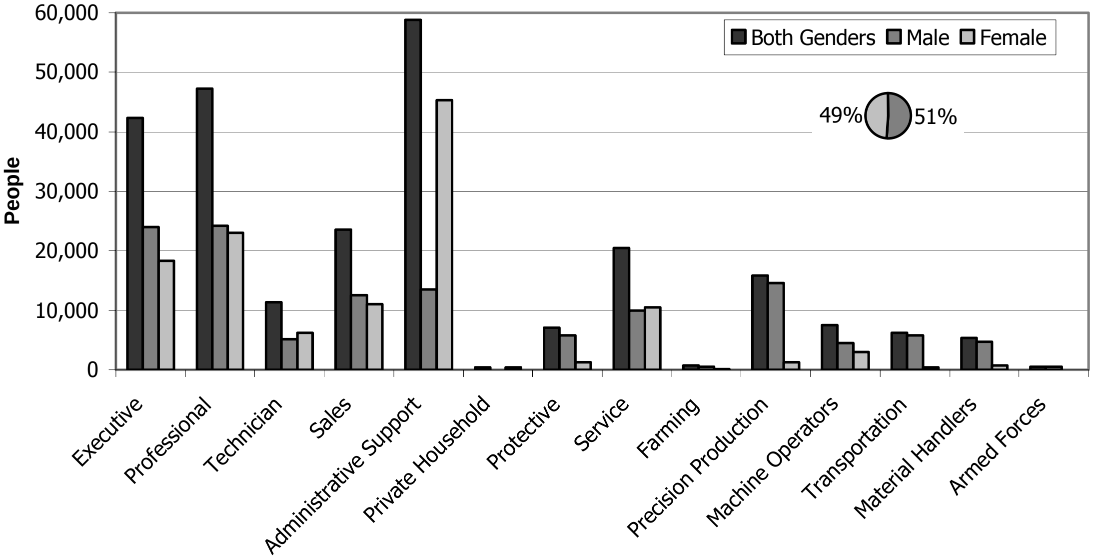

Figure **5.4**: Employment for Center City by gender and occupation

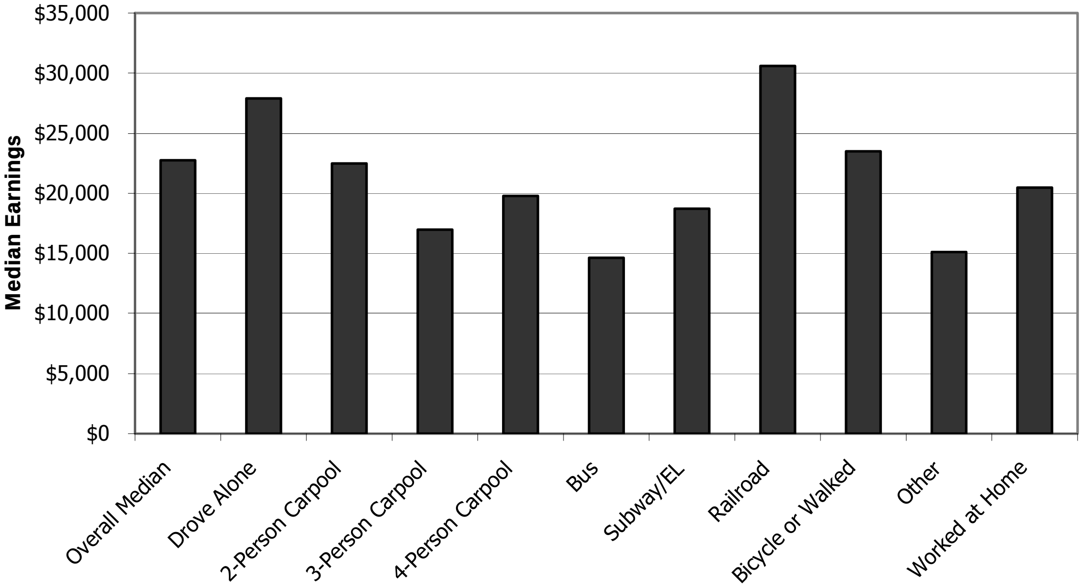

Figure **5.5**: Median earnings of Center City workers by mode of transportation are further away from Center City than the places from which the most commuters originated. As with the percentages in Table 5.3, the difference between Figures 5.3.a and 5.3.b is due largely to the fact that emissions are the result of the total number of trips and the distance driven by each commuter. This pattern holds for most of the 14 places examined in this chapter, with a few important exceptions discussed in subsequent sections.

Those working in Center City were primarily white-collar workers; most workers in the city were executives, professionals, or administrative support staff (Figure **5.4)**. Other important occupations included sales, technical professions, precision production, and jobs in the service industry, including protective services such as police or security officers. While employment in the city was split more or less evenly between men and women, men outnumbered women in most occupations, with some very notable exceptions. The clear majority of administrative support personnel were women, and women slightly outnumbered men in the service sector and in the jobs as technicians. While it is unclear what role this played in emissions in the region due to the lack of origin-destination data by occupation or gender, these employment patterns were quite different in other places, and warrant further investigation. While breakdowns of occupation by race are unavailable, roughly 25 percent of all Center City workers identified themselves as black during the 1990 census.

While suburban commuters were responsible for the lion's share of emissions from commuting, it is important to note that a significant number of suburban commuters did use the rail system to get to work – only 35 percent of all Center City commuters drove to work alone (Table **5.2**). Furthermore, the stereotype that public transportation is only for the poor is contradicted by the analysis in Figure **5.5**, which shows that the commuters traveling to Center City by regional rail were the highest earners of all workers in the city. Nonetheless, those driving to work were nearly as affluent and had median earnings substantially higher than the overall median earnings. This fact is particularly relevant when comparing emissions and commuting patterns of Center City to other places, particularly suburban places. It also is important to note that those using other modes of transportation, including most carpoolers, bus riders, and subway riders, earned considerably less then the overall median level. Those in two-person carpools and those walking or riding a bicycle to work had earnings at about the overall median level.

North Philadelphia

The area defined here as North Philadelphia is bounded by Poplar street on the south and the Delaware River on much of its eastern border. However, its northern and western borders are not easily defined using a single road or physical feature. This is not because North Philadelphia, as a region, is poorly defined on publicly available maps. However, North Philadelphia, as it is defined here, refers specifically to the portions of North Philadelphia in which most people are employed. As such, much of the residential area is excluded from this analysis. The parts of North Philadelphia that are included in this analysis include areas that were parts of Kensington and of the District and Township of Penn before the 1854 consolidation. Today, one of the primary employers in the area is Temple University. There also is some significant industrial employment, particularly along the Delaware River.

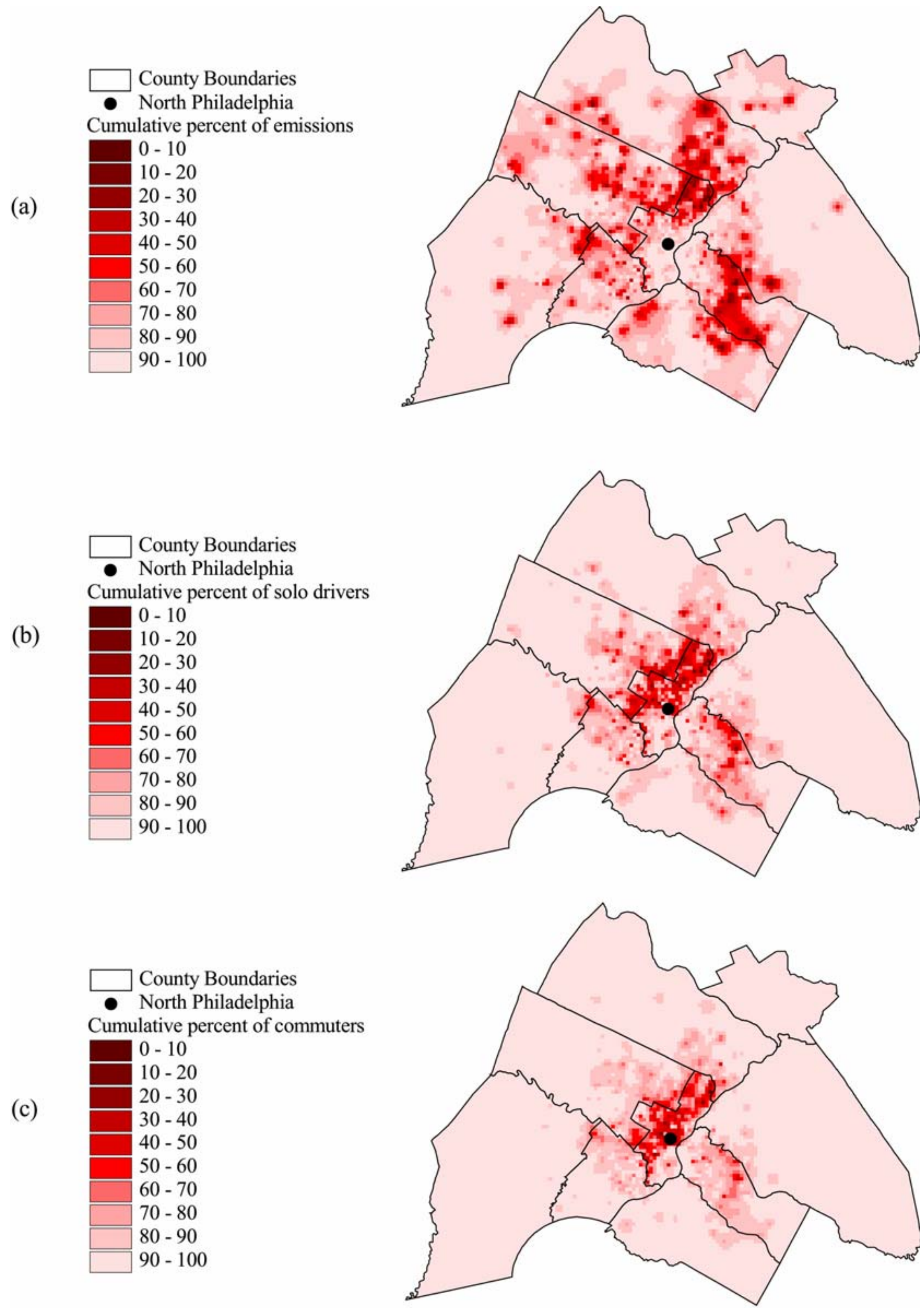

Figure **5.6**: GHG emissions resulting from the commute to North Philadelphia (a), and drivers (b) and commuters (c) destined for North Philadelphia

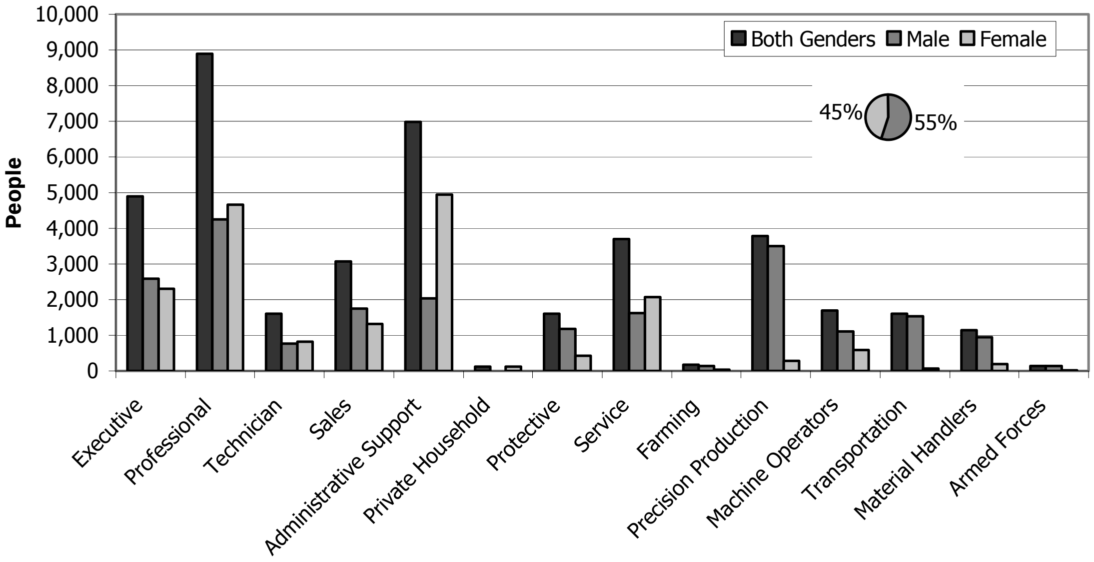

Figure **5.7**: Employment for North Philadelphia by gender and occupation

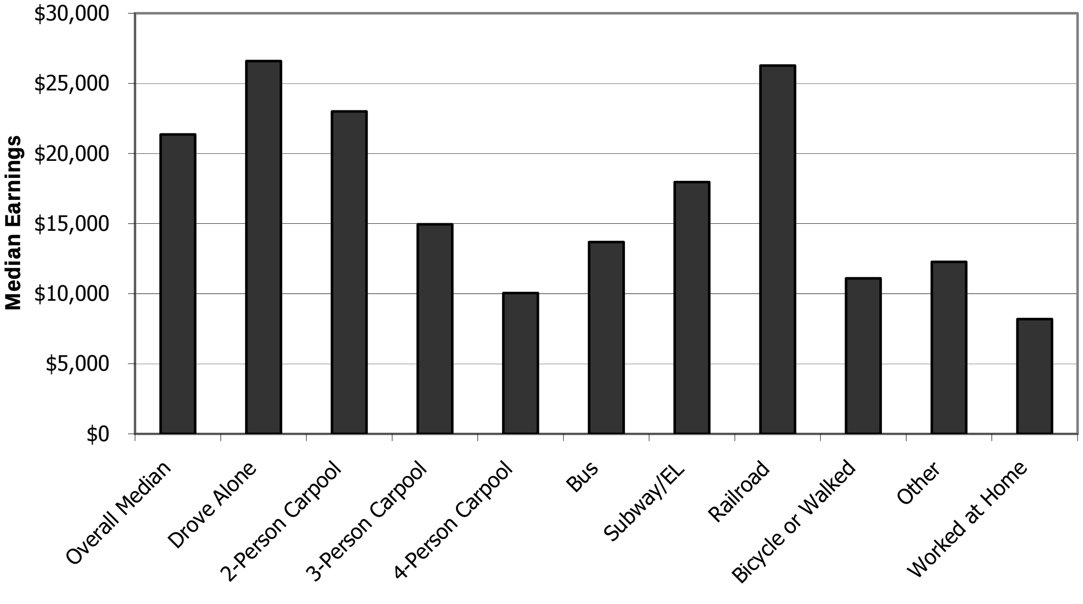

Figure **5.8**: Median earnings of North Philadelphia workers by mode of transportation

The work-shed, car-shed and emission-shed for North Philadelphia are shown in Figure **5.6**. Like Center City, the largest concentrations of commuters working in North Philadelphia lived within the city boundaries (Figure **5.6**.c), and again like Center City, about 60 percent of all commuters working in North Philadelphia were urban. However, compared to Center City, an even greater percentage of the drivers and emissions for North Philadelphia were attributable to suburbanites (see Table **5.3, Figure 5.6**.a, and **Figure 5.6**.b).

North Philadelphia employed about 37,735 commuters in 1990, which accounted for only 1.79 percent of total commuters (Table **5.1**). About 55 percent of these commuters were men, despite the fact that professional women slightly outnumbered professional men, and the professional category accounted for the most workers in the area (Figure **5.7**). Women also outnumbered men in administrative support positions, the occupation with the second greatest number of employees working in North Philadelphia. There were also more women technicians and more women in service jobs, but this finding was offset by the importance of industrial employment in the area, with such occupations such as precision production, machine operators, transportation jobs, and materials handlers, which all were dominated by men. In addition, despite the fact that women outnumbered men in the professional occupations, there were still more executive men than executive women. The distribution of overall employment by occupation reflects the influence of Temple University and the industrial areas. Twenty-nine percent of all workers in the area identified themselves as black.

The distribution of income among commuters using various modes of transit to commute to work again was similar to that of Center City – the commuters earning the highest salaries were those who rode the rail system, with those driving alone earning almost as much (Figure **5.8**). There are some differences, however. Those riding in 2-person carpools earned more than the overall median salary, and the relative poverty of those riding buses or subways was more pronounced that it was for Center City. Furthermore, a greater share of suburban commuters drove alone to get to work; 47 percent of drivers were suburban, and about 50 percent of all commuters drove (Table **5.3**, Table **5.2,** respectively). Comparisons between Tables **5.2** and **5.3** reveal that while about 17 percent of all commuters to Center City were suburbanites who drove alone, more than 23 percent of commuters destined for North Philadelphia were suburban drivers. This finding suggests that North Philadelphia was not served as efficiently by regional rail as was Center City. These factors all led to a lower overall efficiency per commuter in North Philadelphia, or conversely, higher emissions per commuter (Table **5.2**).

University City

From the perspective of the city's residents, the boundaries of University City are in flux. There clearly is a point at which this part of the city is exclusively part of the communities associated with the University of Pennsylvania and Drexel. In contrast, the surrounding area is largely an urban slum. Between the two is contested space where the University of Pennsylvania is trying to expand the size of its community and some of the minority residents are resisting this expansion. As with other workplaces in this thesis, University City is defined here by its emission profile – those areas with above-average emissions are defined as part of University City, and those with average or below-average emissions are excluded from its boundaries. Therefore, University City is an area that reaches as far west as 45th Street along Market Street, but contracts eastward to form a semicircle with the Schuylkill River bounding it on the east. The semicircle reaches as far north as Mantua Street and as far south as Baltimore Street, but only in the portions of University City that are closest to the Schuylkill River. In addition to the university community, there is a small portion of this neighborhood with commercial enterprises more suited to the residents of the surrounding area, but the area is primarily dominated in character and function by the universities located there.

Figure **5.9** displays the work-shed, car-shed, and emission-shed patterns for commuters working in University City. While the majority of the commuters (60 percent; see Table **5.3**) were urban dwellers, the commuters were more sparsely distributed in the cityscape than the commuters for either Center City or North Philadelphia (Figure **5.9**.c). A similar pattern for drivers and emissions to that of North Philadelphia is evident from Figure **5.9**.a and Figure **5.9**.b; suburbanites accounted for about 48 percent of all drivers and 65 percent of all emissions from commuters driving to work in University City (Table **5.3**).

Employment in University City was similar to that of North Philadelphia, but without a pronounced emphasis on industrial jobs. Nonetheless, men did outnumber women in the workplace, owing to a substantial amount of employment in precision production and a slight edge for men in executive positions. Professional and administrative jobs were the dominant form of employment, though, and both employed more women than men (Figure **5.10**), which was due in large part to the dominance of Drexel University and the University of Pennsylvania in the area's employment.

Overall, workers in University City, 30 percent of whom were black, were better off than were workers in many other parts of the city. While those who rode the bus or subway

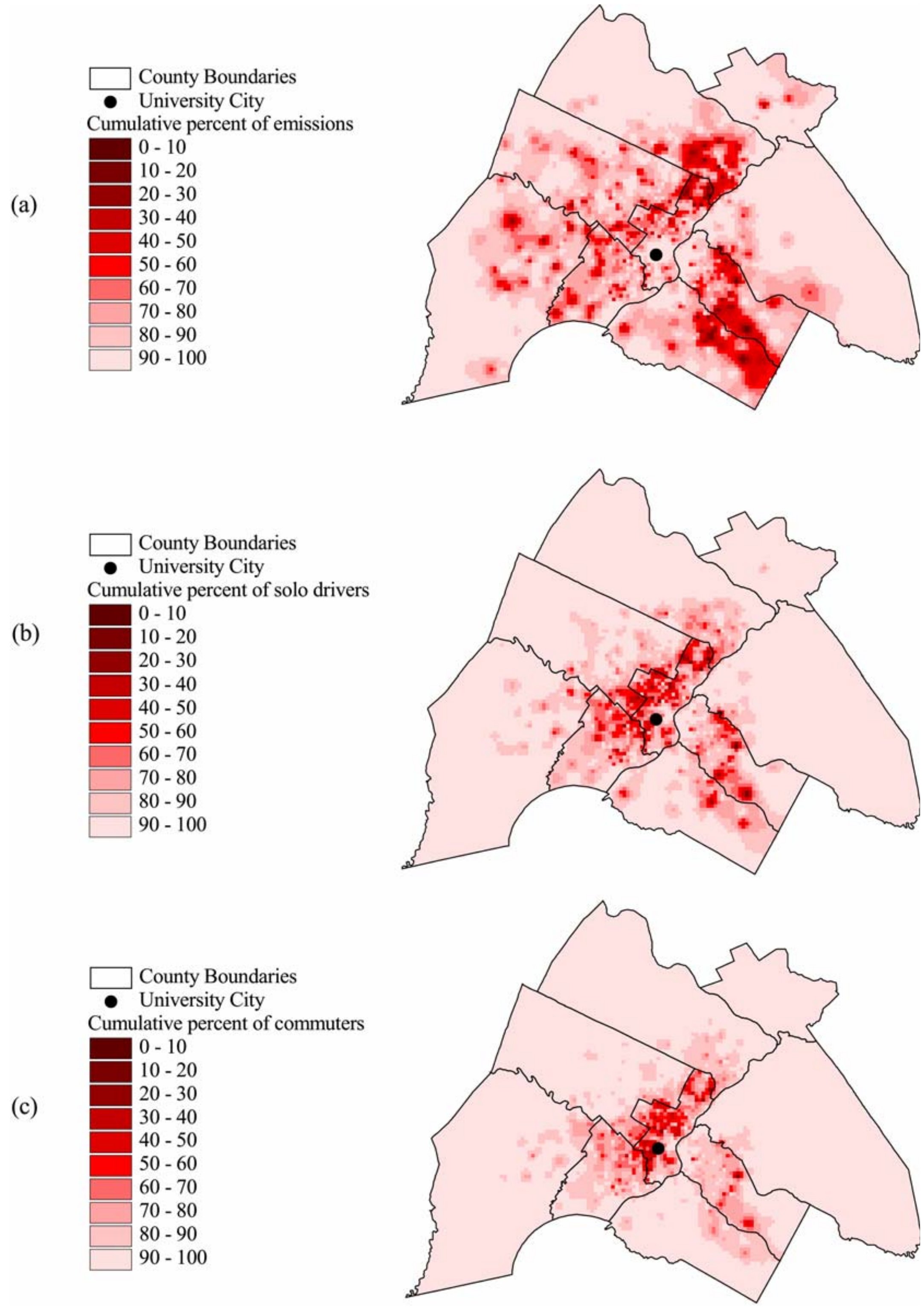

Figure **5.9**: GHG emissions resulting from the commute to University City (a), and drivers (b) and commuters (c) destined for University City

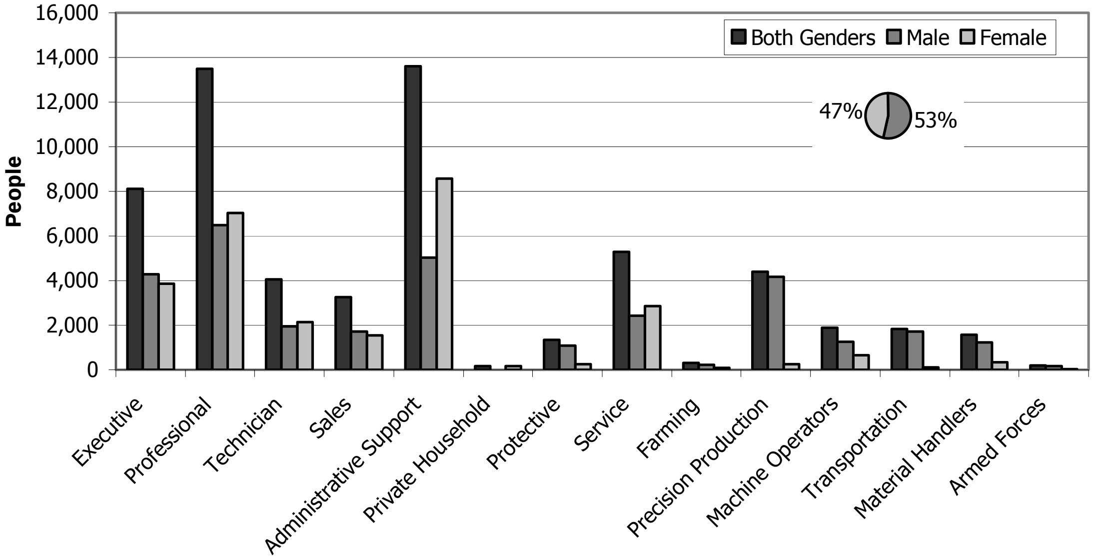

Figure **5.10**: Employment for University City by gender and occupation

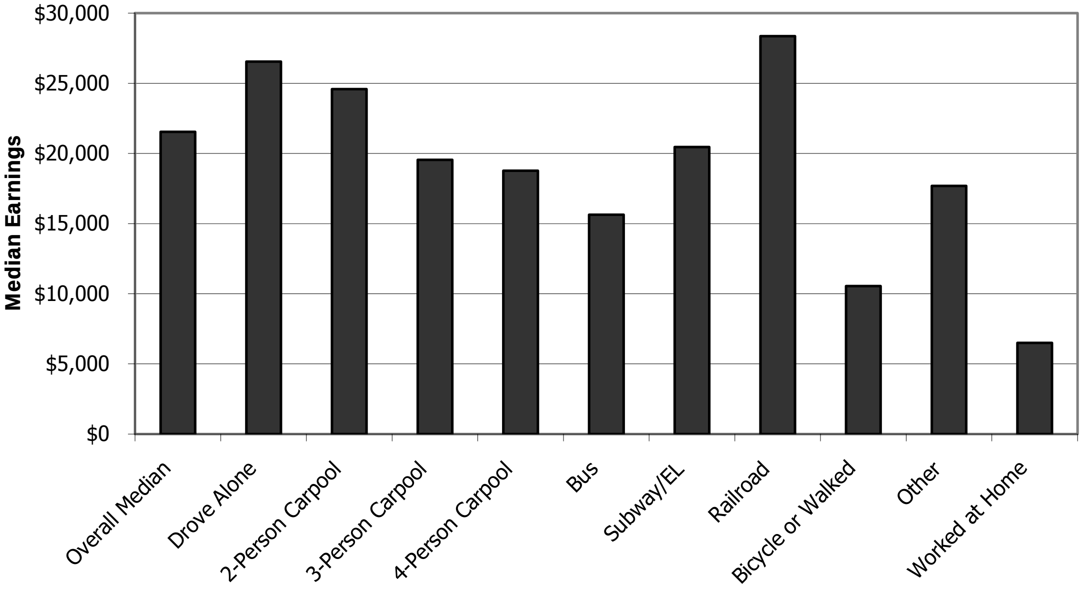

Figure **5.11**: Median earnings of University City workers by mode of transportation systems still earned less than the overall median for the area, the distinction was much less stark than, for instance, North Phildadelphia. The exception to this pattern was commuters who walked or rode their bicycle (see Figure **5.11**). This result may have been due in part to the relative poverty in the surrounding neighborhoods, but more likely was the result of the large population of students, who often did not own cars and did not work full time. The effect was lessened in North Philadelphia, despite the presence of Temple University. This reduction was probably attributable to the fact that Temple is considered more of a commuter university for Philadelphia natives, while Drexel and the University of Pennsylvania tend to have more full-time students who moved to Philadelphia specifically to attend school and who live on or within walking distance of the campuses.

South Philadelphia

South Philadelphia consists of the old Southwark district and most of the old Moyamensing district. For this thesis, it is defined as the area south of South Street and north of Wharton, but it goes further south along both rivers to include some industrial plants still in operation. South Philadelphia is one of the few neighborhoods that is fairly integrated, with strong African-American and Italian-American communities. This integration is due in large part to a lack of mobility among much the Italian-American community and other white residents during the post-war boom. The result has been far from harmonious, and South Philadelphia continues to be characterized by racial tension and occasional racial violence (Adams et al. 1991).

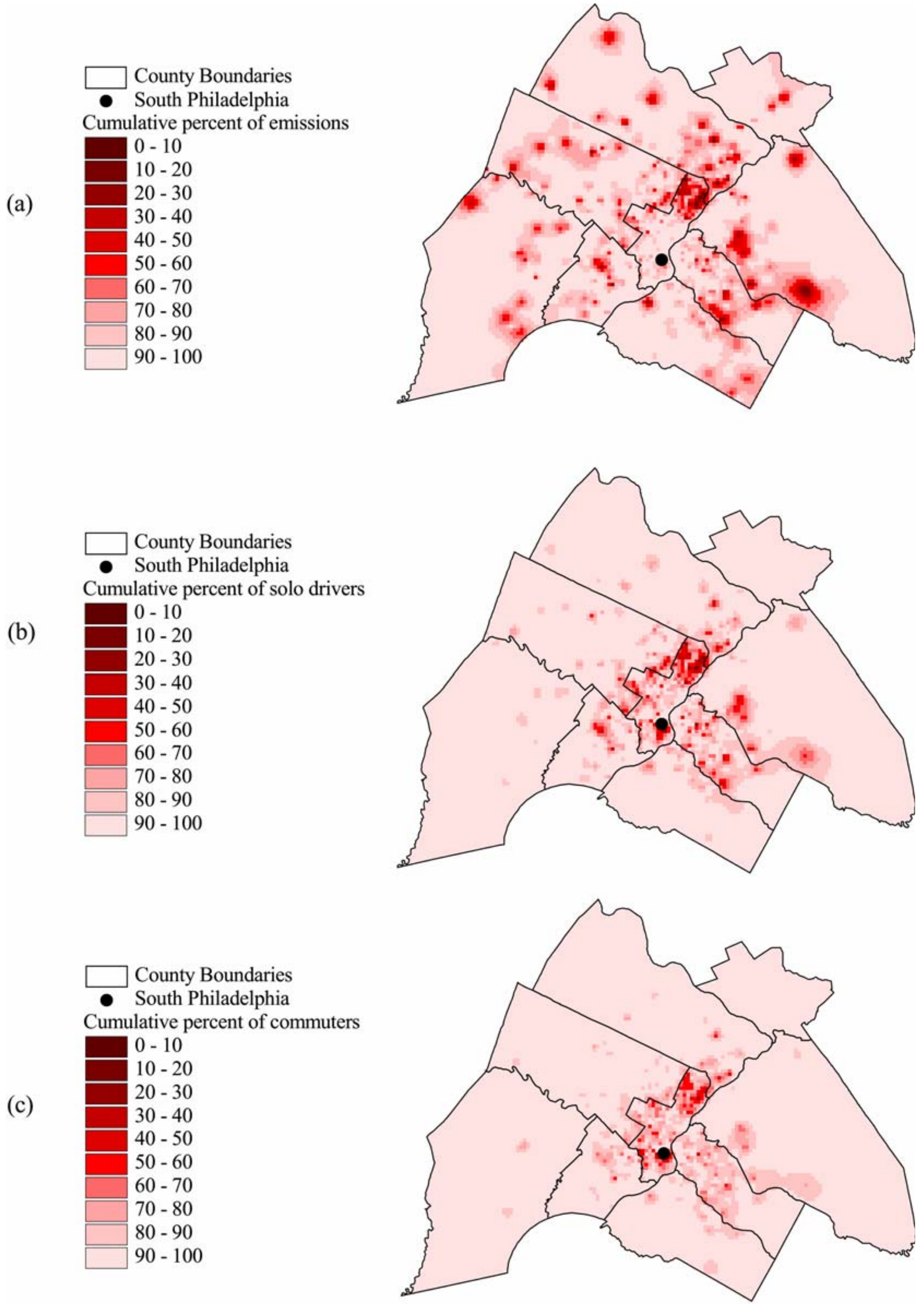

Figure **5.12**: GHG emissions resulting from the commute to South Philadelphia (a), and drivers (b) and commuters (c) destined for South Philadelphia

South Philadelphia has very different commuting, driving, and emissions patterns than the rest of the city (Figure **5.12**). Unlike most other urban workplaces discussed so far, South Philadelphia is itself one of the primary places of origin for its workers. In addition, a large number of workers commute to South Philadelphia from Northeast Philadelphia – a portion of the city that is often considered one of the first automobile suburbs of the city and a favorite destination for former South Philadelphia residents who were affluent enough or qualified for government programs to build new homes after World War II. Interestingly, these early suburbanites seem to have retained a unique connection to their former neighborhoods, presumably in the form of family businesses such as stores and restaurants, both of which are prevalent in the area. This hypothesis cannot be tested using census data, since Hispanic people were the only ethnic group identified in the census. About 28 percent of the workers in South Philadelphia were black, which is on par with other urban hotspots examined here.

Despite the apparent suburban nature of the driving and emissions patterns in Figure **5.12**.b and Figure **5.12**.a, respectively, the proportion of suburban drivers and emissions mirrored the other urban locations. About 44 percent of all drivers started their commute in suburban locations, and these commuters were responsible for about 71 percent of the emissions generated during the commute to South Philadelphia. So, rather than being exceedingly suburban, the workers in South Philadelphia were simply more sparsely distributed throughout the metropolitan area than they were for some of the other workplaces. However, within this distribution, there were clear clusters of residence. These clusters may have exited because of the ethnic history of South Philadelphia; that is, it is

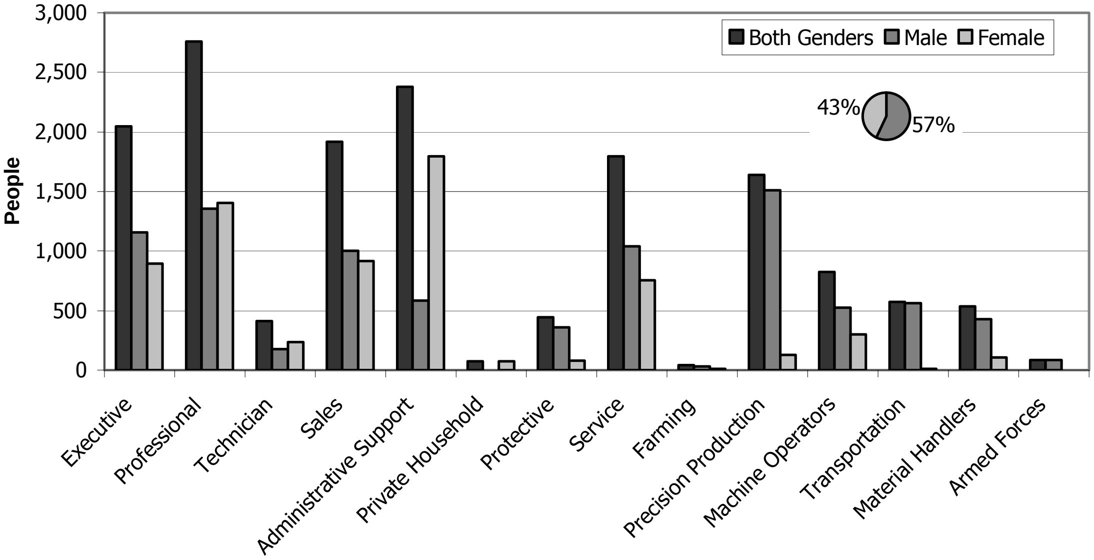

Figure **5.13**: Employment for South Philadelphia by gender and occupation

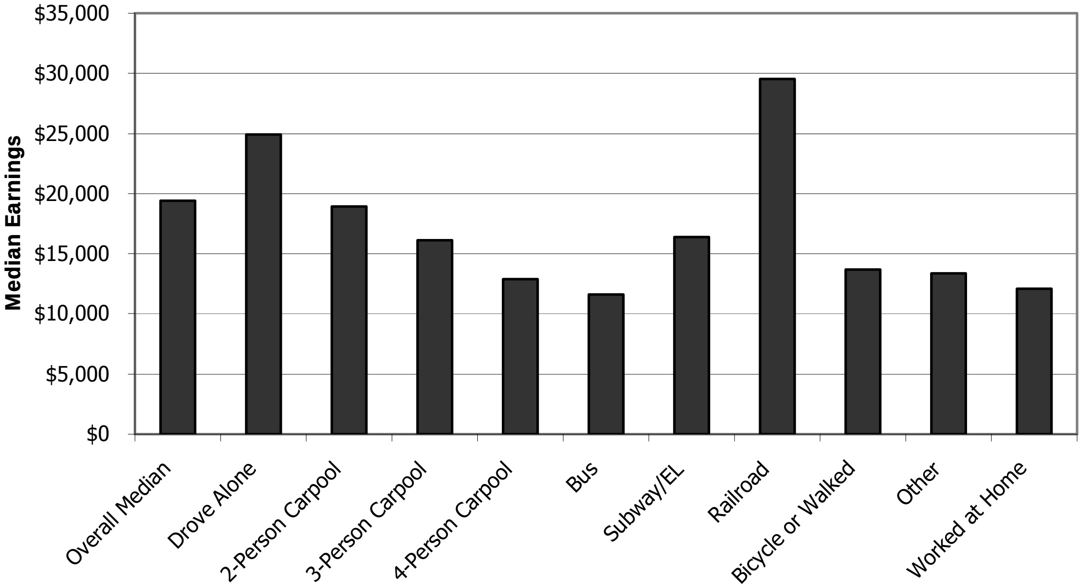

Figure **5.14**: Median earnings for South Philadelphia workers by mode of transportation possible that these clusters of settlement occurred as those moving from the city to the suburbs attempted to keep their families and circles of friends together.

Employment in South Philadelphia was dominated overwhelmingly by men. It also is distributed among a diverse group of occupations. Executive, professional, administrative, service, and industrial jobs all were important in South Philadelphia. One interesting attribute of the employment distribution for the area is that men far outnumber women in service jobs (see Figure **5.13**). This finding may be due in part to the prevalence of family businesses and restaurants in the area. South Philadelphia had similar earnings patterns by mode of transport to those of North Philadelphia (Figure **5.14**), which also had a diversity of types of employment. However, the differences among modes of transport are starker. Those who took the rail system to work are by far the biggest earners in the area, with those driving alone a distant second. Those carpooling or using the bus or subway system earned noticeably less than these affluent commuters and less than their counterparts working in North Philadelphia.

Germantown

Germantown was one of Philadelphia's first suburbs, dating back almost to the founding of Philadelphia itself. According to Hotchkin (1889), the drawing of lots for Germantown took place in the cave of Pastorius in 1683, one year after William Penn sent surveyor Thomas Holme to lay out the systematic grid for the first Philadelphia streets. As such, it has undergone numerous transformations, but over the long term, its transformation

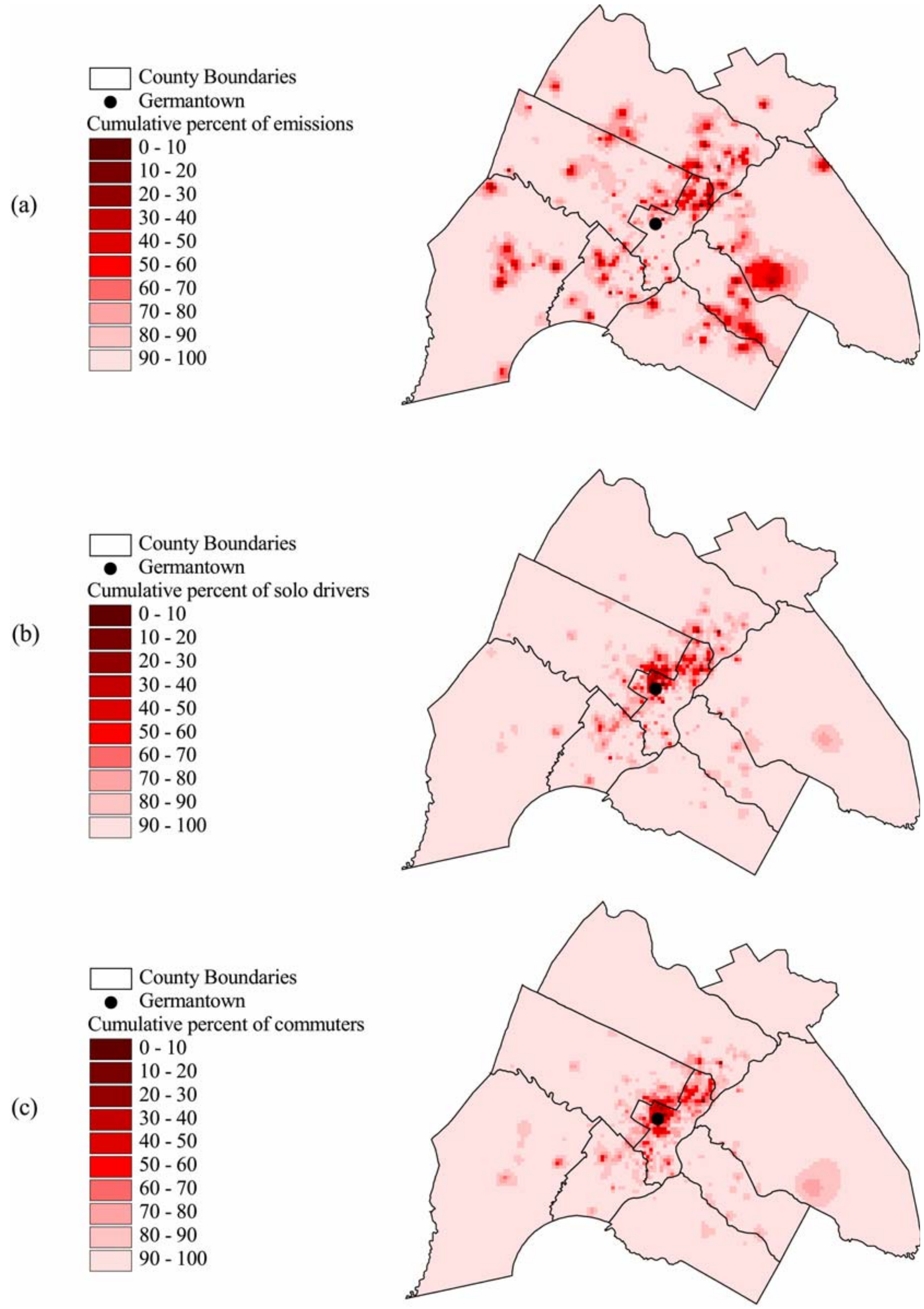

Figure **5.15**: GHG emissions resulting from the commute to Germantown (a), and drivers (b) and commuters (c) destined for Germantown has been from an affluent suburban community of Philadelphia's elite to a typical Philadelphian city neighborhood. Like much of the city, it experienced an exodus during the post-war building boom. However, like South Philadelphia, it also managed to escape the worst of Philadelphia's blight problems and remains a viable, if diminished, employment center.

