Air Quality and Sustainable Redevelopment:
The Case of Construction in Dudley Square

A thesis submitted by
Hanaa Abdel Rohman

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Advisor: Mary Davis, PhD
Reader: John Durant, PhD

ABSTRACT

Redevelopment is often shaped by community planning processes that emphasize sustainability and equity, but how does the construction process reflect the *just sustainability* supported in visioning stages? In this project, fine and ultrafine particles were measured and analyzed during construction of two municipal redevelopment projects in Dudley Square in order to understand the potential environmental health impacts on the surrounding community. Exposures to these particles have been linked to respiratory and cardiovascular diseases. Data were collected from the Ferdinand (July to November 2012) and the B2 Police Station demolitions (November 2014). Results showed significantly elevated levels of particles during high intensity construction days compared to low intensity construction days ($p<0.001$), suggesting a need for emission control strategies.

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LIST OF ABBREVIATIONS

Alternatives for Community and Environment (ACE)
Boston Redevelopment Authority (BRA)
California Air Resources Board (CARB)
Compressed Natural Gas (CNG)
Condensation Particle Counter (CPC)
Criteria Air Pollutant (CAP)
Diesel Oxidation Catalyst (DOC)
Diesel Particulate Filter (DPF)
Emission Factors (EF)
Environmental Justice (EJ)
Environmental Protection Agency (EPA)
EPA Speciation Trends Network (EPA-STN)
Geographic Information System (GIS)
Leadership in Energy and Environmental Design (LEED)
Massachusetts Department of Environmental Protection (MassDEP)
National Ambient Air Quality Standards (NAAQS)
National Oceanic and Atmospheric Administration (NOAA)
Partial Diesel Particulate Filter (pDPF)
Particle Matter (PM)
Particle Number Concentration (PNC)
Reactive Organic Gas (ROG)
Sustainable Development (SD)
Ultrafine Particle (UFP)
Volatile Organic Compounds (VOCs)

CHAPTER 1: INTRODUCTION

Redevelopment is a common process in cities as they adapt to the changing needs and values of their local communities. The process may begin with community visioning, which looks to an aspired future and lays the groundwork to get there. A subsequent and important part of the process is construction. In Dudley Square (Boston, Massachusetts), realizing *Dudley Vision* has created significant redevelopment activity in the area. Heavy duty construction vehicles and equipment, fenced off lots and orange cones are inevitable sights on any visit. How does construction affect environmental health in this transient stage of development? How does this process fit into a community's development framework, especially as it emphasizes sustainability and equity? In this thesis, I will explore the air quality impacts of construction activity in what has been called the "social heart of Roxbury" by studying two municipal redevelopment projects: the Bruce C. Bolling Municipal Building (also known as the Ferdinand building) and the former B2 Police Station (Boston Redevelopment Authority 2004). Understanding the changes in air quality during construction in Dudley Square will help define a need for healthful design and environmental justice sensitivity during the development process itself and not simply as an end-goal of sustainable redevelopment.

Redevelopment presents many opportunities for communities, whether the goal is economic or cultural revitalization. At the same time, there is an opportunity to take a holistic approach and address pollution exposure and equity as a part of the redevelopment process. After a thorough literature review of the construction, health equity, and air pollution research, this thesis will focus on the following objectives: (1) to conduct a background assessment of the Dudley Square case study through descriptive mapping and analysis of published planning documents, (2) to measure and analyze levels of fine and ultrafine particulate matter that are released during construction activities in Dudley Square, and (3) to use the results to recommend construction-related air pollution mitigation strategies.

URBAN REVITALIZATION IN DUDLEY SQUARE

"At the intersection of Washington and Warren Streets: The Dudley Plan. A roadmap for revitalizing Boston's core. Where these two roads meet, wait crosses to action."

–Former Mayor Thomas Menino

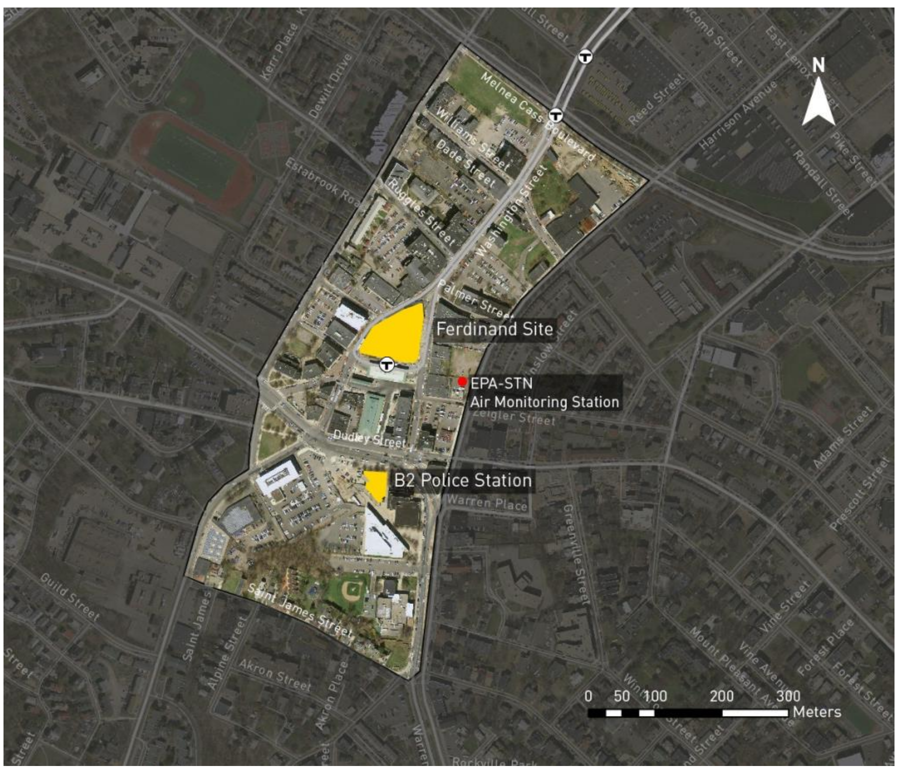

Figure 1.1: Ferdinand and the Dudley Square commercial district. Cartography by Hanaa Abdel Rohman.

Dudley Square's Ferdinand Building, once home to New England's largest furniture retailer, was a commercial anchor and strategically located at the core of Dudley Square Commercial District, which encompasses the area shown in Figure 1.1. The Ferdinand Blue Store (it was painted an iconic blue) as it was known, was constructed in 1895 and stood at the corner of a block like the bow of a ship, with Washington Street and Warren Street streaming by on either side (Figure 1.2). Although the business closed in the mid-1970s, the building remains an architectural centerpiece of the neighborhood. Its façade is a hallmark of the district and is the only part of the building preserved in the construction of the new Bruce C. Bolling Municipal Center. Until 1987, the old elevated Orange Line train operated on tracks that wrapped around the Ferdinand parcel and terminated at Dudley Station (Figure 1.3).

Figure 1.2: An advertisement featuring the Ferdinand Building. Source: Boston 2013.

Figure 1.3: Dudley Square in 1910, with the Ferdinand Building in the background. Source: Historic Boston 2011.

Today, Dudley Station is still a critical transportation hub with bus connections to the rest of Boston and the nearby MBTA rail lines at Ruggles and Roxbury Crossing. Thirty thousand people pass through the area daily on buses fueled by compressed natural gas (CNG), a victory in local environmental advocacy efforts. According to the Dudley Square Transportation and Air Quality Study (Bruce et al. 2001), more than 4,000 vehicles an hour pass through Dudley Square during peak commute hours and 180 MBTA buses access Dudley Square Station during peak hours on a total of 16 bus routes. Local businesses, community organizations, and residents occupy the dense urban fabric around the block while many more pass through in a daily routine. Still, there is work to be done in realizing the community visions articulated in the 2004 Roxbury Strategic Master Plan.