Figure **5.15** shows the work-shed, car-shed, and emission-shed for Germantown for 1990. The patterns were very similar to South Philadelphia, but Germantown appears to have relied even more on the local residents for its workers. Compared to the other urban workplaces examined in this chapter, it had one of the highest percentage of urban commuters (65 percent; see Table **5.3**) and the highest percentage of black workers (more than 41 percent). Germantown had the highest percentage of drivers who were urban dwellers and the highest percentage of emissions that resulted from urban dwellers driving to work (see Table **5.3**).

While there is diversity in occupation among the workers in Germantown, the single most dominant category of jobs is professional, which is overwhelmingly dominated by women. Women also dominated the administrative and service jobs. Nonetheless, more men than women were employed in Germantown, but only marginally. This finding resulted from the importance of precision production jobs, which were dominated by men, and executive positions, in which men slightly outnumbered women (Figure **5.16**). Germantown had an income distribution pattern similar to that of South Phildelphia and North Philadelphia (Figure **5.17)**. Still, despite the fact that those riding the regional rail system to work made a bit more than the overall median earnings level, those who drove alone were clearly the most affluent group among Germantown workers.

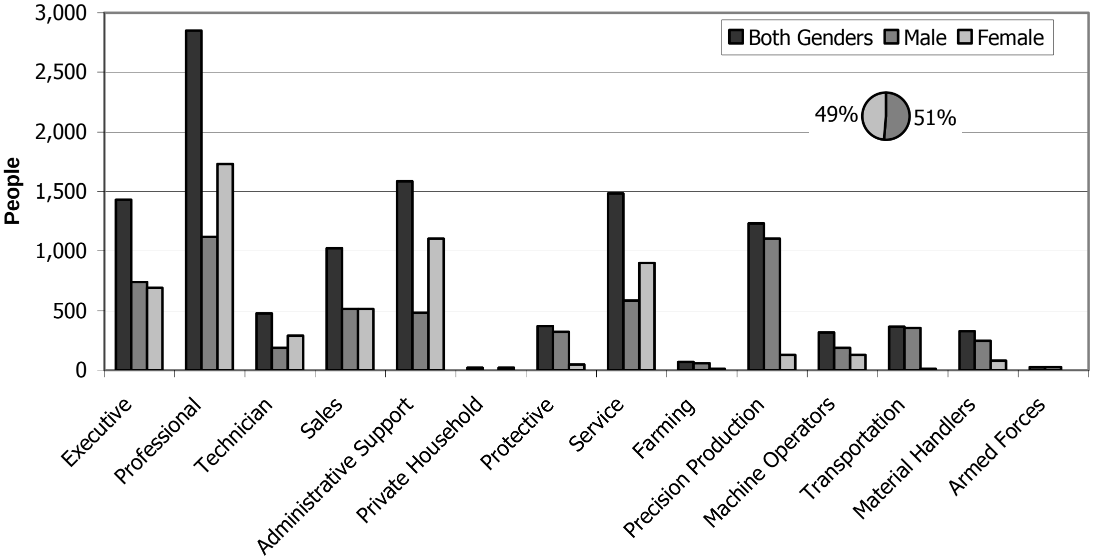

Figure **5.16**: Employment for Germantown by gender and occupation

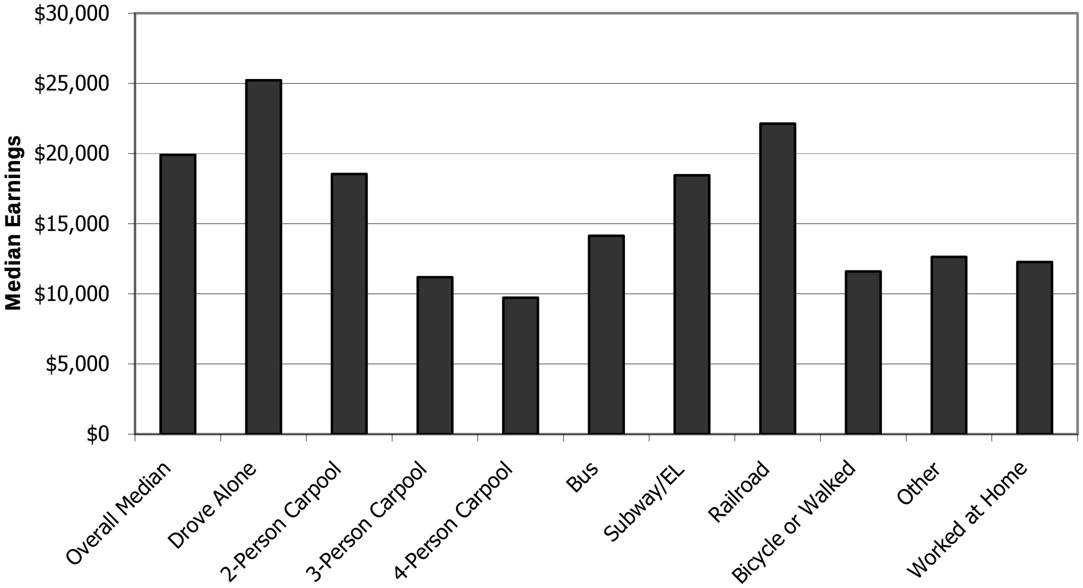

Figure **5.17**: Median earnings for Germantown workers by mode of transportation

Summary

As noted in the introduction to this section, commuters who worked in the urban places examined here shared similar patterns of origin. Similarly, consistent patterns also emerged from all urban workplaces when examined for those commuters who drove and the emissions they caused. Viewed in succession from commuter to driver to emitter, this pattern of consumption was centrifugal in nature. That is, as measures of commuting shifted from one of numbers of people towards ones of commuting behaviors and energy consumption, those commuters living in the suburbs furthest from the city were increasingly the most significant consumers. These workers tended to be the white workers. In contrast, the urban workplaces had a high percentage of black employees (20 to 40 percent, compared to a 15 percent black population in the overall metropolitan area), and most blacks lived in the city (see Chapter 4). This finding has implications for social and environmental justice, and these implications are explored in Chapters 6 and 7. Nonetheless, the most affluent of those commuters working in the city turned out to be those riding the regional rail system to work. Due to the earnings profile, the nature of the regional rail system and the demographic characteristics of the suburbs, it is safe to assume that these commuters are white suburbanites. Placing responsibility for emissions, then, is not as simple as blaming wasteful affluent suburbanites; there are other processes at work.

It may help to compare the types of employment and the modes of transportation used to get to work in urban areas to those of suburban workplaces. In general, white collar work dominated the employment profile of the urban workplaces, although a number of places also showed significant industrial employment. Men typically dominated employment overall, but women were more likely than men to work in administrative support positions.

Differentially gendered employment also existed in the professional and service industry jobs. Men typically outnumbered women in industrial jobs of all types. Overall, there was a diversity of job types in the city. Still, it is unclear whether or not these patterns in employment (gendered or not) are important when examining commuter behavior. In the hopes of discovering their relevance, they will be compared with the patterns in suburban workplaces in the next section.

Suburban Hotspots

As previously noted, urban hotspots were typically those within the political boundaries of the city of Philadelphia, with a few exceptions. Suburban hotspots typically were those located outside the city (see Figure **5.2**). This section examines six different suburban workplaces – King of Prussia, West Chester, Media, Abington, Newtown and Pottstown. As with the section on urban hotspots, the coverage of each place contains a brief history of its development and a short description of its current character. The work-shed, car-shed, and emission-shed for each place are then contextualized with brief discussions about the nature of employment and transportation in each place. After all six places are discussed, a summary is presented that draws some common themes and highlights some significant differences among these suburban places.

King of Prussia

Originally known as Reeseville, King of Prussia got its name from an inn that dates back to 1786. The official name of the town became King of Prussia around 1851 (Morrison, 2005). Today, it is contains the largest shopping complex in the world, made up of the two-mall agglomeration of the Plaza at King of Prussia and the Court at King of Prussia (BrainyEncyclopedia, 2005). In addition to the shopping area, King of Prussia has several large industrial parks, is home to countless hotels and restaurants, and hosts numerous strip malls. There also are many residential neighborhoods, primarily consisting of development from the 1950s through the present. Like many suburban places, a precise history of King of Prussia is difficult to glean from the literature, but the character is that of a large edge city that has developed primarily since the post-war building boom.

King of Prussia also was the second-most significant hotspot for GHG emissions from commuting, next to Center City. In 1990, it employed nearly 54,000 commuters, 2.56 percent of the total for the metropolitan area (see Table **5.1**). As a workplace, it was responsible for 3.5 percent of the total GHG emissions from driving commuters for the entire metropolitan area – about half that of Center City. These estimates do not include the massive amount of automobile traffic generated by the malls and other commercial operations every day. If the data for such an analysis were available, it is possible, based on anecdotal observations, that the GHG emissions in King of Prussia would outweigh a similar estimate for Center City.

Figure **5.18** presents the work-shed, car-shed and emission-shed for 1990 King of Prussia. While King of Prussia workers come primarily from the surrounding suburbs, a little more than eight percent of all workers (about one in 12) come from urban areas (Figure **5.18**). More than 83 percent of all workers drove to work (Table **5.2**), and 93 percent of those drivers were suburbanites while six percent were from urban areas (Table **5.3**).

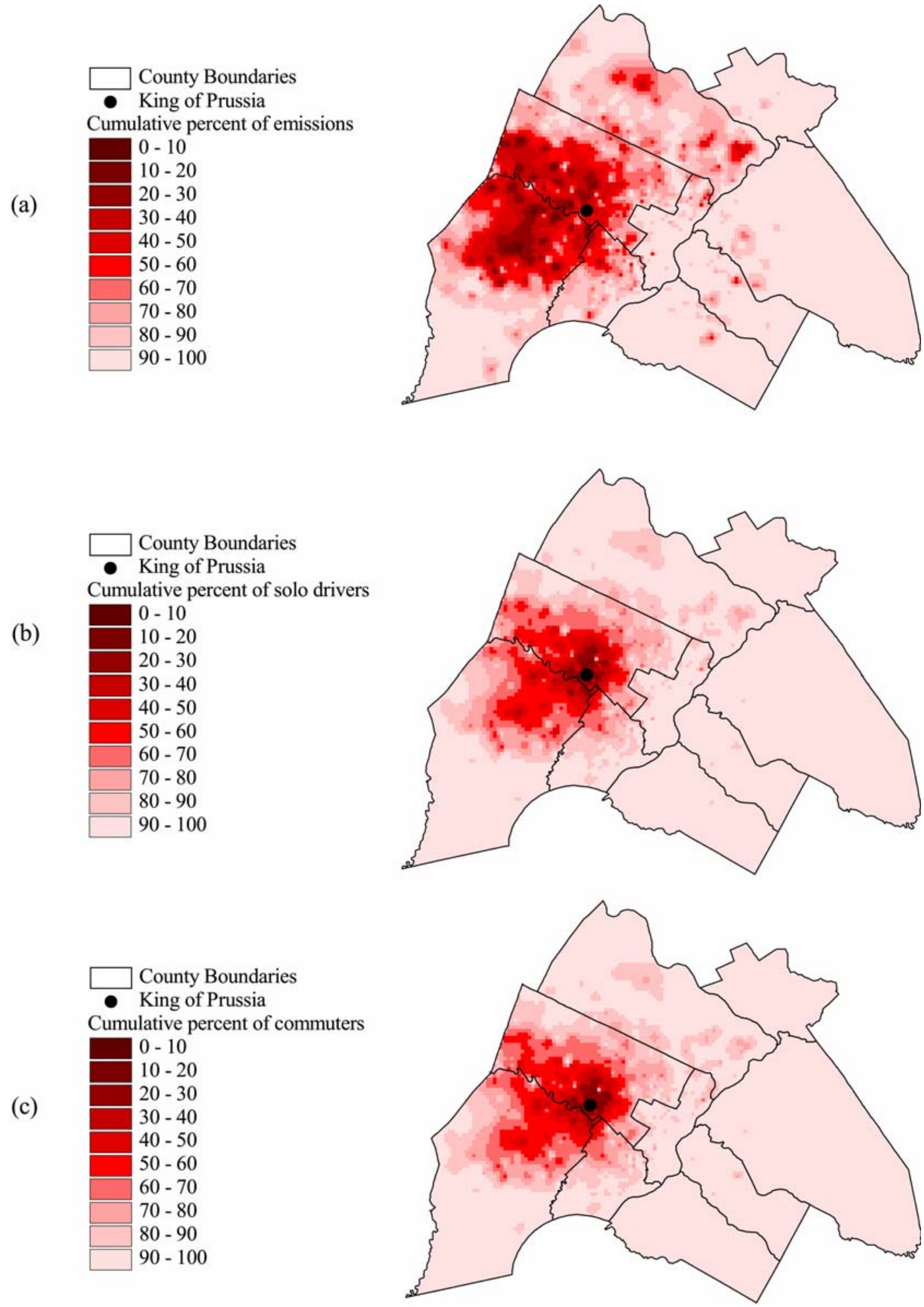

Figure **5.18**: GHG emissions resulting from the commute to King of Prussia (a), and drivers (b) and commuters (c) destined for King of Prussia

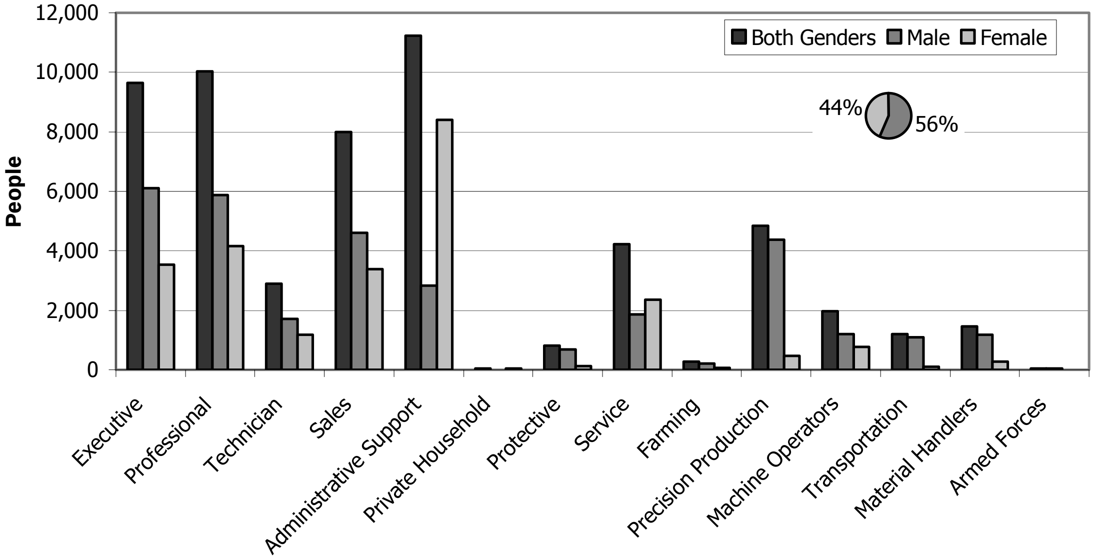

Figure **5.20**: Employment for King of Prussia by gender and occupation

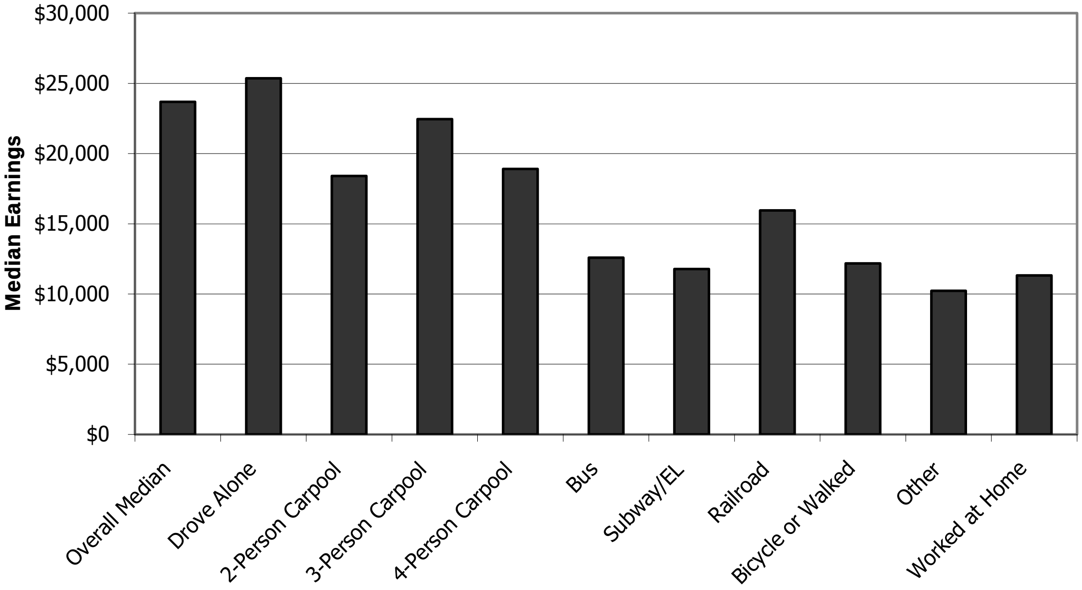

Figure **5.19**: Median earnings of King of Prussia workers by mode of transportation

Thus, 5 percent of all commuters were reverse commuters who drove, and only three percent were reverse commuters using public transit. As a result, the efficiency that was attributed to urban populations in urban hotspots vanishes when examining urban commuters to King of Prussia. In fact, Table **5.3** shows that urban commuters driving to work in King of Prussia were a little less efficient than the suburban drivers. Overall, the GHG emissions per commuter were more than double that of Center City, and even when considering the efficiency for drivers only, King of Prussia drivers emitted more per driver than did Center City drivers (Table **5.2**). As Figure **5.18** shows, the majority of commuters, drivers and emitters among King of Prussia employees are suburbanites.

The employment characteristics of King of Prussia were quite different than any of the urban hotspots (Figure **5.20**). This finding was to be expected due to the drastically different nature of the place, but the differences are worth noting. For the first time in this place-by-place accounting of employment, sales positions were significant, employing about 8,000 workers. The other important occupations were executive, professional, and administrative, with precision production and service being important secondary forms of employment in the area. Overall, men made up the majority of the workforce, outnumbering women by 12 percent. Whites far outnumbered blacks in the workplace, comprising 89 percent of the workforce compared to just eight percent for blacks.

The pattern of earnings among commuters using different modes of transportation also differed from the urban patterns considerably (Figure **5.19**). Commuters who drove alone were the most affluent group, followed by carpoolers traveling in carpools of varying size. There was a clear distinction between these groups and the groups using any form of public transportation or walking or biking. This difference probably existed because few workplaces were directly reachable by public transportation, thus increasing the travel time for these public transit users compared to public transit users commuting to urban workplaces.

West Chester

West Chester is a different kind of suburb than King of Prussia. In 1784, West Chester became the new county seat, taking over the role from Chester, located along the Delaware River.[10] In 1800, the population of West Chester was just 374 (Borough of West Chester 2004). By 1888, the population had grown to about 8,000 people within its borders and about another 4,000 people living in the surrounding area. At this time, West Chester enjoyed a booming economy with a diverse mix of manufacturing, financial, legal, retail, artisan and service businesses (West Chester Pa. Board of Trade, 1888). Though self-described as "the most important suburb of Philadelphia," it is possible that West Chester was one of the first American edge cities, loosely defined. About 50 minutes from central Philadelphia by train, it was part of the metropolitan area and traded heavily with the city (West Chester Pa. Board of Trade, 1888). Despite this heavy interaction with Philadelphia, West Chester also was a city in itself.

Present-day West Chester retains much of this character. Its street grid is clogged with heavy traffic most of the day and the downtown area hosts a diversity of thriving local

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[10] The residents of Chester did not take this laying down. At one point, a group of Chester residents even descended on West Chester with the intent of tearing down the West Chester courthouse, still under construction. The intended destruction did not take place, and in 1789, Delaware County was formed out of the eastern portion of Chester County, thus preserving Chester's stature as a county seat (Borough of West Chester, 2005). They would again lose their stature as county seat to Media (see subsection on Media).

businesses, including offices, banks, retail stores, restaurants, and even its own brew pubs. Industrial parks have sprung up to the northeast and, if entering the region from the sparsely populated areas to the west, one might mistake West Chester as the region's urban center. Indeed, for many in Chester County, West Chester is the center of public life, both financial and social. Still, West Chester is not without its problems; many of the town homes are in a state of disrepair, and the city suffers from a certain degree of poverty and other urban troubles.

The commuters working in West Chester in 1990 came from a much tighter area than the commuters of King of Prussia (Figure **5.21**). While some commuters came from Delaware County, West Chester was primarily an employer for Chester County, not the larger metropolitan area. More than 97 percent of all commuters were suburban, and the drivers and GHG emitters were primarily suburban, with only four percent of all GHG emissions being generated by urban dwellers (Table **5.3**). Per commuter and per driver, the workers of West Chester emitted less than those working in King of Prussia did, but the commuters were still much less efficient than urban commuters (Table **5.2**). Thus, while West Chester retains a vibrant central business district and appears urban in character, it lacks an effective public transit system to transport workers from the surrounding area; its commuters behaved more like other suburban workers than those working in urban workplaces.

Despite being different from King of Prussia in character, the types of employment offered by West Chester were similar (Figure **5.22**). The most important occupations in the area were executive, professional administrative, sales, service, and precision production.

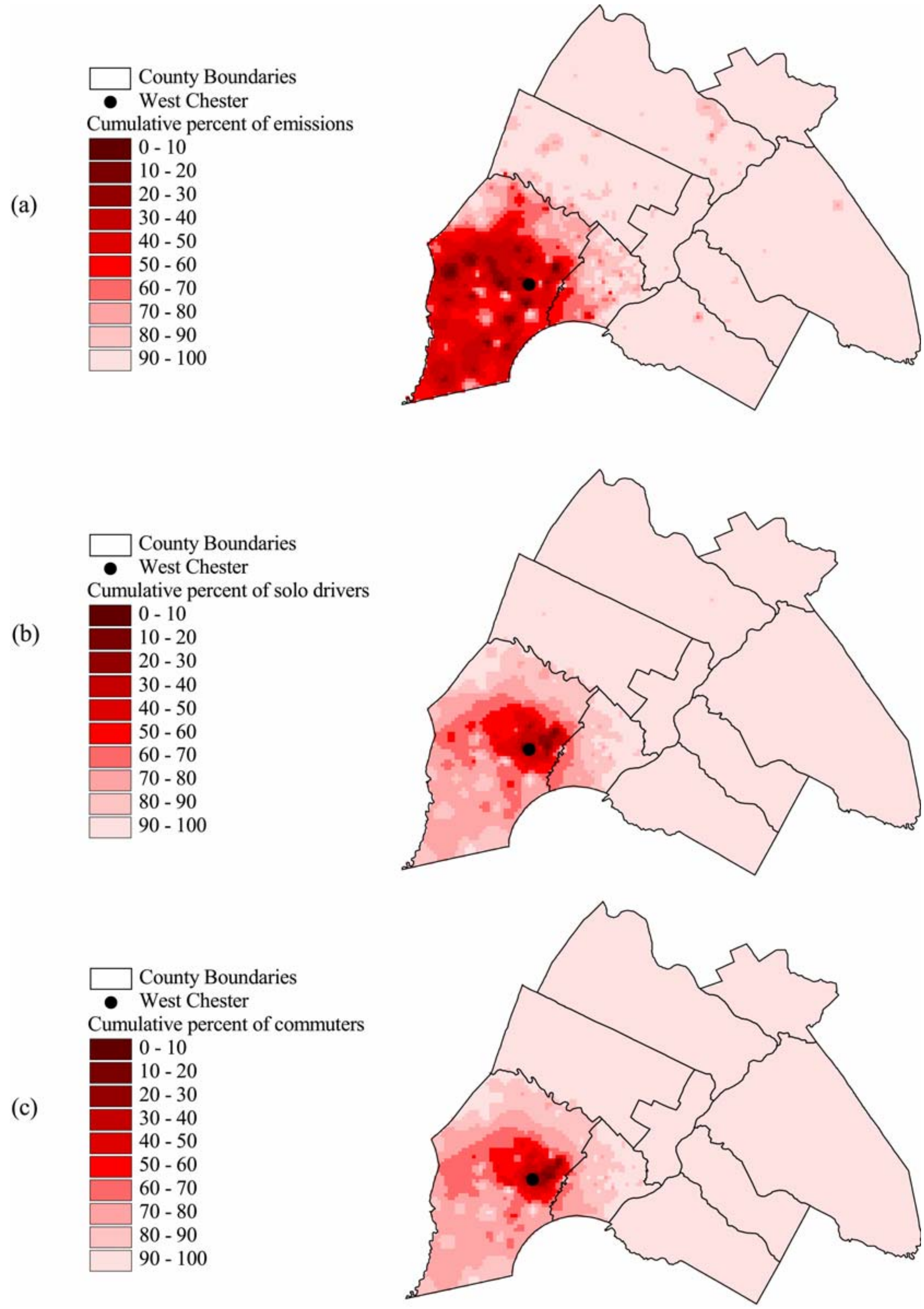

Figure **5.21**: GHG emissions resulting from the commute to West Chester (a), and drivers (b) and commuters (c) destined for West Chester

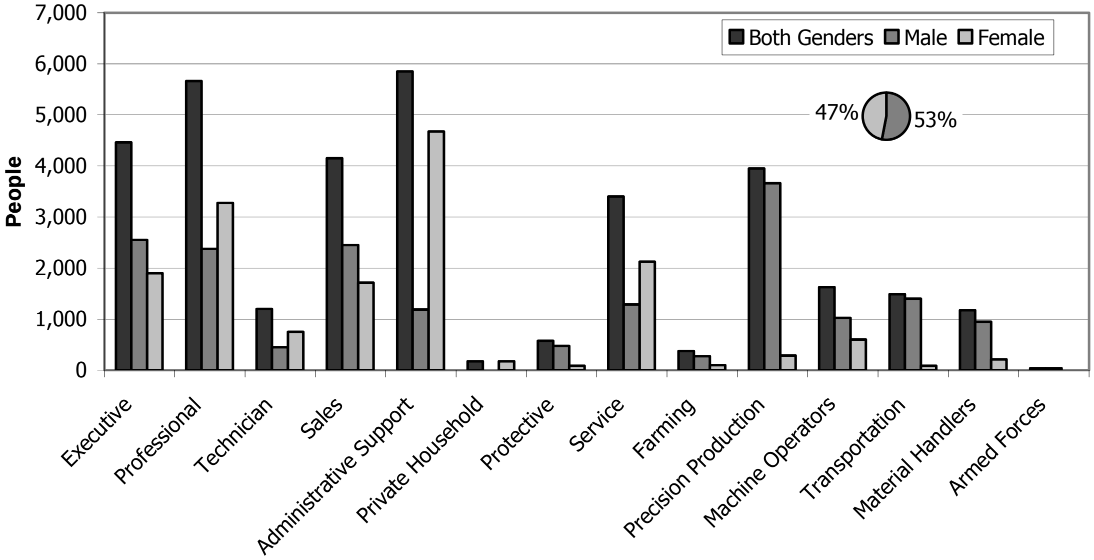

Figure **5.22**: Employment for West Chester by gender and occupation

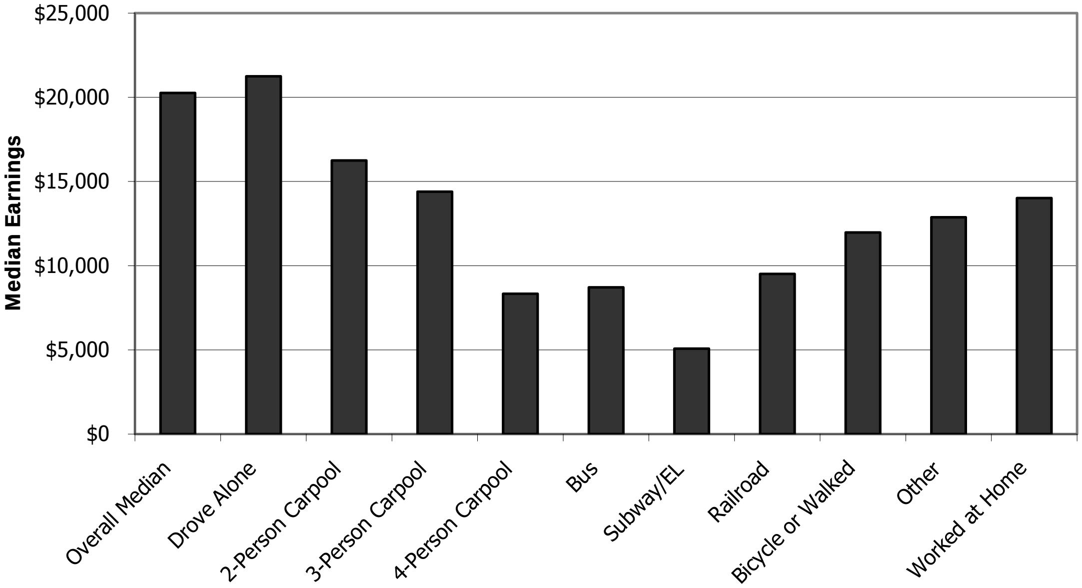

Figure **5.23**: Median earnings of West Chester workers by mode of transportation

Technicians were a bit less important than in King of Prussia and there were some other minor differences, but the similarity in the character of employment was nonetheless striking. This comparison serves as evidence that it is possible to support similar types of economic activity within different urban and suburban forms. Still, there were some significant differences between King of Prussia and West Chester in the type of transit used by different economic groups (Figure **5.23**). As with King of Prussia, those driving alone were the most affluent group. However, carpoolers were much less likely to be high earners, and those using public transportation were likely to have even lower salaries than those with similar commuting patterns to King of Prussia. The racial character of the workplace was similar to that of King of Prussia – whites accounted for 88 percent of the workers, while blacks accounted for about nine percent.

Media

Like West Chester, Media is a county seat and largely a regional employer, in this case for Delaware County. Around 1850, Media was incorporated by the state legislature and named the county seat of Delaware County as the result of considerable dissatisfaction among residents with the previous county seat in Chester. Before this date, Media had been known as Providence, but was renamed Media to signify its central location within the county (Borough of Media, 2005). As with many suburbs, Media grew in spurts. The downtown area retains a small-town feel, complete with a local movie theater and other local businesses, although more and more businesses have sprung up in strip malls at the city's outskirts. Still, Media's website (2005) brags about the downtown area, proclaiming that it is the last suburban town in American to have a streetcar running down the main street and describing the many amenities available within walking distance of many of the older homes in the town. Media's character is probably best summed up with its slogan, "Everybody's Hometown."

Figure **5.24** shows the work-shed, car-shed and emission-shed for Media. As discussed above, the workers in Media came primarily from Delaware County, and it is these residents who were primarily responsible for GHG emissions resulting from the commute to work, with the exception of a few commuters traveling from Chester County. Despite efforts to self-describe Media as a pedestrian town, slightly more than 81 percent of all commuters drove to work in Media. Nevertheless, due to the short distance between home and work, the commuters of Media emit fewer GHGs per capita than most suburban hotspots (Table **5.2**).

Media is one of the few workplaces examined in this thesis where women significantly outnumbered men in the workplace, largely because of the heavy emphasis on administrative support jobs, but also because women outnumbered men in professional employment. The other important form of employment in Media was executive employment; service, sales, and production also stood out, but were of secondary importance (Figure **5.25**). As with King of Prussia and West Chester, blacks made up only 9 percent of the workforce.

The transportation profile appears to be a cross between the profiles of urban and suburban places examined so far. While those commuters who drove alone were the most affluent group, workers in two-person carpools also earned slightly above the overall median

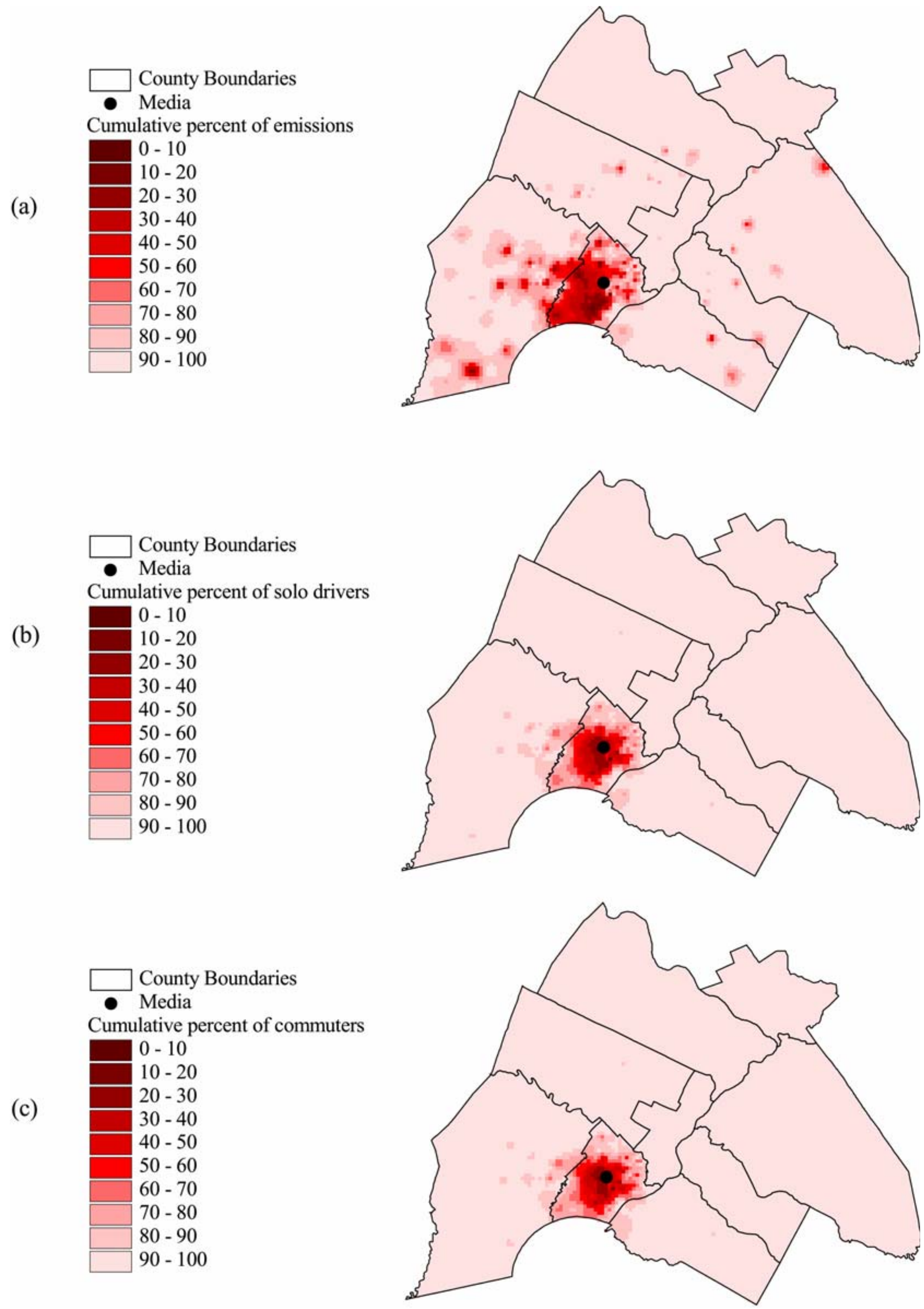

Figure **5.24**: GHG emissions resulting from the commute to Media (a), and drivers (b) and commuters (c) destined for Media

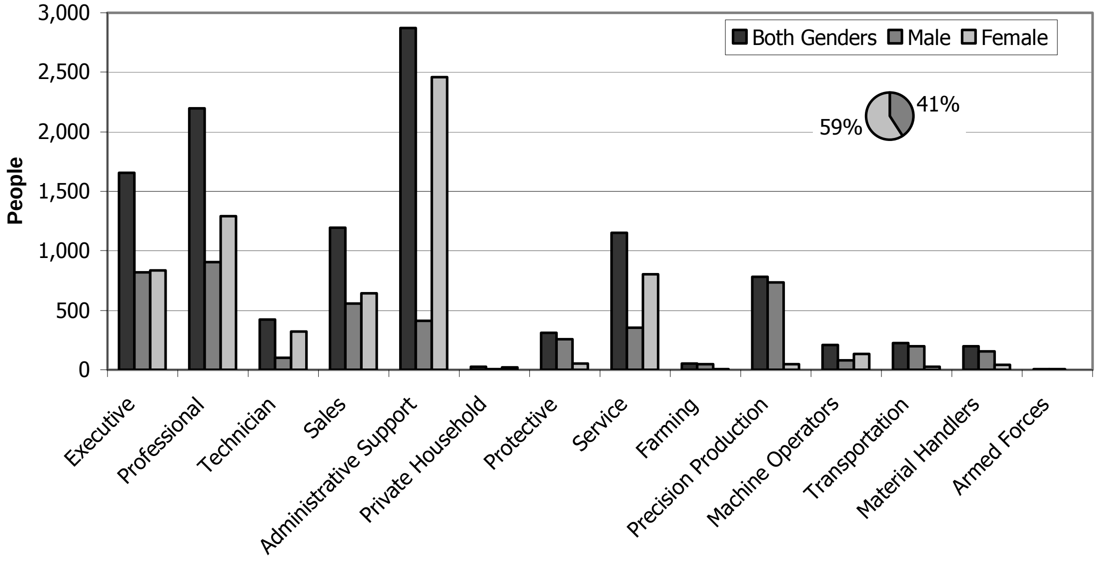

Figure **5.25**: Employment for Media by gender and occupation

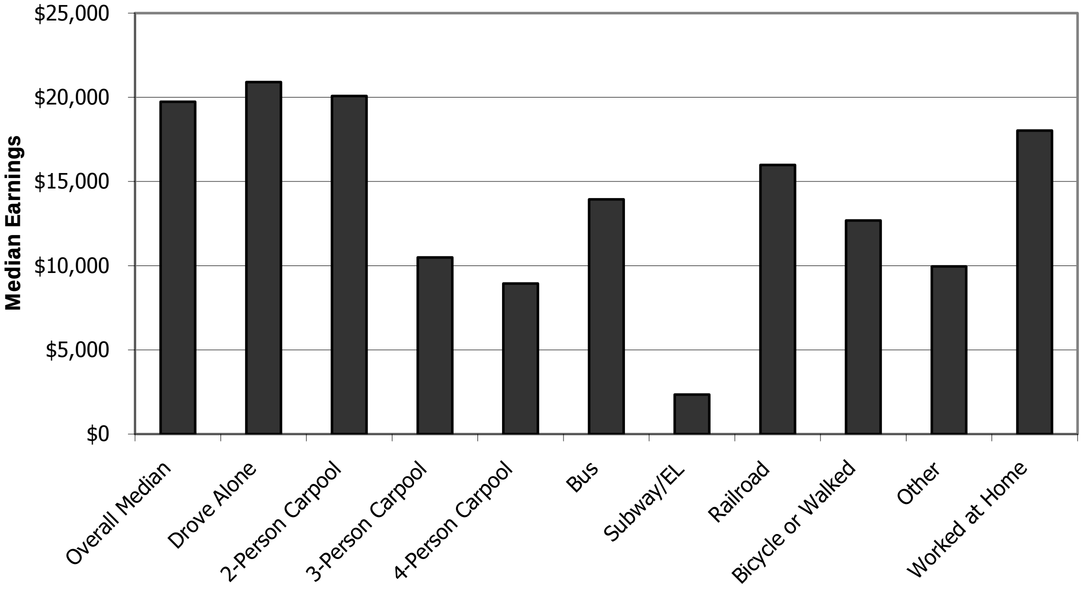

Figure **5.26**: Median earnings of Media workers by mode of transportation earning level for Media workers. In addition, those using public transit, both bus and rail, were significantly better off than their counterparts in West Chester or King of Prussia. Perhaps most striking is the high, but still below-median earning level for those who worked at home (Figure **5.26**).

Abington

Located in Montgomery County near borders with both Philadelphia County and Bucks County, Abington is an affluent suburb with a diversity of businesses and occupations. The median household income is more than $44,000 and the median home value is more than $125,000 (Abington Township, 2004). Abington is host to a satellite campus of Penn State, numerous financial and business offices, many high-end retail shops, restaurants, and industrial parks with precision manufacturing and additional office space. Over 25,000 commuters work in and around Abington, and it is among the metropolitan area's top-ten hotspots for GHG emissions (Table **5.1**).

Abington primarily draws its workers from surrounding Montgomery and Bucks counties, although many also commute from Philadelphia, including Northeast Philadelphia (Figure **5.27**). Nearly 20 percent of those employed in Abington are urban dwellers (Table **5.3**). About 78 percent of all workers drove to work, 15 percent of whom were urban residents. Overall, even though more of its workers live in Philadelphia, Abington's per driver and per commuter GHG efficiencies are only marginally better than West Chester, but are significantly better than King of Prussia (Table **5.2**).