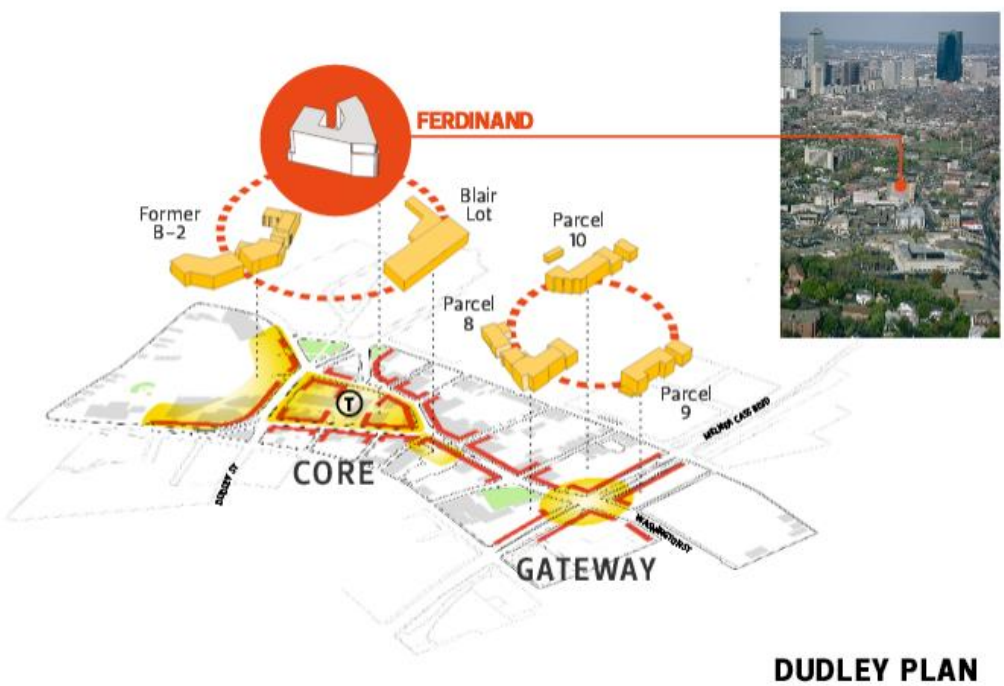

Figure 1.4: The Ferdinand Building as the catalyst for urban revitalization in the Dudley Square Commercial District. Source: City of Boston, 2011.

In a 2011 press release on the “Dudley Plan,” the renowned Boston mayor Thomas Menino said of the area, “We will never know how great Boston can be until Dudley Square is great once again” (City of Boston 2011). The Ferdinand’s institutional redevelopment is seen as a catalyst for urban revitalization in Dudley Square and so its redevelopment is critical in a portfolio of projects proposed by the City of Boston (Figure 1.4). There are many ambitions and aspirations articulated in this redevelopment project and among these are notions of sustainable development, which incorporates ideas of economic, social and environmental equity. These qualities make the area a pertinent study for understanding environmental health impacts of the redevelopment process.

AIR QUALITY AND THE ENVIRONMENTAL JUSTICE MOVEMENT IN DUDLEY SQUARE

Dudley Square meets criteria that designates it an environmental justice area with high minority, non-English-speaking, and low-income population. According to the Environmental Protection Agency, environmental justice refers to the fair treatment of all people in regards to environmental policies and regulations (2012). Environmental justice sensitivity is important in Roxbury, which today has disproportionately high asthma hospitalizations among black and Latino residents and the highest rate of heart disease hospitalizations among all Boston neighborhoods (Boston Public Health Commission Research Office 2013). Roxbury children had an average annual rate of asthma emergency department visits of 59.7 per 1,000 children under age 5, as compared with 31.5 in Boston as a whole (Boston Public Health Commission Research Office 2013).

Dudley Square has a rich history of civic engagement stemming from an effort to take back the area by local residents after disinvestment in the 1960s and 70s and a defeated Interstate 95 project that left the neighborhood with many abandoned lots and a depressed local economy. Manufacturing jobs in Roxbury declined from 20,000 in 1947 to 4,000 in 1980, and businesses in Dudley Square declined from 129 in 1950 to 26 in 1980 (Loh and Sugerman-Brozan 2002). By 1997, the area was taken over by "noxious and polluting land uses" and more than 1,000 diesel vehicles operating out of bus and truck depots located within 1.5 miles of Dudley Square (Loh and Sugerman-Brozan 2002, 116). In 2002, a report entitled "Unequal Exposure to Ecological Hazard: Environmental Injustices in the Commonwealth of Massachusetts" ranked the larger Roxbury neighborhood number eight on a list of "most intensively overburdened communities in Massachusetts" (Faber and Krieg 2002, 278). Throughout the twentieth century, the language characterizing Dudley Square shifted from emphasizing commercial prosperity to concern for environmental justice issues.

In 1993, Alternatives for Community and Environment (ACE) was founded and has since advocated for environmental justice through youth-led initiatives and community organizing. The organization seeks to "create alternative paths toward sustainable and just communities" (Loh and Sugerman-Brozan 2002, 117). Among the achievements of these environmental justice efforts are community-based participatory projects that have led to the use of CNG in city buses and the creation of an air quality monitoring station in Dudley Square.

Given Dudley Square's legacy of commercial vibrancy and environmental justice, this thesis will elaborate on the importance of understanding construction impacts in revitalizing Dudley Square through a shared community vision of sustainable redevelopment. With vacant land available for redevelopment as one of its most valuable economic resources and municipal plans for more redevelopment projects in the area, Dudley Square is set to remain a hotspot of intense construction activity. It is reasonable to assume that residents who live near construction sites have a higher risk of exposure to construction-related air pollution (Brugge 2008), and therefore it is important to characterize air quality around these construction sites. This thesis will use these two characteristics of the Dudley Square context (its environmental justice designation and its history and mobilization towards redevelopment) as motivation to construct a more robust picture of redevelopment by investigating air quality during a moment in the process. This analysis will both contribute to the body of literature on air quality impacts of construction and to the understanding of how construction fits into community development frameworks emphasizing sustainability and equity.

CHAPTER 2: LITERATURE REVIEW

OVERVIEW

This project addresses issues of air quality and health equity during construction that is part of a broader sustainable redevelopment process. There is extensive literature on each of these topics and this chapter delves into some of the research that is relevant to understanding the Dudley Square context. A literature review frames the project and gives current understandings on sustainable development theory and practice, how construction fits into this framework and its impacts on air quality and health, and regulatory mechanisms for addressing air quality during construction. I give a brief overview of several primary pollutants that are typically released during construction processes (e.g. nitrogen oxides, black carbon) but will focus on fine and ultrafine particulates because of (1) research indicating significant detrimental effects on public health, (2) the previously identified need for more research on construction-related particle emissions, and (3) neighborhood concerns about local health impacts from particulate matter. The literature review was conducted through analysis of studies found through searches in several databases including Web of Science and Science Direct and in many journals, including *Atmospheric Environment, Journal of Construction Engineering and Management, Environmental Health Perspectives* and *Journal of Hazardous Materials*, among others.

SUSTAINABLE RE/DEVELOPMENT AND EQUITY

Sustainable development (SD) is a broad term often used in describing the aspired balance between environment and societal needs as a community changes. Economy, equity and environment are all pieces that a community may focus on, though not mutually exclusive to one another. *Our Common Future* describes sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs,” (Brundtland 1987, 43). This is the most widely recognized definition of sustainable development, encouraging systems thinking. However, any further details about the definition differ widely. Some literature suggests that a clear definition of sustainability is necessary in order to formulate policies (referenced in Bolis et. al 2014). Others interpret sustainable development as a more fluid conversation about how to live in the world today and in the future, rather than about moving towards a predetermined type of society (Robinson 2004). Scott Campell (1996, 297) points out that sustainability as a planning concept ought to act as a “lightening rod” in focusing conflicting interests or else fall into the same pitfalls of previous idealistic planning concepts. This suggests that in a given community, either there is a prevailing view of sustainable development, or that one should be articulated in the participatory planning context.

Although an aspect of the environment seems inherent in any definition of sustainable development, it is often not the focus of SD efforts, especially when other community issues are of more pertinent concern. This is contrary to the environmentally-focused origins of the notion of sustainable development. Sustainable development can just as readily refer to a framework that promotes health, culture and economy, among other environmental goals like reducing carbon emissions or conservation. The Roxbury Strategic Master Plan (2004) is an example of community visioning that presents its own nuanced definition in light of the community's history and hopes for the future. Environmental health does not appear in the seven guiding principles agreed upon by the community and by the Boston Redevelopment Authority, but such language punctuates the planning document itself, especially given the community's familiarity with and sensitivity to environmental justice. Increasingly, notions of SD include social justice as well as the economy and environment.

Environmental justice

According to the EPA, environmental justice is the "fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to development, implementation, and enforcement of environmental laws, regulations, and policies" (Environmental Protection Agency 2012). The EJ framework is critical of top-down, "expert-led processes of risk assessment and research" and instead values citizen participation and transparency in planning processes (Agyeman 2005, 21). As a result, the literature on environmental justice efforts includes many studies that are undertaken by community-driven efforts or by research partnerships between the community and an additional institution (Loh et. al 2002).

In regards to air pollution, environmental justice links health and equity through the following characteristics: (1) groups with lower socioeconomic status are exposed to higher concentrations of air pollution and other environmental hazards, (2) these groups already suffer the burden of reduced health from social factors such as poverty and psychosocial stress, and (3) the burden of reduced health from social determinants interacts with air pollution to produce more serious health effects in the groups (Health Effects Institute 2010). In Boston, populations with high asthma hospitalization rates have been shown to be of lower socioeconomic status compared to populations with relatively low asthma rates (Gottlieb, O'Connor and Beiser 1995).

There is a close relationship between sustainability and environmental justice, such that Faber and McCarthy (2003) define the latter as "a movement based on environmental issues but situated within the history of movements for social justice". Agyeman argues that environmental justice considerations are part of sustainable development, defining the term *just sustainability* as "the need to ensure a better quality of life for all, now and into the future, in a *just* and equitable manner, while living within the limits of supporting ecosystems" (Agyeman et al. 2003, 2).

DUDLEY PLAN AND SUSTAINABLE REDEVELOPMENT

Dudley Square (Figure 1.4) is Roxbury's central business and commercial district. It was targeted for revitalization by the Boston Redevelopment Authority under the *Dudley Plan* (2011), which is the implementation of both *Dudley Vision (2007)* (see Appendix B), and the overarching planning framework for Roxbury, the *Roxbury Strategic Master Plan* (2004). According to the Dudley Plan, the revitalization efforts consist of: (1) creating an anchor site at the former Ferdinand Building, (2) releasing an RFP for the former B2 Police Station for commercial/retail development, (3) redeveloping Blair Lot, currently a parking lot, (4) improving the Dudley Library, and (5) reorienting the Dudley Square MBTA station to keep people and economic activity in the Square (City of Boston 2011). The total area of the projects is approximately 135,000 square feet and will cost approximately $100 to 115 million (City of Boston 2011).

In 2002, an ambitious community visioning process began in Roxbury, which was notable for its departure from top-down planning processes that were typical in community development. Several major themes of concern were already identified through public and informal meetings in the preceding years, among which were improving environmental conditions and an overall theme of protecting and ensuring economic growth and opportunities for local residents (Jennings 2004). In this document, sustainable redevelopment refers to economic ("sustainable jobs", "sustainable and diverse economy"), social ("sustainable affordable housing") and equity ("sustainable development and environmental justice") objectives (Boston Redevelopment Authority 2004).

Air quality degradation was identified as one of the neighborhood's greatest problems (Boston Redevelopment Authority 2004, 44). One of the goals under "transit-oriented development" is to "raise environmental justice and air quality standards in the community and the city" through controls on one well-understood source of pollutants: MBTA buses. The Plan calls for low-emission public transportation buses as well as school buses traversing the area and adoption of the recommendations outlined in the Dudley Square Transportation and Air Quality Study (2001). The Transportation and Air Quality Study itself mentions that redevelopment projects including the future Bruce C. Bolling Municipal Center should meet the goals and objectives of studies including the Roxbury Strategic Master Plan. However, the air quality impacts studied were restricted to changes in traffic due to the redevelopment projects, not through their development process itself. Given that many of the projected improvements to air quality have been realized (replacement of diesel buses with CNG buses, relocation of Bartlett Yard MBTA Facility, increase in public transportation use by addition of Silver Line), it is important to consider the non-mobile sources of air pollution that may impact environmental health in the wave of construction taking place in Dudley Square, especially as pedestrian access is improved.

AIR QUALITY AND CONSTRUCTION

Pollutants generated by construction

Emissions from construction processes originate from both the physical processes of demolition and construction and emissions from the heavy machinery used to carry out the work (non-road vehicles). Construction activity may include operation of diesel-fueled machinery, processes including crushing, screening, cutting, drilling, bulldozing, pulling/tearing down, and site work including excavation, soil-stripping, and ground leveling (Kumar et. al 2012). According to the Sacramento Metropolitan Air Quality Management District, among the emissions generated from construction activities are (1) exhausts of particulate matter (coarse, fine, ultrafine) and nitrogen oxides from fuel combustion in diesel and gasoline-powered equipment, (2) fugitive particulate matter from soil disturbance and demolition activity, (3) evaporative emissions of reactive organic gases (ROGs) or volatile organic compounds (VOCs), and (4) greenhouse gases including carbon dioxide, methane, and nitrous oxide (2009). Of these, the criteria air pollutants (CAPs) that are regulated by the National Ambient Air Quality Standards (NAAQS) and are of most concern in construction processes are particulate matter (PM_{10} and $PM_{2.5}$) and ozone (Sacramento Metropolitan Air Quality Management District 2009).

Ultrafine (UFP, <0.1µm) and fine particles ($PM_{2.5}$, <2.5µm) are largely formed from combustion, high-temperature processes and atmospheric reactions. This includes the combustion of diesel fuel, coal, gasoline, oil and wood (EPA 2013). UFPs can be made up of sulfates, elemental carbon, metal compounds, and organic compounds (EPA 2013). Their atmospheric half-life is minutes to hours while fine particles have an atmospheric half-life of days to weeks (EPA 2013).

While there are extensive studies focusing on vehicle-related pollutants (Levy et al. 2010; Frank and Engelke 2005; Health Effects Institute 2010), including the diesel machinery used at construction sites (Zhu et. al 2011; Lewtas 2007; Lindgren 2010), relatively few studies measure ambient fine and ultrafine emissions of the physical demolition and construction processes themselves (Azarmi et. al 2014; Kumar et. al 2012; Hansen et. al 2008).