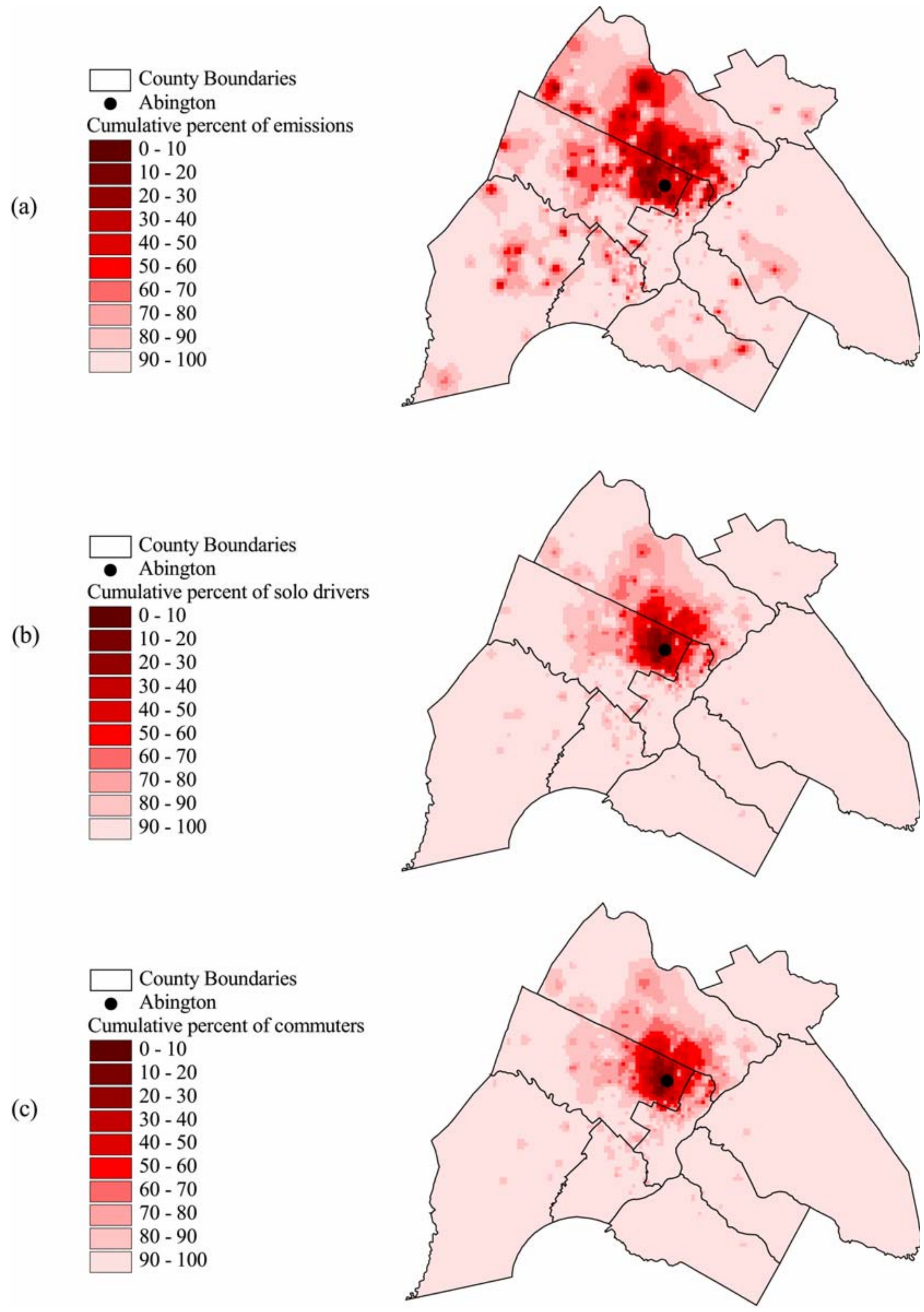

Figure **5.27**: GHG emissions resulting from the commute to Abington (a), and drivers (b) and commuters (c) destined for Abington

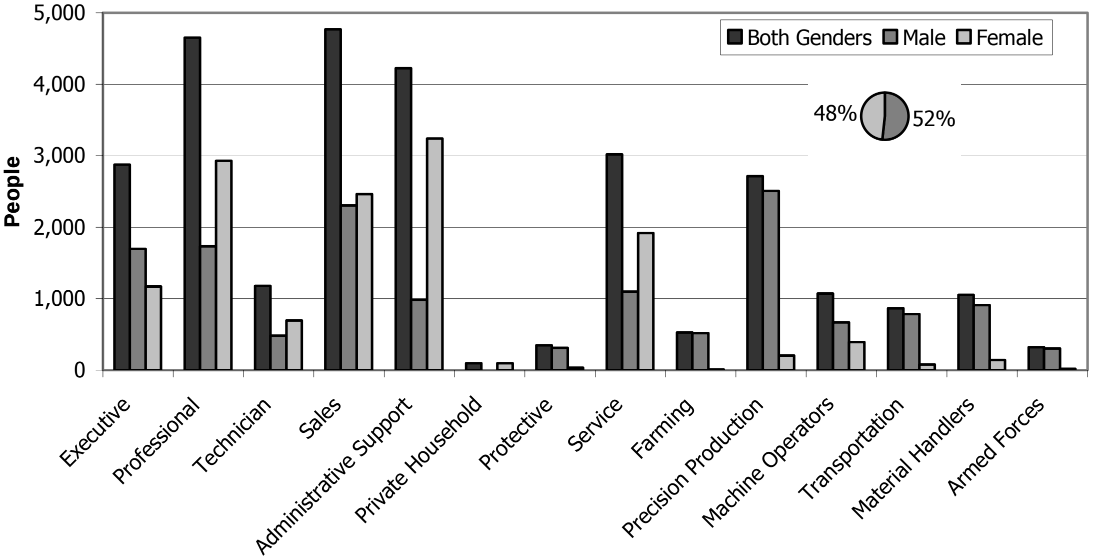

Figure **5.28**: Employment for Abington by gender and occupation

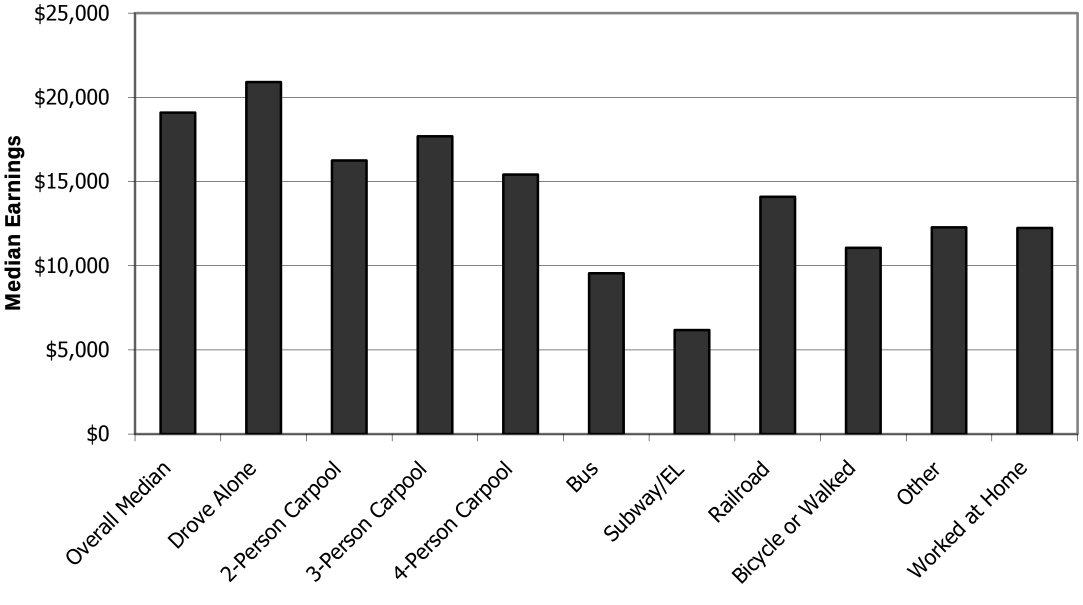

Figure **5.29**: Median earnings of Abington workers by mode of transportation

Figure **5.28** demonstrates the diversity of commercial and industrial activity in the area. Sales positions are the primary employment category, but professional and administrative jobs are also important. Additionally, executive positions and work in service and precision production employ more than 2,000 workers each. Slightly more men than women are employed in Abington, and the most important employment sectors for women are professional, sales, administrative support, and service. Probably owing to the larger than average urban component of the workforce, more than 13 percent of Abington's workers are black – considerably higher than other suburban workplaces, but still much lower than urban workplaces.

The pattern of earnings in relation to mode of transportation appears to be a function of the mix of urban and suburban commuters working in the area. Those driving alone were the most affluent, but all classifications of carpoolers also enjoyed considerable earnings, albeit a bit below median (Figure **5.29**). While the earnings of those using public transit were considerably below median levels, they were better than in many other suburban workplaces. It also should be noted that while residential incomes are fairly high in the area, median earnings of the workers employed here were considerably lower than many other workplaces examined above.

Newtown

Loaded with a mix of historic homes, a vibrant and unique downtown area, office and industrial parks, roadside farm stands and open space, Newtown typifies the collision of multiple land uses, cultures and cultural periods typical of much of Bucks County. The downtown area is filled with historic homes and small, densely packed storefronts. Unlike Media, another suburban "hometown," Newtown's downtown shops include national and global retailers side by side with locally owned antique and sundry shops. The highways leading into town contain similar contradictions, like a splendid view of new industrial and office buildings from a roadside farmer's stand, which could have existed (and probably did exist) more than 50 years ago. Like much of Bucks County, the suburban population is affluent and the area is characterized by historic homes and new development with large lots and large houses. Yet, it is set in a landscape in which there still is considerable farmland and a corresponding population that considers itself rural, not suburban.

Newtown drew its workers primarily from the rest of Bucks County, with a small number also coming from nearby Northeast Philadelphia and northern Montgomery County (Figure **5.30**). More than 90 percent of all the commuters were suburbanites and almost 84 percent of all commuters drove to work in 1990 (Tables **5.1** and **5.3**). Most emissions were a result of the drivers coming from both nearby and remote locations within Bucks County (Figure **5.30**).

Like Media, Newtown was one of the few locations where women outnumbered men in the workplace (Figure **5.31**), and like Media, it was one of the few locations where those working at home made a respectable living (Figure **5.32**). In fact, those working at home were actually the most affluent workers in 1990. Those driving alone were close behind and still had above-median incomes. However, unlike Media, Newtown is poorly served by public transit; only those making a low wage attempted to reach Newtown workplaces via public transit. Newtown also had fewer black workers than nearly all

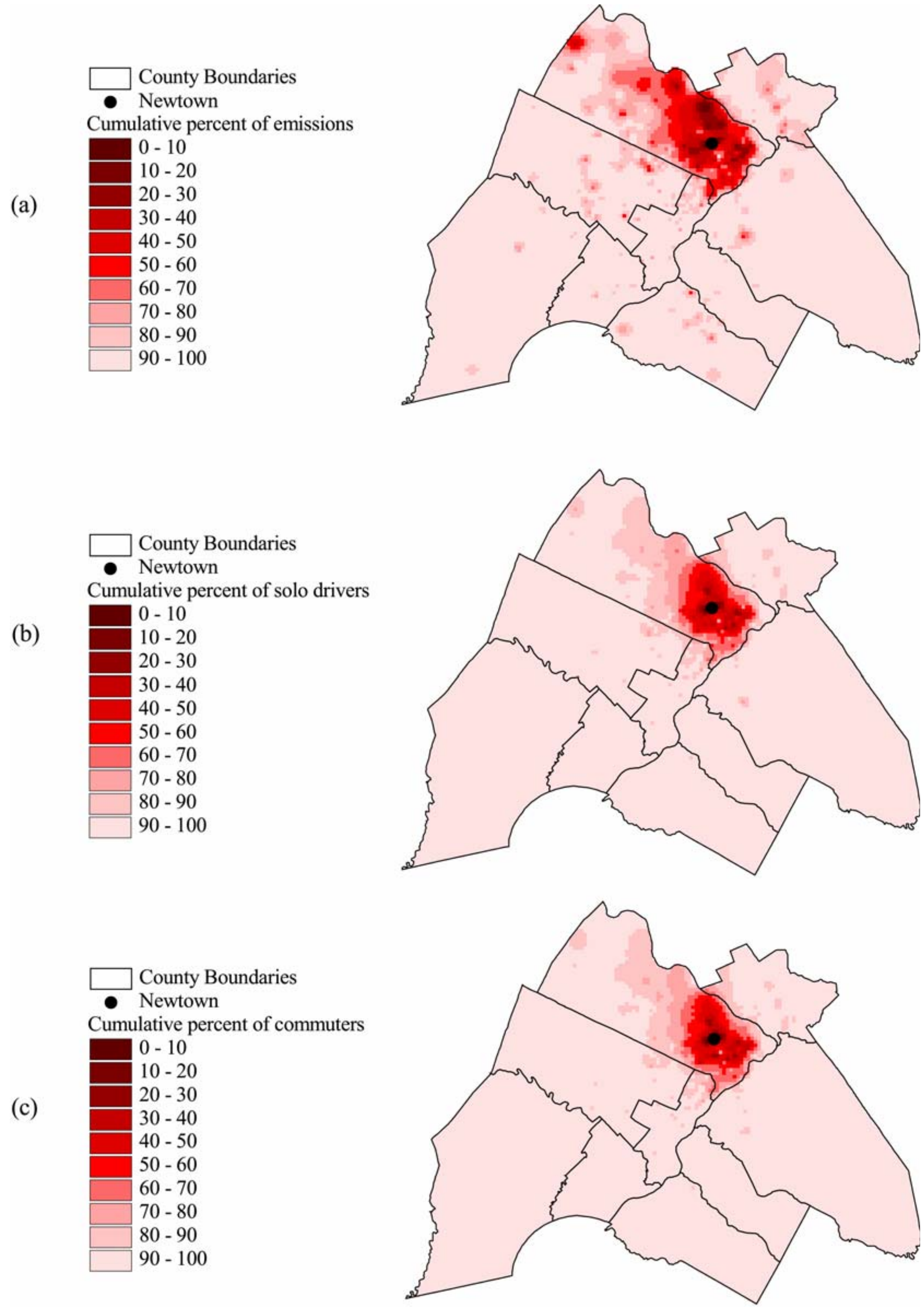

Figure **5.30**: GHG emissions resulting from the commute to Newtown (a), and drivers (b) and commuters (c) destined for Newtown

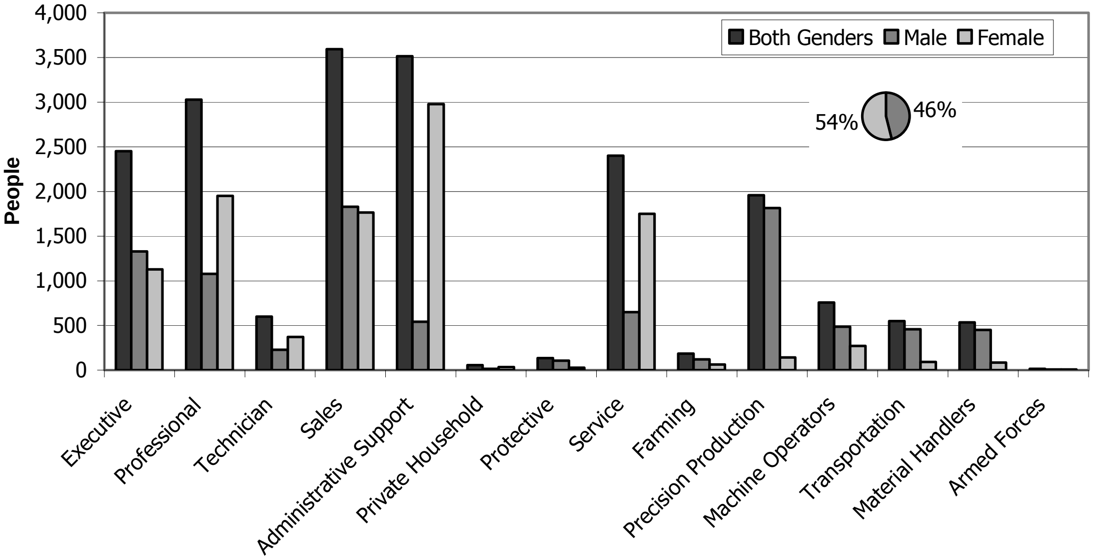

Figure **5.31**: Employment for Newtown by gender and occupation

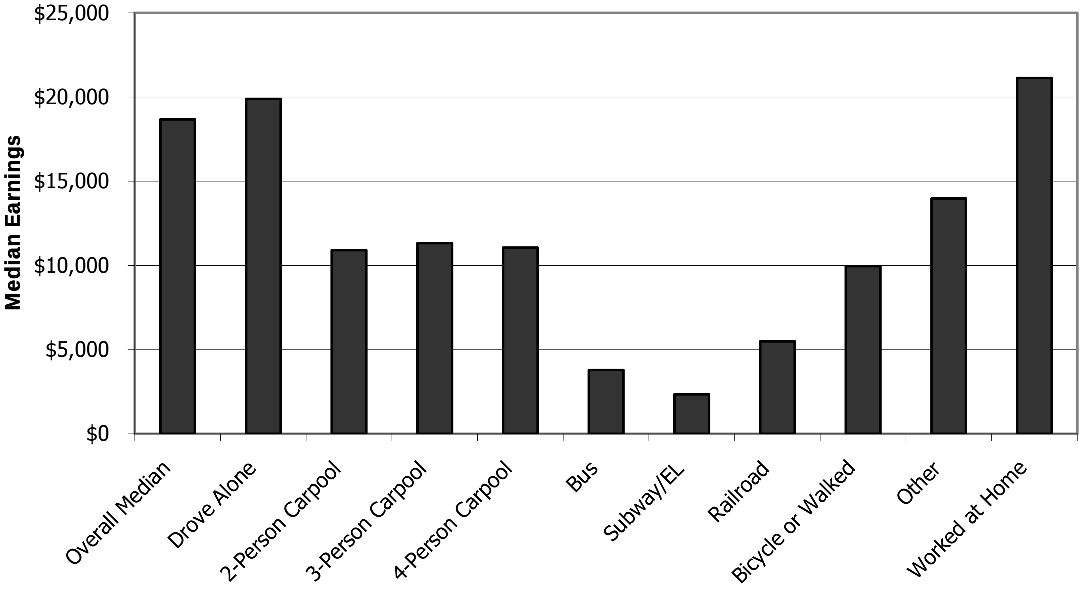

Figure **5.32**: Earnings of Newtown workers by mode of transportation suburban hotspots – only 4.7 percent of all commuters identified themselves as black during the 1990 census.

Pottstown

Pottstown is unlike any other workplace examined in this chapter. Located on the western edge of the metropolitan area on the border between Montgomery and Chester counties, Pottstown more closely resembles a rustbelt town of the Great Lakes region than it does a Philadelphia suburb. Pottstown was once a great steel town, but in the 1980s both Bethlehem Steel and Firestone, the two largest employers at the time, pulled out. Since then, several industrial parks have fueled a partial recovery, although the wide streets of its downtown still contain many empty storefronts.

Figure **5.33** shows the work-shed, car-shed and emission-shed for 1990 Pottstown. Pottstown was a fairly close-knit community, drawing most of its commuters from the immediately surrounding area. Less than one percent of all workers in Pottstown were urban dwellers; more than 99 percent of everyone working in Pottstown during 1990 lived in a suburb, and suburbanites were primarily responsible for GHG emissions resulting from the drive to work.

As alluded to previously, industrial occupations such as precision production and machine operating were among the most important jobs in the area. Also important were white-collar jobs, such as executive, professional and administrative positions, as well as service and sales jobs (Figure **5.35**). Despite the industrial nature of employment in the area

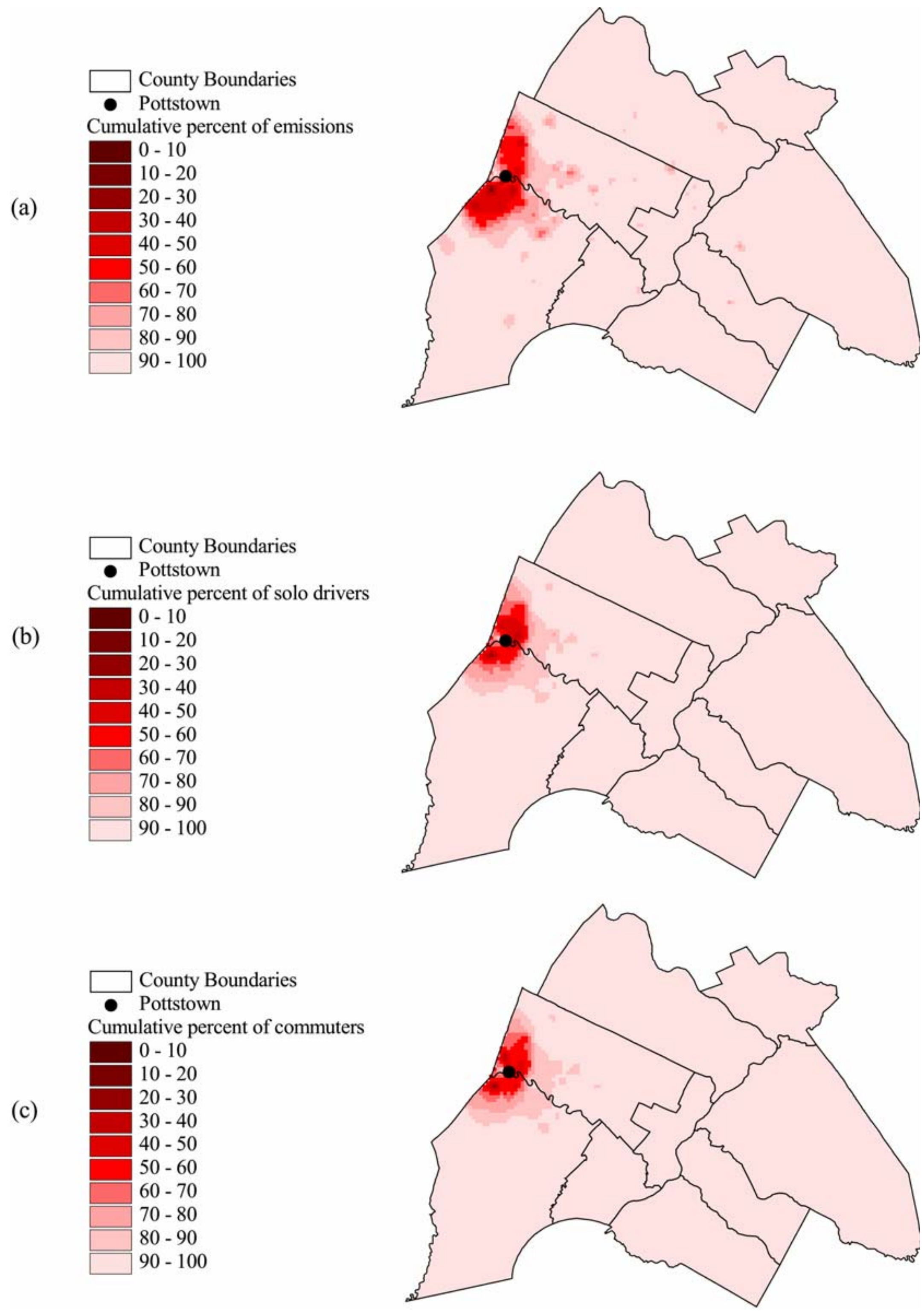

Figure **5.33**: GHG emissions resulting from the commute to Pottstown (a), and drivers (b) and commuters (c) destined for Pottstown

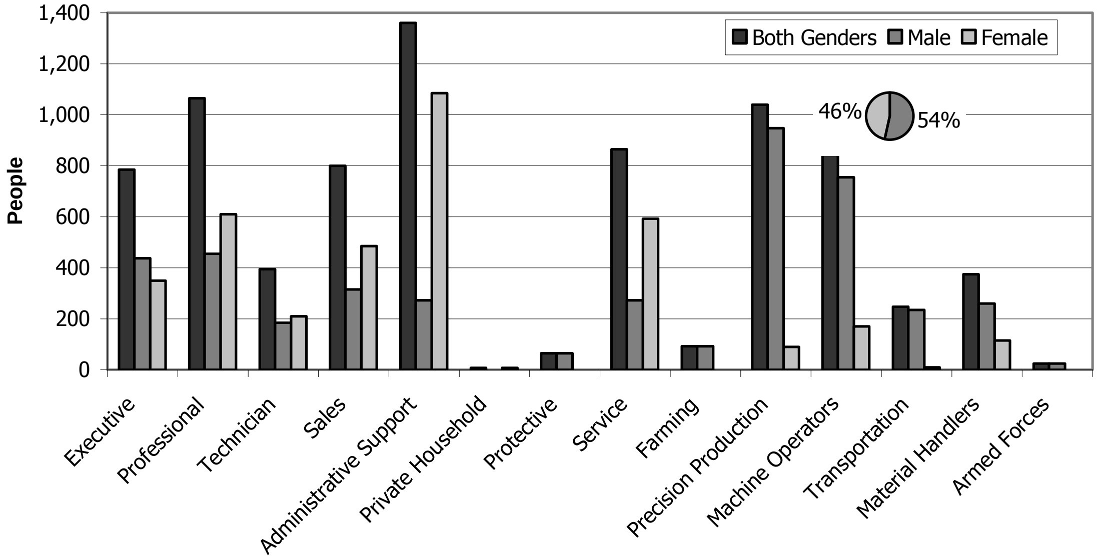

Figure **5.35**: Employment for Pottstown by gender and occupation

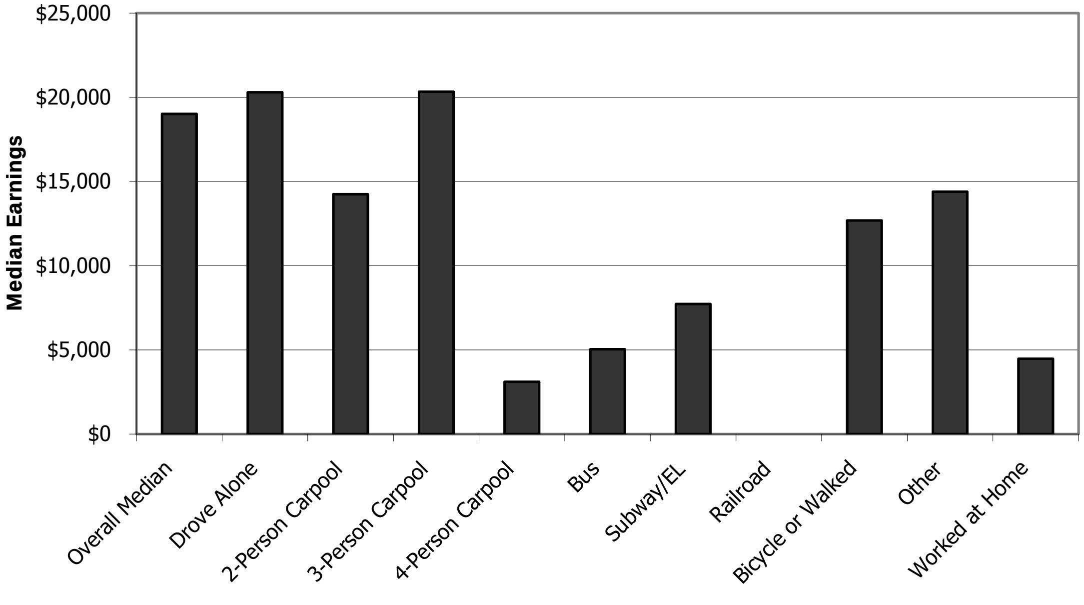

Figure **5.34**: Median earnings of Pottstown workers by mode of transportation and the tendency for those jobs to be filled by men, women outnumbered men in the workplace here by eight percent. Pottstown employed even fewer blacks than Newtown – only 4.2 percent of those commuting to work in Pottstown were black.

Public transit was essentially nonexistent in the area and the earners of higher wages in the area traveled in a car, either alone or as part of a carpool (Figure **5.34**). Nonetheless, there was mixed land use in Pottstown, with residences fairly close to stores and industrial areas. As such, it was possible to walk to work, and some of the lower earners did.

Summary

The preceding discussion highlights the fact that there is considerable diversity among the suburban workplaces in the Philadelphia metropolitan area. This diversity is much greater than the diversity found within the city, at least in terms of character of place. However, one place that diversity is not found in these suburban workplaces is in the racial identity of the workers. Even Abington, with its 20 percent black workforce, had far fewer black workers than the urban workplaces, and Abington was exceptionally diverse compared to places like Newtown and Pottstown. Another important difference between the urban and suburban areas was the increased focus on consumption – in addition to lower per-commuter and per-driver efficiencies in the suburbs, the workplaces in the suburbs were more focused on consumption than were the urban workplaces. As evidence, a greater proportion of people made their living as salespeople in nearly every suburban hotspot than in any of the urban workplaces.

Another commonality among most of the suburban workplaces was the general pattern of commuting, driving and emissions. Like urban hotspots, the pattern of consumption was centrifugal in that those who lived further away from work consumed more energy, and thus generated more emissions, in their daily commute. However, unlike the urban workplaces, which drew workers from all of the surrounding suburbs, most suburban locations drew only from the nearby suburbs within the same county, with the notable exception of King of Prussia, which is widely recognized as Philadelphia's only edge city. It is also worth noting that these patterns were more tightly clustered in workplaces that were well established before the post-war boom, such as West Chester, Pottstown, and Media. Places such as Abington, King of Prussia, and even parts of Newtown, which saw greatly accelerated growth during the last half of the 20th century, tended to have more distributed commuting and emissions patterns.

There were other important similarities among suburban workplaces, including commuter characteristics. For instance, suburbanites typically made up more than 90 percent of total employment in suburban workplaces, while urban hotspots typically got less than 35 percent of their commuters from the suburbs. While there were a few exceptions to this comparison, the share of suburban workers was always much greater in suburban workplaces than in urban workplaces. This increased share of suburban residents in the suburban workplace meant that suburban drivers were responsible for an even greater proportion of emissions. As with urban workplaces, there were other attributes common to suburban workplace, and also significant diversity among places. In fact, there were arguably more and greater differences among suburban places than among urban workplaces.

From the history of Chester and Pottstown to the malls of King of Prussia and the hometowns like Newtown, different forces were driving residential and commercial development. As different as these places may have been from each other, however, they were similar in terms of their consumptive patterns, at least regarding energy use in the commute to work. They also were more alike than different in terms of the nature of work and the demographic composition of the workplace, although on this latter point differences do exist.

Other Hotspots

While the suburban hotspots discussed above are less like each other than the urban workplaces are, they are more alike than three odd locations that are both urban and suburban, and at the same time neither urban nor suburban. These "other" hotspots all exist within the boundaries of the city of Philadelphia, but their consumption and employment patterns are such that to classify them as urban without closer examination would be to ignore their uniqueness and possibly obscure their importance in the consumptive landscape. These three places – Northeast Philadelphia, Fairmount Park, and the Philadelphia International Airport – have commuting, emissions, employment, and transit patterns different to every other place in the metro area. Chapter 6 demonstrates that dividing the city's workplaces into urban and suburban places is useful, but I have become increasingly dissatisfied with attempts to force these three places into either category.

It is in this context that Soja's (1996) concept of "thirding-as-othering" becomes appealing. In his words, this process transforms "the categorical and closed logic of either/or to the dialectically open logic of both/and also …" (p. 60). Soja is careful to differentiate this thirding-as-othering from traditional Marxist dialectics, which relies on binary opposites working in conflict. Rather, the thirding that Soja describes introduces an "other than" or alternate choice that through its very existence critiques the binary of "either/or." In Soja's words, this third choice is an "open alternative that is both similar and strikingly different" (p. 61). It is not clear to me that all three of the places discussed below fit into the same "other," but Soja's concept of thirding-as-othering do not require them to. In fact, quite the opposite is true. This othering creates spaces that open the possibility of even more others and more critiques. Thus, this concept of thirding is appealing because the patterns of differential consumption presented in this thesis, which I contend are a strong factor in the production of several social and environmental problems, cannot be addressed effectively if we continue to think of places in the cityscape as *either* urban *or* suburban.

This focus on a third, or other, possibility does not stem simply from my dissatisfaction with the urban/suburban binary to categorize places adequately. That is, this discussion of thirding and othering is not simply about creating an additional category for the sake of more accurately describing the landscape. If that were the case, there would be no need to invoke Soja's writings. It would be enough simply to point at the data, demonstrate that the current categories are insufficient to describe them and suggest new categories that describe these outliers. The fact remains that the data presented in this section do not support a simple urban/suburban distinction among places, but the goal here is not to develop a better system for categorizing and dividing cityspace.

Rather, the goal is to begin to think about place differently. If there already are places within the Philadelphia cityscape that defy simple urban/suburban categorization, then these places, simply by existing, subvert this binary lens through which most people see metropolitan areas. If I am correct in my assertion that this binary between urban and suburban places is, at least in part, driving the centrifugal progression of consumption and the outward expansion of the built environment in metropolitan areas, then the places highlighted in this section serve as powerful counterpoints to this driving force. However, they are not simply objects that serve my purposes, as a subject studying urban environments. Instead, extending Malpas (1998), these places are themselves subjects – I do not give them their power to critique the urban/suburban binary. They, by existing, already are engaged in that critique. Still, as a researcher I can amplify and focus the voices of these places and bring them to bear in specific discourses. It is with that purpose that I turn the discussion to the places of Northeast Philadelphia, Fairmount Park and the Philadelphia International Airport.

Northeast Philadelphia

Here, I define Northeast Philadelphia as the area north and east of Pennypack Park, a park that follows Pennypack Creek from the western city border to the Delaware River, essentially dividing Northeast Philadelphia from the rest of the city (Figure **5.2**). Northeast Philadelphia was largely undeveloped until it was connected to the rest of the city by a Work Project Administration (WPA) road-building project (Adams et al. 1991). The resulting increased accessibility of the area helped drive new home construction during the post-war construction boom in the 1940s and 1950s. Northeast Philadelphia, along with several suburban communities just past the city boundary, were rapidly developed during this time as the result of mortgage programs run by the Federal Housing Authority (FHA) and the Department of Veterans Affairs (VA) loan programs, both of which largely limited the availability of loans to new housing stock (Adams et al. 1991). This information alone might be enough to convince most readers that Northeast Philadelphia is better treated as a suburb, particularly in a study on commuter behavior and the role of place in consumption patterns. However, this classification is not supported by all of the available data.

Figure **5.36** shows the emission-shed, car-shed and work-shed for Northeast Philadelphia. The work-shed in particular has a different pattern from most urban places – a much smaller proportion of commuters are urban (50 percent compared to 60 percent for Center City; see Table **5.3**). Still, this pattern was found in Fairmount Park as well, and the centrifugal pattern from work-shed to car-shed to emission-shed found for urban workplaces also is found for Northeast Philadelphia (Figure **5.36** and Table **5.3**). The 62 percent of commuters driving (Table **5.2**) is higher than most urban places, but less than the 68 percent who drove to work in Fairmount Park. Similarly, Northeast Philadelphia efficiencies per driver and commuter are greater than and equal to, respectively, those for Fairmount Park (see below).

Figure **5.37** provides little help in categorizing Northeast Philadelphia – this pattern could appear in either an urban or a suburban area. Figure **5.38**, however, may prove useful. As with many urban areas, those commuters using the rail system to get to work are the most affluent commuters working in Northeast Philadelphia, and those commuters who drove alone were the second highest earners. Interestingly, those in 4-person carpools also had high earnings, a phenomenon only noticed in the commuting patterns for the airport

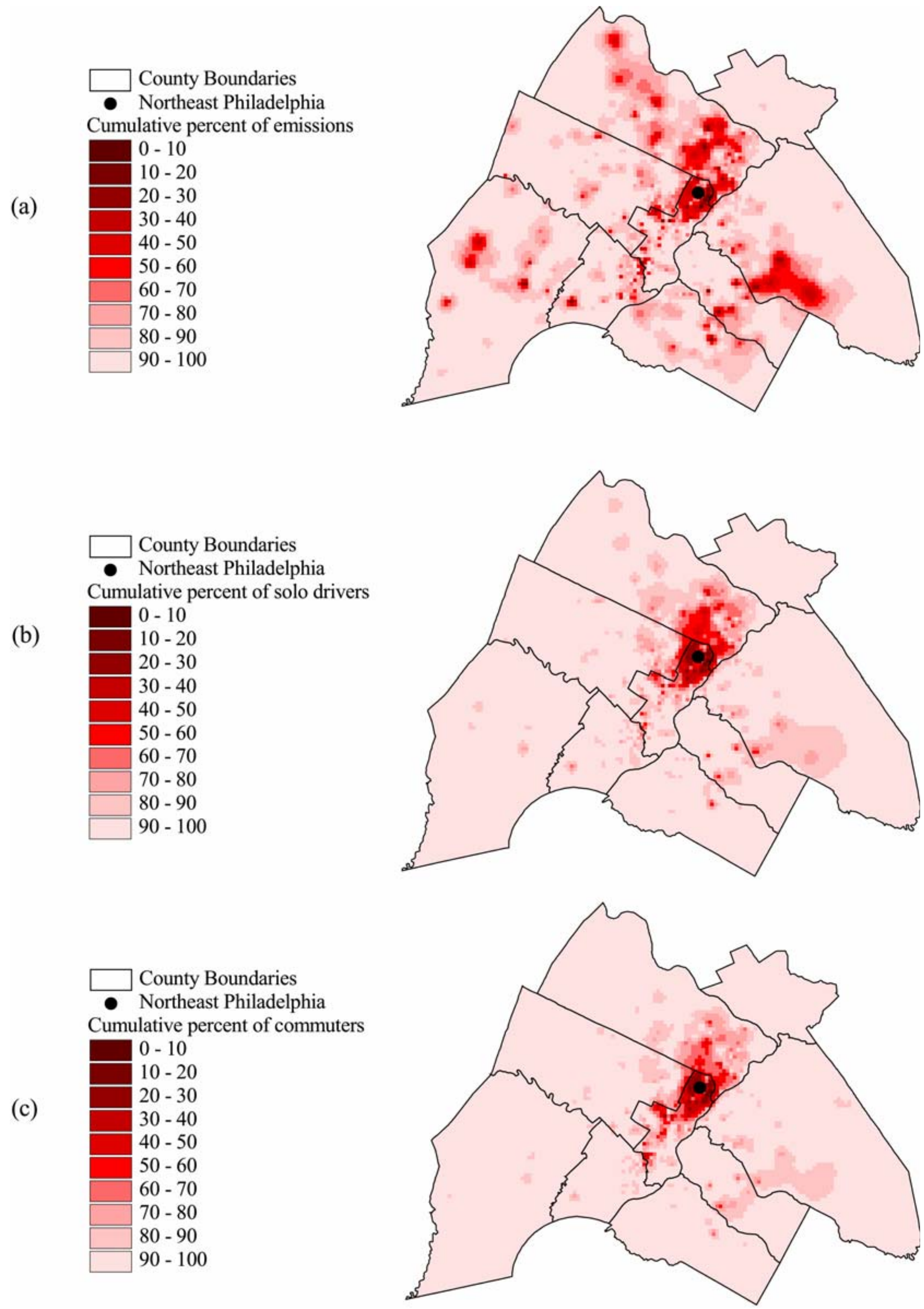

Figure **5.36**: GHG emissions resulting from the commute to Northeast Philadelphia (a), and drivers (b) and commuters (c) destined for Northeast Philadelphia

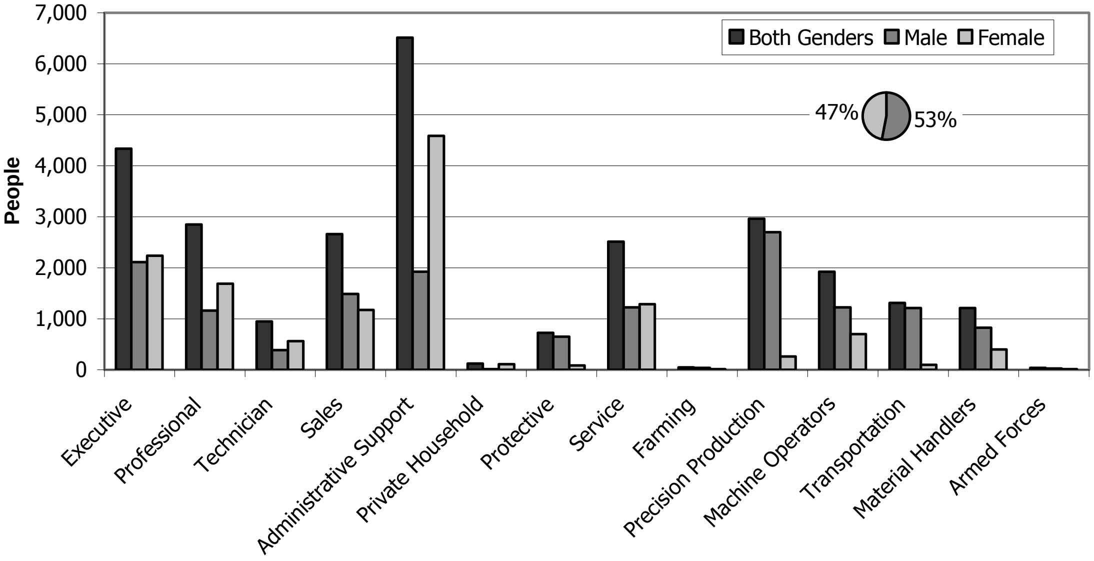

Figure **5.37**: Employment for Northeast Philadelphia by gender and occupation

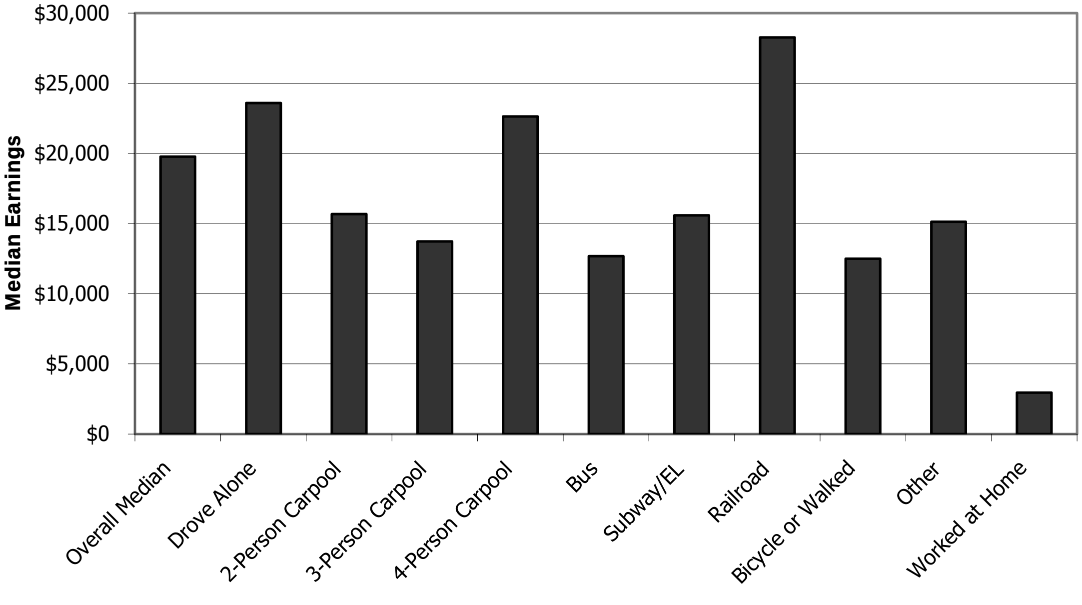

Figure **5.38**: Median earnings for Northeast Philadelphia by mode of transportation (see below). In addition, while those commuters using public transit earned less than the median wage, they earned considerably more than their counterparts working in suburban places. Further, about 26 percent of all workers in Northeast Philadelphia were black, a characteristic typical of urban areas, but not seen in any suburban workplaces.

The form and function of Northeast Philadelphia is typically described as suburban. There are few or no areas north of Pennypack Park with mixed uses – one must drive simply to buy a gallon of milk. The experience of Northeast Philadelphia is primarily that of being in a car. Businesses are located in strip malls with large parking lots, and often there are no sidewalks along major roads. Each home stands alone – there are no townhouses in Northeast Philadelphia, although there are some apartment buildings. Many homes have driveways and garages, and those that do not have cars parked in front on the street. In short, Northeast Philadelphia feels like a suburb; the Northeast Philadelphia experience is a suburban one. As discussed earlier, this is point is not lost on its residents.