According to Kumar (2012), the lack of study in this area means that it is largely unknown whether there is “unintended release” of ultrafine particles from building activities (262). In a study measuring particles released during simulated construction activities (crushing, drilling through concrete), the same author found that the “majority of new particles by number were released in the UFP size range whilst the bulk of particle mass concentration (PMC) consisted of particles over 100 nm in size,” (Kumar et. al 2012, 262). UFP dust particles are differentiated from the volatile UFPs produced by combustion processes in that they are “likely non-volatile and may have a much longer atmospheric lifetime” (Kumar et. al 2012, 263). Kumar points out that it is important to further investigate the large local source of UFPs from construction processes because of the magnitude of UFP generation, which is comparable and sometimes much greater than particle number concentrations (PNCs) generated in road-tire interactions, which has been associated with toxicological effects (Kumar et. al 2012; Gustafsson et. al 2007). It is important to quantify UFP because of increased likelihood of emission: the practice of recycling concrete by crushing and screening has increased from 35 to 61 percent between 1999 and 2008 and often occurs at the site of demolition activity in urban environments (Kumar et. al 2012).

Strategies for reducing particle dispersion during construction include water spraying and wind speed reduction (Azarmi et. al 2014; Wallace 2013; Dimari 2008; EPA 1995). Water spraying has been found to be an effective suppressing strategy for reducing UFP release in physical recycling processes, where an order of magnitude difference was found between a wet and dry process (Azarmi et al. 2014). However, this is not likely to reduce the UFP created from combustion processes with more volatile composition (Azarmi et al. 2014). There are several studies investigating the effect of construction on indoor air quality, especially in places where children are found, like schools and child care centers (Burtscher and Schüepp 2012; Buonanno et al. 2013).

Emissions can vary significantly depending on intensity of construction activity, the specific operation in action and meteorological conditions including wind direction (Chang et al. 1999). As a result, it is difficult to assess the contribution of these emissions to overall air pollution in a region, although localized emissions can be quantified and are perhaps of greater concern to proximate populations. In 1976, 3.8 percent of total particulate emissions from open sources in the United States were estimated to be from construction activities (Font et al. 2014). The London Atmospheric Emissions Inventory estimated that in 2010, 1.4 percent of PM_{10} emitted in the city was from construction and demolition activity (Font et al. 2014). In comparison, many studies have shown that vehicular sources can represent up to 80 percent of particulates in urban areas (Kumar et al. 2012).

Further research is needed to quantify the magnitude of construction impacts on air quality (Kumar et al. 2012). Numerous studies have developed protocols for investigating traffic-related air pollution, but similar metrics have not been applied in studying construction. For example, the most common traffic indicators used in traffic and particulate models are traffic counts, length of road and proximity to roads. Review of the literature at this time reveals a lack of similar metrics for measuring the relationship between construction and particulate matter. In the two studies that have looked at the air quality impacts of construction: Azarmi et al. (2014) measured emissions from simulated construction processes, while Hansen et al. (2008) measured air quality during the demolition of a hospital.

Emissions factors (EF) are used to relate the quantity of a pollutant released into the air with a source activity and help estimate emissions from various sources of air pollution, but the EF for construction activities are uncertain. This is due to limited existing research. The EPA's emission factor handbook (AP-42) section on "heavy construction activities" cites only one study from 1975 that has attempted to relate emissions from construction to an emissions factor (Muleski and Cowherd 2005; EPA 1995). Appendix A lists some of the annual emissions from heavy duty equipment typically used in construction processes.

Health impacts of fine and ultrafine particles and exposure

There are several categories of people that may be exposed to construction-related air pollutants: (1) people on site, (2) people passing by a construction site and (3) people occupying nearby buildings (Kumar et. al 2012). Proximity as well as wind speed and direction and duration of exposure are all important factors in determining exposure intensity. For workers on a construction site, exposures can additionally differ depending on whether personal protection equipment is used.

Due to their small size, fine and ultrafine particles can travel through the lungs and into the blood stream when inhaled (Figure 2.1). Particular properties of ultrafine particles, including high surface reactivity and ability to cross cell membranes, may increase their toxicity (Kumar et al. 2010). Among the pollutants emitted by motor vehicles, $PM_{2.5}$ in particular has been associated with premature mortality (Levy et. al 2010; Laden et al. 2006). The American Heart Association has found that exposure to $PM_{2.5}$ over a few hours to weeks can trigger cardiovascular disease-related mortality and nonfatal events, while longer-term exposure (a few years) increases the risk of cardiovascular mortality to an even greater extent, reducing life expectancy within more highly exposed segments of the population by several months to a few years (Brook et al. 2010). Additionally, reductions in PM levels are associated with decreases in cardiovascular mortality within a time frame as short as a few years (Brook et al. 2010).

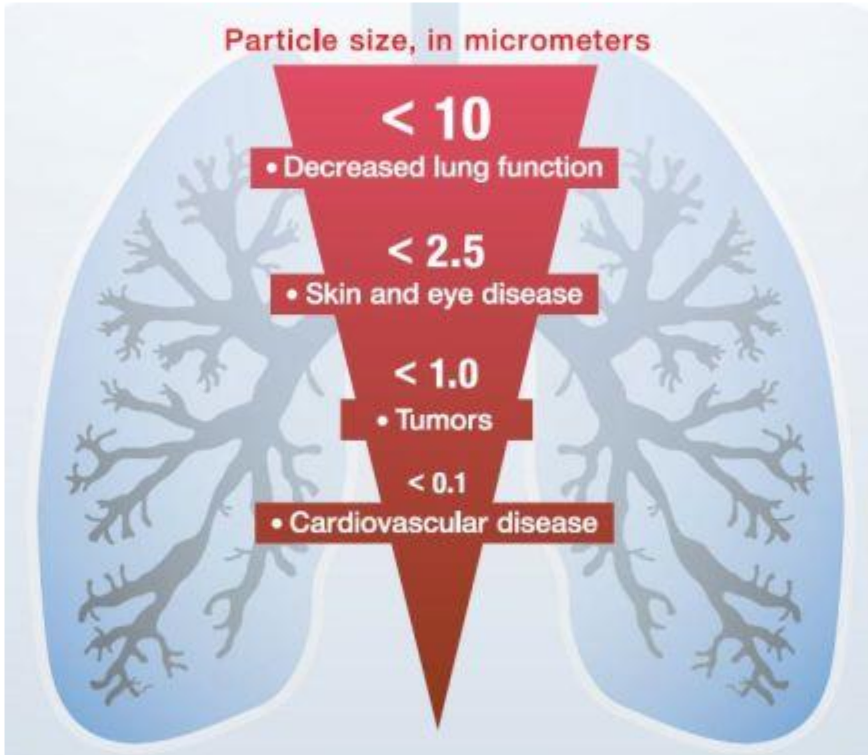

Figure 2.1: Particle size and associated health effects. Source: Brüning 2006.

A 2009 EPA report that reviewed research on health effects of UFPs found inadequate evidence for establishing a causal relationship between long term exposure to UFPs and cardiovascular and respiratory effects (Health Effects Institute 2013). However, the review also noted an inadequate base of evidence with which to make the assessment. Most of the evidence has been provided by toxicological studies, not epidemiological studies. Furthermore, the combustion sources of UFP are understood to affect mortality (Health Effects Institute 2013, 52).

Diesel emissions are a significant source of fine and ultrafine particles and pose seven times the lung cancer risk of all 181 other air toxics tracked by EPA combined (Clean Air Task Force 2014). Suffolk County has the greatest average lifetime cancer risk from diesel soot in the state and region, ranking in the top 1% nationally (41 out of all 3,109 counties in the nation) - a risk 309 times greater than what the EPA considers acceptable (Clean Air Task Force 2014). In Boston, older diesel engines annually contribute to over 47 non-fatal heart attacks, 43 premature deaths, almost 42,000 minor restricted activity days, and 7,350 days of lost work productivity (Clean Air Task Force 2014). The International Agency for Research on Cancer (which is a part of the World Health Organization) has classified diesel exhaust as carcinogenic to humans (International Agency for Research on Cancer 2012).

CONTROL STRATEGIES AND REGULATIONS

There are several policies that work to limit air pollution from construction processes at varying levels of government as well as non-regulatory practices for clean construction.

Emission Control Strategies

There are three types of interventions that can be taken to mitigate the release of fine and ultrafine particles into the atmosphere. These are: (1) fuel-based strategies, (2) engine-based strategies, and (3) dispersion-control strategies (Gladstein, Neandross & Associates 2013). The ultra-low sulfur diesel fuel specification (15 parts per million maximum sulfur concentration in fuel) for nonroad engines (including construction equipment) was phased in from 2007 to 2014, which will reduce exhaust emissions by about 90 percent (EPA 2012).

Diesel particulate filters (DPFs) and diesel oxidation catalysts (DOCs) are two emissions control technologies that can be installed onto diesel equipment to reduce several air pollutants, including particulate matter. The Table 2.1 lists typical emissions reduction and costs for installation of each retrofit technology.

Table 2.1: Diesel retrofit devices and typical emissions reductions. Source: EPA 2013.

	Typical Emission Reductions (percent)			Typical Costs ($)
Technology	**PM**	**HC**	**CO**	
Diesel Oxidation Catalyst (DOC)	20-40	40-70	40-60	material: $600-$4,000 installation: 1-3 hours
Diesel Particulate Filter (DPF) Active or Passive	85-95	85-95	50-90	material: $8,000–$50,000 installation: 6-8 hours
Partial Diesel Particulate Filter (pDPF) Partial or Flow-through	up to 60	40-75	10-60	material: $4,000–$6,000 installation: 6-8 hours

DOCs work by causing a catalytic reaction that breaks down pollutants. They require little to no maintenance, and are most effective with low-sulfur fuels (15ppm or less). DPFs use a filter (porous ceramic, cordierite substrate or metallic filter) to physically trap particles and must be used with low-sulfur diesel. In DPFs, operating temperatures need to be high enough to combust accumulated particles and they require periodic cleaning.

While both DOCs and DPFs have been shown to reduce fine particulate matter in the atmosphere, more research needs to be done to understand the effect on UFPs. While several studies cite DPFs as effective in reducing UFPs (Gladstein, Neandross & Associates 2013), other studies have found that the benefits of PM reduction are confounded by an increase of NO_2 and UFP emissions (Karthikeyan et. al 2013).

Regulations

While National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$ already exist in the United States, ultrafine particles are not currently regulated. There are several challenges to developing a regulating framework for nanoparticles: (1) the lack of standardization of measurement parameters (e.g. particle size distribution, shape, number concentrations, and surface area), (2) insufficient knowledge about the chemical composition of UFPs in different environments, and (3) insufficient knowledge about exposure-response relationships (Heal et. al 2012; Kumar et. al 2011). $PM_{2.5}$ is currently regulated by mass concentrations.

In regards to standards for vehicle emissions, the Euro 5 and Euro 6 emissions standards were the first regulations for particle number and apply to on-road vehicle tailpipe exhausts in European Union member states (Kumar et. al 2011). They both establish a protocol for measuring UFPs and establish a limit on particle number (Gladstein, Neandross & Associates 2013). However, due to limitations in technology available at the time of adoption, particles less than 23 nm are not counted. In September 2014, the European Commission proposed Stage V emission regulations that were the first to put a limit on particle number on mobile non-road engines at 1×10^{12} kWh^{-1} (particle number per kWh)(DieselNet 2014).

In the U.S., the first federal standards for new non-road diesel vehicles were adopted in 1994 under Tier 1 emission standards (DieselNet 2014). Tiers 1 through 3 limit exhaust through engine design. With the adoption of Tier 4 (phased in from 2008-2015), emissions must be reduced by about 90 percent, which can be met through the use of dispersion-control filters. Additionally, while the Tier 1-3 emissions standards did not regulate sulfur content in nonroad diesel engines, Tier 4 mandates 15 ppm sulfur (ultra-low sulfur diesel) which became effective in 2010 for nonroad fuel (DieselNet 2014). Ultra-low sulfur diesel is needed to run the most effective DPFs. These emissions standards do not apply to already existing diesel-fueled construction equipment, therefore necessitating retrofit policies. While there are no national regulations requiring retrofit technology on construction equipment, several states have implemented mostly voluntary policies or have adopted state and city contracting policies requiring fleets working on government projects to meet certain emissions reduction targets (Clean Air Task Force 2010).

CHAPTER 3: METHODS

OVERVIEW

The overall goal of this thesis is to draw attention to construction as a transient but significant stage in redevelopment and to understand how community development frameworks of sustainability and equity applied throughout the redevelopment process can also be consistent through construction. To do this, I investigated construction impacts on air quality (specifically fine and ultrafine particles) during redevelopment projects that were anticipated in the Roxbury Strategic Master Plan.

Dudley Square was chosen as the case study for this project because of the existence of a neighborhood strategic master plan that strove to be inclusive of community members and comprehensive of values, the neighborhood's designation and history as an environmental justice area, the amount of construction underway as a result of the realization of the master plan, and the proximity of the specific redevelopment sites to the Environmental Protection Agency's Speciation Trends Network (EPA-STN), from which air quality and meteorological data were available. Together, these four components help compose a more robust snapshot of the neighborhood during one moment of the redevelopment and construction process.

First, I conducted a background assessment of Dudley Square by exploring its historical, social and environmental context through analysis of published planning documents and descriptive mapping using geographic information systems (GIS) and U.S. Census (2010) and American Community Survey (2013) data (Objective 1). Then, I gathered and analyzed pollutant data to understand changes in air quality during the demolition of the Ferdinand Building and the demolition of the former B2 Police Station

(Objective 2). Finally, I present possible mitigation policies and regulations for air quality-related construction impacts (Objective 3).

Through this study, we will be able to understand whether and how principles of environmental justice and sustainable redevelopment (*just sustainability* as it has been described) are put into practice throughout the redevelopment process by investigating an environmental health issue.

OBJECTIVE 1: BACKGROUND ASSESSMENT

Overview

Dudley Square has a rich history of both social and environmental activism. This legacy is also present in the Roxbury Strategic Master Plan, which was published after an extensive participatory planning process in 2004 (Boston Redevelopment Authority 2004). In this section, I present the context in which current construction projects are underway and establish the themes of sustainability and equity that structure the redevelopment conversation. I draw attention to concerns about air quality articulated in the Roxbury Master Plan and analyze this in terms of both the process and the end-product.

Additionally, I set the context for Dudley Square in the Roxbury neighborhood by explaining demographics and health statistics. Using data from the sources described in Table 3.1, I produced descriptive maps of Dudley Square using the geographic information systems software ArcGIS 10.2 (GIS) in order to present a more complete picture of the neighborhood and illustrate how density may impact the number of people exposed to changing air quality. GIS was also used to define a 200 and 300 meter radius around the redevelopment sites to show the possible extents of elevated pollutant exposures. These distances were chosen based on traffic-related air pollution that found pollutant levels decrease to background levels within 300 to 400 meters (980 to 1300 feet) (Sanderson et al. 2005; Diez Roux et al. 2008; Brauer et al. 2003; Padró-Martínez et al. 2012).

Table 3.1: Data analyzed in background assessment.