Overall, the consumption patterns, history, form, and feel are suburban, but they are densely suburban, unlike workplaces such as King of Prussia. However, Northeast Philadelphia is also unlike West Chester, another dense suburb, in that Northeast Philadelphia has no downtown or central locus of economic activity. To complicate matters further, the nature of work in Northeast Philadelphia is urban. Unlike suburban workplaces, blacks are not excluded, despite the lack of a good public transportation network between Northeast Philadelphia and the rest of the city. Even with these shortcomings in the public transportation network, the patterns of public transit usage are more like urban areas than suburban areas. Affluent workers use the rail system, and those workers using the bus and subway system are more likely to earn a living wage than their suburban counterparts.[11] When these facts are considered together, the answer to the question, "Is Northeast Philadelphia urban or suburan?" might be "urban," "suburban," "both," "neither," or simply "no," depending on who is asked. For the purposes of this thesis, I classify it as "other."

Fairmount Park

Technically, Fairmount Park refers to all the parks in Philadelphia, including parks not physically connected to the original Fairmount Park, which first appeared on a map in 1682 (Klein 1974). According to a 19th Century guide book (Keyser 1872), there were two principal sections of the park, with the section bordering the Schuylkill River making up most of the park's lands. This section started at Fairmount, a point along the river about 1.5 miles from the city center, and ran north all the way to Chestnut Hill. At that time, the park contained more than 50 miles of carriage road and 100 miles of roadways, paths, and connections. Since that time, numerous parks have been added to the collection of parks known as Fairmount Park, including Pennypack Park in Northeast Philadelphia.

The hotspot named Fairmount Park for the purposes of this thesis should not be confused with this collection of parks, or even with the original Fairmount Park. Rather, the name Fairmount Park as it is used here refers to the neighborhood of housing and commercial property adjacent to the original Fairmount Park. Even though the neighborhood is mostly within Philadelphia's political boundaries, this neighborhood is

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[11] Recall that workers using public transportation to reach their suburban workplaces have earnings much lower than median for their workplace, while workers using public transportation to reach their urban workplaces have earnings much closer to the median earnings for their workplaces.

difficult to classify as urban or suburban for several reasons. These reasons are more evident when discussed within the context of commuter behavior and the nature of employment in the area.

Figure **5.39** shows the work-shed, car-shed and emission-shed for Fairmount Park. While most other urban places drew their commuters from within the city's political boundaries, many of Fairmount Park's commuters came from nearby suburbs. The other urban hotspots drew between 60 and 70 percent of their commuters from the city, whereas Fairmount Park drew less than half of its workers from Philadelphia County (Table **5.3**). However, Fairmount Park still drew considerably more of its commuters from the city than the suburban workplaces, and the area had a driving and emissions pattern similar to urban hotspots (Figures **5.39**.a and **5.39**.b). While 44 percent of all Fairmount Park workers were urban dwellers, only 35 percent of the drivers lived in urban areas, and those living in the city were responsible for only 21 percent of the emissions resulting from the drive to work. This pattern explains the high efficiency of Fairmount Park compared to suburban workplaces (Table **5.2**). Still, it should be noted that overall commuter efficiency falls between urban and suburban levels – Fairmount Park commuters emitted, on average, .18 KgCE per capita, while those working in Center City emitted only .10 KgCE per capita and those working in King of Prussia emitted .26 KgCE per capita. Thus, the consumption patterns with regard to energy and the commute to work can be thought of as neither urban nor suburban, and yet both urban and suburban.

Figure **5.40** presents an employment pattern similar to urban workplaces. Executive, professional and administrative positions dominate employment in the area and, in the

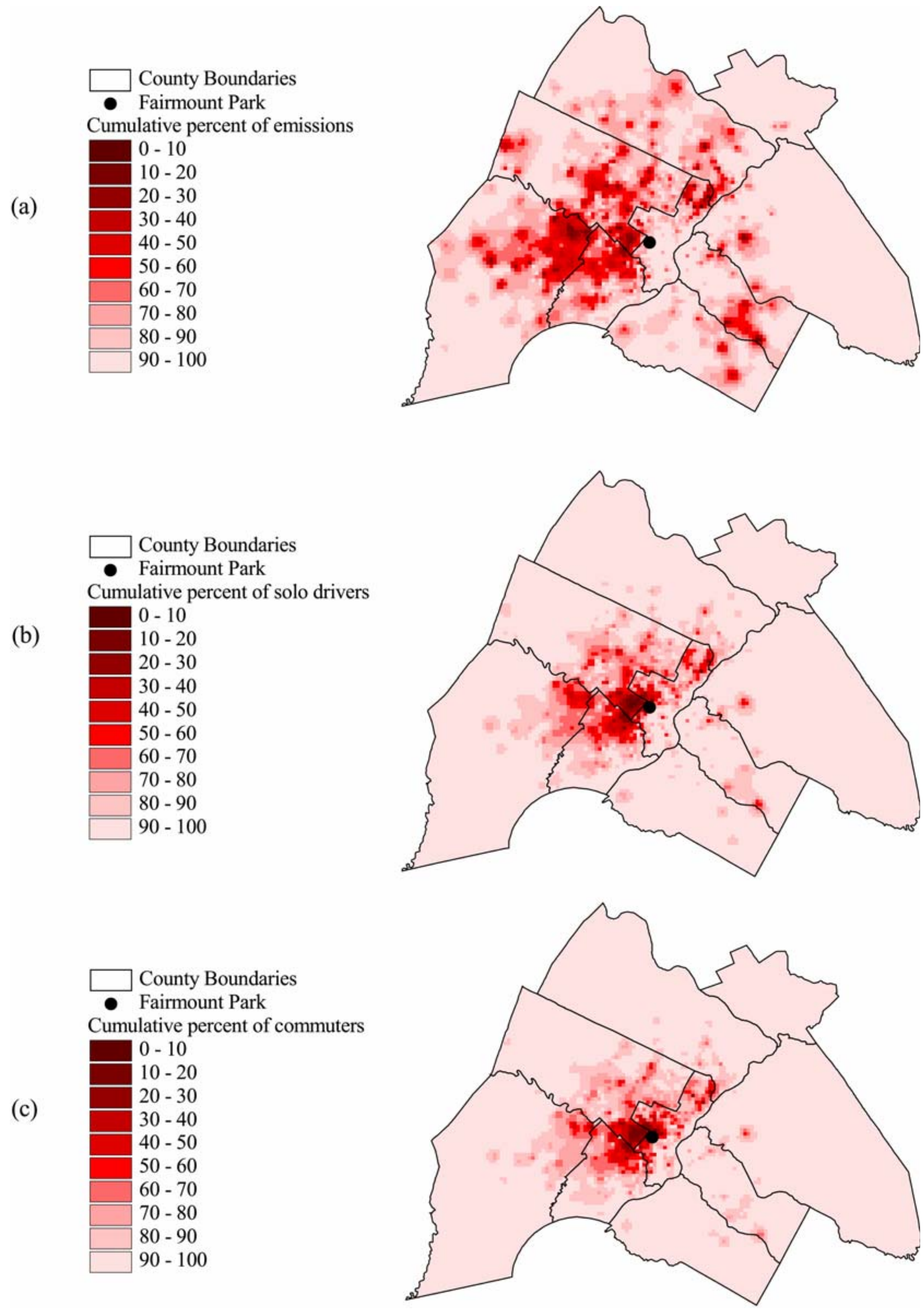

Figure **5.39**: GHG emissions resulting from the commute to Fairmount Park (a), and drivers (b) and commuters (c) destined for Fairmount Park

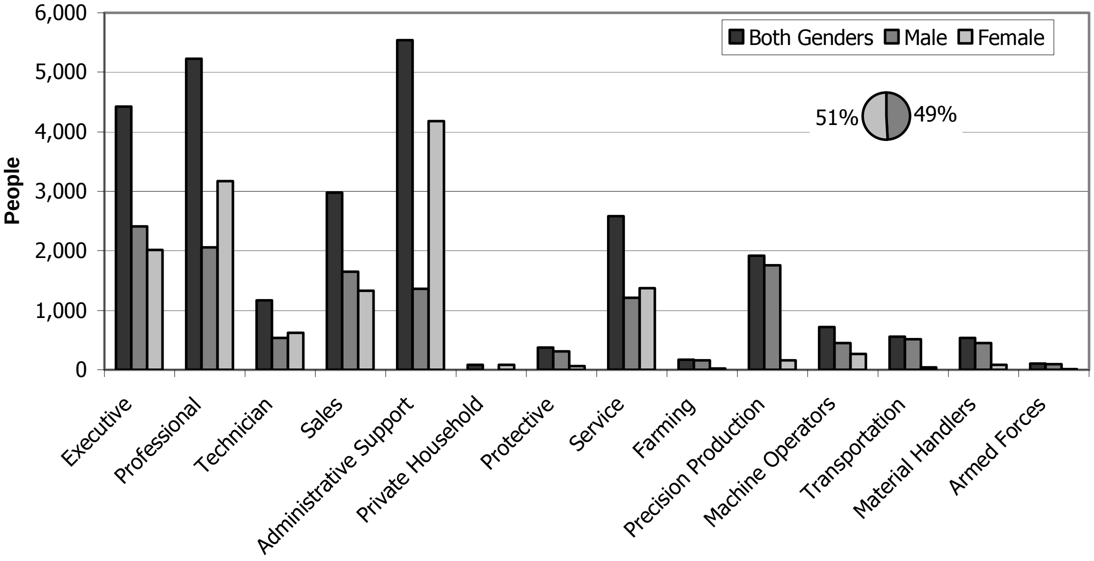

Figure **5.40**: Employment for Fairmount Park by gender and occupation

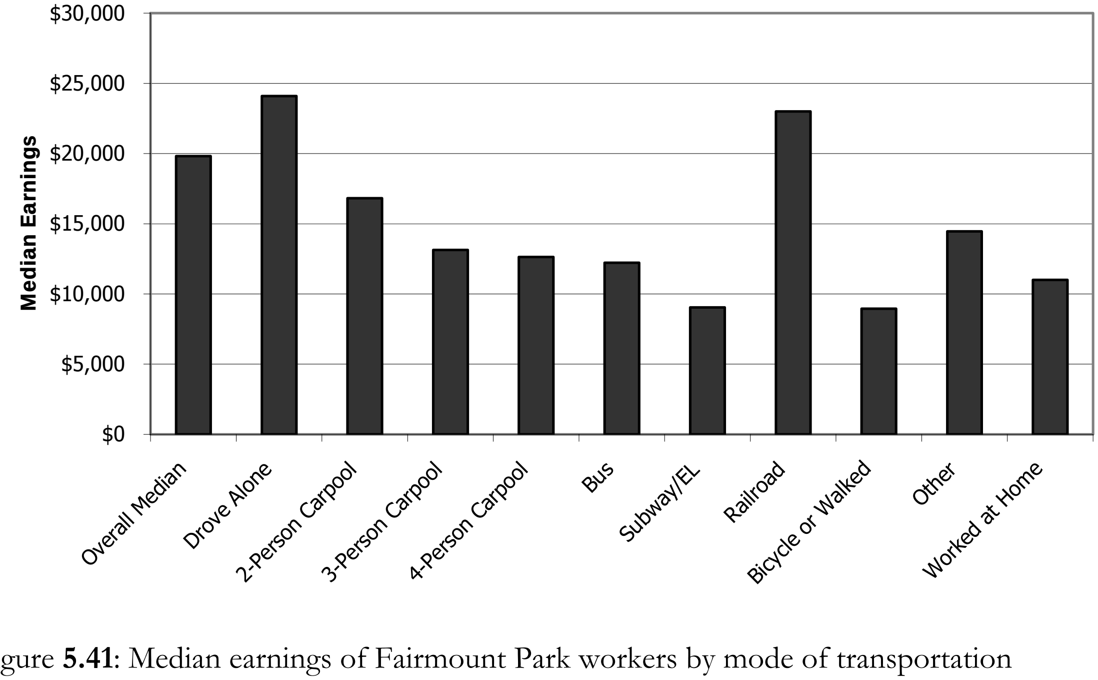

Figure **5.41**: Median earnings of Fairmount Park workers by mode of transportation aggregate, women probably outnumber men in these positions. Nonetheless, women do not tend to outnumber men in urban workplaces overall, as they do in Fairmount Park. Sales jobs are more important in Fairmount Park than they are in most urban hotspots, though, making this workplace character more suburban in nature. About 22 percent of all workers in Fairmount Park identify themselves as black, considerably higher than the 13 percent black workforce of Abington, the next most diverse suburban workplace. As with consumption patterns, the nature of work and the workforce in Fairmount Park does not provide cut-and-dried answers to the urban-ness or suburban-ness of the workplace

Another important difference between the urban and suburban places in the metro area is the accessibility of the workplaces via public transit. While some suburban workplaces were more accessible than others, the earnings figures for urban workplaces all revealed that those commuters riding the regional rail system to work were among the most affluent. Figure **5.41** repeats this pattern for the Fairmount Park neighborhood and also demonstrates that while other public transit riders made less money than those workers riding the rail system, they earned more money compared to other commuters, such as those carpooling.

In addition to these measures of urban and suburban process, one must consider the feel of a place. Fairmount Park is part of the Philadelphia grid. It is a mixed-use neighborhood with residences and businesses in the same blocks, and it is accessible to pedestrians (see Jacobs 1961 for a justification of these criteria). While these attributes alone do not necessarily make Fairmount Park an urban place, when considered in the context of commuter behavior and employment patterns, they contribute to a feel of the neighborhood that is more urban than suburban. Just as Harlem is no less urban simply because it borders Central Park, the urban-ness of the neighborhood bordering Fairmount Park is not diminished by its location. However, most of the considerable recreational traffic through the park is automobile traffic, unlike urban parks in cities like Chicago or New York.

In the end, the Fairmount Park neighborhood may feel more urban that suburban, but – particularly from the perspective of consumption of energy and the atmosphere during the commute to work – this place is both urban and suburban. The workplace has elements of both environments. In short, classifying this place as either urban or suburban when it is clearly both, at least from the perspective taken in this thesis, is not reasonable.

Airport

The area surrounding and including the Philadelphia International Airport is a fundamentally different place from Fairmount Park. While Fairmount Park is defined by its aesthetics, the airport is defined by its function. The pace is accelerated, the image conjured by the word "airport" is one of steel and concrete, and the feel is one of constant motion and industrial process. It is neither urban nor suburban, but a place of transitions. It is a place where people make a transition from the surrounding regions to distant cities, and vice versa. With relatively equal effort, one can get in a car to King of Prussia and never experience the city, or one can board the elevated train and end up at City Hall, never really experiencing the suburbs. The airport is by its very nature a crossroads between places, and as such almost lacks a sense of place itself.

For those who work there, however, the airport is a real place. Perhaps they would find the effort to classify it as urban or suburban questionable, but they would not argue that it lacks a sense of place or that its sense of place transcends their bounded experience of it.

Because it is through the process of commuting that I am attempting to understand the places in Philadelphia's cityscape, it is this tangible and experiential sense of place that most interests me. Nonetheless, for those interested in transportation and the commute to work, the airport presents a quandary. The work-shed presented in Figure **5.42**.c is diffuse and unlike any other presented in this chapter. The car-sheds and emission-sheds presented in Figures **5.42**.b and **5.42**.a, respectively, are even more diffuse and of little help in the quest to classify the airport as either urban or suburban.

The data presented in Table **5.3** are of some help, but only as much help as they were for Fairmount Park – despite the fundamental differences between the two places, they share some characteristics with regard to commuting. Specifically, roughly half of the commuters destined for the airport are urban (in this case, slightly less than half), and half are urban. However, like Fairmount Park, suburbanites make up a proportionally larger percentage of the drivers and are responsible for an even greater percentage of the emissions. While this centrifugal pattern is stronger for places like central Philadelphia, it does suggest a certain urban-ness, because it is not really found in suburban places, except perhaps Abington.

The airport had an employment pattern unlike any other place – 71 percent of the workers at the airport were men (Figure **5.43**). This also is the only place where industrial employment was the overwhelmingly dominant form of work and where the armed forces played a significant role in the nature of work. Figure **5.44** presents more newness. People traveling in 4-person carpools earned more than those driving alone. Even those who traveled by subway to work made more than $20,000.

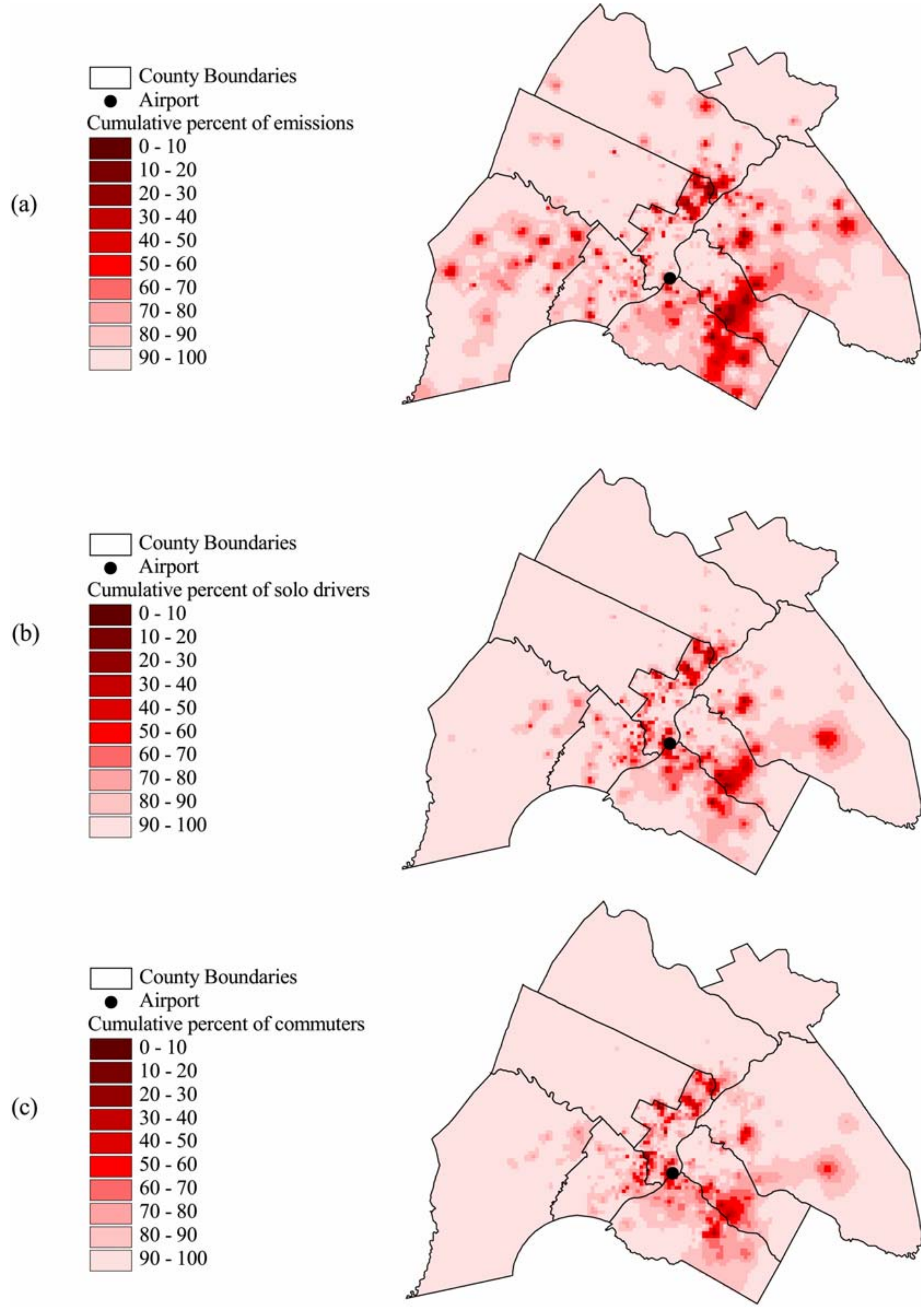

Figure **5.42**: GHG emissions resulting from the commute to the Philadelphia Airport (a), and drivers (b) and commuters (c) destined for the Philadelphia Airport

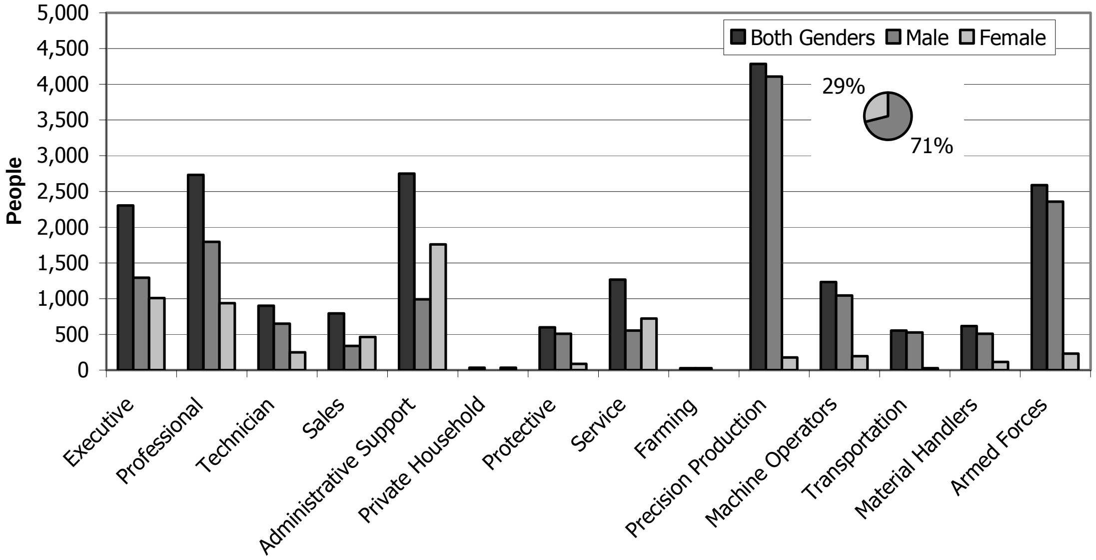

Figure **5.43**: Employment for the Airport by gender and occupation

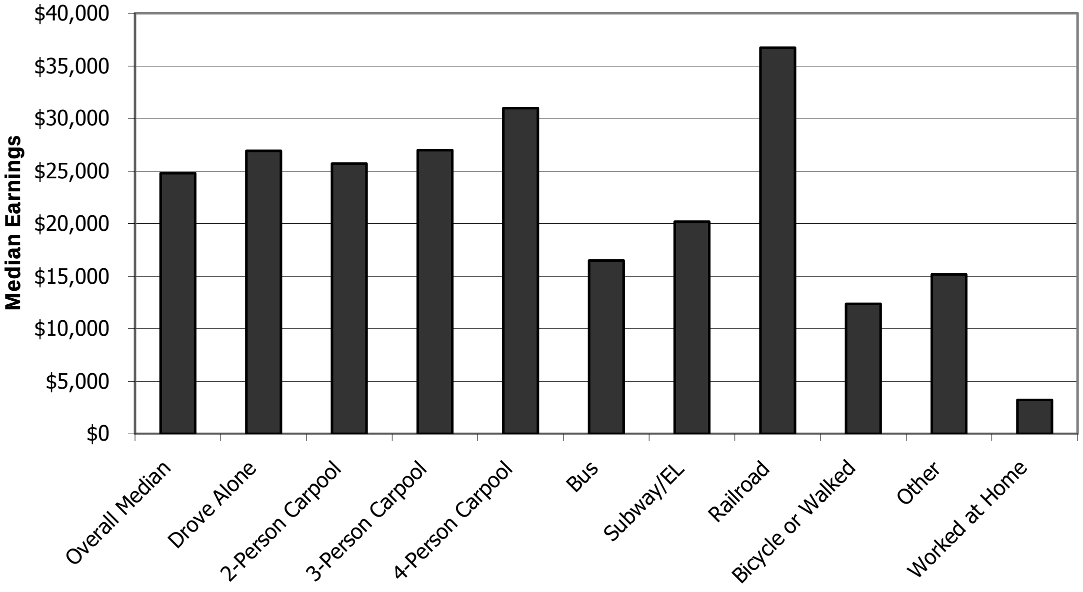

Figure **5.44**: Median earnings of Airport workers by mode of transportation

Summary

In the end, classifying any of these places as urban or suburban cannot be justified. While it is possible that Northeast Philadelphia and Fairmount Park are roughly the same kind of place, the airport is in a class by itself among the places examined in this chapter. I stop short of finding new categories for these places – as described earlier, that is not the reason for othering them. Rather, these places stand as counterexamples to the urban/suburban dichotomy through which researchers and residents so often view metropolitan areas. A full discussion of the significance of this point is saved for Chapter 6.

Conclusions

This chapter has presented the consumptive landscape of the Philadelphia metropolitan region through the perspective of energy consumption and GHG emissions resulting from the commute to work. Fourteen hotspots, or workplaces with above-average concentrations of GHG emissions, were identified, analyzed, and discussed. Attention was paid to the history of each hotspot and the transformations each experienced as it developed. In addition, modeling results and demographic data were used to describe the commuting, transportation, consumption and employment patterns associated with each place. This analysis and discussion had two goals.

One goal was to explore the characteristics of consumption and work in urban and suburban areas. In general, urban areas were shown to draw about one third of its workers from the suburbs, and two thirds from urban areas. Typically, the drivers commuting to these urban places were disproportionately suburbanites, and an increasing percentage of the emissions from commuters came from those workers residing in suburbs increasingly far away from the city. In contrast, most suburban workplaces drew 90 percent or more of their commuters from suburban locations, and these locations were typically closer to the workplace than in those cases when people commuted from suburban residences to the city. Still, due to the overwhelming number of workers traveling from the suburbs to work in these suburban locations, suburban drivers shouldered responsibility for GHG emissions from the commute. There also were significant differences in the character of the workplace. Most notably, sales jobs made up a larger share of employment in suburban workplaces than in urban workplaces. In addition, most urban locations had a high percentage of African-American workers, while the suburbs mostly employed a very low percentage of African-Americans. Finally, there were important differences with regard to the mode of transportation used to get to work. In urban workplaces, the most affluent workers were those who used the regional rail system or drove alone to work. Nonetheless, those using other forms of public transit, such as the light rail or bus systems, often made a living wage, even if that wage was below the median earnings in a given area. In contrast, working in the suburbs clearly requires a car – the only people using public transit to get work in the suburbs had earnings substantially below median wages for a given workplace.

In the process of exploring these differences, a second goal for place-by-place exploration of Philadelphia's consumptive landscape emerged. That goal was to discuss the process by which places are classified as either urban or suburban. This discussion led to an "other" category for places that are neither urban nor suburban. Discussion of the full implications of this third category is left for Chapter 6. One implication is hinted at in this chapter, however – that by their very existence, these "other" places challenge the urban/suburban dichotomy through which many researchers, planners and residents view the metropolitan area. If this dichotomy is part of the discursive causes of socially and environmentally undesirable development patterns, then challenging it may open spaces for further critiques that help to subvert the processes leading to these undesirable patterns.

Careful examination of the forces shaping each place, while worthwhile, is outside the scope of this thesis but is planned for future work. However important this future work may be to understanding the economic, social and cultural forces shaping the consumptive landscape, it could not succeed without the kinds of preliminary comparative analyses presented in this chapter describing the consumptive landscape. Nonetheless, it does little good to describe the consumption patterns of a metropolitan area without interpreting those findings. Chapter 6 interprets the consumptive landscape described here from the perspective of socially responsible development patterns and social and environmental justice and equity. It also explores the role of the urban/suburban dichotomy in the production of Philadelphia's consumptive landscape.

Chapter 6

INTERPRETING PHILIADELPHIA'S CONSUMPTIVE LANDSCAPE: THE POLITICS OF EXCLUSION AND THE ETHOS OF CONSUMPTION

Introduction

The two previous chapters presented some important differences and similarities between urban and suburban places that bear repeating. Urban workplaces employed more African Americans than suburban workplaces. In fact, African American employment in most urban workplaces exceeded the regional average of 15 percent, while African Americans made up a much smaller percentage of the suburban workforce. Furthermore, similar patterns were found in the characteristics of the residents of these places – whites tended to live in the suburbs, and blacks tended to live in the city, or in some cases, near the centers of the larger suburban agglomerations. Both the working and living spaces in Philadelphia were highly segregated, but the city was more spatially segregated based on place of residence than it was based on workplace. Places that were classified as neither urban nor suburban tended to be diverse workplaces, but that diversity was not always reflected in the composition of their residents. For instance, Northeast Philadelphia employs a high percentage of black workers, but those workers commute primarily from other parts of the city.

With regards to energy consumption, comparisons of urban and suburban places yielded both similarities and differences. Both kinds of workplaces exhibited centrifugal progressions from the locations of workers, to the locations of drivers, to the origins generating GHG emissions. Suburban workplaces tended to be local employers, while urban workplaces drew workers from the entire metropolitan area. The exception was King of Prussia, Philadelphia's quintessential edge city, which was a regional employer. Suburban places also showed lower energy efficiency in their overall commutes, particularly per worker, owing to the reliance of their commuters on the automobile. Interestingly, occupations like sales and service were more prominent in the suburbs than they were in the city, reinforcing the notion that suburbia is a place of increased consumption compared to urban places.

Still, Chapter 5 presented only a small sample of all of the places in the metro area. As important as it is to examine places within the metropolitan landscape in detail, caution should be exercised against drawing broad conclusions based solely on these individual cases. While Chapter 4 presented some regional patterns of racial and economic segregation, regional patterns of energy consumption have yet to be fully explored. The next section of this chapter does just that – it explores regional patterns of commuting and consumption through the examination of a handful of summary maps and tables. These maps and tables organize workers, drivers, and emissions into a few distinct categories: those originating in the suburbs, city, or other places; those destined for the suburbs, city, or other places; and the nine possible combinations thereof. A similar analysis is presented for the efficiency metrics that were presented for individual places in Chapter 5. Finally, because so many of the commuters and drivers worked in places that were not classified as hotspots, the aforementioned analyses incorporate comparisons between places that were and were not hotspots in the consumptive landscape of Philadelphia.

The second half of this chapter then draws connections between the racial and economic segregation in the metro area and the consumption of energy from transportation. In doing so, some theoretical issues are discussed, including linkages and extensions of Soja's notion of *fractal cities* and the environmental justice literature.

From Place to Space: Regional patterns of commuting and energy consumption

Table **6.1** presents a summary of all possible combinations of the various origins and destination classifications used in this thesis. Origins are shown in the columns and are classified simply as urban, suburban, and other. Destinations are shown in the rows and are classified two ways. First, hotspots and non-hotspots are displayed separately. Second, within those broader classifications, the destinations are further subdivided into the categories urban, suburban, and other. In addition, totals are shown for all categories and subcategories. Finally, the table presents three sets of data: emissions, drivers, and commuters. Thus, each cell in the table presents the corresponding percentage it contributes to the total emissions, total drivers, or total commuters for the Philadelphia metro area.

Table **6.1** shows that nearly 84 percent of all single-driver emissions in the metro area were emitted by commuters originating in suburban locations, although this group represented only 70 percent of the workforce. Conversely, urban dwellers made up 25 percent of the workforce but were responsible for only 12 percent of the total single-driver emissions. "Other" places were relatively insignificant in terms of percentages of the totals due to their relatively small size.

Table **6.1**: Percentage of the total emissions, drivers, and commuters from each origin-destination classification.

	Destination Type		Origin Type			
			Suburban	Urban	Other	Total
Emissions	Hotspots	Suburban	18.0%	1.7%	0.6%	20.3%
		Urban	7.9%	3.6%	1.3%	12.8%
		Other	2.0%	1.0%	0.3%	3.2%
		Sub Total	28.0%	6.3%	2.1%	36.4%
	Not Hotspots	Suburban	51.2%	3.0%	1.0%	55.2%
		Urban	4.1%	2.4%	0.8%	7.3%
		Other	0.6%	0.4%	0.1%	1.2%
		Sub Total	55.9%	5.8%	1.9%	63.6%
	Total	Suburban	69.2%	4.7%	1.6%	75.5%
		Urban	12.1%	6.0%	2.0%	20.1%
		Other	2.7%	1.4%	0.4%	4.4%
		Total	83.9%	12.1%	4.0%	100.0%
Drivers	Hotspots	Suburban	18.2%	1.3%	0.4%	20.0%
		Urban	5.4%	6.1%	1.1%	12.6%
		Other	1.5%	1.2%	0.4%	3.1%
		Sub Total	25.1%	8.6%	2.0%	35.7%
	Not Hotspots	Suburban	52.0%	2.4%	0.9%	55.3%
		Urban	3.0%	4.0%	0.8%	7.8%
		Other	0.4%	0.4%	0.3%	1.2%
		Sub Total	55.4%	6.8%	2.0%	64.3%
	Total	Suburban	70.2%	3.7%	1.3%	75.3%
		Urban	8.4%	10.1%	2.0%	20.5%
		Other	1.9%	1.6%	0.7%	4.3%
		Total	80.5%	15.4%	4.1%	100.0%
Commuters	Hotspots	Suburban	15.1%	1.5%	0.4%	17.0%
		Urban	6.8%	12.5%	1.3%	20.7%
		Other	1.3%	1.6%	0.5%	3.4%
		Sub Total	23.2%	15.6%	2.2%	41.1%
	Not Hotspots	Suburban	44.3%	2.6%	0.8%	47.7%
		Urban	2.6%	6.5%	0.8%	9.9%
		Other	0.4%	0.6%	0.4%	1.3%
		Sub Total	47.3%	9.7%	1.9%	58.9%
	Total	Suburban	59.4%	4.1%	1.2%	64.7%
		Urban	9.5%	19.0%	2.1%	30.6%
		Other	1.7%	2.2%	0.8%	4.8%
		Total	70.5%	25.3%	4.1%	100.0%

Further examination of Table **6.1** reveals that suburb-to-suburb commuting was by far the most significant source of single-driver emissions – more than 69 percent of all such emissions resulted from this type of commute. Furthermore, more than 51 percent of all emissions were the result of trips from suburban homes to suburban workplaces not designated as hotspots. In fact, as mentioned in Chapter 5, 63.6 percent of all single-driver emissions were the result of trips to non-hotspot workplaces. Still, it is telling that the majority of those emissions were the result of commutes to *suburban* non-hotspot workplaces.

The relationships between emissions and the number of drivers and commuters can be more easily discerned from Table **6.2**, but even without looking at the detail presented in that table, it is clear that the centrifugal patterns from commuters to drivers and ultimately to emissions hold up in the aggregate. That is, the less centralized the workplace and/or place of residence, the greater the percentage of emissions that place is responsible for, compared to the percentage of drivers. The same is true comparing the percentage of drivers to the percentage of commuters – as the origin and/or destination becomes less centralized, more of the commuters end up driving alone to work. In addition to comparisons between urban and suburban places (with "other" places serving as an intermediate step between the two), this centrifugal pattern holds up (in approximate terms) when comparing hotspots to non-hotspots. For instance, suburbanites who worked in non-hotspots made up 47.3 percent of the workforce and 55.4 percent of the single drivers and were responsible for 55.9 percent of the single-driver emissions.

Table **6.2**: Three different efficiency metrics for each origin-destination classification.

	Destination Type		Origin Type			
			Suburban	Urban	Other	Average
Percentage of Commuters Driving	Hotspots	Suburban	83%	62%	76%	81%
		Urban	54%	33%	59%	42%
		Other	78%	50%	61%	62%
		Average	74%	38%	63%	60%
	Not Hotspots	Suburban	81%	62%	80%	80%
		Urban	77%	43%	71%	54%
		Other	81%	50%	57%	61%
		Average	80%	48%	72%	75%
	Average	Suburban	81%	62%	79%	80%
		Urban	61%	36%	64%	46%
		Other	78%	50%	59%	62%
		Average	78%	42%	67%	69%
Driver Efficiency (KgCE)	Hotspots	Suburban	0.27	0.35	0.36	0.28
		Urban	0.41	0.17	0.31	0.28
		Other	0.38	0.22	0.17	0.29
		Average	0.31	0.20	0.29	0.28
	Not Hotspots	Suburban	0.27	0.36	0.31	0.28
		Urban	0.38	0.16	0.25	0.26
		Other	0.40	0.26	0.11	0.28
		Average	0.28	0.24	0.26	0.27
	Average	Suburban	0.27	0.35	0.33	0.28
		Urban	0.40	0.17	0.29	0.27
		Other	0.39	0.23	0.14	0.29
		Average	0.29	0.22	0.27	0.28
Commuter Efficiency (KgCE)	Hotspots	Suburban	0.23	0.22	0.27	0.23
		Urban	0.22	0.05	0.18	0.12
		Other	0.30	0.11	0.10	0.18
		Average	0.23	0.08	0.18	0.17
	Not Hotspots	Suburban	0.22	0.22	0.25	0.22
		Urban	0.30	0.07	0.18	0.14
		Other	0.33	0.13	0.06	0.17
		Average	0.23	0.11	0.19	0.21
	Average	Suburban	0.22	0.22	0.26	0.22
		Urban	0.24	0.06	0.18	0.13
		Other	0.30	0.12	0.08	0.18
		Average	0.23	0.09	0.18	0.19

This point is driven home by Table **6.2**, which shows that, although 78 percent of all suburbanites drove to work, variation exists around that mean – 74 percent of suburbanites working in hotspots drove alone to work, while 80 percent of suburbanites working in non-hotspots drove alone. The same pattern holds for urban dwellers, but on a different scale – only 42 percent of all urban dwellers drove alone to work, but of those working in non-hotspot workplaces, 48 percent drove, compared to only 38 percent of those working in hotspot locations. The percentages of those living in "other" locations fell in between the percentages for urban and suburban dwellers, but followed a similar internal pattern. In addition, a centrifugal pattern can be seen when comparing workplaces – on average, 69 percent of all commuters drove, but only 46 percent of those working in urban locations drove to work. The same holds for hotspots vs. non-hotspots – 60 percent of all those who worked in any hotspot location drove alone, while 75 percent of those working in places not classified as hotspots drove alone to work. This pattern appears again for urban hotspots and non-hotspots, and yet again for their suburban counterparts. That is, more people drove to urban non-hotspots than to urban hotspots (but still much less than to suburban hotspots). Not surprisingly, these patterns are repeated for kilograms of carbon equivalent (KgCE) per commuter. When more commuters drive alone, there are bound to be more single-driver emissions per commuter.

The portion of Table **6.2** showing KgCE per driver, however, paints a different picture. Interestingly, the type of destination plays very little role in the average efficiency per driver – the overall mean is .28 KgCE per driver, and there is only moderate fluctuation around that figure for the various types of destinations. In other words, it makes little difference whether people worked in the city or in the suburbs, or in a hotspot or not; based solely on workplace, they used roughly the same amount of energy and produced about the same amount of GHG emissions, on average, as others driver commuting to work.

The difference was in where they lived. Overall, the original patterns hold – urban dwellers produced, on average, .22 KgCE per driver, compared to .28 KgCE for suburbanites and .26 KgCE for those from "other places. However, upon closer examination, another trend reveals itself – one that is not particularly surprising, but is important. The rule is this: if the drivers traveled to a place similar to their place of residence, their emissions were lower than if they traveled to a workplace in a different category. Drivers who lived in the city and worked in the city, on average, produced fewer emissions than those who lived in the city but worked in the suburbs or in an "other" workplace. Surprisingly, those who lived and worked in "other" locations drove the shortest distance, despite the overriding pattern of "other" locations falling somewhere in between urban and suburban places using nearly every other metric of raw consumption and efficiency. These "other" places also broke another pattern – commuters originating from these places reached workplaces in the suburbs *more* efficiently than they reached urban workplaces. In all cases, these patterns can be explained by proximity. Urban places are not near most suburban places, and vice versa. Thus, it makes sense that it would be more energy-intensive to drive from the suburbs to the city than it would be to make a suburb-to-suburb commute. Similarly, the "other" places in the Philadelphia landscape are near several suburban places, and Figure **6.1** demonstrates that many of the workers and drivers originating in "other" places are destined for places nearby, whether urban, suburban, or "other."

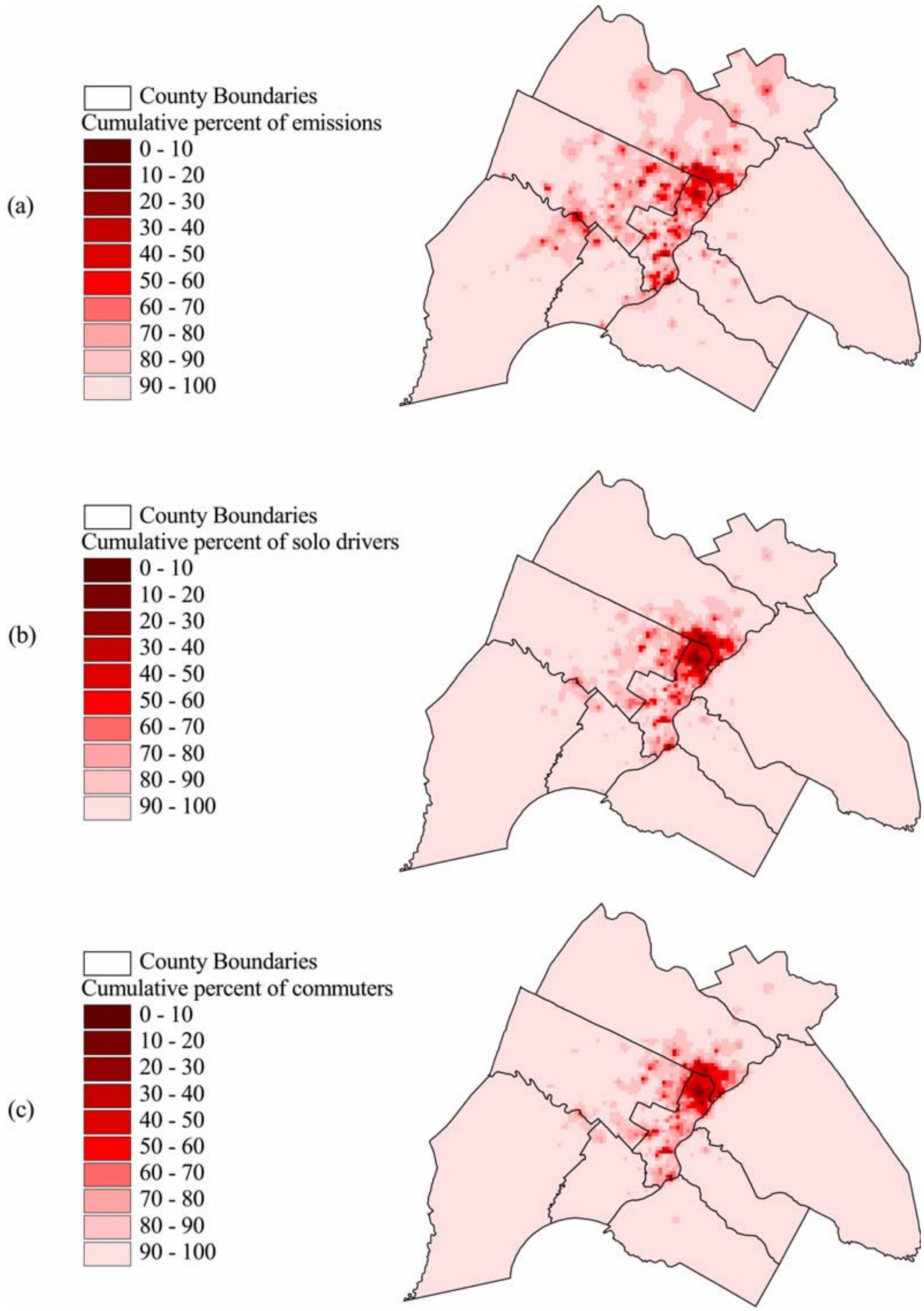

Figure **6.1**: GHG emissions resulting from the commute from all "other" locations (a), and drivers (b) and commuters (c) originating in "other" locations.