DATA	SOURCE	VARIABLES
Demographics	US Census, 2010 American Community Survey, 2013	Race, age, sex, income
Environmental Justice Populations	MassGIS/Office of Energy and Environmental Affairs, 2012 based on 2010 Census	Minority, minority and income, minority, income and English isolation
Zoning/Land Use	Boston Redevelopment Authority, 2014	Residential, Commercial, Industrial
Infrastructure	MassGIS/ Massachusetts Department of Transportation - Office of Transportation Planning, 2014	Roads, railroads, MBTA stations
EPA Air Monitor Locations	EPA AirData, 2014	Monitoring Networks
Health Indicators by Neighborhood	Boston Public Health Commission, 2013	Asthma emergency department visits, heart disease hospitalizations, cerebrovascular disease hospitalizations, asthma rate

OBJECTIVE 2: AIR QUALITY ANALYSIS

Overview

Two primary methods were used to understand how construction activity impacts levels of fine and ultrafine particles in the atmosphere. First, a retrospective study analyzed construction and pollutant data from the demolition processes at the Ferdinand Site in 2012. Second, an observational study measured and analyzed air quality during demolition of the former B2 Police Station in November 2014.

Ferdinand Site Demolition

Groundbreaking for the Bruce C. Bolling Municipal Center at the site of the former Ferdinand building began in March 2012 and construction followed in several stages. Demolition (with preservation of building skins) occurred from July to November 2012, steel erection and concrete decks were installed throughout 2013, exterior framing and building skin work took place in fall 2013, interior mechanical, electrical and plumbing and finishes occurred in 2014, and green roof installation and landscaping is to be completed in 2015. The demolition period was chosen for study for several reasons: (1) the equipment used during demolition processes are those found to have the highest PM emissions according to the Massachusetts 2002 Diesel Particulate Matter Inventory (see Appendix A), (2) clearly indicated start and end to the demolition process articulated in the daily construction logs, and (3) consistency with the second part of this study measuring air quality during the former B2 Police Station demolition. Demolition of the Ferdinand refers to the total Ferdinand site on which the Bruce C. Bolling Municipal Center was constructed. The site itself is made up of several buildings including the Ferdinand Building, the Waterman Building and the Curtis Building. The complete site is highlighted in yellow in Figure 1.1.

Air quality data from the study period was obtained from the Environmental Protection Agency's Speciation Trends Network (EPA-STN) located at the intersection of Harrison Street and Ziegler Avenue, approximately 100 meters east of the Ferdinand demolition site. Ultrafine particle data were obtained from Tufts University's air monitoring station at the same site. Daily construction logs were obtained from the City of Boston's Property and Construction Management Department. Table 3.2 lists the data obtained from these sources.

Table 3.2: Data analyzed in air quality study.
*This represents the general time frame that data were available; there are gaps in the data because data were removed when various faults occurred in the monitoring equipment or when there was a lapse in data collection.
**There are some gaps in the daily construction logs when logs were not completed or reported (September 24-28, 2012).

VARIABLE	DATES	FREQUENCY	UNITS	SOURCE
PM 2.5	7/19/2012-11/5/2012*	1 hour and 1 day	micrograms/m^3	EPA-STN
UFP (Ultrafine Particles) – PNC (Particle Number Concentration)	7/19/2012 – 11/5/2012*	1 minute	Particles/cm^3	Tufts
Wind speed	7/19/2012-11/5/2012	1 Hour	Miles/hour	EPA-STN
Wind direction	7/19/2012-11/5/2012	1 Hour	Degrees compass	EPA-STN
Construction activity	5/20/2012 – 12/31/2012**	1 Day		City of Boston

Particle number concentration (PNC) was used as a proxy for measuring ultrafine particles. The data were restricted by time to include only the 8-hour construction work day indicated by the Property and Construction Management Department, 7AM to 3PM. The raw data were put through a quality control process to remove points that had any associated errors during collection. As a result of this quality control process, some days are missing a significant amount of data, which would potentially give an inaccurate idea of median pollutant levels. The data were arbitrarily restricted to only include days where there was at least 50 percent of the minute-level data available during the 8-hour work day. This eliminated one day, October 12, 2012, where 66 percent of the data was missing. The EPA-STN data for $PM_{2.5}$ and wind speed and direction were already quality controlled when received and did not include data logged with errors.

The daily construction logs contained information about the subcontractors present on the construction site each day and their role in the construction process (i.e. demolition, masonry, restoration, temporary power, etc.), the number of workers present on the construction site (0-17 during demolition days where air quality data were also available), the equipment used on site (excavators, cranes, front-end loaders, etc.), and a brief overview of the activities undertaken each day ("Bobcat removing debris, piling outside," August 3, 2012). These variables were used to indicate high and low intensity demolition days based on the work taking place. For example, days where the daily construction log indicated there was no equipment in use but workers were on site were coded as low construction days.

To summarize, there were several steps that were taken prior to statistical analysis. These included (1) identifying high and low construction intensity days by analyzing daily construction logs, (2) identifying days when air quality data was available and excluding non-work hours and work days with less than 50 percent available data after quality control, and (3) converting wind direction from degrees to cardinal direction, and then identifying which days had winds coming from a predominately northwestern direction so that pollutants coming from the Ferdinand could be measured at the EPA-STN monitoring station located to the southeast of the construction site.

After the preliminary work was finished, the data were analyzed using the program Minitab. Time series graphs and t-tests results are presented in the next chapter.

Former B2 Police Department Demolition

In the second part of the air quality study, real-time data was gathered during demolition of the former B2 Police Station in Dudley Square (Figure 1.1) to understand air quality impacts of demolition on a more granular, minute-by-minute level. For this part of the study, the Tufts Air Pollution Monitoring Lab (TAPL) was used to gather data during one day of demolition activity (November 11, 2014). The TAPL was parked downwind of the demolition site, according to NOAA prediction of wind direction for the day, and measured several pollutants in real time. Fine and ultrafine particle measurements were descriptively and graphically explored to understand whether demolition activity was correlated with changes in pollutant levels. Data from the B2 demolition site (frequency of 5 seconds) was compared to concurrent data measured at the background EPA-STN site using a separate, stationary condensation particle counter (CPC) at a frequency of 1 minute. The program Minitab was used to explore time-series data and to run t-tests.

OBJECTIVE 3: POLICY IMPLICATIONS

The final component of this thesis discusses regulations, policies and design strategies that can be used to address short-term construction exposure in areas similar to Dudley Square, with high density and high pedestrian activity. I address current Boston regulations pertaining to construction emissions and discuss local efforts to pass a Diesel Emissions Reduction Ordinance. The discussion draws from the literature review outlining current regulations for $PM_{2.5}$ and ultrafine particles (including European regulations for UFP) and strategies for reducing diesel particulate emissions from the Environmental Protection Agency (Diesel Emissions Reduction Act). I discuss the implications of implementing policy based on pollutant dispersion research and the challenges that this strategy faces. Based on the background assessment and literature review, I also suggest frameworks that can be used to advocate for emissions mitigation as well as private sector approaches to clean construction.

CHAPTER 4: RESULTS

BACKGROUND ASSESSMENT

Geographic Analysis

Roxbury is located at the geographical center of Boston's twenty-three neighborhoods (Figure 4.1). The neighborhood boundaries depicted here are those used in the Roxbury Strategic Master Plan, which predate the boundaries created in 1988 by the Boston Redevelopment Authority for planning purposes. There are seven census block groups encompassing and adjacent to the Dudley Square epicenter at the site of the former Ferdinand Building, representing a radius of about 800 meters (half a mile). Thirty-seven census blocks give us a more granular understanding of the population around Dudley Square, representing about a 400 meter (quarter mile) radius around the Ferdinand epicenter, which includes the 300 meter range where particle concentrations have been observed to drop off to background levels. This 400 meter radius encapsulates Roxbury's busiest hub, where businesses and transportation activities are concentrated. Dudley Square is also pedestrian intense as center of social life for the residential neighborhoods that immediately surround the area, including a school complex, a library, restaurants, groceries stores, and parks (Dudley Square Transportation and Air Quality Study 2001).

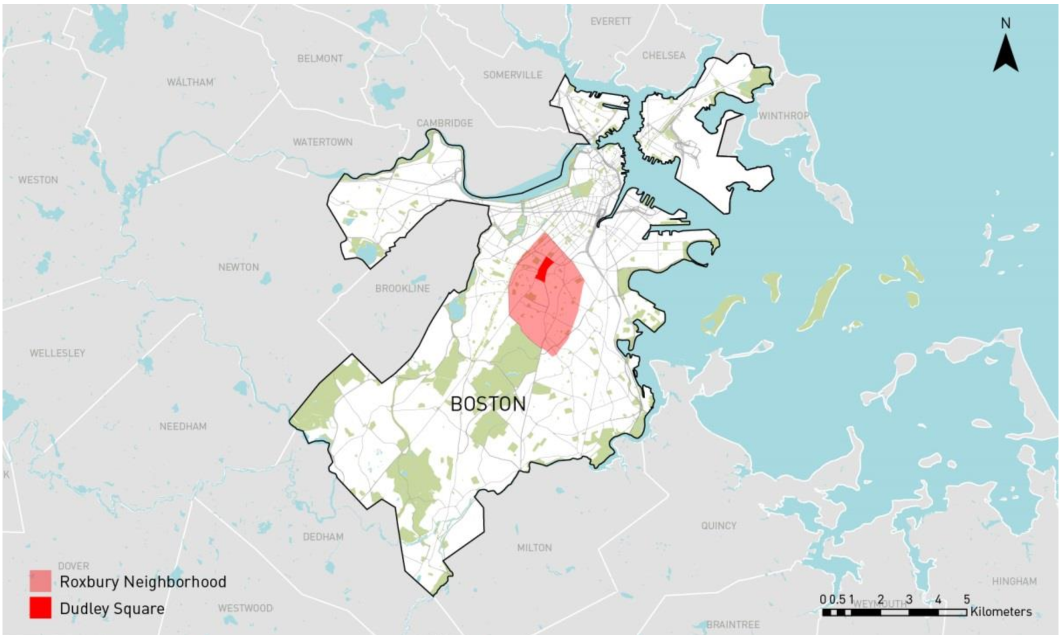

Figure 4.1: Dudley Square and Roxbury neighborhood in regional context. Cartography: Hanaa Abdel Rohman.

According to the 2010 Census, there were 2,174 people living in this area. 60.5 percent identified as black or African American, 15 percent as white, 14 percent as other race, 8 percent as two or more races, 1.5 percent as Asian, and 1 percent as Native American. Of the total population, 37 percent identified as Hispanic. This suggests that Dudley Square is a very diverse community. The median age in this area was 36 in 2010. Twelve percent of the population were 18 and under and 5 percent were 65 and older. Forty-three percent identified as male and 57 percent as female. Block group level data from the 2013 American Community Survey estimates the median household income as $26,713 while Boston as a whole had a median household income of $53,601.

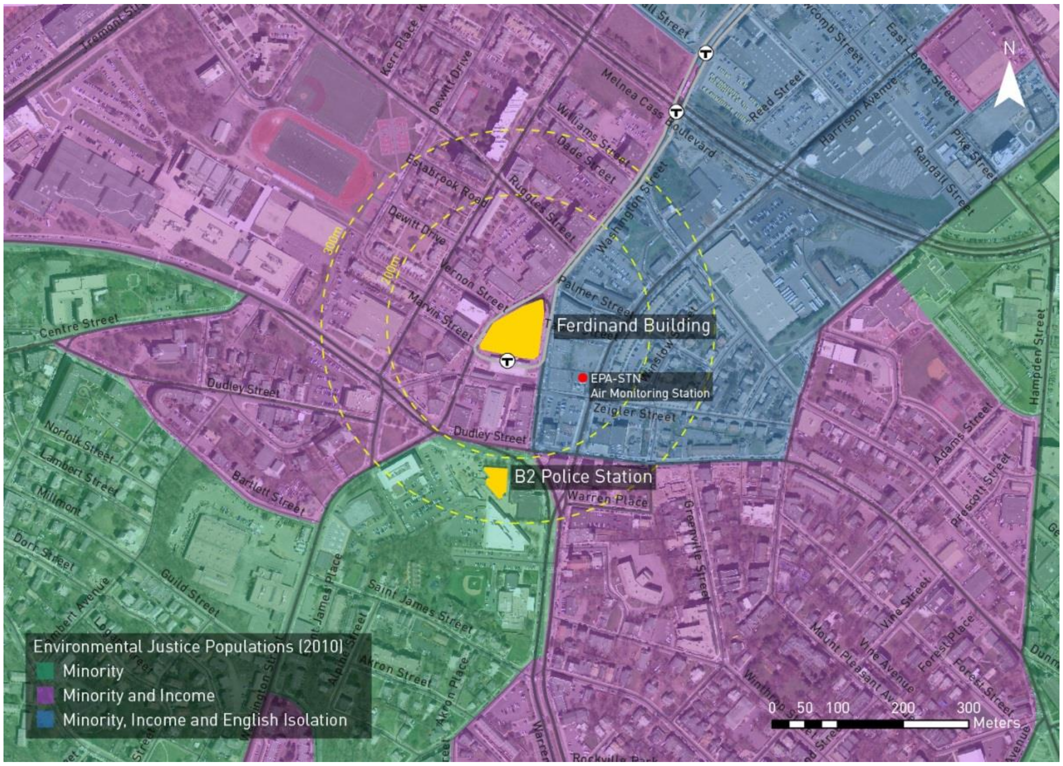

Figure 4.2: Environmental justice population categories in Dudley Square. Cartography: Hanaa Abdel Rohman.

Importantly, the Dudley Square area has been identified as an environmental justice community based on the combination of minority, income and English-speaking populations, (Figure 4.2). This implies that development or policies applicable to this area should be sensitve to environmental health impacts on the community. There are three categories of environmental justice population within the 300 meter buffer for pollutant exposure: (1) minority; (2) minority and income; and (3) minority, income and English isolation. Minority population is defined as the percent of “not Hispanic, white alone” population greater than 25 percent in a given block group, using data from the 2010 U.S. Census. The income category includes any block group with a median household income of less than or equal to $40,673, which is 65.49 percent of the 2010 Massachusetts state median income. English isolation was defined as households in which no person 14 years old and over speaks only English and no person 14 years old and over who speaks a language other than English speaks English "very well". Block groups with 25 percent or more of all households identified as English-isolated were designated an EJ population.

While Dudley Square itself is mostly zoned as an economic development area, the areas immediately adjacent to it are residential (Figure 4.3). The large area to the west of Dudley Square (in gray) is a school complex including Madison Park Technical Vocational High School and O'Bryant School for Math and Science.