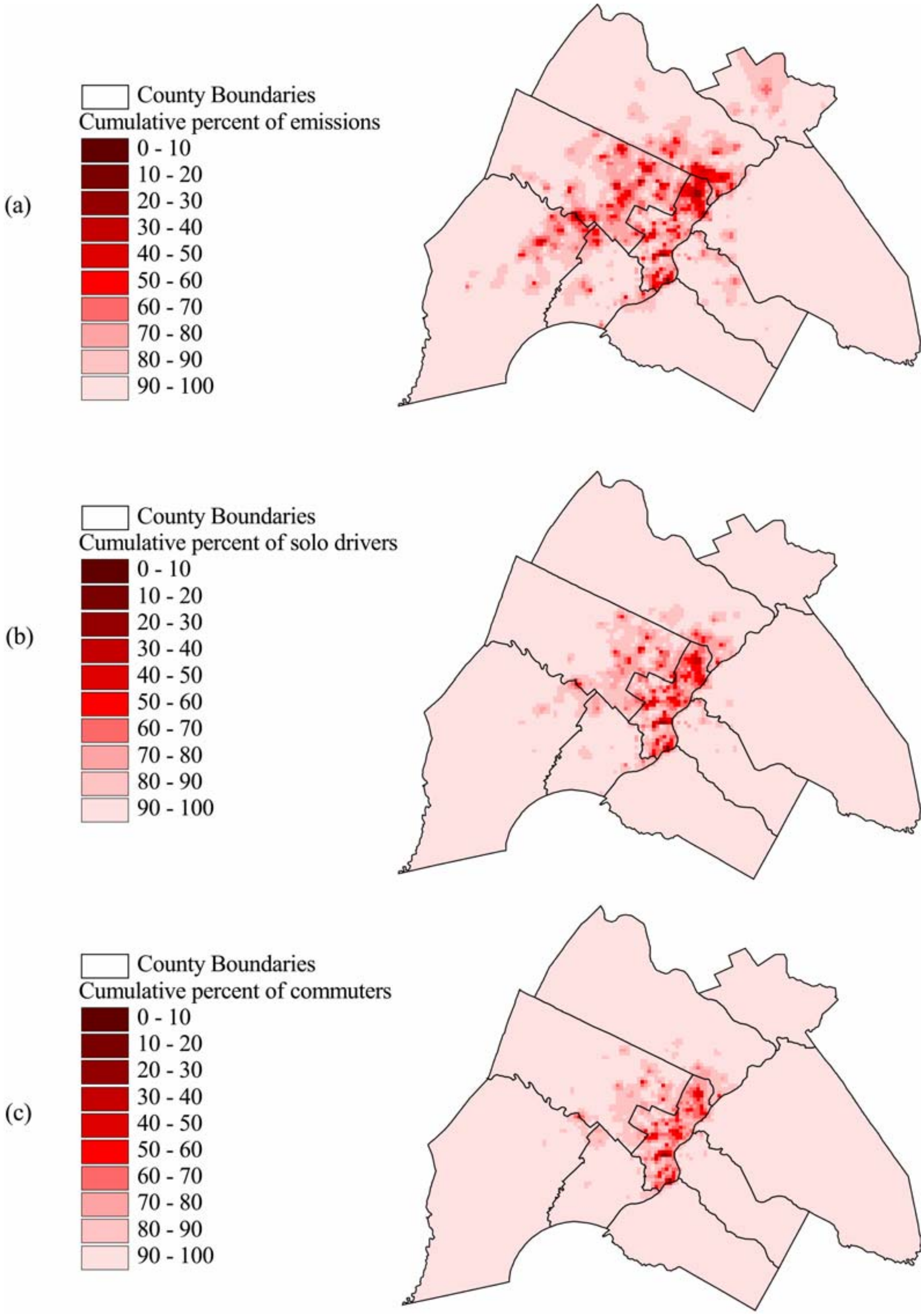

Figure **6.2**: GHG emissions resulting from the commute from all urban locations (a), and drivers (b) and commuters (c) originating in urban locations.

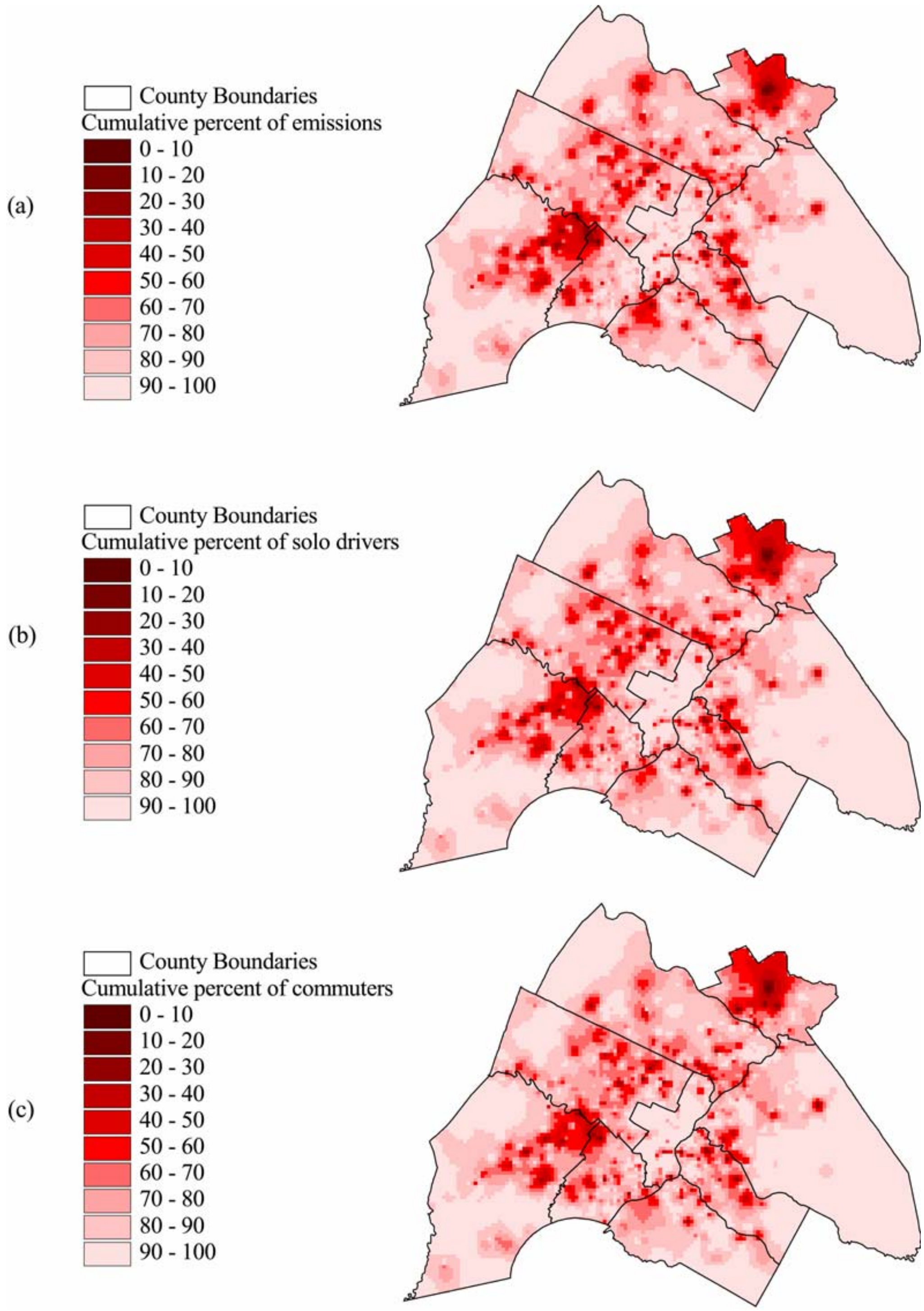

Figure **6.3**: GHG emissions resulting from the commute from all suburban locations (a), and drivers (b) and commuters (c) originating in suburban locations.

Figures **6.2** and **6.3** show similar patterns for urban and suburban places – workers who live in urban places tend to work in urban places, and people who live in suburban places tend to work in suburban places. Figure **6.2**.a shows that while they are few in number (Figures **6.2**.b and **6.2**.c; Table **6.1**), reverse commuters are responsible for more than their "fair share" of emissions. Strikingly, the typical centrifugal pattern does not hold for suburban origins. Figure **6.3** shows little difference between the three panes for commuters, drivers, and emissions, which was unexpected. Given previously discussed patterns, one would expect that the emissions map would emphasize the city as a problem destination when considering commuters from the suburbs. However, even though suburb-to-suburb commuting is more efficient than suburb-to-city commuting (Table **6.2**), it appears that the raw number of suburb-to-suburb commuters (Table **6.1**) keeps the emissions profile from drifting towards the city in Figure **6.3**.a.

Fractals, Polarities and Equity: Towards a synthesis

In *Postmetropolis*, Soja presented the notion of *fractal city* as one of six fundamental discourses about contemporary urban form. He adopted the term uneasily and with less conviction than the naming of some of the other discourses he discussed, but nonetheless settled on the term for two reasons. First, using a very broad definition of a fractal as anything that contains in its parts self-similar images of the whole, he was attracted to the idea that this perspective would allow "us to see in every empirical site, from the body to the global sphere, the fundamental nature of the spatiality of human life in all its richness and complexity …" That is, he saw a connection between the basic structure of fractals and some of his theories, particularly his ideas about lived space. The general argument is that just as an individual biography can lead to considerations of various aspects of the human condition, even an urban geography at a scale as small as the personal scale might give us insights about larger-scale processes.

The second reason he adopted the term fractal cities is not well articulated, but generally stems from a hope that this perspective may help researchers make sense out of the complex and chaotic structures in city space, due to the close association of fractals with chaos theory. Basically, his hope was that by using new and different interpretive lenses, one might discover significant patterns from an otherwise intractably complex landscape.

I believe that I have found such patterns in this study of energy consumption and transportation patterns for Philadelphia. While the patterns are not terribly surprising, it is important to articulate them based on empirical data because they have implications for the role that urban form plays in the generation of GHG emissions from transportation. Furthermore, these patterns have strong relationships to the patterns of racial and economic segregation in Philadelphia's cityscape. If both sets of patterns have fractal-like properties, then it is possible that their causes are similar to the causes of similar patterns at larger scales. While it is outside the scope of this thesis to articulate those causes in detail, it is my hope that future work might benefit from the patterns presented here.

Fractals are identified and defined by their nested patterns. There were several patterns in automobile use and energy consumption in my research findings that apply consistently at multiple scales. The first has to do with the percentage of commuters who drove alone to work and the level of agglomeration of the origins and destinations. To briefly reiterate the pattern, places with high degrees of agglomeration generate fewer drivers, proportionately, than places with relatively lower degrees of agglomeration. This particular pattern holds for both workplaces and places of residence. So the city of Philadelphia as a workplace generated fewer drivers than suburban places, which at a regional scale are less centralized and less concentrated. However, at the local scale, suburban hotspots become the sites of agglomeration compared to their surrounding areas, and tended to generate fewer drivers than suburban non-hotspots. Finally, urban residents drove less frequently than suburbanites, indicating that this pattern holds for both workplace and residence. In all cases, the "other" places fell somewhere in between these comparisons, as intermediate steps between the highly agglomerated city and the more sparsely agglomerated suburbs.

The second compelling pattern had to do with the energy consumed by drivers once they made the decision to drive to work. Since all automobiles were assumed to operate with equal efficiency, the amount of energy consumed by each driver was, by definition, a mathematical function of the distance she drove. Clearly, then, trips in which the home and workplace were close together generated fewer GHG emissions than trips in which the home and workplace were far apart. The interesting pattern generated by this fact was that trips between similar kinds of places generated fewer emissions than trips between different kinds of places. That is, if one must work in the suburbs and must drive to work, it is more efficient to live in the suburbs than it is to live in the city, at least from a transportation perspective. Similar findings were presented for the urban workplaces and "other" places.

However, the expected pattern was broken in one respect. Whereas the percentage of commuters driving from "other" locations fell between those from urban and suburban places, this was not always the case for KgCE per driver. In the aggregate, the pattern did hold. However, trips from "other" places to "other" places were the most efficient automobile trips in the matrix (Table **6.2**). Furthermore, drivers to suburban non-hotspots, and suburban workplaces on average, were more efficient if they started in "other" locations than they were if they started in urban locations. Paradoxically, drivers from "other" places to suburban hotspots were the least efficient of those driving to these agglomerated suburban workplaces. As the maps presented in Figures **6.1** show, this paradox is due to complexities of the location of these "other" locations relative to their suburban workplaces. Still, these "other" places do interrupt a set of patterns that otherwise repeat themselves at multiple scales. The significance of this interruption will be discussed shortly.

First, it is important to discuss one of the dangers of using fractal logic to organize the patterns revealed by my research. In coining the term *fractal city*, Soja considered several alternatives, including *multipolarities*. The idea behind *multipolarities* was that several polarizing inequities are present in contemporary American cities, and they should be considered together because of the complex interactions among them. Soja briefly discusses three – racial divisions, gendered divisions, and economic divisions. He eventually settled on fractals because it seemed to be a good way of expressing the spatial patterning of these multipolarities, which is the same reason I find the concept attractive. I have added a fourth polarization – that between the efficiencies of highly agglomerated places compared to the elevated energy consumption in relatively less agglomerated places – but the concept remains basically the same[12].

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[12] While I have drawn relationships between racial and economic polarities and energy consumption, I have not done the same with gendered polarities. This is not because Philadelphia's workplace is not gendered – the analysis in Chapter 5 clearly shows that it is. Nor do I believe that linkages between energy and gender do not exist. However my exploration of available data has not yet clearly revealed compelling and clearly identifiable

The danger in this logic is that it is tempting to continue to rely on the underlying binary logic, which can have a normalizing effect. For instance, Soja discusses at some length various discourses that normalize economic inequality in American cities as an inherent characteristic of capitalist economies. Without discussing the variations on this theme in detail, the idea is that the net effect is to make inequality "normal." In doing so, it is reified, which is often the opposite of what is intended. There is a similar danger in my use of fractals to discuss the multi-scale patterns of energy consumption within an urban/suburban dichotomy or, more precisely, a binary between dense and sparse urban economic and social organization. In doing so, there is the possibility that the reader may decide "that's the way it is"; that elevated consumption in areas with less social and economic agglomeration is simply the cost of living and working in these places – that it is normal.

This danger is multiplied by relating the polarity between efficiency and inefficiency to the degree of economic and racial segregation in the Philadelphia cityscape. Just as commutes to and from less-agglomerated areas are less energy efficient, these areas of sparser population and economic concentration are less diverse and more affluent than the regional average, and are therefore sites where racial and economic segregation are manifest. Furthermore, the transit network itself is economically segregated. Some of the region's most affluent commuters use the regional rail network to commute from the suburbs to the city. However, suburban workers riding the buses are among the lowest earners in the metro area. At first glance, this may appear to make a counter case by locating high income workers within the city and low income workers within the suburbs. Obviously, however, those using

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linkages between the two. I therefore concentrate my efforts here on linkages between racial and economic segregation and energy consumption.

the regional rail system reside in the suburbs and probably identify most with the suburbs, even though they earn their living in the city. Furthermore, the fact that only low-income workers use the suburban bus network indicates that it is not a very desirable mode of transportation, and therefore does little to make suburban workplaces more accessible. Chapter 4 demonstrated that far fewer workers living in the city have automobiles available than their suburban counterparts. The added inaccessibility of suburban workplaces by public transit means that workers living in Philadelphia's more underprivileged neighborhoods are even more spatially excluded from the economic opportunities in the suburbs. This *spatial mismatch* is precisely the mechanism identified by Wilson (1987, 1996) as an underlying cause of the disappearance of jobs in American cities and the chronic unemployment found among many of the urban poor. This spatial mismatch has led to a new literature on *transportation racism* and *just transportation* (e.g. Bullard and Johnson 1997, Bullard et al. 2004). By relating these issues of racial and economic equity to their causes (rather than just their uneven effects), this thesis contributes to the environmental justice literature, which also tries to draw connections between racial segregation and environmental issues.

Thus, there is increased danger in tying processes driving energy consumption to social and economic inequity; as already discussed, there are many discourses, both liberal and conservative, that normalize this racial and economic segregation in urban landscapes as an unfortunate and *unavoidable* consequence of capitalist modes of accumulation. If energy consumption is tied to the same manifestations of capitalism, the reader might conclude that, as unfortunate as it may be, this increased consumption also is an unavoidable consequence of economic growth. This conclusion would reinforce the notion that GHG emissions are tied to economic growth and can only be curbed by curbing that growth, which is a notion I am trying to challenge with this thesis. It also would reinforce the notion that the best way to curb emissions is through market-based mechanisms, another notion that I take issue with in Chapter 2.

Such conclusions are precisely why I have emphasized places in the Philadelphia cityscape that do not fit the mold – the "other" places that are neither urban nor suburban and simultaneously both, the places in the Philadelphia landscape that subvert this binary distinction and disrupt the fractal-like patterns of energy consumption and economic and racial segregation in the metropolitan area. These places are important because they suggest that these patterns are not "just the way it is." These places, instead, suggest that there are alternatives. These alternatives are not tied to the abstract notions of new urbanism, which have not yet made a dramatic impact on Philadelphia's cityscape. Rather, they are examples of real, concrete, functioning workplaces and residential areas that directly challenge the notion that the only options available are urban or suburban living (or working). This is not to say that these "other" places in the cityscape are utopias. Even if such places existed (which I sincerely doubt), Northeast Philadelphia, Fairmount Park, and the airport area are far from perfect. However, if suburbanization has at least partially been driven by discourse, painting the suburbs as places of new economic hope and the urban places as places of decay, then the existence and prominence of these non-urban, non-suburban places is important.

While it is beyond the scope of this thesis to explore the intricacies of how these other places have come to exist and persist, it is my hope that future work on this subject will suggest alternative modes of urban development and the mechanisms by which those alternatives can be realized. Furthermore, if disruptions in the troubling connections between economic and racial segregation and energy consumption can be found at the metropolitan scale, it is possible that they also can be found at larger scales. With this new hope, let us now return to the global scale and consider the potential paths for future work that have been suggested by this thesis.

Chapter 7

FROM GLOBAL TO LOCAL AND BACK AGAIN: FRACTALS OF POWER, LESSONS LEARNED, AND THE WAY FORWARD

From Global to Local …

I began Chapter 2 with a discussion of the global-scale scientific discourses regarding global climate change. After presenting critiques of the global thinking that dominate the literature about climate change and GHG emissions, I argued in favor of two approaches. The first was a postmodern approach to understanding the processes that generate GHG emissions. The second was the study of consumptive landscapes, or geographies of consumption, as a necessary prerequisite of a more substantive approach to studying GHG emissions. While it is not necessary to invoke postmodern philosophy to advocate the study of consumption, neither is the ultimate end of this thesis the study of consumption. Rather, the study of consumption is a means to achieve the stated goal of this thesis: to find new approaches to understanding GHG emissions that are more useful in efforts to mitigate those emissions than are current approaches.

Towards that end, postmodern theory is helpful in at least two ways. First, it changes the criteria by which research is judged. Rather than "getting the numbers right" (or more broadly, creating accurate representations of a phenomenon), postmodern theory instructs us to create knowledge that is useful for a given goal – in this case, the mitigation of GHG emissions. In other words, postmodern theory provides the basis upon which the primary goal of this thesis rests. Without this theoretical basis, the usefulness of the research presented here would be irrelevant. As an academic, I would instead be charged with creating accurate representations of GHGs, regardless of whether or not those representations were helpful to anyone interested in mitigating GHG emissions. My emphasis on the usefulness of science is also at the heart of my critiques of existing approaches to understanding climate change and the GHG emissions that drive it.

Second, postmodern theory also suggests new approaches that are based on more substantive questions, such as “why are inefficient vehicles popular in the United States?” or “why are cities growing faster in physical size than they are in population?” Instead of viewing GHG emitting or energy consumption solely as an economic activity, the view of GHG emissions borrowed from Yapa (1996) in Chapter 2 suggests an infinite number of ways to view the processes that generate GHG emissions and an infinite number of agents whose decisions either are part of those processes or can influence them, or both.

However, this thesis does not explore these numerous representations and actors in exhaustive detail. Rather, it concerns itself with producing knowledge upon which more substantive research can be built. Because there is little known about the consumption patterns that generate GHG emissions at local or regional scales, I advocate the study of consumptive landscapes, or geographies of consumption, that describe spatial patterns of consumption, contextualize that consumption within the places where it occurs, and explain the processes that enable and drive it. As a test case, this thesis examined the consumption of gasoline in the Philadelphia Metropolitan Area by commuters who drove alone to work.

Chapter 3 presented a method for generating spatially specific estimates of gasoline consumption, and thereby GHG emissions, from origin-destination data supplied by the US

Census for all metropolitan areas in the United States. Before I presented the results of this method in Chapter 5, I provided some local historical context for Philadelphia in Chapter 4. I focused on the changes in urban form and function that have occurred over time, paying specific attention to the transportation network. I also discussed the racial and economic segregation in contemporary Philadelphia's cityscape. I did not focus on these details by chance: I selected them specifically because I believe they are linked to the patterns of transportation and GHG emissions presented in Chapters 5 and 6.

Chapter 5 presented results for 14 different workplaces within the metro area and some general patterns emerged from that discussion. Urban workplaces employed more African Americans than suburban workplaces, following an even stronger regional trend of residential segregation. In contrast, the few places that I classified as neither urban nor suburban tended to be diverse workplaces, but not necessarily diverse places of residence. All workplaces exhibited a spatially centrifugal progression from the residential locations of their workers, to the residential locations of their driving commuters, to the residential locations of their top emitters. Unlike urban workplaces, suburban workplaces tended to be local employers except for King of Prussia, Philadelphia's largest (and possibly only) edge city. Urban workplaces and King of Prussia were instead regional employers, drawing their workforces from the broader metro area.

Chapter 6 explored the similarities between urban and suburban places in more detail, yielding some interesting patterns. First, highly agglomerated places generated smaller percentages of drivers than less agglomerated places, and this pattern was true for both workplaces and residential areas. Second, people who live and work in the same kinds of places (e.g., those who work in the suburbs and also live in the suburbs) generated fewer emissions, on average, than those who commute from one kind of place to another (e.g., those who work in the suburbs but live in the city). These patterns are related to the patterns of racial and economic segregation presented in Chapter 4 – places that were more agglomerated were less segregated. Furthermore, many of the white workers in the city commuted every day from the suburbs. Thus, the settlement and commuting patterns that result in segregation in Philadelphia are the same patterns that result in elevated GHG emissions. While some exceptional places that disrupt these patterns do exist, the overall pattern is one where increased racial and economic exclusion coincides with increased gasoline consumption by commuters. That is, the spatial separation between racial and economic groups that is produced in Philadelphia through a variety of processes is also linked to increased emissions of GHGs, at least with regard to energy use in the commute to work.

… And Back Again

In a recent review in *Geoforum*, Jonathan Beaverstock and colleagues (2004) suggested that the global "super rich" were "getting away" with using the globalizing economy to line their pockets at the expense of the rest of the world's population. The idea that the rich are getting richer while the poor are getting poorer is by no means new. However, Beaverstock et al. argue that this process is accelerating. Furthermore, they contend that the elite are somehow escaping accountability for their hoarding of the world's wealth due in part to a surprising lack of geographies of the global "super rich." In other words, the argument is not only that these elites are enriching themselves at the expense of most of the world's population, but also that no one is documenting the processes by which this transfer of wealth is occurring. This argument is similar to that made by Yapa (1996), who suggests that by focusing on the poor and the places and spaces they occupy, social scientists reify a problem/non-problem binary, continuing to locate the rich within the non-problem despite their obvious links to the processes that create and perpetuate poverty.

The same principle could be applied to GHG emissions. It is well documented that the richer countries of the world are responsible for most GHG emissions (e.g., see Paterson 1996, UNFCCC 1996). However, it is not clear who within those countries is emitting what. Nor is it particularly clear how or why they are producing those emissions. Similarly, the growing emissions in countries like China and India are often attributed to the growing economies of those countries. However, there is a lack of detailed studies of energy consumption in those places. By all accounts, capitalist development in many other countries is more uneven than it is in the United States. Whether or not the patterns found in this thesis apply to other places and other scales remains to be seen. Nevertheless, if energy consumption, even if only in transportation, is directly tied to the manner in which the "haves" of the world separate themselves from the "have nots," then the world's elite are getting away with more than Beverstock et al. suggested.

Studying consumptive landscapes is a new way of producing geographies of the rich that engage notions of environmental justice. The environmental justice literature has traditionally focused on uneven exposure to risk from environmental hazards, such as air or water pollution, among disadvantaged groups (e.g., Bullard 1994), and the benefits reaped by those doing the polluting have largely been an important but understudied subtext. Climate change has changed this dynamic. The negotiations behind the UNFCCC and the Kyoto

Protocol have highlighted both the differential vulnerability to climate change worldwide, but also the economic benefits enjoyed by those consuming the most energy and producing the most emissions (Paterson 1996). The notion that the word's rich are creating the problem of climate change while the world's poor are most likely to suffer its negative impacts has also led to new activist groups (e.g., http://www.ejcc.org/). However, as noted in Chapter 2, framing discourses around climate change in a way that emphasizes the global economy tends to focus on the problem as solely economic.

In contrast, studying consumption at multiple scales and in specific places puts a face on the question of uneven consumption. Beaverstock et al. (2004:609) hope that geographies of the super-rich "might result in social and economic redistribution policies that would curb the excessive wealth and profligacy of the super-rich, and result in a more socially just world." Despite the appeal of social justice, by suggesting the study of consumptive landscapes, I am not so bold as to suggest that doing so might result in more equitable consumption patterns. Nor is it my intent to use this new research approach to lay blame at the feet of any particular group. Moreover, simply pointing to racial segregation in Philadelphia and its links to energy consumption is insufficient to reach the goal of GHG mitigation or even environmental justice. However, it is my hope that the research findings in this thesis will pave the way for future work that can achieve those goals.

Lessons Learned and the Way Forward

The study of consumptive landscapes is an initial step in a longer research process. As I have demonstrated, consumptive landscapes can provide answers to questions such as, "who consumes the most gasoline, and where do they live?" or "what workplaces generate the most GHG emissions during daily commutes?" These questions are not easy to answer empirically. This thesis has therefore made a methodological contribution to research communities that are interested in measuring consumption of energy in metropolitan areas. In addition, the findings from Philadelphia suggest that energy consumption may be linked to other processes that contribute to racial and economic segregation. Those links have implications for more than just Philadelphia; I have briefly explored some potential connections to literatures on environmental and social justice. However, like much of scientific inquiry, this thesis leads me to ask more questions than I have answered. As such, I will end this thesis with a discussion of my next steps and some suggested research directions for those who may be interested in following up on the research presented here.

Perhaps the most obvious question is whether or not I have achieved my goal. Recall that in Chapter 1, I proclaimed that the goal of this thesis was "to find new approaches to understanding GHG emissions that are more useful in efforts to mitigate those emissions than are current approaches." In evaluating my success, I find myself in a familiar position of academics – only time will tell how useful the information I have presented here will be. I have presented my findings to few stakeholders or decision makers; the handful of county and transit officials I have talked to thought that the findings might be useful in their efforts to improve public transportation. Still, the maps, tables, and text presented in this thesis were not intended to be immediately useful in GHG mitigation – the consumptive landscape they comprise was intended as a foundation for future work that could ask more substantive questions about the consumption of gasoline.

Along the way, I categorized hotspots and residential areas as either urban, suburban, or "other," a third category that offered alternatives to the more traditional urban/suburban dichotomy that is partially responsible for the desire-driven development patterns in suburbia and the disenfranchisement of many of Philadelphia's city neighborhoods. Returning to Soja (1996), this third category is not meant to be homogenous or permanent. Rather, it is meant to be a way of beginning to think about the metropolitan area in new and different ways. Expanding suburban development is in part driven by the discourses of the desirability of suburban living in contrast to urban living (e.g., Warner 1968, Garreau 1991). A third category subverts this dichotomy by presenting alternatives that are neither strictly urban nor suburban. This thirding therefore subverts one of the discursive causes of suburban expansion and in doing so becomes useful in combating the elevated GHG emissions originating from suburbia. However, its usefulness does not end there.

The places that were classified as "other" in Chapter 5 also disrupt otherwise robust fractal-like patterns in the metropolitan cityscape that link the economic and racial segregation of suburban life with elevated gasoline consumption. As discussed in Chapter 6, associating segregation with elevated energy consumption is dangerous because doing so can have a normalizing effect. Just as there are many discourses that characterize the disenfranchisement of the urban poor as an unfortunate but unavoidable consequence of economic "progress," linking energy consumption patterns to the same processes might lead readers to conclude that the increased energy consumption in suburban landscapes is also an unavoidable consequence of the economic geographies of urban places. In contrast, these "other" places demonstrate that there are alternative ways of living and working in Philadelphia. The trichotomy that has been created in this thesis therefore directly challenges the notion that energy consumption and the resulting GHG emissions are solely economic activities.

Thus, this thesis supports the more substantive view of GHG emissions put forward in Chapter 2 at the same time that it lays the foundation upon which more substantive questions can be asked. I have shown that GHG emissions are *discursive-material formations*. That is, GHG emissions are simultaneously constituted of discursive and material elements; rather than being solely economic phenomena, these emissions are constituted of infinite discursive-material causes that I initially categorized as academic, ecological, technical, political, and cultural entities. Conversely, these entities also represent sites at which changes can occur that might result in GHG mitigation. Exploring and refining these categories is outside the scope of this thesis. Still, I have begun to present a detailed geography of agency within the Philadelphia metro area by attributing GHG emissions to the places of residence and work that generate the trips resulting in emissions and to the people living and working within those places who make the decisions that most proximately cause various levels of gasoline consumption.

Now that I have identified where consumption is occurring, and by whose hand, I can ask more substantive questions of "how" and "why." Since such questions are infinite, I will not detail them here. Rather, I will characterize them as research questions that ask about the processes that produced the patterns described in this thesis. For example, why has the transit network evolved in such a way that suburbs are inaccessible by public transportation? What has prevented most of Philadelphia's urban poor from living near areas of economic opportunity? Is segregation driving energy use, or is energy use enabling segregation, or is neither the case? What of the "other" places in the landscape – can lessons be learned from the ways they function and the ways they have evolved? A deeper examination of these questions, and more, is in order.

These questions should not stop with Philadelphia. Within the United States alone, many cities have vastly different histories, forms, and characters than Philadelphia has. I would expect to find great differences between the transportation results presented in this thesis and the results of applying my model to commuters in New York, Chicago, Los Angeles, Atlanta, Phoenix, Portland, Cleveland, Detroit, and so on. However, the goal of such applications would not simply be to produce more maps of consumption for different places. The aim of comparing the results from different places would be to learn more about the processes occurring in each place. One possible strategy for the short term is to compare findings for a city with a similar history to Philadelphia, such as Chicago, to confirm the patterns and processes observed in this thesis. Other options include comparisons between different kinds of growth, for instance, Chicago and/or Philadelphia with "new" growth cities such as Atlanta, or to a city with an active growth boundary, such as Portland.

More broadly, I hope that the idea of consumptive landscapes as a topical focus in geography will have some traction. Rather than focusing only on areas of high consumption, new geographies of consumption could be concerned with describing consumption patterns across space in a given place and with linking those patterns to processes that influence, and are influenced by, the surrounding landscape. New research on consumptive landscapes need not focus on transportation, or even GHG emissions. Water consumption, for instance, might be a topic that could benefit from the perspective used in this thesis. In producing geographies of consumption, I investigated not only where consumption is occurring, but also who is doing the consuming. I also have begun to find linkages between the processes driving consumption and other processes at work in the landscape. It is my hope that this information will lead to more substantive questions about consumption and its drivers.

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Appendix A

ALGORITHMS, HEURISTICS, AND PROCEDURES USED IN TARN

All-or-Nothing (AON) Traffic Assignment

There are two types of traffic assignment – one that optimizes travel cost for individual commuters and one that optimizes travel cost for the entire network. The first assumes that commuters act in a manner consistent with the slogan "everyone for themselves," while the second assumes that travelers act in such a way that minimizes the total travel cost of travel by everyone. On the one hand, the first assumption is obviously more realistic with regard to individual commuters' attitudes, the second assumption allows for a single unique correct answer. That is, it is possible for an algorithm to optimize the network for total travel cost. On the other hand, it is not possible for an algorithm to find the single optimal solution in a situation where each commuter is trying to optimize their travel costs, at least not in a network where congestion is a factor. In this case, there are only heuristics, or approaches that approximate a possible optimal solution.

TARN does not include congestion or even time in its traffic assignment calculations for three reasons. First, the required data are unavailable. While some records in the NATD and census TIGER files do identify the road's name and type, most do not, and no speed limit or lane number data are available. In the absence of these data, it is difficult to generate congestion cost or even speed cost estimates without extensive field work, which is outside the scope of this thesis. Second, one goal of this thesis is that the approach be easily replicable in other places – data-intensive analyses such as congestion effects and traffic speed would make this goal less achievable. Finally, the traffic assignment analysis is intended simply to provide a relative estimate of distance traveled. As such, precise estimates are less important than distance estimates that are realistic given the available transportation network.

As such, TARN uses an all-or-nothing (AON) traffic assignment heuristic. The method is simple: for each destination, find the shortest path to all possible origins; for each origin-destination pair with a given destination, assign all commuters to the shortest path between the origin and destination; repeat for each destination. The efficiency of this algorithm varies according to the method used to find the shortest path, but could range from $O(n^3)$ in the worst case to $O(n^2 \cdot \log(n))$, depending on whether or not heaps are used (see the next two sections of this appendix).

If the full road network were used with this method, it would be likely that emissions would be underestimated because more people would be assigned to side streets than could realistically travel on those streets due to congestion, speed limits, and cross traffic. Thus, as described in Chapter 3, the analysis in this thesis uses a sparser network made up of largely national and state highways. This strategy has the added benefit of simplifying a very complex transportation network. As such, the emission estimates generated are probably fairly close to actual emissions. If speed and congestion data were available, an incremental traffic assignment could be used to test this hypothesis. Under this method, a percentage of total commuters are assigned using the AON method. Then, edge lengths are changed based on congestion information. A smaller percentage of commuters are then assigned, and edge lengths are again updated based on congestion information. This process is continued until all commuters have been assigned.

In any case, the estimates produced by the AON traffic assignment method described here are assumed to be fairly accurate, at least relative to emissions from other origin-destination pairs in the network. The focus of the rest of this appendix is on improving the efficiency of the algorithm used to find the shortest paths between these sets of origins and destinations.

(Reverse) Dijkstra's Algorithm

The core algorithm in TARN is an implementation of Dijkstra's (1959) algorithm. Although Dijkstra's algorithm is a standard in the civil engineering and transportation literatures, it is not widely known in all geographic communities, including the global change community. Therefore, a short description of the algorithm, followed by a simple example, is provided here to familiarize readers with the methods used in the transportation model.

The implementation used here is actually a reverse implementation of Dijkstra's algorithm – Dijkstra's original algorithm worked out paths from a single origin to all possible destinations in a graph, or network. The reverse implementation simply finds the shortest possible paths from all possible origins to a single destination. This is typically the implementation used because the data structure and analytical procedures are a bit simpler. However, it does not improve the efficiency of the algorithm – in both cases, the worst-case scenario is $O(n^2)$.

Figure **A.1** shows the basic steps involved in the reverse implementation of Dijkstra's algorithm. For the initiated, this may be a bit too terse, however, and further explanation

```
Reverse Dijkstra:

Let each node x have attributes:
        d, the distance of the best path between starting node s and node x
        scanned, a binary variable indicating the status of node x
        bstar*[], an array of pointers to the nodes that can directly reach node x
        next*, a pointer to the next node in a path
Let node y* be a pointer to the current node
Let node s* be a pointer to the starting node

Step 1. Initialization
        a. For each node x, x->scanned=0
        b. Label starting node s
        c. For each node x, x->d = ∞
        d. For each node x, next=nil
        e. s->d = 0
Step 2. y = node with the minimum d value and a value of scanned == 0
        a. y->scanned =1
        b. For each node x in bstar of y
                i. if x->scanned, continue
                ii. if x->d > (y->d + dist(x,y))
                        a. x->d = (y->d + dist(x,y))
                        b. x->next = y
Step 3. If there are no unscanned nodes with d<∞, stop. Otherwise, do step 2.
```

Figure **A.1**: The reverse implementation of Dijkstra's algorithm used in TARN.

may be required. The first portion of the text in Figure **A.1** describes the most important components of the data structure for this algorithm. The node attributes “d” and “scanned” are both integers and both change throughout the implementation of the algorithm; d is the distance between the given node and the destination node and scanned is a 0/1 variable that whether or not the particular node has been scanned yet. The array bstar*[] is described in more detail in Chapter 3, but essentially it is an array of pointers that point to all nodes that are connected to and can reach the given node. Finally, the pointer next* is a pointer to the next node in the shortest path to the destination node. In other words, the next* pointer indicates the next node that must be traveled to in order to reach the destination node following the shortest path.

Step 1 in the algorithm is simply the initialization step. Each node is marked as unscanned (1.a), a starting node s is defined as the destination node, d is set to an infinite distance for all nodes (except the starting node, the distance of which is set to 0), and the next* pointer of all nodes is set to nil.

Most of the work of the algorithm is done in step 2. First, a pointer y is set to equal the unscanned node with the minimum d value. In the first iteration, this is the s node, since its d is 0, while all others have an infinite d. As soon as this node is selected, it is marked as scanned. Next, for each node in the bstar*[] of y, comparisons are made and if appropriate, some of the attribute values are changed. First, if the node has already been scanned, then it is safe to assume that its d value has already been minimized. Thus, the node is skipped and the next node in the bstar*[] of y is examined. If it is unscanned, however, a check is made to determine whether or not the d value can be lowered. The d value can be lowered for a node x in the bstar*[] of y if (y->d + dist(x,y)) < x->d. In other words, if the d value stored for node x is greater than the distance between node y and the destination node plus the distance between nodes y and x, then it would be shorter to change the path from x to the destination node to travel through node y. In this case, the d value is set to y-> d + dist (x,y), and x->next is set to equal y. Once this evaluation has been made for each node in the bstar*[] of y, step 2 is completed.

Step 3 simply checks to see whether there are any other unscanned nodes that can reach the destination in the given graph. If there are no unscanned nodes with d<∞, then any remaining unscanned nodes cannot reach the destination in the given graph, and the algorithm is done. Otherwise, step 2 is repeated, beginning with the selection of a new node to scan.

A brief example will help clarify the steps in this algorithm. Figure **A.2** shows a sample graph and the steps taken to find the shortest paths to the destination node. Figure **A.2**(a) shows the entire graph. Node IDs are shown inside the circles representing each node, the distance between nodes is shown along each arc, and the distance from each node to the destination node (the d value) is shown in squares next to each node. The subsequent subfigures show what happens to the data during each iteration of the algorithm. In each case, the node being scanned is highlighted in grey, and nodes that have already been scanned are noted with grey, rather than black, circles.

Figure **A.2**(b) shows the first iteration, where the destination node (node 6) is scanned. Nodes 3 and 5 are in the bstar*[] of node 6, so they will be examined, and if necessary their d values will be altered. Since 0+5<∞, node 3's d value is reduced to 5 (a substantial improvement, indeed). Similarly, the d value for node 5 is reduced to 3.

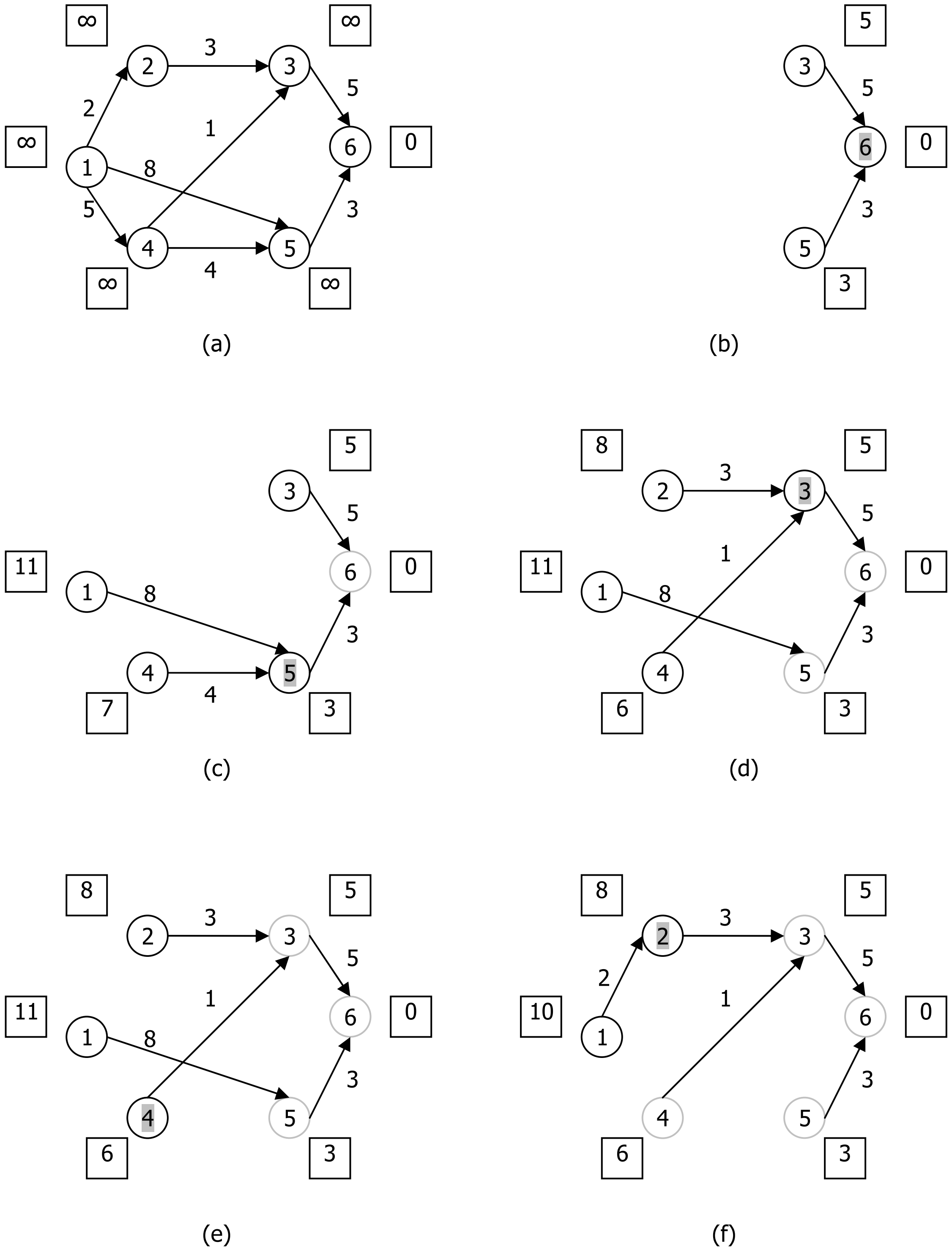

Figure **A.2**: A sample graph for demonstrating the reverse implementation of Dijkstra's algorithm. See text for explanation of symbols.

In Figure **A.2**(c), node 5 is selected because it has the lowest d value of all unscanned nodes. Nodes 1 and 4 are in its bstar*[], and are examined. Because $8+3<\infty$, node 1's d value is reduced to 11. Similarly, the value for node 4 is set to 7.

In Figure **A.2**(d), node 3 is selected because it has the lowest d value of all unscanned nodes. Because $3+5<\infty$, the d value for node 2 is change to 8, and because $5+1<7$, the value for node 4 is change to 6. Also, note that the path from node 4 to the destination node is altered so that it now passes through node 3 instead of node 5.

In Figure **A.2**(e), node 4 is selected because its value of 6 is the lowest of all the unscanned nodes. Node 6 only has one node in its bstar*[] – node 1. However, since 6+5 is not less than 11 (it is, in fact, equal), no changes are made to the path from node 1 to node 6, and no changes to the d values are made.

Lastly, in Figure **A.2**(f), node 2 is selected because it is the minimum unscanned node. As before, node 1 is the only node in the bstar*[] of node 2. However, in this case, $8+2<11$, so node 1's path is altered to pass through node 2, and node 1's d value is reduced to 10.

A final step would be to scan node 1. However, since scanning node 1 cannot possibly have any effect on the outcome, this step is not shown in Figure **A.2**.

As noted above, the worst-case scenario for the efficiency of this algorithm is $O(n^2)$. That is, it is on the order of n^2, where n is the number of nodes in a graph. In a fully connected graph, all nodes will be scanned, so step 2 must be repeated n times. Within step 2, the bottle neck is node selection. The simplest, but most inefficient, way to select the the minimum unscanned node is to examine every node, or to loop through n nodes. Thus, step 2, which must be repeated n times, itself has a worst case efficiency of $O(n + m/n)$. This is because node selection is *O*(n), and in addition, examining every node in the bstar*[] of a given node is *O*(m/n), on average (m=number of edges in the graph). Muliplying *O*(n + m/n) * *O*(n) gives us *O*(n^2 + m). Regardless of the number of edges, the best performance we can hope for is *O*(n^2) (this is also the worst case scenario, which occurs when m=n^2).

For simple graphs, such as the one shown in Figure **A.2**, this set of calculations is trivial. However, for a graph with a thousand or more nodes, it would take more than 1,000,000 loops to find the shortest path for just one destination. As discussed earlier shown the discussion of AON traffic assignment, this operation must be performed for every destination. So, in such a graph where there are 1,000 destinations, a full traffic assignment would take 1 billion loops. Even on today's computers, this becomes prohibitively expensive for large complex networks.

However, there are many ways to improve the efficiency of Dijsktra's algorithm. For instance, Dial (1967) showed that for sparse graphs, using buckets can greatly improve the efficiency of the algorithm. Luckily, transportation networks are often very sparse graphs, with only a handful of edges per node. Buckets are simply containers, or arrays, where nodes are stored. In this case, there would be two buckets – a "scanned" bucket, and an "unscanned" bucket. When a node is scanned, it is moved from the unscanned bucket to the scanned bucket. Thus, when node selection is performed in step 2, there are fewer nodes to examine. On the first iteration, n-1 nodes must be examined; on the second iteration, only n-2 nodes must be examined, and so forth. Nonetheless, the nodes are not stored in any particular order in these buckets, so every node in the unscanned bucket must still be examined during each iteration in order to find the one with the minimum value.

A more efficient solution is to store the nodes in the unscanned bucket in such a way that the minimum unscanned node is always in the same place. That is, if the nodes were all stored in order from lowest to highest, it would be easy to find the node with the minimum value, and the efficiency of the algorithm would be greatly improved. This requires an efficient sorting algorithm and some minor modifications to the reverse implementation of Dijkstra's algorithm described in this section. The next section of this appendix describes heaps, the most efficient known sorting algorithm, and the modifications required to use heaps in the reverse implementation of Dijkstra's algorithm.

Heaps

There are a number of sorting algorithms that can sort nodes based on a single value, such as the d attribute value. The simplest (and slowest) sorting algorithm is known as the bubble sort. The details are not important to this thesis, but this algorithm gets its name from the fact that it loops through each node and "bubbles" it up through the array. Each node is compared with its neighbor in the array and swapped if it is less than its neighbor. This comparison and swap is performed for each node against all other nodes in the array, for an efficiency of $O(n^2)$. Thus, using the bubble sort would not improve the efficiency of Dijkstra's algorithm.

However, the quicksort, which uses heaps, has an efficiency of $O(n \cdot \log(n))$, as this section will demonstrate, and improves the overall efficiency of Dijkstra's algorithm to $O(n \cdot \log(n))$ for sparse graphs. Clearly, this is a marked improvement for sparse graphs. In fact, it is widely suggested that a quicksort running on a desktop computer can beat a bubble sort running on a supercomputer, assuming the data being sorted are sufficiently random and the array is a large enough size. Because the comparison between the bubble sort and the quicksort is the same as the comparison in efficiency between the brute-force implementation of Dijkstra's algorithm and the implementation with heaps, this also demonstrates the importance of improving the efficiency of our implementation of Dijkstra's algorithm.

Figures **A.3** - **A.5** demonstrate various aspects of quicksorts and heaps. Figures **A.3** shows a quicksort of an initially random heap. Figure **A.4** shows the processes of "popping" and "promotion" and their role in constructing a sorted array. Finally, Figure **A.5** shows the process of "sifting" a node up through a heap after its value has been reduced (for instance, during step 2 of Dijkstra's algorithm). Each of these processes, and their role in an improved shortest-path algorithm will be explained in detail in this section. However, first it is important to clarify a few terms.

A heap is a tree with very specific rules. First, each node has a specified and equal number of "children." While that number does not need to be 2, a heap with two children per node (a 2-ary heap) will be used in this example, and in the implementation for TARN[13]. Furthermore, each node in the tree is numbered, starting with 1 for the root node, then working across the next row of children from left to right, then the next row, and so on.

So, in the sorted heap shown in Figure **A.3**(f), the value of node 1 is 32, then value of node 2 is 45, node 3 has a value of 56, node 4 has a value of 52, node 5 has a value of 99,

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[13] The optimal number of children per node varies with the number of nodes, but is typically very small (most often 3, but the resulting improvement in efficiency is rarely a significant improvement beyond a 2-ary heap; see below). Further, the greatest improvement in efficiency results from using heaps; the number of children per node has a minimal effect on efficiency, by comparison. While the number of children could be optimized based on the number of nodes and would more often than not result in a 3-ary heap rather than a 2-ary heap, the improvement is minimal and is therefore not pursued.

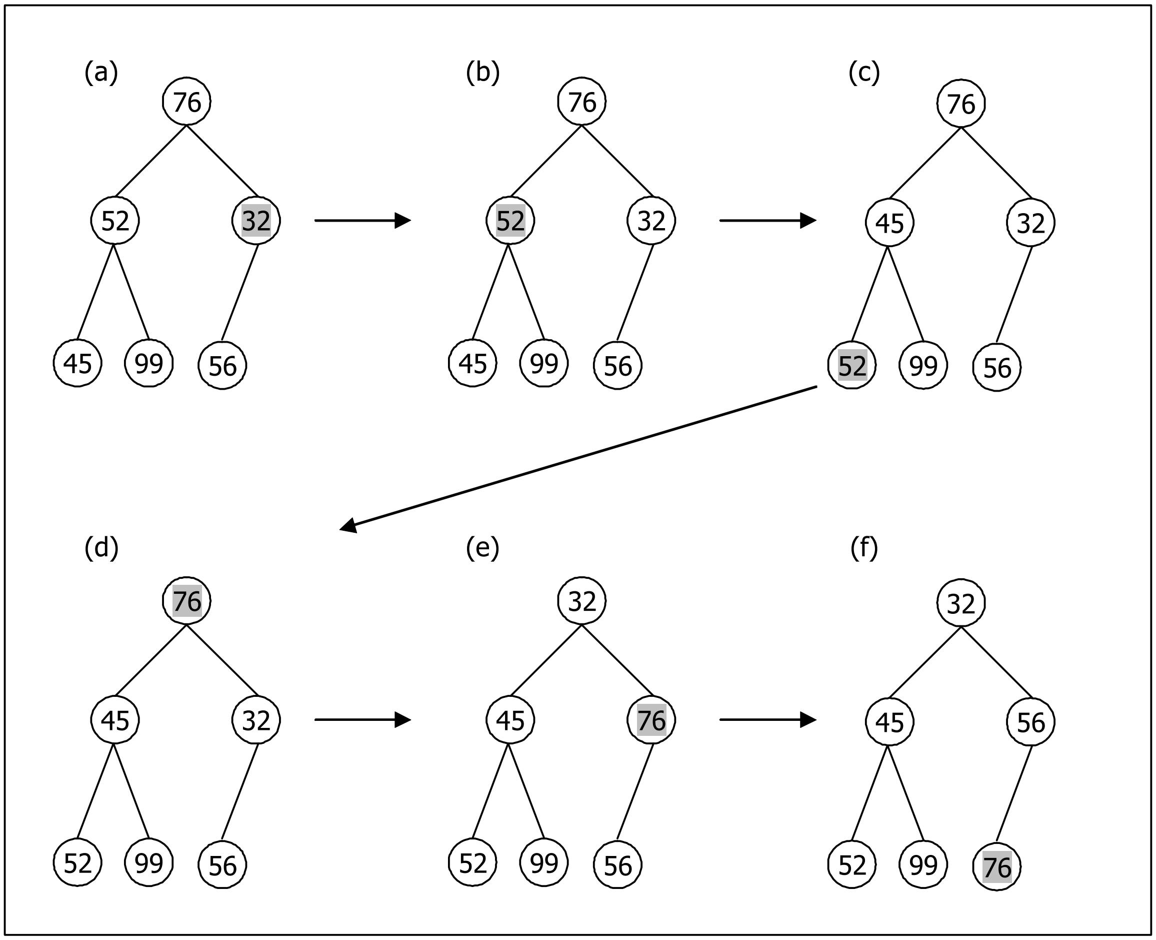

Figure **A.3**: Sample heap demonstrating the sorting process.

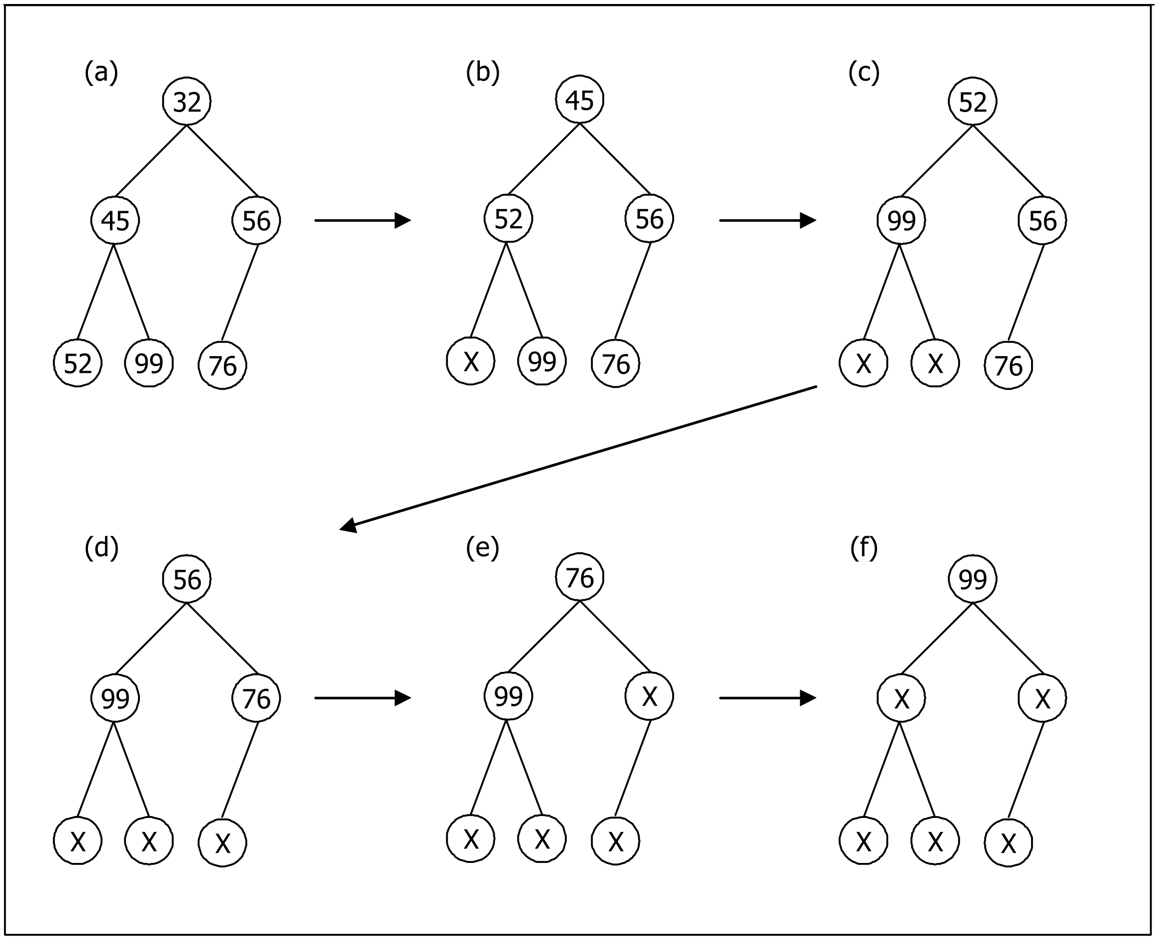

Figure **A.4**: Sample heap demonstrating the processes of popping and promoting nodes.

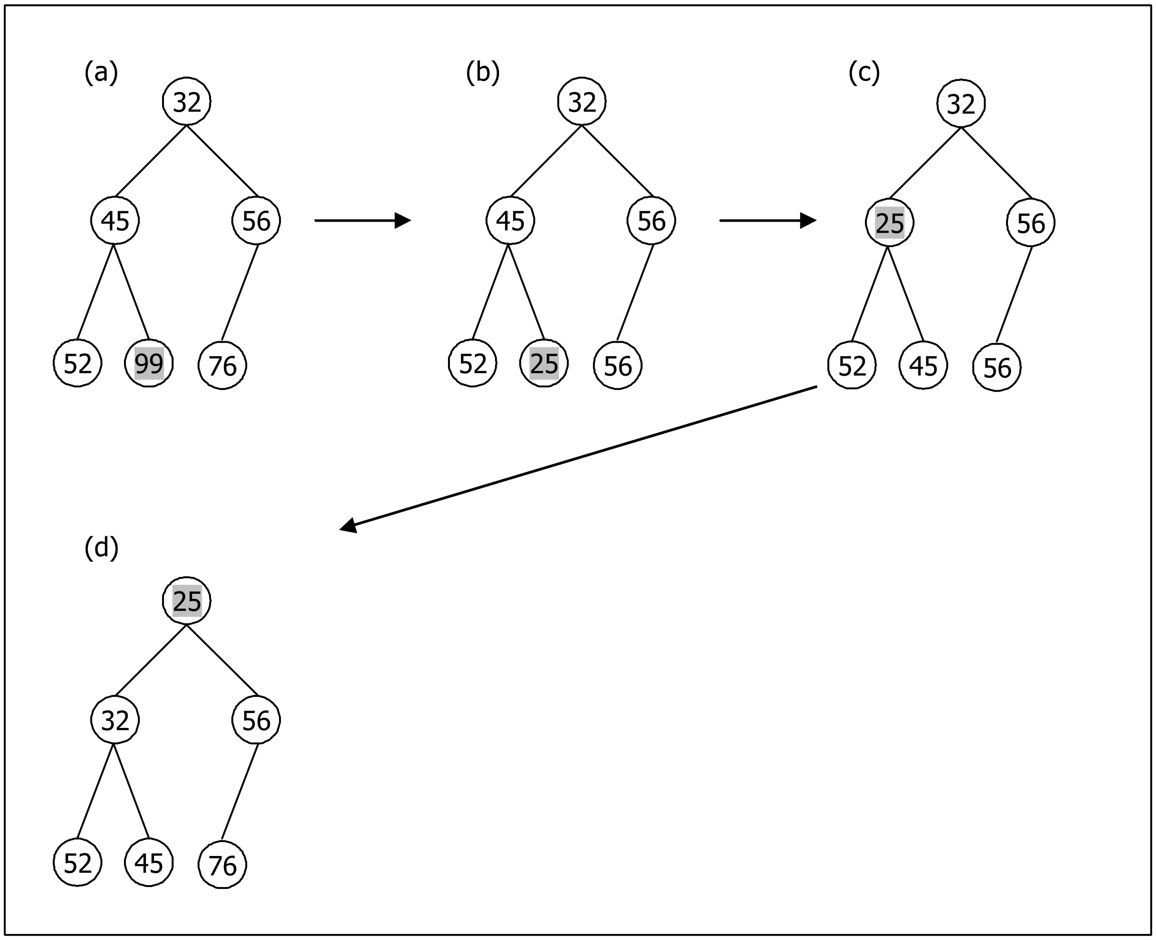

Figure **A.5**: Sample heap demonstrating the process of sifting an altered node up the heap.

and node 6 has a value of 76. Note that node 7, while nill, would be the final child in this row, and would be the child of node 3. In order to find nodes within heaps (and the related nodes), each node has an attribute value typically called nth (or node-to-heap), which is an integer value referring to its node number. Thus, node 6 has a nth value of 6. Similarly, each heap has an array of pointers htn*[], which points to each node. So, htn*[1] points to node 1, and so on.

The children and parent of any node can be located using simple equations. In this heap, the children of node 1 are (1*2), and (1*2+1). Likewise, the parent node of nodes 2 and 3 are int(2/2) and int(3/2), respectively. These formulas are generalizable so that the parent of any child in a d-ary heap can be found using the formula int(nth/d), and the children of any node are (nth*d + 0), (nth*d +1), …, (nth*d + (d-1)). The final rule for heaps is that the parent's value must be less than or equal to all of the values of its children (and by extension, all of its children's children, and so on). However, as the sorted heap in Figure B.3(f) demonstrates, a node's value need not be lower than all of the nodes in lower levels, so long as its value is lower than its children – while 56>52, the heap is still properly sorted because node 4 is not a child of node 3.

Once a heap is constructed, it must be sorted. Sorting a heap is a straightforward process. For every node that has at least one child (beginning with the last such node), the node is sifted downward in the heap if its value is greater than the value of its child. When a node is sifted downward, it is always swapped with the child of lowest value. Working through the example in Figure B.3 will help demonstrate simplicity and elegance of this sorting method.

In the first iteration (Figure **A.3**.a), the last node with a child is node 3. Because its value is less than the value of its only child (node 6), it is not moved.

Working up the heap, the next node with children is node 2. Because it greater than node 4, one of its children (52>45), it is sifted downwards in the heap. Node 4 is the node with the lowest value, so it is swapped with its parent (Figures **A.3**.b,c).

Finally, the last node to be scanned is the root node (node 1). In the first comparison, it can be seen that node 1 is great than both of its children (Figure **A.3**.d). The swap (Figure **A.3**.e) is made with node 3 rather than node 2 because node 3 has the lowest value of all three nodes. This sifting process must continue all the way down the heap until the original root node no longer has a value greater than its children, so another swap is made between what is now node 3 and its child, node 6 (Figure **A.3**.f). The heap is now properly sorted.

Note that this process has an efficiency of $O(n \cdot \log n)$. There are several steps that are completed. First, the heap itself must be created. This is simply the process of setting the values for each node (nodes 1 to nodes 6, in this case). This has an efficiency of $O(n)$. Next, the heap is sorted. Because each node with a child is scanned, the outer loop is performed (n/2) times, which is $O(n)$. There is an inner loop, by which any node found to be greater than its children is sifted down the heap. There are a maximum of log(n) times that a node will need to be compared and swapped with its children. Thus, the overall sorting process is $O(n \cdot \log(n))$.[14] Taking the construction of the heap and the sorting of the heap together ($O(n \cdot \log(n)) + O(n)$), the overall efficiency is $O(n \cdot \log(n))$.

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[14] More accurately, this is $O(n \cdot d \cdot \log_d(n))$, where d is the number of children per node, because in sifting a node down through a heap, one must make d comparisons to determine which child to promote. Conversely, the

The final step in constructing a sorted array would be to "pop" each node off the top of the heap, promote its child with the lower value, and continue the process until all nodes have been popped from the heap (Figure **A.4**). Each time the root node is popped from the heap, the child with the lower value is promoted. As part of its promotion, its lower-value child must also be promoted. So, in the example of the promotion between Figure **A.4**.a and Figure **A.4**.b, node 2 has a value lower than node 3. Thus, node 2 is promoted to become the new root node. This leaves node 2 unassigned, so nodes 4 and 5 are compared, and node 4 is promoted to node 2. Because there are no children of node 4, it is simply left unassigned, and the heap is again in proper order. Thus, the root node is again popped, and the cycle is continued (Figure **A.4**.c-d). In this example, the resulting array would be: 32-45-52-56-76-99.

However, the goal of using heaps is not simply to produce a sorted array. The purpose is two-fold. One goal is to make selecting the minimum unscanned node as simple as possible. As illustrated in the preceding paragraph, this is easily achieved by popping the root node from the heap and promoting its children. The second goal, rather than simply producing a sorted array, is to keep the rest of heap in proper order during the scanning process. That is, during step 2 in the reverse Dijkstra implementation, the value of each node can change many times before it is finally selected for scanning. Every time a node's value is changed, it must be "sifted" up through the heap to ensure that it does not have a value that is less than its parent, grandparent, and so on.

---

depth of the heap is reduced as d increases. The optimal value for d varies with n, but is a small number, most typically 3, and the value of d has a very small effect on the number of loops performed compared to other factors. As such, this is most often represented simply as O(n·log(n)).

Figure **A.5** demonstrates the process of sifting a node up the heap. In this example, the value of node 6 is changed from 99 to 25, placing the heap out of order. So, it is sifted through the heap. This is very similar to sifting down a heap, discussed earlier. The node is compared with its parent, and found to have a lower value. Therefore, it is swapped with its parent. This comparison continues until the node either becomes the root node or no longer has a value lower than its parent's value. In the example in Figure **A.5**, node 6 eventually becomes root node as a result of the sifting process. However, had the value been changed to 36 rather than 25, the sifting process would have stopped at node 2. As with sifting down a heap, the efficiency of sifting up a heap is $O(\log(n))$.

Finally, these processes need to be incorporated into the implementation of Dijkstra's algorithm. This has already been partially described, but is described in its entirety in Figure **A.6**. These steps have already been explained, but it is worth noting the calculations for the overall efficiency of the modified shortest-path algorithm. As noted before, constructing and sorting the heap is $O(n\cdot\log(n))$. As before, each node must be scanned, so the outer loop in step 2 is $O(n)$. However, node selection is now $O(1)$, a dramatic improvement. This is mitigated somewhat by the added step of sifting nodes up the heap, but this process is only $O(\log(n))$. Recall that this is embedded in a loop that is repeated m/n times, on average. Therefore, the efficiency of step 2 becomes $O(n\cdot(m/n)\cdot\log n)$, or $O(m\cdot\log(n))$. Thus, the overall efficiency of the new algorithm is $O(n\cdot\log(n)) + O(m\cdot\log(n))$, or simply $O(m\cdot\log(n))$, assuming that $m>n$ (a safe assumption in transportation networks).

Note that in the worst-case scenario of a dense graph where $m=n^2$, this becomes $O(n^2\cdot\log(n))$, which is actually worse than if heaps had not been used at all. However, for all

Reverse Dijkstra with heaps:

```
Let each node x have attributes:
        d, the distance of the best path between starting node s and node x
        scanned, a binary variable indicating the status of node x
        bstar*[], an array of pointers to the nodes that can directly reach node x
        next*, a pointer to the next node in a path
Let node y* be a pointer to the current node
Let node s* be a pointer to the starting node

Step 1. Initialization
        a. For each node x, x->scanned=0
        b. Label starting node s
        c. For each node x, x->d = ∞
        d. For each node x, next=nil
        e. s->d = 0
        f. Construct a heap containing all nodes
        g. Sort the heap based on the d values.
Step 2. y = the root node in the heap.
        (Pop the root node and promote its children.)
        a. y->scanned =1
        b. For each node x in bstar of y
                i. if x->scanned, continue
                ii. if x->d > (y->d + dist(x,y))
                        a. x->d = (y->d + dist(x,y))
                        b. x->next = y
                        c. sift node x up the heap
Step 3. If there are no unscanned nodes with d<∞, stop. Otherwise, do step 2.
```

Figure **A.6**: Description of a reverse implementation of Dijkstra’s algorithm with heaps. Added and modified steps are highlighted in bold and italics.

cases where $m < (n^2/\log(n))$, there is improvement in the efficiency if heaps are used, and further decreases in the number of edges per node substantially improve the efficiency of the algorithm. In hypothetical example of a network with 1000 nodes, this means that so long as there are less than 100,000 edges, or 100 edges per node, using heaps improves the efficiency of the algorithm. Since it is unlikely that the average number of edges per node in a transportation network will exceed 4, it is safe to assume that implementing shortest path algorithm with heaps is much more efficient than implementing it without heaps. In this case where $m=4n$, for instance, the efficiency of the algorithm becomes $O(4n\cdot\log(n))$, or simply $O(n\cdot\log(n))$. Thus, it is often simply stated that for sparse graphs, the efficiency of dijkstra's algorithm using heaps is $O(n\cdot\log(n))$.

Appendix B

CODE FOR TRAFFIC ASSIGNER BY ROB NEFF (TARN)

```
/* TARN (Traffic Assigner by Rob Neff) Version 4.0 */
/* Copyright 2004, all rights reserved */
/* tarn.h -- macros, arrays, data structures, etc. */

#define NODEFILES "nodefiles"
#define ARCFILES "arcfiles"
#define OUTFILES "outfiles"
#define MAX_NODES 5000
#define MAX_ARCS 7000
#define SYSLOG "syslog"
#define ARR_SIZE 1000
#define MAX_WORDS 10
#define WORD_LEN 2000
#define MAX_LINKS 40
#define MODES 2
#define ROWS 1
#define COLS 2
#define COMMA 1
#define TAB 2
#define SPACE 3
#define MATRIX_ROWS 5000
#define MATRIX_COLS 5000

struct node_struct{
   int x_coord;
   int y_coord;
   struct node_struct *fstar[MAX_LINKS], *bstar[MAX_LINKS];
   char old_id[10];
   struct arc_struct *farc[MAX_LINKS], *barc[MAX_LINKS];
   int scanned;
   struct node_struct *next;
   int cost;
   int d;
   char type[50];
   struct net_struct *net;
   int nth;
};
typedef struct node_struct *NODE_OBJECT;

struct arc_struct{
   struct node_struct *to_node, *from_node;
   char old_id[10];
   int load;
   int len;
   char type[50];
   struct arc_struct *farc[MAX_LINKS], *barc[MAX_LINKS], *next;
```

```
   struct net_struct *net;
};
typedef struct arc_struct *ARC_OBJECT;

struct net_struct{
   struct node_struct *node[MAX_NODES], *dest;
   struct arc_struct *arc[MAX_ARCS];
   struct net_struct *next, *prev;
   char name[50];
   int htn[MAX_NODES+1];
   int n;
};
typedef struct net_struct *NET_OBJECT;

NET_OBJECT net_first, net_last;

struct dest_struct{
   struct node_struct *node;
   char type[MAX_NODES*MODES][10];
   char orig_id[MAX_NODES*MODES][10];
   int commuters[MAX_NODES*MODES];
   int dist_driven;
   int dist_driven_by_origin[MAX_NODES*MODES];
   struct dest_struct *prev, *next;
};

typedef struct dest_struct *DEST_OBJECT;

DEST_OBJECT dest_first, dest_last;

struct collumn_struct{
   char name[15];
   int row[MATRIX_ROWS];
};

typedef struct collumn_struct *COL_OBJECT;


char word[MAX_WORDS][WORD_LEN+1];
int word_count;
char text[ARR_SIZE*3];
char comword[WORD_LEN+1];
char *delimtype[]={"","Comma","Tab","Space"};
char *delimparse=",,\t ";
//char *progress="";
char *command[]={"loadnodes",
   "loadarcs","createnet","linknodes","loadod","loadmultiod","aon","quit",
   "sum","addlink","run","wd","help","sumtab","*"};
enum comvals
   {LOAD_NODES,LOAD_ARCS,CREATE_NET,LINK_NODES,LOAD_OD,LOAD_MULTI,DO_AON,Q
   UIT,SUM_NET,ADD_LINK,RUN_SCRIPT,SET_WD,HELP,SUMTAB} com_num;
int quit;
```

```
/* Tarn (Traffic Assigner by Rob Neff) Version 4.0 */
/* Copyright 2004, all rights reserved */
/* tarn2.h -- header file with all prototypes */

/***Heap Data Structure ***/
void heapsort(NET_OBJECT net);
void downheap(NET_OBJECT net, int root);
void swap(NET_OBJECT net, int parent, int child);
void construct_heap(NET_OBJECT net);
NODE_OBJECT new_get_min_unscanned(NET_OBJECT net);
NODE_OBJECT pop(NET_OBJECT net);
void promote(NET_OBJECT net, int heapnode);
void sift(NET_OBJECT net, int i);

void help_commands();
int sum_dist_table(char *inpstr);
void do_help();
int set_wd(char *inpstr);
int create_node(NET_OBJECT net);
int create_arc(NET_OBJECT net, NODE_OBJECT node1, NODE_OBJECT node2);
NET_OBJECT create_net();
int add_node_net(NET_OBJECT net, NODE_OBJECT node);
int add_arc_net(NET_OBJECT net, ARC_OBJECT arc);
void write_syslog(char *str);
void clear_words();
void destruct_net(NET_OBJECT net);
void init_globals();
void prompt_user();
int load_nodes(char *inpstr);
NET_OBJECT get_net(char *the_word);
int load_arcs (char *inpstr);
int make_net(char *inpstr);
int wordfind(char *inpstr);
int link_nodes(char *inpstr);
int load_od(char *inpstr);
int do_aon(char *inpstr);
int calc_dist(NODE_OBJECT node1,NODE_OBJECT node2);
NODE_OBJECT find_nearest(NODE_OBJECT node1, char *type, int dist);
DEST_OBJECT create_dest(NODE_OBJECT node);
DEST_OBJECT get_dest(char *id);
void init_loads(NET_OBJECT net);
void do_rev_dijkstra(NET_OBJECT net, NODE_OBJECT start);
NODE_OBJECT get_min_unscanned(NET_OBJECT net);
ARC_OBJECT get_arc(NET_OBJECT net, NODE_OBJECT node1, NODE_OBJECT node2);
void assign_traffic(NET_OBJECT net, DEST_OBJECT dest);
void do_rev_road_dijkstra(NET_OBJECT net, NODE_OBJECT start);
void assign_road_traffic(NET_OBJECT net, DEST_OBJECT dest);
void do_rev_rail_dijkstra(NET_OBJECT net, NODE_OBJECT start);
int summarize_net(char *inpstr);
ARC_OBJECT get_rail_arc(NET_OBJECT net, NODE_OBJECT node1, NODE_OBJECT
   node2);
int add_link(char *inpstr);
void exec_com(char *inpstr);
int run_script(char *inpstr);
```

```
/* TARN (Traffic Assigner by Rob Neff) Version 4.0 */
/* Copyright 2004, all rights reserved */
/* main.c -- Main file with all routines */

/*Include a bunch of standard headers */
#include <stdio.h>
#include <sys/types.h>
#include <fcntl.h>
#include <netdb.h>
#include <netinet/in.h>
#include <unistd.h>
#include <setjmp.h>
#include <errno.h>
#include <dirent.h>
#include "/usr/include/math.h"
#include <string.h>
#include <arpa/inet.h>
#include <stdlib.h>
#include <ctype.h>
#include <signal.h>

/*Include special headers for tarn*/
#include "tarn.h" //defines macros, data structures, arrays, etc.
#include "tarn2.h" // prototypes

int main(int argc, char *argv[])
{
   //Main subroutine ... This is where we start when the program is
   initialized
   //Initialize some variables ...
   char inpstr[ARR_SIZE];
   int len,flag,i;
   inpstr[0]='\0';
   quit=0; // When quit=1, we quit.
   flag=0;
   len=0;
   i=-1;
   init_globals();
   printf("\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n");
   printf("Welcome to Traffic Assigner by Rob Neff [TARN] \n");
   printf("This is version 4.0\n");
   printf("Please don't use this without Rob's permission.\n");
   printf("\n\n");
   while(!quit) //We keep looping until the user types -> quit
   {
         //Clear variables from last command
         inpstr[0]='\0';
         text[0]='\0';
         clear_words();
         flag=0;
         i=0;
         com_num=-1;
         prompt_user(); //Get user command
         while(strlen(inpstr)<1)
         {
```

```
            fgets(inpstr,ARR_SIZE-1,stdin);
        }
        word_count=wordfind(inpstr); //parse command string
        exec_com(inpstr); //interpret command string and execute command
   }
   printf("Thanks for using TARN. Hope you had fun :)\n"); // We only get
   here if quit=1
   exit(0);
}
/*************************************************************************/
/**************** Parsing and Interpreting User Input *****************/
/*************************************************************************/

void exec_com(char *inpstr)
{
   int flag;
   int len,i;
   len=0;
   i=0;
   flag=0;
   if((len=strlen(word[0]))==0)
   {
         printf("Nice try. This time, try entering a command.\n"); //Error
   trap
         return;
   }
   strcpy(comword,word[0]);
   //Loop through all commands. When we find a command that matches the
   first word,
   //break out of the loop, with the command number stored in com_num.
   while(command[i][0]!='*')
   {
         if (!strncmp(comword,command[i],len)) //match found
         {
               com_num=i;
               break;
         }
         ++i;
   }
   //Execute the command indicated by com_num. The macros used here are
   defined in tarn.h
   //If flag is returned with valued -1, something went wrong, so we
   notify the user.
   switch(com_num)
   {
   case LOAD_NODES:
         flag=load_nodes(inpstr);
         break;
   case LOAD_ARCS:
         flag=load_arcs(inpstr);
         break;
   case CREATE_NET:
         flag=make_net(inpstr);
         break;
   case LINK_NODES:
```

```
         flag=link_nodes(inpstr);
         break;
   case ADD_LINK:
         flag=add_link(inpstr);
         break;
   case LOAD_OD:
         flag=load_od(inpstr);
         break;
   case DO_AON:
         flag=do_aon(inpstr);
         break;
   case QUIT:
         quit=1;
         break;
   case SUM_NET:
         summarize_net(inpstr);
         break;
   case RUN_SCRIPT:
         flag=run_script(inpstr);
         break;
   case SET_WD:
         flag=set_wd(inpstr);
         break;
   case LOAD_MULTI:
         //Not really needed, and was never implimented.
         //This is a hold-over from a time when each destination's o-d
   table was loaded individually
         //But now the entire o-d table is loaded with a single command
   (loadod)
         printf("Yeah ... that would be nice. But Rob hasn't finished
   coding that baby yet.\n");
         break;
   case HELP:
         do_help();
         break;
   case SUMTAB:
         flag=sum_dist_table(inpstr);
         break;
   default:
         //If we get here, then the user entered a non-command.
         printf("Unknown command. Enter \"help\" for help.\n");
         break;
   }
   if(flag==-1) //Something went wrong. Notify the user and log details.
   {
         printf("Command not successfully executed.\n");
         sprintf(text,"ERROR: command \"%s\" returned a negative
   flag.\n",inpstr);
         write_syslog(text);
         flag=0;
   }
   return;
}

void do_help()
```

```
{
   if(word_count<2 || !strcmp(word[1],"commands"))
   {
         help_commands(); //List all the commands
         return;
   }
   printf("I'd like to help you ... really I would.\nHowever, Rob hasn't
   added command-specific help yet.\n");
   return;
   //It would be nice to have command-specific commands, but since this
   entire model needs
   //To be fully integrated into ArcMap anyway, I'm the only one who uses
   this interface
}

void help_commands()
{
   //List all commands. This comes in real handy.
   int com,cnt;
   char temp[100];
   com=0;
   cnt=0;
   text[0]='\0';
   printf("                       *** Commands Available ***\n");
   printf("=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-
   =-=-=-=-\n    ");
   while(command[com][0]!='*')
   {
         sprintf(temp,"%-13s ",command[com]);
         strcat(text,temp);
         if (cnt==4)
         {
               strcat(text,"\n    ");
               printf(text);
               text[0]='\0';
               cnt=-1;
         }
         ++cnt;
         ++com;
   }
   if(cnt)
   {
         strcat(text,"\n\n");
         printf(text);
         text[0]='\0';
   }
   printf("=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-
   =-=-=-=-\n");
   //printf("For specific help, type -> help <command>.\n");
   //No command-specific help since this interface because it would take
   time
   //and this interface is obsolete.
   return;
}
```

```
int set_wd(char *inpstr)
{
   //Change working directory to simply key strokes
   int retval;
   int errnum;
   retval=chdir(word[1]);
   if(retval==-1)
   {
         errnum=errno;
         sprintf(text,"Cannot change to directory %s :
   %s\n",word[1],strerror(errnum));
         printf(text);
   }
   return retval;
}

int run_script(char *inpstr)
{
   //This is the smartest thing I did in the whole program.
   //Executes a script rather than requiring me to type in every single
   //command every time I need a new model run.
   FILE *fp;
   char *result;
   char *filename;
   int i;
   //Initialize some variables ...
   char line[500][ARR_SIZE+1];
   result=NULL;
   filename=NULL;
   for(i=0;i<500;++i)
   {
         line[i][0]='\0';
   }
   if(word_count<2)
   {
         printf("Usage: run <script_file>\n"); //Command was entered by
   itself. Remind user of usage.
         return -1;
   }
   filename=word[1];
   if(!(fp=fopen(filename,"r")))
   {
         //Error trap. Log and report error and return.
         sprintf(text,"ERROR: Couldn't open file %s in
   run_script",filename);
         write_syslog(text);
         printf(text);
         free(fp);
         return -1;
   }
   i=0;
   //Read in the script and store it in memory. I do this to avoid having
   //too many files open at any given time.
   result=fgets(line[i],ARR_SIZE,fp); // Read first line of the file.
   while(result!=NULL) // As long as  a new line is read, do the loop.
```

```
   {
         ++i;
         if(i>=500) break; //500 lines max. This is arbitrary.
         result=fgets(line[i],ARR_SIZE,fp);
   }
   fclose(fp); //Close script file.
   for(i=0;i<500;++i) // Loop through all the lines in the script.
   {
         if(line[i][0]=='\0') //If line is blank, we're done. Break out of
   loop/
               break;
         if(line[i][0]=='#') //Skip comments in the script.
               continue;
         strcpy(inpstr,line[i]); //Use global variable for input string.
         clear_words(); //Clear last command
         word_count=wordfind(inpstr); //Treat script line just like user
   input ... parsing ..
         exec_com(inpstr); // ... and executing ...
   } //Keep on looping until done.
   return 1; //Always return 1. I.E., ignore errors. That's what screen
   output and logs are for.
}

/* some basic routines called by main()*/
void prompt_user()
{
   printf("Command [help for help] >> ");
   //Just your basic prompt ... Separate function for standardization.
 }
void init_globals()
{
   //Called at the start of the program.
   clear_words();
   net_first=NULL;
   net_last=NULL;
   com_num=-1;
   dest_first=NULL;
   dest_last=NULL;
}
int wordfind(char *inpstr)
{
   //Parse input string.
   //Each seperate word is stored in global array word[]
   int wn,wpos;
   wn=0; wpos=0;
   do
   {
         while(*inpstr<33) if (!*inpstr++) //We're at the end of the input
   string.
               return wn; //Return the word count.

         while(*inpstr>32 && wpos<WORD_LEN-1)
         {
               //We have a non-space. Add the character to word[wn] and
   advance.
```

```
               word[wn][wpos]=*inpstr++;
               wpos++;
         }
         //Found a space, or another character that ends a word like a
   null character.
         word[wn][wpos]='\0'; //terminate the current word with a null
   character.
         wn++; //Start working on the next word.
         wpos=0; //Reset character pointer.
   } while (wn<MAX_WORDS);
   return wn-1; //Exceded Max_words. Trudge on with the words we were able
   to read
   // Note: We really should never get here.
}

void clear_words()
{
   //Reset all the command words in preparation for a new command.
   int w;

   for(w=0;w<MAX_WORDS;++w)
         word[w][0]='\0';

   word_count=0;
}

/*****************************************/
/********* Object Handling Routines *****/
/****************************************/
int create_node(NET_OBJECT net)
{
   //Allocate memory for the node, and initialize all values
   int i;
   NODE_OBJECT node;
   node=NULL;
   i=0;
   if ((node=(NODE_OBJECT)malloc(sizeof(struct node_struct)))==NULL)
   {
         write_syslog("ERROR: Memory allocation failure in
   create_node().\n");
         return -1;
   }
   node->x_coord=0;
   node->y_coord=0;
   for (i=0;i<MAX_LINKS;++i)
   {
         node->fstar[i]=NULL;
         node->bstar[i]=NULL;
   }
   node->old_id[0]='\0';
   for(i=0;i<MAX_LINKS;++i)
   {
         node->farc[i]=NULL;
         node->barc[i]=NULL;
   }
```

```
   node->scanned=0;
   node->next=NULL;
   node->cost=0;
   node->d=0;
   node->type[0]='\0';
   if((i=add_node_net(net,node))==-1)
   {
         sprintf(text,"Error in create_node: Node not added to network
   %s.\n",net->name);
         write_syslog(text);
         node->net=NULL;
         return -1;
   }
   node->nth=0;
   return i;
}

NODE_OBJECT get_node(NET_OBJECT net, char *type, char *old_id)
{
   //Find a node and return it.
   //Search based on the type of node and its ID.
   //No sorting ... could be faster, but even with a few thousand nodes,
   we're okay.
   int i;
   for(i=0;i<MAX_NODES;++i)
   {
         if(net->node[i]==NULL)
         {
               return NULL; //We're out of nodes ... No matches.
         }
         if(!strcmp(net->node[i]->type,type))
         {
               if(!strcmp(net->node[i]->old_id,old_id))
               {
                     return net->node[i]; //Type and id both match. Return
   node.
               }
         }
   }
   return NULL;
}
ARC_OBJECT get_arc(NET_OBJECT net, NODE_OBJECT node1, NODE_OBJECT node2)
{
   //Find an arc and return it.
   //Search based on the two nodes at either end.
   ARC_OBJECT arc;
   int i;
   int j;
   i=0;j=0;
   arc=NULL;
   for(i=0;i<MAX_ARCS;++i)
   {
         if(net->arc[i]==NULL)
         {
               return NULL; //We're out of arcs. Return NULL.
```

```
		}
		arc=net->arc[i];
		if(arc->to_node==node1 || arc->to_node==node2)
		{
			if(arc->from_node==node2 || arc->from_node==node1)
			{
				return arc; //Arc matching both nodes found. Return
	it.
			}
		}
	}
	return NULL;
}

ARC_OBJECT get_rail_arc(NET_OBJECT net, NODE_OBJECT node1, NODE_OBJECT
	node2)
{
	//Same as get_arc, but specifically for rail arcs.
	//This function is never called, but was part of an earlier
	implimentation
	ARC_OBJECT arc;
	int i;
	int j;
	i=0;j=0;
	arc=NULL;
	for(i=0;i<MAX_ARCS;++i)
	{
		if(net->arc[i]==NULL)
		{
			return NULL;
		}
		if(strcmp(net->arc[i]->type,"rail"))
			continue;
		arc=net->arc[i];
		if(arc->to_node==node1 || arc->to_node==node2)
		{
			if(arc->from_node==node2 || arc->from_node==node1)
			{
				return arc;
			}
		}
	}
	return NULL;
}
DEST_OBJECT get_dest(char *id)
{
	//A destination is a special kind of node.
	//Search based on ID.
	DEST_OBJECT dest;
	dest=NULL;
	for(dest=dest_first;dest!=NULL;dest=dest->next)
	{
		if(!strcmp(dest->node->old_id,id))
		{
			return dest; //Found a match. Return it.
```

```
         }
   }
   return NULL; // No match found. Return NULL.
}
NET_OBJECT create_net()
{
   //Create a network. Allocate memory and initialize values.
   //A network is a container for all the other object types.
   NET_OBJECT net;
   int i;
   if ((net=(NET_OBJECT)malloc(sizeof(struct net_struct)))==NULL)
   {
         write_syslog("ERROR: Memory allocation failure in
   create_net().\n");
         return NULL;
   }

   /* Append object into linked list. */
   if (net_first==NULL)
   {
         net_first=net;  net->prev=NULL;
   }
   else
   {
         net_last->next=net;  net->prev=net_last;
   }
   net->next=NULL;
   net_last=net;
   for(i=0;i<MAX_NODES;++i)
   {
         net->node[i]=NULL;
         net->htn[i]=0;
   }
   net->dest=NULL;
   for(i=0;i<MAX_ARCS;++i)
   {
         net->arc[i]=NULL;
   }
   net->name[0]='\0';
   return net;
}
void destruct_net(NET_OBJECT net)
{
   //Destroy the network. Free all memory allocated to the network and
   adjust pointers.
   if(net==net_first)
   {
         net_first=net->next;
         if (net==net_last) net_last=NULL;
         else net_first->prev=NULL;
   }
   else
   {
         net->prev->next=net->next;
         if (net==net_last)
```

```
        {
              net_last=net->prev;
              net_last->next=NULL;
        }
        else
              net->next->prev=net->prev;
   }
   free(net);
}
int create_arc(NET_OBJECT net, NODE_OBJECT node1, NODE_OBJECT node2)
{
   //Create an arc between two nodes. Allocate memory and intialize
   variables.
   ARC_OBJECT arc;
   int i;
   arc=NULL;
   i=0;
   if ((arc=(ARC_OBJECT)malloc(sizeof(struct arc_struct)))==NULL)
   {
         write_syslog("ERROR: Memory allocation failure in
   create_arc().\n");
         printf(text);
         return -1;
   }
   arc->from_node=node1;
   arc->to_node=node2;
   arc->old_id[0]='\0';
   arc->load=0;
   arc->len=0;
   arc->type[0]='\0';
   for(i=0;i<MAX_LINKS;++i)
   {
         arc->farc[i]=NULL;
         arc->barc[i]=NULL;
   }
   if((i=add_arc_net(net,arc))==-1)
   {
         sprintf(text,"Error: Maximum number of arcs exceeded. Arc not
   added to network %s\n",net->name);
         printf(text);
         write_syslog(text);
         arc->net=NULL;
         return -1;
   }
   arc->net=net;
   return i;
}

DEST_OBJECT create_dest(NODE_OBJECT node)
{
   //Create a destination, which is a special kind of node.
   DEST_OBJECT dest;
   int i;
   if ((dest=(DEST_OBJECT)malloc(sizeof(struct dest_struct)))==NULL)
   {
```

```
        write_syslog("ERROR: Memory allocation failure in
   create_dest().\n");
        return NULL;
   }

   /* Append object into linked list. */
   if (dest_first==NULL)
   {
        dest_first=dest;  dest->prev=NULL;
   }
   else
   {
        dest_last->next=dest;  dest->prev=dest_last;
   }
   dest->next=NULL;
   dest_last=dest;
   dest->node=node;
   dest->dist_driven=0;
   for(i=0;i<(MAX_NODES*MODES);++i)
   {
        dest->orig_id[i][0]='\0';
        dest->type[i][0]='\0';
        dest->commuters[i]=0;
        dest->dist_driven_by_origin[i]=0;
   }
   return dest;
}

NET_OBJECT get_net(char *the_word)
{
   //Find a network based on the network name.
   NET_OBJECT net;
   net=NULL;
   for(net=net_first;net!=NULL;net=net->next)
   {
        if(!strcmp(the_word,net->name))
        {
             return net; // Match found.
        }
   }
   return NULL; //No match found.
}

/*object insertion routines*/
int add_node_net(NET_OBJECT net, NODE_OBJECT node)
{
   //Add a node to a network.
   //The node must be created first (see create_node)
   int i;
   int flag;
   flag=0;
   i=0;
   for(i=0; i<MAX_NODES; ++i)
   {
        if(net->node[i]==NULL)
```

```
            {
                  //find the first NULL spot in the array, then insert node.
                  net->node[i]=node;
                  node->net=net;
                  flag=1;
                  break;
            }
      }
      if(!flag)
      {
            write_syslog("Error in add_node_net: Number of maximum nodes
      exceeded.");
            return -1;
      }
      return i;
   }
   int add_arc_net(NET_OBJECT net, ARC_OBJECT arc)
   {
      //Add an arc to the net.
      //The arc must already be created.
      int i;
      int flag;
      flag=0;
      i=0;
      for(i=0; i<MAX_ARCS; ++i)
      {
            if(net->arc[i]==NULL)
            {
                  //Find the first NULL spot, then insert the arc.
                  net->arc[i]=arc;
                  arc->net=net;
                  flag=1;
                  break;
            }
      }
      if(!flag)
      {
            write_syslog("Error in add_node_net: Number of maximum nodes
      exceeded.");
            return -1;
      }
      return i;
   }
   int load_nodes(char *inpstr)
   {
      //Load a set of nodes from a file.
      NET_OBJECT net;
      DEST_OBJECT dest;
      char filename[WORD_LEN];
      FILE *fp;
      int i;
      char *result;
      char line[ARR_SIZE+1];
      fp=NULL;
      line[0]='\0';
```

```
net=NULL;
dest=NULL;
result=NULL;
i=0;
if(word_count<3)
{
      //Error trap. If word count doesn't match requirements, show user
how to use the command.
      printf("Usage: loadnodes <network> <filename>\n");
      free(fp);
      return -1;
}
if((net=get_net(word[1]))==NULL)
{
      //Another error trap.
      sprintf(text,"Network \"%s\" does not exist.\n",word[1]);
      printf(text);
      free(fp);
      return -1;
}
strcpy(filename,word[2]);
if(!(fp=fopen(filename,"r")))
{
      //Yet another error trap.
      sprintf(text,"ERROR: Couldn't open file %s in
load_nodes\n",filename);
      write_syslog(text);
      printf(text);
      free(fp);
      return -1;
}
result=fgets(line,ARR_SIZE,fp); //Read first line
while(result!=NULL)
{
      i=create_node(net); //Create a new node.
      if(i==-1)
      {
            //Ooops -- couldn't creat the node for some reason.
            sprintf(text,"ERROR load_nodes(net): Node not properly
created for net %s. Failed at line %s in file %s.\n",net-
>name,line,filename);
            printf(text);
            write_syslog(text);
            return -1;
      }
      sprintf(text,"%d %d %s %s \r",net->node[i]->x_coord,net->node[i]-
>y_coord,net->node[i]->type,net->node[i]->old_id);
      printf(text);
      sscanf(line,"%d\t%d\t%s\t%s",&net->node[i]->x_coord,&net-
>node[i]->y_coord,net->node[i]->type,net->node[i]->old_id);
      //Get data from line and write it to the node's attribute
variables.
      net->node[i]->type[0]=tolower(net->node[i]->type[0]); //set node
type to lower case.
      if(!strcmp(net->node[i]->type,"dest"))
```

```
         {
               //This is a destination. Create a new dest object.
               if((dest=create_dest(net->node[i]))==NULL)
               {
                     sprintf(text,"Error creating destination for node %s
   %s\n",net->node[i]->type, net->node[i]->old_id);
                     printf(text);
               }
               else
               {
                     sprintf(text,"Created node %s %s as a
   destination.\n",dest->node->type,dest->node->old_id);
                     printf(text);
               }
         }
         result=fgets(line,ARR_SIZE,fp); //get next line
   }
   fclose(fp); //Done. Close file.
   return 1;
}

int load_arcs (char *inpstr)
{
   //Load arcs from file.
   NET_OBJECT net;
   NODE_OBJECT node1,node2;
   char filename[WORD_LEN+1];
   char fnode_temp[50],tnode_temp[50],id_temp[50];
   FILE *fp;
   int i,len_temp,j;
   char line[ARR_SIZE+1], type[ARR_SIZE+1];
   char *result;
   result=NULL;
   fp=NULL;
   line[0]='\0';
   type[0]='\0';
   fnode_temp[0]='\0';
   tnode_temp[0]='\0';
   id_temp[0]='\0';
   len_temp=0;
   j=0;
   net=NULL;
   node1=NULL;
   node2=NULL;
   i=0;
   if(word_count<4)
   {
         //If word count is less than expected, show the user how to use
   the command.
         printf("Usage: loadarcs <network> <type> <filename>\n");
         free(fp);
         return -1;
   }
   if((net=get_net(word[1]))==NULL)
   {
```

```
      //Error trap.
      sprintf(text,"Network \"%s\" does not exist.\n",word[1]);
      printf(text);
      free(fp);
      return -1;
}
strcpy(type,word[2]);
strcpy(filename,word[3]);
if(!(fp=fopen(filename,"r")))
{
      //Another error trap.
      sprintf(text,"ERROR: Couldn't open file %s in
load_arcs\n",filename);
      write_syslog(text);
      printf(text);
      free(fp);
      return -1;
}
result=fgets(line,ARR_SIZE,fp); //Get first line.
while(result!=NULL)
{

      sscanf(line,"%s\t%s\t%d\t%s",fnode_temp,tnode_temp,&len_temp,id_t
emp); //Get data from line.
      if((node1=get_node(net,type,fnode_temp))==NULL)
      {
            //Error trap -- Nonexitant node.
            sprintf(text,"ERROR: couldn't find node of type %s with id
%s in load_arcs.\n",type,fnode_temp);
            printf(text);
            write_syslog(text);
            result=fgets(line,ARR_SIZE,fp);
            continue;
      }
      if((node2=get_node(net,type,tnode_temp))==NULL)
      {
            //Same error trap for node2.
            sprintf(text,"ERROR: couldn't find node of type %s with id
%s in load_arcs.\n",type,tnode_temp);
            printf(text);
            write_syslog(text);
            result=fgets(line,ARR_SIZE,fp);
            continue;
      }
      if((i=create_arc(net,node1,node2))==-1) //Create the arc, and if
there's a problem, trap it.
      {
            sprintf(text,"ERROR: Problem occured when trying to create
arc.\n");
            printf(text);
            write_syslog(text);
            result=fgets(line,ARR_SIZE,fp);
            continue; //But don't let one bad arc ruin it for everyone.
      }
      j=0;
```

```
         //Okay. Now elaborate on the relationship between the nodes ...
         while(node1->fstar[j]!=NULL)
         {
               ++j;
         }
         node1->fstar[j]=node2;
         node1->bstar[j]=node2; //Create pointers in both directions. All
   arcs are two-way.
         node1->farc[j]=net->arc[i];
         node1->barc[j]=net->arc[i]; //Do pointers in both directions for
   arcs, too.
         j=0;
         while(node2->fstar[j]!=NULL)
         {
               ++j;
         }
         node2->fstar[j]=node1;
         node2->bstar[j]=node1; //Again, two-way pointers.
         node2->barc[j]=net->arc[i];
         node2->farc[j]=net->arc[i]; //Once more .. two-way pointers.
         net->arc[i]->len=len_temp; //Assign length to arc.
         strcpy(net->arc[i]->old_id,id_temp); //Assign id.
         strcpy(net->arc[i]->type,type); //Assign type.
         result=fgets(line,ARR_SIZE,fp); //Next line, please.
   }
   fclose(fp);
   return 1; //Done.
}

int make_net(char *inpstr)
{
   //User command to create a new network.
   NET_OBJECT net;
   net=NULL;
   if(word_count <2)
   {
         printf("Usage: createnet <name>\n");
         return -1;
   }
   if((net=get_net(word[1]))!=NULL)
   {
         //Only one network per unique name.
         sprintf(text,"Network %s alread exists.\n",net->name);
         printf(text);
         sprintf(text,"ERROR: network %s already exists in
   make_net.\n",net->name);
         write_syslog(text);
         return -1;
   }
   if((net=create_net())==NULL)
   {
         //Problem creating net. Report the problem.
         sprintf(text,"Error: create_net returned a NULL net\n");
         printf(text);
         return -1;
```

```
   }
   strcpy(net->name,word[1]); //Set the network's name.
   return 1;
}
int link_nodes(char *inpstr)
{
   // User command for linking two nodes that don't already have an arc
   connecting them.
   // This would be used to link road and rail networks, for instance.
   // It's not really useful in the current implimentation.
   char type1[50],type2[50];
   int dist,c_dist;
   NET_OBJECT net;
   NODE_OBJECT node1,node2;
   int i,j,k,cnt;
   i=0;j=0;k=0;cnt=0;c_dist=0;
   net=NULL;
   node1=NULL;
   node2=NULL;
   dist=0;
   type1[0]='\0';
   type2[0]='\0';
   if(word_count<4)
   {
         //Make sure input string is valid ...
         printf("Usage: linknodes <net> <type1> <type2> {distance}\n");
         return -1;
   }
   if(word_count==5)
   {
         //If optional value distance was provided, collect the data.
         //dist is the search radius. If the nodes are further appart than
   this,
         //we don't create the link.
         sscanf(word[4],"%d",&dist);
   }
   else
   {
         dist=999999; //Otherwise, set the search radius really really
   high.
   }
   if((net=get_net(word[1]))==NULL)
   {
         //Error trap
         sprintf(text,"ERROR: Net %s does not exist in
   link_nodes\n",word[1]);
         write_syslog(text);
         printf(text);
         return -1;
   }
   strcpy(type1,word[2]);
   strcpy(type2,word[3]);
   for(i=0;i<MAX_NODES;++i) //Loop through all the nodes.
   {
         if(net->node[i]==NULL)
```

```
	{
		if(i==0)
		{
			sprintf(text,"ERROR: No nodes exist for net %s in
link_nodes\n.",net->name);
			write_syslog(text);
			printf(text);
			return -1;
		}
		printf("\n\nEnd of node list reached.\n");
		sprintf(text,"Created %d new arcs.\n",cnt);
		printf(text);
		return 1;
	}
	if(strcmp(type1,net->node[i]->type))
	{
		continue;
	}
	node1=net->node[i];
	if((node2=find_nearest(node1,type2,dist))==NULL)
	{
		sprintf(text,"No match found for node %s %s within distance
of %d.\r",node1->type,node1->old_id,dist);
		printf(text);
		continue;
	}
	//If we got this far, create the link.
	if((j=create_arc(net,node1,node2))==-1)
	{
		sprintf(text,"ERROR: Problem occured when trying to create
arc.\n");
		printf(text);
		write_syslog(text);
		continue;
	}
	c_dist=(int)calc_dist(node1,node2);
	k=0;
	while(node1->fstar[k]!=NULL)
	{
		++k;
	}
	node1->fstar[k]=node2;
	node1->bstar[k]=node2;
	node1->farc[k]=net->arc[j];
	node1->barc[k]=net->arc[j];
	k=0;
	while(node2->fstar[k]!=NULL)
	{
		++k;
	}
	node2->fstar[k]=node1;
	node2->bstar[k]=node1;
	node2->barc[k]=net->arc[j];
	node2->farc[k]=net->arc[j];
	net->arc[j]->len=c_dist;
```

```
		sprintf(net->arc[j]->old_id,"%d",j);
		strcpy(net->arc[j]->type,"link");
		sprintf(text,"Linked nodes %s %s and %s %s to create %s arc %d
	with length of %d.\n",node1->type,node1->old_id,node2->type,node2-
	>old_id,net->name,j,net->arc[j]->len);
		printf(text);
		++cnt;
	}
	printf("\n\nMax number of nodes reached.\n");
	sprintf(text,"Created %d new arcs.\n",cnt);
	printf(text);
	return 1;

}
int add_link(char *inpstr)
{
	//Manually insert a link between two specific nodes.
	//This is really useful for inserting bridges or other missing arcs
	into your data.
	//Much faster and easier than using ESRI products, and can be called
	from a script
	//to make sure the links are added every time.
	char type1[50],type2[50];
	char id1[50],id2[50];
	int dist,c_dist;
	NET_OBJECT net;
	NODE_OBJECT node1,node2;
	int i,j,k,cnt;
	i=0;j=0;k=0;cnt=0;
	net=NULL;
	node1=NULL;
	node2=NULL;
	dist=0;c_dist=0;
	type1[0]='\0';
	type2[0]='\0';
	id1[0]='\0';
	id2[0]='\0';
	if(word_count<6)
	{
		//Standard usage trap ...
		printf("Usage: addlink <net> <type1> <id1> <type2> <id2>\n");
		return -1;
	}
	if((net=get_net(word[1]))==NULL)
	{
		//Error trap ...
		sprintf(text,"ERROR: Net %s does not exist in
	add_link\n",word[1]);
		printf(text);
		return -1;
	}
	//Set local variables, and find the nodes we're interested in ...
	strcpy(type1,word[2]);
	strcpy(type2,word[4]);
	strcpy(id1,word[3]);
```

```
strcpy(id2,word[5]);
if((node1=get_node(net,type1,id1))==NULL)
{
      sprintf(text,"No match found for node %s %s \n",type1,id1);
      printf(text);
      return -1;
};
if((node2=get_node(net,type2,id2))==NULL)
{
      sprintf(text,"No match found for node %s %s \n",type2,id2);
      printf(text);
      return -1;
}
if((j=create_arc(net,node1,node2))==-1) //Create the arc ...
{
      sprintf(text,"ERROR: Problem occured when trying to create
arc.\n");
      printf(text);
      write_syslog(text);
      return -1;
}
c_dist=calc_dist(node1,node2); //Calcuate the distance between the
nodes.
//Set attribute variables of new arc, and relate the nodes to each
other ...
k=0;
while(node1->fstar[k]!=NULL)
{
      ++k;
}
node1->fstar[k]=node2;
node1->bstar[k]=node2;
node1->farc[k]=net->arc[j];
node1->barc[k]=net->arc[j];
k=0;
while(node2->fstar[k]!=NULL)
{
      ++k;
}
node2->fstar[k]=node1;
node2->bstar[k]=node1;
node2->barc[k]=net->arc[j];
node2->farc[k]=net->arc[j];
net->arc[j]->len=c_dist;
sprintf(net->arc[j]->old_id,"%d",j);
if(strcmp(type1,type2))
{
      strcpy(net->arc[j]->type,"link");
}
else
{
      strcpy(net->arc[j]->type,type1);
}
```

```
   sprintf(text,"Linked nodes %s %s and %s %s to create %s arc %d with
   length of %d.\n",node1->type,node1->old_id,node2->type,node2-
   >old_id,net->name,j,net->arc[j]->len);
   printf(text);
   ++cnt;
   sprintf(text,"Created %d new arcs.\n",cnt);
   printf(text);
   return 1;

}

NODE_OBJECT find_nearest(NODE_OBJECT node1, char *type, int dist)
{
   //Find the nearest node. Used in link functions.
   NODE_OBJECT node2;
   NET_OBJECT net;
   int i;
   int c_dist,temp_dist;
   net=node1->net;
   node2=0;
   i=0;
   c_dist=0;
   temp_dist=999999;
   for(i=0;i<MAX_NODES;++i) //loop through all nodes.
   {
         if(net->node[i]==NULL)
         {
               break;
         }
         if(strcmp(net->node[i]->type,type))
         {
               continue;
         }
         c_dist=calc_dist(node1,net->node[i]); //Calculate distance
   between node1 and current loop node.
         if((temp_dist>c_dist) && (c_dist<=dist))
         {
               //If the distance is shorter than the shortest so far,
               //and if the distance is inside the set search radius
   (dist),
               //set the pointer to the loop node.
               temp_dist=c_dist;
               node2=net->node[i];
         }
   }
   if(node2==NULL)
   {
         return NULL; //there doesn't appear to be a nearest node within
   the search radius.
   }
   return node2; //There's a match. Return it.
}
int calc_dist(NODE_OBJECT node1, NODE_OBJECT node2)
{
   //Simple distance calculator.
```

```
   double d_dist;
   double x;
   double y;
   int dist;
   x=(double)((double)node1->x_coord-(double)node2->x_coord);
   y=(double)((double)node1->y_coord-(double)node2->y_coord);
   d_dist=hypot(x,y);
   dist=(double)(1.22*d_dist); /*circuity factor*/
   return dist;
}
int load_od(char *inpstr)
{
   //Load origin-destination data.
   NET_OBJECT net;
   DEST_OBJECT dest;
   char line[ARR_SIZE], *result;
   FILE *fp;
   int i, cnt;
   char type[50];
   char desttemp[50];
   char origtemp[50];
   char dummy[50];
   int commuterstemp;
   type[0]='\0';
   i=0;cnt=0;
   net=NULL;
   dest=NULL;
   dummy[0]='\0';
   if(word_count<4)
   {
         //Standard usage trap ...
         printf("Usage: loadod <net> <type> <filename>\n");
         return -1;
   }
   strcpy(type,word[2]);
   if((net=get_net(word[1]))==NULL)
   {
         //Error trap ...
         sprintf(text,"Network %s doesn't exist.\n",word[1]);
         printf(text);
         return -1;
   }
   if (!(fp=fopen(word[3],"r")))
   {
         //Error trap ...
         sprintf(text,"Couldn't open file %s\n",word[3]);
         printf(text);
         return -1;
   }
   result=fgets(line,ARR_SIZE,fp);     /*discard header line*/
   result=fgets(line,ARR_SIZE,fp); //Get first line ...
   while(result!=NULL)
   {
         i=0;
```

```
         sscanf(line,"%s\t%s\t%d\n",desttemp,origtemp,&commuterstemp);
   //Get data from line.
         if ((dest=get_dest(desttemp))==NULL)
         {
               //o-d data needs to be assigned to origins and
   destinations. If they don't exist,
               //report the error.
               sprintf(text,"Destination %s doesn't exist.\n",desttemp);
               printf(text);
               result=fgets(line,ARR_SIZE,fp); //Get next line and move
   on.
               continue; //Don't let one bad entry ruin the whole job.
         }
         while(dest->orig_id[i][0]!='\0')
         {
               ++i; //Find the next available slot in the destination's
   origin table ...
         }
         if(i>=(MAX_NODES*MODES))
         {
               printf("Max number of origins exceeded \n");
               result=fgets(line,ARR_SIZE,fp); //Read next line and move
   on
               continue; //One bad entry doesn't ruin the whole batch.
         }
         strcpy(dest->orig_id[i],origtemp); //Record the data for this
   origin table entry.
         dest->commuters[i]=commuterstemp;
         strcpy(dest->type[i],type);
         ++i;
         ++cnt;
         result=fgets(line,ARR_SIZE,fp); //Get next line.
         sprintf(text,"Got data for dest %s from %s orig %s: %d -- i=%d
   \n",dest->node->old_id,dest->type[i-1],dest->orig_id[i-1],dest-
   >commuters[i-1],i-1);
         write_syslog(text); //Debugging tool.
   }
   fclose(fp); //done. Close file.
   return 1;

}



int summarize_net(char *inpstr)
{
   //Dump the data stored in the network into a series of files.
   NET_OBJECT net;
   ARC_OBJECT arc;
   DEST_OBJECT dest;
   NODE_OBJECT tempnode;
   NODE_OBJECT origin[1400];
   int orig_dist[1400];
   char filename[80];
   char temp[10];
```

```
FILE *fp;
FILE *fq;
FILE *fr;
int i,j;
net=NULL;
arc=NULL;
dest=NULL;
tempnode=NULL;
fq=NULL;
i=j=0;
filename[0]='\0';
temp[0]='\0';
if(word_count<2)
{
      printf("Usage: sum <net>\n");
      return -1;
}
if((net=get_net(word[1]))==NULL)
{
      printf("Network %s does not exist.\n",word[1]);
      return -1;
}
for (i=0;i<1400;++i)
{
      origin[i]=NULL;
      orig_dist[i]=0;
}
for(i=0;i<1400;++i)
{
      sprintf(temp,"%d",i);
      origin[i]=get_node(net,"origin",temp);
}
printf("Got network.\n");
//Dump all load data from rail arcs (file isn't useful in current
implimentation)
if(!(fp=fopen("railout.txt","w")))
{
      fprintf(stdout,"Couldn't open rail out file.\n");
      free(fp);
      return -1;
}
fprintf(fp,"rail_id\ttype\tload\n");
for(i=0;i<MAX_ARCS;++i)
{
      if(net->arc[i]==NULL)
      {
            break;
      }
      arc=net->arc[i];
      if(!strcmp(arc->type,"rail"))
      {
            fprintf(fp,"%s\t%s\t%d\n",arc->old_id,arc->type,arc->load);
      }

}
```

```
fclose(fp);
//Dump all load data from the road arcs. Very useful for checking the
validity of the model run
//and for finding gaps in the transportation network.
if(!(fp=fopen("roadout.txt","w")))
{
      fprintf(stdout,"Couldn't open road out file.\n");
      return -1;
}
fprintf(fp,"road_id\tload\n");
for(i=0;i<MAX_ARCS;++i)
{
      if(net->arc[i]==NULL)
      {
            break;
      }
      arc=net->arc[i];
      if(strcmp(arc->type,"road"))
      {
            continue;
      }
      fprintf(fp,"%s\t%d\n",arc->old_id,arc->load);
}
fclose(fp);
//Dump loads on all of the links. Not really useful, but the data exist
and disk space is cheap.
if(!(fp=fopen("linkout.txt","w")))
{
      fprintf(stdout,"Couldn't open link out file.\n");
      return -1;
}
fprintf(fp,"link_id\tload\n");
for(i=0;i<MAX_ARCS;++i)
{
      if(net->arc[i]==NULL)
      {
            break;
      }
      arc=net->arc[i];
      if(strcmp(arc->type,"link"))
      {
            continue;
      }
      fprintf(fp,"%s\t%d\n",arc->old_id,arc->load);
}
fclose(fp);
//Here's the money table. This shows the total distance driven by all
commuters between each
//destination and origin.
if(!(fp=fopen("o-d-dist.txt","w")))
{
      fprintf(stdout,"Couldn't open origin-destination distance
matrix");
      return -1;
}
```

```
//This one is just repackaging the origin-destination table (number of
commuters),
//but this is critical because we need all the tables in the same
format for the sum_table function.
if(!(fr=fopen("o-d-comm.txt","w")))
{
      fprintf(stdout,"Couldn't open origin-destination commuter
matrix");
      return -1;
}
//create header rows in both tables ... First, the Dest column name,
then a column for each origin.
fprintf(fr,"Dest");
for(i=1;i<MAX_NODES;++i)
{
      sprintf(temp,"%d",i);
      if(!(tempnode=get_node(net,"origin",temp)))
      {
            continue;
      }
      fprintf(fp,",%s",temp);
      fprintf(fr,",%s",temp);
}
fprintf(fp,"\n");
fprintf(fr,"\n");
fclose(fp);
fclose(fr);
//Done with header rows – Data is dumped during the construction of
//next table...
//Next, the "destsum" table .. This shows total distance driven for
each destination.
//This data is used to create the map of total emissions by destination
(work place).
if(!(fq=fopen("destsum.txt","w")))
{
      fprintf(stdout,"Couldn't open dest summary\n");
      return -1;
}
fprintf(fq,"Dest,Distance\n"); //Header row
for(dest=dest_first;dest!=NULL;dest=dest->next) //Loop through each
destination.
{
      fprintf(fq,"%s,%d\n",dest->node->old_id,dest->dist_driven);
      if(!(fp=fopen("o-d-dist.txt","a")))
      {
            fprintf(stdout,"Couldn't open origin-destination distance
matrix to append.\n");
            return -1;
      }
      if(!(fr=fopen("o-d-comm.txt","a")))
      {
            fprintf(stdout,"Couldn't open origin-destination commuter
matrix to append.\n");
            return -1;
      }
```

```
      fprintf(fp,"%s",dest->node->old_id); //First column in each row
is the dest id.
      fprintf(fr,"%s",dest->node->old_id); //First column in each row
is the dest id.
      for(i=1;i<1400;++i)
      {
            //Find the next origin.
            sprintf(temp,"%d",i);
            if(!(tempnode=get_node(net,"origin",temp)))
            {
                  continue;
            }
            //There *has* to be a faster way. Cycle through all origins
            //for a destination and get a match.
            //If no match, write a 0 (no traffic), else write distance
            //driven.
            //There is no match if (1) we reach the end of the array of
            //origins, or (2) For the given dest,
            //we hit the terminating NULL value.
            for(j=0;j<MAX_NODES*MODES;++j)
            {
                  if(dest->orig_id[j][0]=='\0')
                  {
                        fprintf(fp,",0");
                        fprintf(fr,",0");
                        break;
                  }
                  if(!strcmp(dest->orig_id[j],tempnode->old_id)) //if
origin id's match, write values
                  {
                        fprintf(fp,",%d",dest-
>dist_driven_by_origin[j]);
                        fprintf(fr,",%d",dest->commuters[j]);
                        if(origin[i]!=NULL && !strcmp(origin[i]-
>old_id,temp))
                        {
                              orig_dist[i]=orig_dist[i]+dest-
>dist_driven_by_origin[j];
                        }
                        break;
                  }
            }
            if(j==MAX_NODES*MODES)
            {
                  //if no matches, write 0.
                  fprintf(fp,",0");
                  fprintf(fr,",0");
            }

      }
      fprintf(fp,"\n");
      //Done with this destination. End both rows with a return char.
      fprintf(fr,"\n");
      fclose(fp);
      fclose(fr);
```

```
      sprintf(text,"Done dumping all origins for destination
%s.\r",dest->node->old_id);
      printf(text);
}
fclose(fq); //Done with all destinations. Close the destination summary
file.
if(!(fp=fopen("orig-dist.txt","w"))) //Now we do the origin summary
table.
{
      fprintf(stdout,"Can't open orig-dist.txt for writing.\n");
      return -1;
}
fprintf(fp,"Origin,Distance\n"); //Header row
for(i=0;i<1400;++i)
{
      if(origin[i]!=NULL)
      {
            fprintf(fp,"%s,%d\n",origin[i]->old_id,orig_dist[i]);
//Nice and simple ...
      }
}
return 1;
//Done dumping all data!!!
}

int sum_dist_table(char *inpstr)
{
   //sum_net dumps a lot of data, and it can't all be read or interpretted
   very easily.
   //Most importantly, the origin-destination table and its corresponding
   distance table
   //contain way too much detail. This function adds specified rows or
   columns together,
   //and creates a 2-column (or row) table that contains the sums.
   //int m[1450][1400];
   COL_OBJECT col[MATRIX_COLS];
   int ms[MATRIX_COLS];
   int wn,wpos;
   char *result;
   //char colname[1450][10];
   char rowname[MATRIX_ROWS][15];
   char headname[MATRIX_COLS][15];
   char lineword[MATRIX_COLS][15];
   char line[(MATRIX_COLS*15)+2];
   char readmask[(MATRIX_COLS*15)+2];
   char *str;
   int sumflag,outflag,delimiter,colcount,rowcount;
   int headptr[MATRIX_COLS];
   int i,j,k,z;
   FILE *fp;
   printf("Initializing .... \n");
   i=j=sumflag=outflag=delimiter=colcount=rowcount=k=0;
   result=NULL;
   line[0]='\0';
   //This is a work around for the maximum array size problem.
```

```
//Rather than represent the matrix as a 2-dimmensional array,
//We create an array of columns. Each column has a number of rows.
//The number of each is set using MATRIX_ROWS and MATRIX_COLS.
//This permits us to have much bigger o-d tables than a 2-dimmensional
//array would allow.
for(i=0;i<5000;++i)
{
      if((col[i]=(COL_OBJECT)malloc(sizeof(struct
collumn_struct)))==NULL)
      {
            fprintf(stdout,"Failed to allocate memory for collumn
%d.\n",i);
            return -1;
      }
}
z=0;
for (i=0;i<MATRIX_COLS;++i)
{
      ms[i]=0;
      col[i]->name[0]='\0';
      rowname[i][0]='\0';
      headname[i][0]='\0';
      for (j=0;j<MATRIX_ROWS;++j)
      {
            //fprintf(stdout,"i=%d ; j=%d
\r",i,j);
            col[i]->row[j]=0;
            //col[i]->name[0]='\0';
      }
      fprintf(stdout,"Initializing: %d
%s\r",(int)((i/MATRIX_COLS)*100),"%");
      if(z==0)
            ++z;
      else
            z=0;

}
if(word_count<5 || word_count>6)
{
      printf("ER1 Usage: sumtab filename <rows|cols>
<headname1,headname2,...,headnameX> <outfile> {outcols|outrows}\n");
      for(z=0;z<5000;++z)
      {
            free(col[z]); //There's a lot of memory being used here ...
make sure to free it when returning!
      }
      return -1;
}
//The next bit figures out whether we're summing rows or columns,
//and whether the output should be written in rows or columns.
//All conceivable combinations are possible (e.g. summing rows and
writing the data out in columns).
if(strcmp(word[2],"rows"))
{
      if(strcmp(word[2],"cols"))
```

```
      {
            printf("ER2 Usage: sumtab filename <rows|cols>
<headname1,headname2,...,headnameX> <outfile> {outcols|outrows}\n");
            for(z=0;z<5000;++z)
            {
                  free(col[z]); //Free the used memory.
            }
            return -1;
      }
      sumflag=COLS;
}
else
{
      sumflag=ROWS;
}
if(word_count<6)
{
      outflag=COLS;
}
else
{
      if(strcmp(word[5],"outrows"))
      {
            if(strcmp(word[5],"outcols"))
            {
                  printf("ER3 Usage: sumtab filename <rows|cols>
<headname1,headname2,...,headnameX> <outfile> {outcols|outrows}\n");
                  for(z=0;z<5000;++z)
                  {
                        free(col[z]);
                  }
                  return -1;
            }
            outflag=COLS;
      }
      else
      {
            outflag=ROWS;
      }
}
//If we've gotten this far, we know how to read and write the data.
if(!(fp=fopen(word[1],"r")))
{
      //Ooops. Bad file name ...
      fprintf(stdout,"Couldn't open file %s.\n",word[1]);
      for(z=0;z<5000;++z)
      {
            free(col[z]);
      }
      return -1;
}
result=fgets(line,5000*12,fp); //Get the header line.
line[strlen(line)-1]=0; //Terminate line string with a null character.
// I got tired of always having to have a specific delimiter,
// so this allows me to read in space, comma, and tab - delimited files
```

```
// and does so in a way that automatically detects the delimiter.
for(i=0;i<strlen(line);++i)
{
      if(line[i]==' ')
      {
            delimiter=SPACE;
            break;
      }
      if(line[i]==',')
      {
            delimiter=COMMA;
            break;
      }
      if(line[i]=='\t')
      {
            delimiter=TAB;
            break;
      }
}
// Count the number of collumns
switch(delimiter)
{
      case TAB:
            for(i=0;i<strlen(line);++i)
            {
                  if(line[i]=='\t')
                  {
                        ++colcount;
                  }
            }
            break;
      case SPACE:
            for(i=0;i<strlen(line);++i)
            {
                  if(line[i]==' ')
                  {
                        ++colcount;
                  }
            }
            break;
      case COMMA:
            for(i=0;i<strlen(line);++i)
            {
                  if(line[i]==',')
                  {
                        ++colcount;
                  }
            }
            break;
      default:
            printf("Yikes. Invalid delimter type. The file needs to be
plain text, delimited by either spaces, commas, or tabs.\nBailing out
of sum_dist_table\n");
            for(z=0;z<5000;++z)
            {
```

```
                  free(col[z]);
            }
            return -1;
}
//Tell the user how many columns and how they're delimited, just so he
knows you know what you're doing ...
fprintf(stdout,"The file %s contains %d %s - delimted
columns.\n",word[1],colcount,delimtype[delimiter]);
//Read each line, header first
printf("Entering loop ...\n"); //Nice to know ...
i=0;
while(result!=NULL)
{
      wn=0; wpos=0;
      str=line;
      for(j=0;j<MATRIX_COLS;++j)
      {
            lineword[j][0]='\n'; //initialize from previous line
      }
      //parse line into individual "words" of maximum length 14 chars
      while(wn<MATRIX_COLS)
      {
            while(*str==delimparse[delimiter] || *str=='\n') if
(!*str++)
                  break;
            while(*str!=delimparse[delimiter] && wpos<14)
            {
                  lineword[wn][wpos]=*str++;
                  wpos++;
            }
            lineword[wn][wpos]='\0';
            wn++;
            wpos=0;
      }
      j=0;
      //Take the words and assign them to variables
      while(lineword[j][0]!='\0')
      {
            if(i==0) //If we're parsing the header row, put all data in
column names.
            {
                  sscanf(lineword[j],"%s",col[j]->name);
            }
            else //Otherwise, the first word is the row name, and all
other words are cell values.
            {
                  if(j==0)
                        sscanf(lineword[j],"%s",rowname[i]);
                  else
                        sscanf(lineword[j],"%d",&col[j]->row[i]);
            }
            ++j;
      }
      ++i;++rowcount;
      result=fgets(line,5000*12,fp); //Next line, please.
```

```
}
fclose(fp); //Done reading. Close file.
fprintf(stdout,"Read in %d rows, including header row.\n",i-1); //Also
nice to know ...
//Initialize some values in anticipation of the summing part of the
function ...
wn=0; wpos=0;
str=word[3]; //word[3] is the 4th word in the command string.
//It contains a comma-delimited list of the rows (or columns) to be
summed.
//The following loop parses this string into an array of separate
values called headname[].
for(j=0;j<MATRIX_COLS;++j)
{
      headname[j][0]='\n';
}
for(j=0;j<100;++j)
{
      headptr[j]=-1;
}
while(wn<MATRIX_COLS) //This is the start of the parsing loop.
{
      while(*str==',' || *str=='\n') if (!*str++)
            break;
      while(*str!=',' && wpos<14)
      {
            headname[wn][wpos]=*str++;
            wpos++;
      }
      headname[wn][wpos]='\0';
      wn++;
      wpos=0;
}
j=0;i=0;
//Okay. Now loop through all headname[]s and sum them.
while(headname[j][0]!='\0')
{
      for(k=0;k<MATRIX_COLS;++k) // k starts at 0 ....
      {
            switch(sumflag)
            {
            case COLS:
                  if(col[k]->name[0]=='\0')
                  //If this is true, we're out of columns.
                  {
                        fprintf(stdout,"Column \"%s\" does not
exist.\n",headname[j]);
                        k=MATRIX_COLS;
                        break;
                  }
                  if(!strcmp(col[k]->name,headname[j]))
                  {
                        fprintf(stdout,"Adding Column \"%s\" to list to
be summed.\n",headname[j]);
```

```
                        headptr[i]=k; //This is where it's actually
added to the list.
                        ++i;
                        k=MATRIX_COLS;
                        break;
                  }
                  break;
            case ROWS:
                  if(rowname[k][0]=='\0' && k!=0)
                  //If this is true, we're out of rows.
                  {
                        fprintf(stdout,"Row \"%s\" does not
exist.\n",headname[j]);
                        k=MATRIX_COLS;
                        break;
                  }
                  if(!strcmp(rowname[k],headname[j]))
                  {
                        fprintf(stdout,"Adding Row \"%s\" to list to be
summed.\n",headname[j]);
                        headptr[i]=k;
                        //This is where it's actually added.
                        ++i;
                        k=MATRIX_COLS;
                        break;
                  }
                  break;
            }
      }
      ++j;
}
i=0;
printf("Summing ...\n"); //Nice to know :)
while(headptr[i]!=-1)
{
      switch(sumflag)
      {
      case COLS:
            for(j=1;j<MATRIX_ROWS;++j)
            {
                  ms[j]=ms[j]+col[headptr[i]]->row[j]; //Trust me, this
is correct.
            }
            break;
      case ROWS:
            for(j=1;j<MATRIX_COLS;++j)
            {
                  ms[j]=ms[j]+col[j]->row[headptr[i]]; //Ditto.
            }
            break;
      }
      ++i;
}
printf("Writing ... \n"); //Also nice to know.
if(!(fp=fopen(word[4],"w")))
```

```
   // better to trap the error than see a segfault.
   {
         fprintf(stdout,"Can't open file %s for writing.\n",word[4]);
         for(z=0;z<5000;++z)
         {
               free(col[z]);
         }
         return -1;
   }
   switch(sumflag) //Here's the actual writing.
   {
   case COLS:
         fprintf(fp,"Row,Colsum\n");
         i=1;
         while(rowname[i][0]!='\0')
         {
               fprintf(fp,"%s,%d\n",rowname[i],ms[i]);
               ++i;
               fprintf(stdout,"%d\r",i);
         }
         break;
   case ROWS:
         fprintf(fp,"Col,Rowsum\n");
         i=1;
         while(col[i]->name[0]!='\0')
         {
               fprintf(fp,"%s,%d\n",col[i]->name,ms[i]);
               ++i;
               fprintf(stdout,"%d\n",i);
         }
   }
   fclose(fp);
   printf("Output file closed.\n"); //A little verbose, but this took a
   while to debug.
   for(z=0;z<5000;++z)
   {
         free(col[z]); //don't forget -- this uses a lot of memory.
   }
   return 1;
}

void write_syslog(char *str)
{
   FILE *fp;
   return; //Comment this out to enable logging.
   /*Disabled logging to speed up run. Uncomment to use debugging.*/
   //fp=NULL;
   //if (!(fp=fopen(SYSLOG,"a")))
   //    return;
   //fputs(str,fp);
   //fclose(fp);
}

/*******************************************************************
*  Network Analysis -- AON, Dijkstra, and Traffic Assignment routines *
```

```
**********************************************************************/

int do_aon(char *inpstr)
{
   NET_OBJECT net;
   DEST_OBJECT dest;
   NODE_OBJECT start;
   NODE_OBJECT rail1;
   NODE_OBJECT rail2;
   NODE_OBJECT node;
   ARC_OBJECT arc;
   int i;
   i=0;
   arc=NULL;
   node=NULL;
   net=NULL;
   dest=NULL;
   start=NULL;
   rail1=NULL;
   rail2=NULL;
   if(word_count<2)
   {
         printf("Usage: aon <net>\n");
         return -1;
   }
   if((net=get_net(word[1]))==NULL)
   {
         sprintf(text,"Net %s does not exist.\n",word[1]);
         write_syslog(text);
         return -1;
   }
   //Lots of syslogs, so there will be a small number of comments here.
   write_syslog("Initializing loads\n");
   init_loads(net);
   write_syslog("Initialized.\n");
   for(dest=dest_first;dest!=NULL;dest=dest->next)
   // Loop through all destinations
   {
         write_syslog("inside dest loop...");
         if(dest->node==NULL)
         {
               write_syslog("Yikes. This destination doesn't exist in real
   space. Bailing!\n");
               continue; //One bad dest doesnt' ruin the whole batch
         }
         sprintf(text,"Destination is %s\n",dest->node->old_id);
         write_syslog(text);
         write_syslog(".");
         write_syslog(".");
         write_syslog(".");
         write_syslog(".");
         if(dest->node->net!=net)
         {
               write_syslog("Node not on net.\n");
               continue;
```

```
            }
            write_syslog(".");
            write_syslog("assigning start.");
            start=dest->node;
            write_syslog("Doing roads ...");
            do_rev_road_dijkstra(net,start);
            //find shortest paths to all origins.
            assign_road_traffic(net,dest);
            //Use solution with o-d table to assign the traffic
            write_syslog("done.\n");
      }
      return 1;
   }
   void init_loads(NET_OBJECT net)
   {
      //Your basic initialization routine
      int i;
      i=0;
      for(i=1;i<MAX_ARCS;++i)
      {
            if(net->arc[i]!=NULL)
            {
                  net->arc[i]->load=0;
            }
            else
            {
                  break;
            }
      }
      return;
   }
   void do_rev_road_dijkstra(NET_OBJECT net, NODE_OBJECT start)
   {
      /*Uses heaps to speed up the search portion*/
      NODE_OBJECT node;
      NODE_OBJECT node1;
      ARC_OBJECT arc;
      int i;
      int j;
      int flag;
      int len;
      len=0;
      flag=1;
      i=0;
      j=0;
      arc=NULL;
      node=NULL;
      node1=NULL;
      if(start->net!=net)
      {
            printf("Start node not in network in do_rev_dijkstra.\n");
            return;
      }
      /*Initialization*/
      for(i=0;i<MAX_NODES;++i)
```

```
{
      if(net->node[i]==NULL)
      {
            break;
      }
      net->node[i]->d=999999;
      net->node[i]->next=NULL;
      net->node[i]->scanned=0;
      if (net->node[i]==start)
      {
            net->node[i]->d=0;
      }
}
start->d=0;
construct_heap(net);
/*Flag is always 1. We break out if get_min_unscanned()==NULL */
while(flag)
{
      node=new_get_min_unscanned(net);
      //"new" routine is for heaps
      if(node==NULL) break; //No unscanned nodes. We're done here.
      node->scanned=1; //Mark the node as scanned.
      for(i=0;i<MAX_LINKS;++i)
      {
            if(node->bstar[i]==NULL)
            {
                  /* Next, node, please.*/
                  break;
            }
            //printf("-");
            node1=node->bstar[i];
            if(node1->scanned)
            {
                  /*skip this node. It's marked as scanned.*/
                  continue;
            }
            if(strcmp(node->barc[i]->type,"road") && strcmp(node-
>barc[i]->type,"link"))
            {
                  //Can't travel along this arc ... next, please.
                  continue;
            }
            len=node->barc[i]->len;
            //set travel cost for this leg of the trip
            if(node1->d > node->d + len)
            //If true, the new path is shorter.
            {
                  node1->d = node->d + len; //set d
                  node1->next=node;
                  // ->next pointer points to the next node in a path.
                  sift(net,node1->nth);
                  //d has a new value. Sift the node through the heap.
                  write_syslog("sift returned!\n"); // Nice to know ...
            }
      }
```

```
   }
}

void do_rev_rail_dijkstra(NET_OBJECT net, NODE_OBJECT start)
{
   /*This function is not called in the current implementation*/
   /*As it is written, this is a brute force approach. No heaps, no
   sorting, slowest possible*/
   NODE_OBJECT node;
   NODE_OBJECT node1;
   ARC_OBJECT arc;
   int i;
   int j;
   int flag;
   int len;
   len=0;
   flag=1;
   i=0;
   j=0;
   arc=NULL;
   node=NULL;
   node1=NULL;
   if(start->net!=net)
   {
         printf("Start node not in network in do_rev_dijkstra.\n");
         return;
   }
   /*Initialization*/
   for(i=0;i<MAX_NODES;++i)
   {
         if(net->node[i]==NULL)
         {
               break;
         }
         net->node[i]->d=999999;
         net->node[i]->next=NULL;
         net->node[i]->scanned=0;
         if (net->node[i]==start)
         {
               net->node[i]->d=0;
         }
   }
   start->d=0;
   /*flag is always 1. We break from the while loop if
   get_min_unscanned==NULL*/
   while(flag)
   {
         node=get_min_unscanned(net);
         if(node==NULL) break;
         node->scanned=1;
         for(i=0;i<MAX_LINKS;++i)
         {
               if(node->bstar[i]==NULL)
               {
                     /*Done with all nodes in the back star of node*/
```

```
                     break;
               }
               //printf("-");
               node1=node->bstar[i];
               if(node1->scanned)
               {
                     /*skip this node. It's marked as scanned.*/
                     continue;
               }
               if(strcmp(node->barc[i]->type,"rail"))
               {
                     //We're not allowed to travel over this arc.
                     continue;
               }
               len=node->barc[i]->len;
               if(node1->d > node->d + len)
               {
                     node1->d = node->d + len;
                     node1->next=node;
               }
         }
   }
}

NODE_OBJECT get_min_unscanned(NET_OBJECT net)
{
   //This function has been replaced with new_get_min_unscanned.
   //If you like slow programs, use this function instead.
   NODE_OBJECT node;
   int i;
   int temp_d;
   node=NULL;
   temp_d=-1;
   for(i=0;i<MAX_NODES;++i) //Loop through all the nodes and find the one
   with the smallest value.
   {
         if(net->node[i]==NULL)
         {
               break;
         }
         if(net->node[i]->scanned)
         {
               continue;
         }
         if(net->node[i]->d==0)
               return net->node[i];
         if(temp_d==-1)
         {
               temp_d=net->node[i]->d;
               node=net->node[i];
         }
         else
         {
               if(temp_d>net->node[i]->d)
               {
```

```
                        temp_d=net->node[i]->d;
                        node=net->node[i];
                  }
            }
      }
      if(node==NULL)
      {
            return NULL;
      }
      return node;
}
void assign_road_traffic(NET_OBJECT net, DEST_OBJECT dest)
{
      //takes the results from the shortest path run and assigns the
      commuters to the proper links.
      ARC_OBJECT arc;
      NODE_OBJECT node;
      int i;
      i=0;
      arc=NULL;
      node=NULL;
      while(dest->orig_id[i][0]!='\0')
      {
            if(strcmp(dest->type[i],"road"))
            {
                  ++i;
                  continue;
            }
            if((node=get_node(net,"origin",dest->orig_id[i]))==NULL)
            {
                  sprintf(text,"Warning. Origin %s is on the destination
      table for dest %s but isn't on network.\n",dest->orig_id[i],dest->node-
      >old_id);
                  write_syslog(text);
                  //Shouldn't ever happen, but better to log and skip than
      see that nasty seg fault.
                  ++i;
                  continue;
            }
            while(node->next!=NULL) //Follow the path from node to node and
      assign commuters ...
            {
                  if((arc=get_arc(net,node,node->next))==NULL)
                  {
                        /*This should never happen, but if it does, avoid a
      seg fault and warn user.*/
                        sprintf(text,"a_r_t Warning: node %s %s is in the
      bstar of %s %s but there is no arc between them.\n",node->type,node-
      >old_id,node->next->type,node->next->old_id);
                        write_syslog(text);
                        continue;
                  }
                  arc->load += dest->commuters[i];
                  sprintf(text,"Adding %d (commuters[%d]) to arc %s
      %s\n",dest->commuters[i],i,arc->type,arc->old_id);
```

```
            write_syslog(text);
            if(!strcmp(arc->type,"road") || (!strcmp(arc->type,"link")
   && arc->len>1))
            {     //Add distance to total for destination and origin
                  dest->dist_driven=(int)(dest->dist_driven+(dest-
   >commuters[i]*arc->len));
                  dest->dist_driven_by_origin[i]= (int)(dest-
   >dist_driven_by_origin[i]+(dest->commuters[i]*arc->len));
            }
            node=node->next;
            if(node==dest->node)
            {
                  sprintf(text,"Origin %s reached the
   destination.\n",dest->orig_id[i]);
                  write_syslog(text);
            }
      }
      ++i;
      if(i>=(MAX_NODES*MODES))
            break;
   }
}

/****************************************************************/
/***************Heaped data structure ***********************/
/***** No comments. See thesis for explanation of heaps ********/
/****************************************************************/

void heapsort(NET_OBJECT net)
{
   int i;
   write_syslog("heapsort\n");
   for(i=((int)(net->n/2));i>=1;i--)
   {
         downheap(net,i);
   }
}

void downheap(NET_OBJECT net, int root)
{
   int n;
   write_syslog("downheap\n");
   n=net->n;
   if(root > (int)(n/2))
   {
         return;
   }
   if(net->htn[root*2] == -1)
   {
         return;
   }
   if(net->node[net->htn[root]]->d > net->node[net->htn[root*2]]->d)
   {
         if(net->htn[(root*2)+1]!=-1 && net->node[net->htn[root*2]]->d >
   net->node[net->htn[(root*2)+1]]->d)
```

```
            {
                  swap(net,root,(root*2)+1);
                  downheap(net,(root*2)+1);
            }
            else
            {
                  swap(net,root,(root*2));
                  downheap(net,root*2);
            }
      }
      else
      {
            if(net->htn[(root*2)+1]!=-1 && net->node[net->htn[root]]->d >
      net->node[net->htn[(root*2)+1]]->d)
            {
                  swap(net,root,(root*2)+1);
                  downheap(net,(root*2)+1);
            }
      }

   }

   void swap(NET_OBJECT net, int parent, int child)
   {
      int store_htn;
      write_syslog("swap\n");
      store_htn=0;
      store_htn=net->htn[parent];
      net->htn[parent]=net->htn[child];
      net->node[net->htn[parent]]->nth=parent;
      net->htn[child]=store_htn;
      net->node[net->htn[child]]->nth=child;
   }

   void construct_heap(NET_OBJECT net)
   {
      int i;
      write_syslog("construct_heap\n");
      net->htn[0]=-1;
      net->n=0;
      for(i=0;i<MAX_NODES;++i)
      {
            sprintf(text,"i=%d\n",i);
            write_syslog(text);
            if(net->node[i]!=NULL)
            {
                  net->node[i]->nth=i+1;
                  net->htn[i+1]=i;
                  ++net->n;
                  write_syslog("node added to heap.\n");
            }
            else
            {
                  net->htn[i+1]=-1;
            }
```

```
   }
   heapsort(net);
}

NODE_OBJECT new_get_min_unscanned(NET_OBJECT net)
{
   NODE_OBJECT node;
   write_syslog("new_get_min\n");
   node=pop(net);
   return node;
}

NODE_OBJECT pop(NET_OBJECT net)
{
   NODE_OBJECT ret_node;
   write_syslog("pop\n");
   if(net->htn[1]==-1)
   {
         return NULL;
   }
   ret_node=net->node[net->htn[1]];
   net->htn[1]=-1;
   ret_node->nth=-1;
   if(net->htn[2]==-1 && net->htn[3]==-1)
   {
         return ret_node;
   }
   if(net->htn[2]==-1)
   {
         promote(net,3);
         return ret_node;
   }
   if(net->htn[3]==-1)
   {
         promote(net,2);
         return ret_node;
   }
   if(net->node[net->htn[2]]->d > net->node[net->htn[3]]->d)
   {
         promote(net,3);
   }
   else
   {
         promote(net,2);
   }
   return ret_node;
}

void promote(NET_OBJECT net, int heapnode)
{
   sprintf(text,"promote i = %d\n",heapnode);
   write_syslog(text);
   net->htn[(int)(heapnode/2)]=net->htn[heapnode];
   net->node[net->htn[heapnode]]->nth=(int)(heapnode/2);
   net->htn[heapnode]=-1;
```

```
   if(heapnode>net->n/2) {return;}
   if(net->htn[heapnode*2]==-1 && net->htn[(heapnode*2)+1]==-1)
   {
         return;
   }
   if(net->htn[heapnode*2]==-1)
   {
         promote(net,(heapnode*2)+1);
         return;
   }
   if(net->htn[(heapnode*2)+1]==-1)
   {
         promote(net,heapnode*2);
         return;
   }
   if(net->node[net->htn[heapnode*2]]->d > net->node[net-
   >htn[(heapnode*2)+1]]->d)
   {
         promote(net,(heapnode*2)+1);
         return;
   }
   promote (net,heapnode*2);
   return;
}

void sift(NET_OBJECT net, int i)
{
   write_syslog("sift\n");
   sprintf(text,"Sift: i = %d\n",i);
   write_syslog(text);
   sprintf(text,"Sift: htn = %d\n",net->htn[i]);
   write_syslog(text);
   sprintf(text,"Sift: node_id = %s\n",net->node[net->htn[i]]->old_id);
   write_syslog(text);
   if(i<=1){return;}
   if(net->node[net->htn[i]]->d < net->node[net->htn[(int)(i/2)]]->d)
   {
         swap(net,(int)(i/2),i);
         write_syslog("swap returned!\n");
         if(i>3)
         {
               sift(net,(int)(i/2));
         }
   }
```

Appendix C

AVENUE SCRIPTS USED TO VISUALIZE TRAFFIC MODEL RESULTS

```
'******************************************
'********Splinter Theme********************
'******************************************
'
' Splinter a Theme -- One new theme per feature
'
theView = av.GetActiveDoc
theThemeList=theView.GetThemes
theTheme=MsgBox.List(theThemeList,"Select the theme to
   splinter","Select Theme")
theFtab=theTheme.GetFTab
theField=MsgBox.List(theFTab.GetFields,"Select the field to use for
   Theme names","Select Field")
theDir=MsgBox.Input("Please input the name of the directory where the
   themes should be saved","Input Directory",
   FileName.GetCWD.GetFullName.AsString)
if(theDir=nil) then
  return nil
end
if((theDir.AsFilename.IsDir.NOT) or ((theDir.Right(1)="\").NOT)) then
  theDir=Filename.GetCWD.AsString+"\"
  MsgBox.Error("That isn't a valid directory name. Defaulting to
   "+FileName.GetCWD.GetFullName.AsString+"\.","Bad Directory!")
end
theRecordCount=theFTab.GetNumRecords
theBitMap=BitMap.Make(theRecordCount)
theBitMap.SetAll
notherBitMap=BitMap.Make(theRecordCount)
notherBitMap.ClearAll
for each i in theBitMap
'  MsgBox.Error(i.AsString,"Bitmap Number")
  notherBitMap.Set(i.clone)
  theFTab.SetSelection(notherBitMap)
  theFTab.UpdateSelection
  theValue=theFTab.ReturnValueString(theField,i)
  theFilename=(theDir+theValue).AsFilename
  theFTab.ExportClean(theFileName,true)
  sN  = SrcName.Make(theFilename.AsString+".shp")
  fT  = FTab.Make(sN)
  fTh = FTheme.Make(fT)
  fTh.SetName(theValue)
  fTh.SetLegend(theTheme.GetLegend)
  theView.AddTheme(fTh)
  fTh.SetVisible(true)
  notherBitMap.ClearAll
end
```

```
'***********************
'*****RenameThemes******
'***********************
'
' Rename Themes in Bulk
'
theProject=av.GetProject
theView=av.GetActiveDoc
if(theView.Is(View).NOT) then
  MsgBox.Error("This script requires a View to be the active
   theme.","Not a View")
  return nil
end
theThemeList=theView.GetThemes
theRenamed=MsgBox.MultiList(theThemeList,"Select the themes you wish to
   rename","Select Themes")
if(theRenamed=nil) then
  return nil
end
theName=MsgBox.Input("Enter the new name","Enter
   Name",theRenamed.Get(0).GetName.AsString)
if(theName=nil) then
  return nil
end
for each i in theRenamed
  i.SetName(theName)
end
```

```
'********************************
'**********Quick Grids**********
'********************************
'
' create surfaces for active point theme
'
theView = av.GetActiveDoc
theTheme = theView.GetActiveThemes.Get(0)
theMask = theView.GetActiveThemes.Get(1).GetGrid
theLegend=theView.GetActiveThemes.Get(1).GetLegend
theInterp=Interp.Make
theRect=Rect.MakeXY(1674969.625,2029839.125,1822969.625,2145839.125)
theGridSize={1000,theRect}
theGUI=av.FindGUI("Table").clone
theProject=av.GetProject
aPrj = theView.GetProjection
theTableList=theProject.GetDocsWithGroupGUI(theGUI)
theList=MsgBox.MultiList(theTableList,"Pick a group of tables to be
   relationally joined with the point theme.", "Table Selection")
if (theList=nil) then
  return nil
end
theFTab=theTheme.GetFtab
theFieldList=theFTab.GetFields
theField=MsgBox.List(theFieldList,"Select the field in the Point
   Feature Theme to use to join the data.","Select Feature Theme
   Field")
if (theField=nil) then
  return nil
end
theJoinField=MsgBox.List(theList.Get(0).GetVtab.GetFields,"Select the
   Join Field in your selected VTabs.","Select Join Field")
if (theJoinField=nil) then
  return nil
end
theZField=MsgBox.List(theList.Get(0).GetVtab.GetFields,"Select the
   Field that contains the values for the surface","Select Z Field")
if (theZField=nil) then
  return nil
end
theDir=MsgBox.Input("Please input the name of the directory where the
   grids should be saved","Input Directory",
   FileName.GetCWD.GetFullName.AsString)
if(theDir=nil) then
  return nil
end
if((theDir.AsFilename.IsDir.NOT) or ((theDir.Right(1)="\").NOT)) then
  theDir=Filename.GetCWD.AsString+"\"
  MsgBox.Error("That isn't a valid directory name. Defaulting to
   "+FileName.GetCWD.GetFullName.AsString+"\.","Bad Directory!")
end
for each i in theList
  iVTab=i.GetVtab
  iJoinField=iVTab.FindField(theJoinField.GetName)
  if (iJoinField=nil) then
```

```
    msgbox.info("Error! "+i.GetName.AsString+" doesn't have a field
   named "+theJoinField.GetName.AsString+". Aborting Join.","Join
   Error")
  else
    iZField=iVTab.FindField(theZField.GetName)
    if(iZField=nil) then
      msgbox.info("Error!. "+i.GetName.AsString+" doesn't have a field
   named "+theZField.GetName.AsString+". Aborting
   Interpolation.","Interpolation Error")
    else
'      msgbox.info("I will join "+theFTab.GetName.AsString+" with
   "+i.GetName.AsString,"Selection Display")
      theFTab.join(theField,iVTab,iJoinField)
      zField=theFTab.FindField(theZField.GetName)
      theResult =

   Grid.MakeByInterpolation(theFTab,aPrj,zField,theInterp,theGridSize)
      notherGrid=theResult*theMask
      ' create a theme
      ' check if output is ok
      if (notherGrid.HasError) then
        return NIL
      end
      ' add theme to the view
      theFileName=(theDir+i.GetName.AsString.Left(8)).AsFileName
      theBoolean=notherGrid.SaveDataSet(theFileName)
      if(theBoolean=false) then
        MsgBox.Error("Error! Couldn't save Grid resulting from table
   "+iVTab.GetName.AsString+" as "+theFileName.AsString+". Grid will
   appear in View, but is saved as a generic grid.","Error Saving
   Grid")
        theGTheme = GTheme.Make(notherGrid)
        theGTheme.SetName(i.GetName.AsString.Left(8)+" Unsaved")
        theView.AddTheme(theGTheme)
      else
        theSrcName=Grid.MakeSrcName(theFileName.AsString)
        notherGrid=Grid.Make(theSrcName)
        theGTheme=GTheme.Make(notherGrid)
        theGTheme.SetName("Cummulative percent")
        theView.AddTheme(theGTheme)
      end
      theGTheme.SetLegend(theLegend)
      theGTheme.UpdateLegend
    end
  end
  theFTab.UnjoinAll
end
```

```
'*************************
'***** LinkLegends  *******
'*************************
'
'Links legends so that when master legend is edited, all are changed
'
theProject=av.GetProject
theView=av.GetActiveDoc
if (theView.Is(View).NOT) then
  MsgBox.Error("You must have an active view to perform this
   action.","Active Doc isn't a view")
  return nil
end
theMasterTheme=MsgBox.List(theView.GetThemes,"Select the Theme that
   will provide the master legend.","Select Master")
if(theMasterTheme=nil) then
  return nil
end
theThemeList=theView.GetThemes.clone
for each i in theThemeList.clone
  if(theMasterTheme=i) then
    theThemeList.RemoveObj(i)
  else
    if(theMasterTheme.Is(FTheme)) then
      if(i.Is(GTheme)) then
        theThemeList.RemoveObj(i)
      else

   if((i.GetFTab.GetShapeClass.GetClassName=theMasterTheme.GetFTab.GetS
   hapeClass.GetClassName).NOT) then
          theThemeList.RemoveObj(i)
        end
      end
    else
      if(i.Is(GTheme).NOT) then
        theThemeList.RemoveObj(i)
      end
    end
  end
end
theSlaveThemes=MsgBox.MultiList(theThemeList,"Select the Themes that
   will use the master legend.","Select Slaves")
if(theSlaveThemes=nil) then
  return nil
end

for each i in theSlaveThemes
  i.SetLegend(theMasterTheme.GetLegend)
end
theView.GetWin.Activate
```

```
'*************************
'***** Modify Layout ******
'*************************
'
'Modify Layout -- Creates a 3-View Layout for use with 3View Scripts
'
theGUI=av.FindGUI("View").clone
theLayoutGUI=av.FindGUI("Layout").clone
theProject=av.GetProject
theViewList=theProject.GetDocsWithGroupGUI(theGUI)
theThemeList={}
theViews={}
theViewFrames={}
theCount=Number.MakeNull
theVFCount=Number.MakeNull
theVFCount=0
theCount=0
theThemeCount=Number.MakeNull
theFlag=true
theThemeFlag=true
theLayout=MsgBox.List(theProject.GetDocsWithGroupGUI(theLayoutGui),"Sel
   ect the Layout to Modify","Select Layout")
if(theLayout=nil) then
  return nil
end
theGraphicsList=theLayout.GetGraphics
for each i in theGraphicsList
  if(i.Is(Viewframe)) then
    theViewFrames.Add(i)
    theVFCount=theVFCount+1
  end
end
if(theVFCount=0) then
  MsgBox.Error("There are no view frames in that layout.","No View
   Frames")
  return nil
end
for each i in theViewFrames
  theView=MsgBox.List(theViewList,"Select view
   #"+(theCount+1).AsString+" for the "+theVFCount.AsString+"-view
   layout.","Select View")
  if ((theView=nil).NOT) then
    theViews.Add(theView)
    theViewFrame=theViewFrames.Get(theCount)
    theViewFrame.SetView(theView,true)
    theCount=theCount+1
    theThemeFlag=true
    theThemeCount=0
    theThemeList=MsgBox.MultiList(theView.GetThemes,"Select themes to
   display in View:"+theView.GetName.AsString,"Select Themes")
    if((theThemeList=nil).NOT) then
      theVisThemes=theView.GetVisibleThemes
      for each i in theVisThemes
        i.SetVisible(false)
      end
```

```
      for each i in theThemeList
        i.SetVisible(true)
      end
    end
    if(theCount>=theVFCount) then
      theFlag=false
    end
  else
    theFlag=false
  end
end
'Okay ... now prompt to export the layout as an image file
theAnswer=MsgBox.YesNo("Shall we export it to disk?","Export
   Image?",true)
if(theAnswer) then
  theFilename=theLayout.Export
  if(theFilename=nil) then
    MsgBox.Info("The layout wasn't exported to a file.","FILE NOT
   EXPORTED")
  end
end
```

```
'*************************
'***** 3View.Activate *****
'*************************
theDialog=SELF
```

```
'**************************
'***** 3View.Up  **********
'**************************

'3View.Up
theButton=SELF
theDialog=theButton.GetDialog
theTB=theButton.GetListeners.Get(0)
theView=theButton.GetListeners.Get(1).GetSelection
theSThemes=theTB.GetSelection
theThemes=theView.GetThemes
theSrcNames={}
for each i in theView.GetThemes
  theSrcNames.Add(i.GetSrcName.GetName)
end
theCount=Number.MakeNull
theCount=0
theCount=theThemes.Count-2
for each i in theCount..0 by -1
  theRecord=theThemes.Get(i)
  if((theSThemes.FindByValue(theRecord.GetSrcName.GetName)=-1).NOT)
   then
    theThemes.Shuffle(theRecord,i+2)
  end
end
theView.InvalidateTOC(nil)
theWin=theView.GetWin
theWin.Open
theWin.Activate
theDialog.FindByName("LayoutStore").GetSelection.GetWin.Open
theDialog.FindByName("LayoutStore").GetSelection.GetWin.Activate
theButton.BroadcastUpdate
```

```
'**************************
'***** 3View.Export *******
'**************************

'3View.Export
theButton=SELF
theDialog=theButton.GetDialog
theLayout=theDialog.GetActiveDoc
theFilename=theLayout.Export
if(theFilename=nil) then
  MsgBox.Info("The layout wasn't exported to a file.","FILE NOT
   EXPORTED")
End
```

```
'****************************
'***** 3View.Layout.Refresh *
'****************************

'3View.Layout.Refresh
theButton=SELF
theButton.BroadcastUpdate
theDialog=theButton.GetDialog
theLayout=theDialog.FindByName("LayoutStore").GetSelection
theVFCount=Number.MakeNull
theVFCount=0
theViewFrames={}
theLegends={}
theGraphicsList=theLayout.GetGraphics
for each i in theGraphicsList
  if(i.Is(Viewframe)) then
    theViewFrames.Add(i)
    theVFCount=theVFCount+1
  end
  if(i.Is(LegendFrame)) then
    theLegends.Add(i)
  end
end
View1PD=theDialog.FindByName("View1Select")
View2PD=theDialog.FindByName("View2Select")
View3PD=theDialog.FindByName("View3Select")
theView1=View1PD.GetSelection
theView2=View2PD.GetSelection
theView3=View3PD.GetSelection
theViewFrames.Get(0).SetView(theView1,true)
theViewFrames.Get(1).SetView(theView2,true)
theViewFrames.Get(2).SetView(theView3,true)
theLegends.Get(0).SetViewFrame(theViewFrames.Get(0))
theLegends.Get(1).SetViewFrame(theViewFrames.Get(1))
theLegends.Get(2).SetViewFrame(theViewFrames.Get(2))

theWins={theView1.GetWin,theView2.GetWin,theView3.GetWin,theLayout.GetW
   in}
for each i in theWins
  i.Open
  i.Activate
end
```

```
'*************************
'***** 3View.Open *********
'*************************
'3View.Open
theDialogGUI=av.FindDoc("3View.Dialog")
if(theDialogGUI=nil) then
  MsgBox.Error("Cound't find 3View.Dialog","Dialog not Found")
  return nil
end
theDialog=theDialogGUI.GetDialog
theLayout=theDialog.GetActiveDoc
if (theLayout.Is(Layout).NOT) then
  MsgBox.Error("Active Document MUST be a Layout","Not a layout")
  exit
end
theDialog.SetTitle("Super Duper Map Constructor. Modifying
   Layout:"+theLayout.GetName.AsString)
theDialog.Open
theProject=av.GetProject
theViewSs={}
'Populate initial lists, etc.
View1PD=theDialog.FindByName("View1Select")
View2PD=theDialog.FindByName("View2Select")
View3PD=theDialog.FindByName("View3Select")
View1TB=theDialog.FindByName("View1ThemeBox")
View2TB=theDialog.FindByName("View2ThemeBox")
View3TB=theDialog.FindByName("View3ThemeBox")
if((View1TB=nil) or (View2TB=nil) or (View3TB=nil)) then
  MsgBox.Error("Missing Theme Boxes","ERROR")
end
theGUI=av.FindGUI("View").clone
theViewList=theProject.GetDocsWithGroupGUI(theGUI)
View1PD.DefineFromList(theViewList)
View2PD.DefineFromList(theViewList)
View3PD.DefineFromList(theViewList)
theViewFrames={}
theGraphicsList=theLayout.GetGraphics
for each i in theGraphicsList
  if(i.Is(Viewframe)) then
    theViewFrames.Add(i)
  end
end
View1PD.FindByValue(theViewFrames.Get(0).GetView)
View1PD.SelectCurrent
View2PD.FindByValue(theViewFrames.Get(1).GetView)
View2PD.SelectCurrent
View3PD.FindByValue(theViewFrames.Get(2).GetView)
View3PD.SelectCurrent

View1PD.AddListener(View1TB)
View2PD.AddListener(View2TB)
View3PD.AddListener(View3TB)
RLButt=theDialog.FindByName("RefreshLayout")
RVButt=theDialog.FindByName("RefreshViews")
RLButt.AddListener(RVButt)
```

```
Prom1=theDialog.FindByName("Promote1")
Prom2=theDialog.FindByName("Promote2")
Prom3=theDialog.FindByName("Promote3")
Up1=theDialog.FindByName("Up1")
Up2=theDialog.FindByName("Up2")
Up3=theDialog.FindByName("Up3")
Down1=theDialog.FindByName("Down1")
Down2=theDialog.FindByName("Down2")
Down3=theDialog.FindByName("Down3")
Up1.AddListener(View1TB)
Up1.AddListener(View1PD)
Up2.AddListener(View2TB)
Up2.AddListener(View2PD)
Up3.AddListener(View3TB)
Up3.AddListener(View3PD)
Up1.AddListener(View2TB)
Up1.AddListener(View2PD)
Up2.AddListener(View3TB)
Up2.AddListener(View3PD)
Up3.AddListener(View1TB)
Up3.AddListener(View1PD)
Up1.AddListener(View3TB)
Up1.AddListener(View3PD)
Up2.AddListener(View1TB)
Up2.AddListener(View1PD)
Up3.AddListener(View2TB)
Up3.AddListener(View2PD)
Down1.AddListener(View1TB)
Down1.AddListener(View1PD)
Down2.AddListener(View2TB)
Down2.AddListener(View2PD)
Down3.AddListener(View3TB)
Down3.AddListener(View3PD)
Down1.AddListener(View2TB)
Down1.AddListener(View2PD)
Down2.AddListener(View3TB)
Down2.AddListener(View3PD)
Down3.AddListener(View1TB)
Down3.AddListener(View1PD)
Down1.AddListener(View3TB)
Down1.AddListener(View3PD)
Down2.AddListener(View1TB)
Down2.AddListener(View1PD)
Down3.AddListener(View2TB)
Down3.AddListener(View2PD)
Prom1.AddListener(View1TB)
Prom1.AddListener(View1PD)
Prom2.AddListener(View2TB)
Prom2.AddListener(View2PD)
Prom3.AddListener(View3TB)
Prom3.AddListener(View3PD)
Prom1.AddListener(View2TB)
Prom1.AddListener(View2PD)
Prom2.AddListener(View3TB)
Prom2.AddListener(View3PD)
```

```
Prom3.AddListener(View1TB)
Prom3.AddListener(View1PD)
Prom1.AddListener(View3TB)
Prom1.AddListener(View3PD)
Prom2.AddListener(View1TB)
Prom2.AddListener(View1PD)
Prom3.AddListener(View2TB)
Prom3.AddListener(View2PD)
View1PD.BroadcastUpdate
View2PD.BroadcastUpdate
View3PD.BroadcastUpdate
theLayoutList={theLayout}
theDialog.FindByName("LayoutStore").DefineFromList(theLayoutList)
```

```
'*************************
'***** 3View.PD.Select ****
'*************************
theComboBox=SELF
theListeners=theComboBox.GetListeners
if((theListeners.Count>1) or (theListeners.Count<1)) then
  MsgBox.Error("Needs to be 1 listener","ERROR")
  return nil
end
theListBox=theListeners.Get(0)
theListBox.Update
theComboBox.BroadcastUpdate
```

```
'**************************
'***** 3View.Promote  *****
'**************************
'3View.Promote
theButton=SELF
theDialog=theButton.GetDialog
theTB=theButton.GetListeners.Get(0)
theView=theButton.GetListeners.Get(1).GetSelection
theSel=theTB.GetSelection
theSThemes={}
theThemes=theView.GetThemes
for each i in theThemes
  if((theSel.FindByValue(i.GetSrcName.GetName)=-1).NOT) then
    theSThemes.Add(i)
  end
end
theCount=Number.MakeNull
theCount=0
for each i in theSThemes
  theThemes.Shuffle(i,theCount)
  theCount=theCount+1
end
theView.InvalidateTOC(nil)
theWin=theView.GetWin
theWin.Open
theWin.Activate
theDialog.FindByName("LayoutStore").GetSelection.GetWin.Open
theDialog.FindByName("LayoutStore").GetSelection.GetWin.Activate
theButton.BroadcastUpdate
```

```
'*************************
'***** 3View.TB.Populate **
'*************************
'3View.TB.Populate
theTB=SELF
thePD=theTB.GetBroadcaster
theView=thePD.GetSelection
if(theView=nil) then
  return nil
end
theThemes=theView.GetThemes
theSrcNames={}
for each i in theThemes
  theSrcNames.Add(i.GetSrcName.GetName)
end
'theTB.DefineFromList(theThemes)
theTB.DefineFromList(theSrcNames)
theVisThemes=theView.GetVisibleThemes
theVisSrc={}
for each i in theVisThemes
  theVisSrc.Add(i.GetSrCName.GetName)
end
for each i in theVisSrc
  theTB.FindByValue(i)
  theTB.SelectCurrent(true)
  theTB.ShowCurrent
end
return nil
```

```
'*************************
'***** 3View.TB.Update ****
'*************************
'3View.TB.Update
theBC=SELF.GetBroadcaster
theTB=SELF
if (theBC.Is(ComboBox)) then
  av.Run("3View.TB.Populate",SELF)
  return nil
end
if(theBC.Is(Button)) then
    theListeners=theBC.GetListeners
    thePD=theBC.GetListeners.Get(theListeners.Find(theTB)+1)
    theView=thePD.GetSelection
    theSThemes=theTB.GetSelection
    theSrcNames={}
    for each i in theView.GetThemes
      theSrcNames.Add(i.GetSrcName.GetName)
    end
    theTB.DefineFromList(theSrcNames)
    'theTB.DefineFromList(theView.GetThemes)
    for each s in theSThemes
      theTB.FindByValue(s)
      theTB.SelectCurrent(true)
      theTB.ShowCurrent
    end
end
```

```
'**************************
'***** 3View.Up  **********
'**************************
'3View.Up
theButton=SELF
theDialog=theButton.GetDialog
theTB=theButton.GetListeners.Get(0)
theView=theButton.GetListeners.Get(1).GetSelection
theSThemes=theTB.GetSelection
theThemes=theView.GetThemes
theCount=Number.MakeNull
theCount=theThemes.Count
for each i in 1..(theCount-1)
  theTheme=theThemes.Get(i)
  if((theSThemes.FindByValue(theTheme.GetSrcName.GetName)=-1).NOT) then
    theThemes.Shuffle(theTheme,theThemes.Find(theTheme)-1)
    theCount=theCount+1
  end
end
theView.InvalidateTOC(nil)
theWin=theView.GetWin
theWin.Open
theWin.Activate
theDialog.FindByName("LayoutStore").GetSelection.GetWin.Open
theDialog.FindByName("LayoutStore").GetSelection.GetWin.Activate
theButton.BroadcastUpdate
```

```
'***************************
'***** 3View.View.Refresh**
'***************************
'3View.View.Refresh
theButton=SELF
theDialog=theButton.GetDialog
thePDList=theDialog.FindByClass(ComboBox)
thePDList.RemoveObj(theDialog.FindByName("LayoutStore"))
for each i in thePDList
  theView=i.GetSelection
  theTB=i.GetListeners.Get(0)
  theSel=theTB.GetSelection
  theThemes=theView.GetThemes
  theVisThemes={}
  for each i in theSel
    for each j in theThemes
      if(j.GetSrcName.GetName=i) then
        theVisThemes.Add(j)
      end
    end
  end
  for each j in theThemes
    j.SetVisible(false)
  end
  for each j in theVisThemes
    j.SetVisible(true)
  end
  theWin=theView.GetWin
  theWin.Open
  theWin.Activate
  theLayout=theDialog.FindByName("LayoutStore").GetSelection
  theLayout.GetWin.Activate
end
```

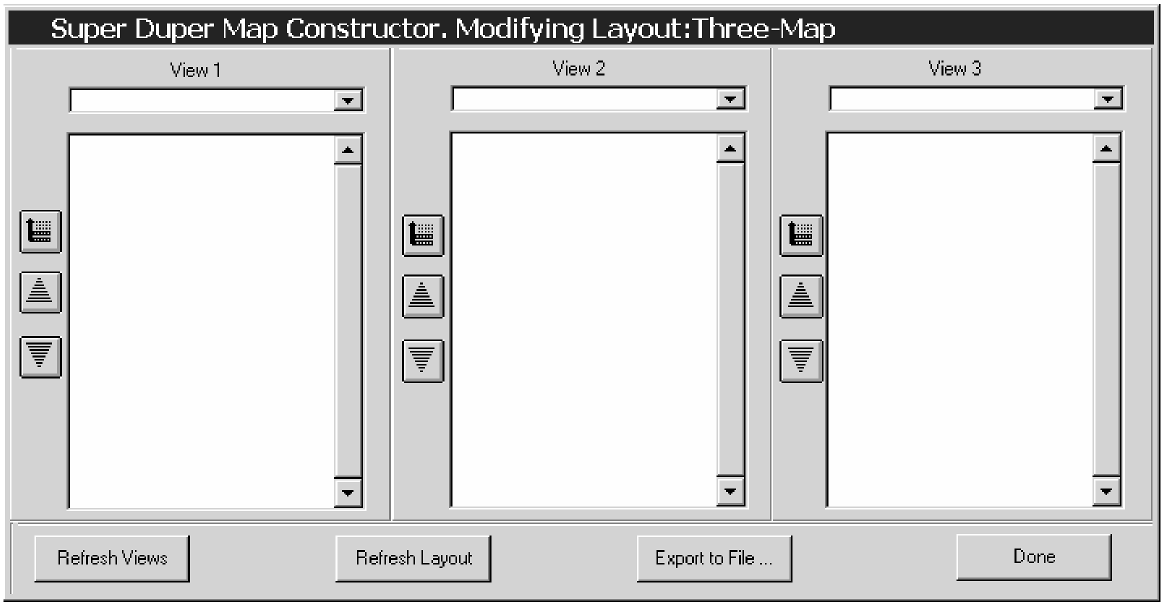

Figure **C.1**: Dialog box used for the 3View family of scripts

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Education

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    - **Thesis Title:** *Impacts of a National Gasoline Tax Increase on Personal Transportation in the United States, and Implications for Greenhouse Gas Abatement Policy*
    - **Advisor:** Benedykt Dziegielewski, Department of Geography
- **1996: B.S** Southern Illinois University at Carbondale, Department of Geography
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Refereed Publications

- **In Review:** Yarnal, B. and **R. Neff**. “Teaching Global Change in Local Places: the HERO Research Experiences for Undergraduates program” Journal of Geography in Higher Education
- **In Press:** Rose, A. **R. Neff**, B. Yarnal, and H. Greenberg. “A Greenhouse Gas Emissions Inventory for Pennsylvania” Journal of the Air and Waste Management Association
- **2004:** Yarnal, B. and **R. Neff. “**Whither Parity? The need for a Comprehensive Curriculum in Human-Environment Geography.” The Professional Geographer **56**(1):28-36
- **2000: Neff, R.**, H. J. Chang, C. G. Knight, R. G. Najjar, B. Yarnal and H. A. Walker. “Impact of climate variation and change on Mid-Atlantic Region hydrology and water resources.” Climate Research **14**(3): 207-218.
- **1999:** O'Connor, R. E., B. Yarnal, **R. Neff**, R. Bord, N. Wiefek, C. Reenock, R. Shudak, C. L. Jocoy, P. Pascale and C. G. Knight. “Weather and climate extremes, climate change, and planning - Views of community water system managers in Pennsylvania's Susquehanna River Basin.” Journal of the American Water Resources Association **35**(6): 1411-1419.