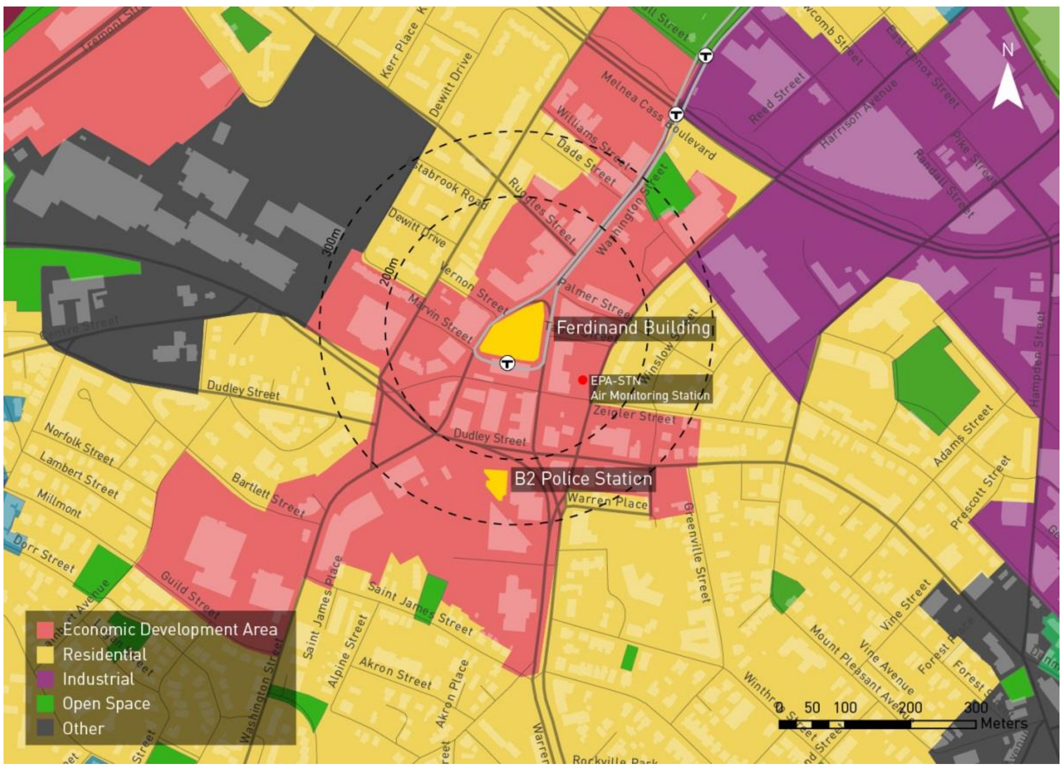

Figure 4.3: Zoning in Dudley Square. The commercial district itself is zoned as an economic development area while a large portion of the surrounding land is residential. Cartography: Hanaa Abdel Rohman.

HEALTH DATA

The most up-to-date information about the health of Boston neighborhoods is published by the Boston Public Health Commission in yearly “Health of Boston” reports, of which 2012-2013 is the most recent. According to this report, the Roxbury neighborhood reports worse outcomes than both Boston as a whole and any other neighborhood for each health outcome. After cancer, the leading cause of death in Roxbury (2005-2010) was “diseases of the heart” (Boston Public Health Commission 2013). In 2010, 15 percent of the adult population had asthma, compared to 11 percent for all of Boston (Boston Behavior Risk Factor Survey 2010, as quoted in Boston Public Health Commission 2013). In children under age 5, annual rates of asthma emergency department visits per 1,000 children were 59.0 and 43.9 for black and Latino children, respectively, compared to 25.6 for white children (2009-2011). To some extent these statistics should be viewed with caution, given the relatively small counts of white children (<20) in the comparison group (Boston Public Health Commission 2013). Similar disparities are observed for heart disease hospitalizations (2009-2011), where black residents had a higher rate of hospitalization (17.5) compared to Latino (13.7) and white (13.5).

AIR QUALITY ANALYSIS

The Ferdinand Site

Since the façade of the Ferdinand Building was to be preserved (Figure 4.4), demolition activity involved supporting the exterior frame while floors and ceilings were demolished using excavators. According to the daily construction logs, the “glory hole” method was used to create a vertical pit through the building and was used to drop demolished materials to the ground floor from upper levels of the five-story building.

Figure 4.4: Demolition of the Ferdinand Building with the façade preserved. Source: City of Boston Property and Construction Management Department, 2012.

Demolition began on the roof and worked its way down the building from July 19 to November 5, 2012, as indicated by dates in the daily construction logs. During this time, the predominant winds were coming from the southwest (Figure 4.5). However, there were also several days when the predominant wind direction was from the northwest, which are the days that the EPA-STN air monitoring station would be able to measure emissions coming from the Ferdinand site.

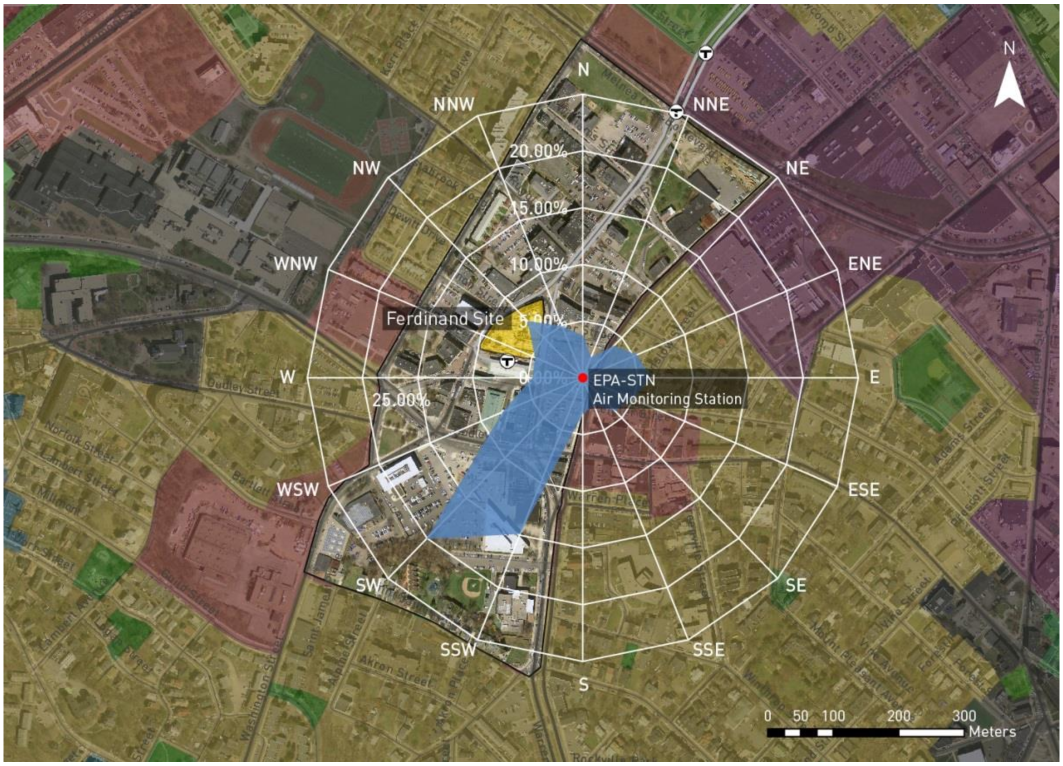

Figure 4.5: Wind direction during the demolition period at the Ferdinand site. Cartography: Hanaa Abdel Rohman.

Out of the 73 work days (not including weekends, when construction logs indicated no activity occurred and one week where there was no construction data recorded), there were 54 high intensity construction days and 19 low intensity construction days (Figure 4.6). Wind blew from a predominantly northwestern direction for at least one hour on thirty-eight days. There were five work days where wind came from a northwestern direction during the entire work day (7/25, 8/16, 9/19, 10/12, 10/16) and eighteen days where wind came from a northwestern direction during at least 50 percent of the day (dates highlighted in yellow in Figure 5.4). After excluding days where either data was not available (eliminated four days) and days where more than 50 percent of the air quality data was missing (eliminated one day), 12 days were left. Of these, four were low intensity construction days and eight were high intensity construction days. These were the days where data was analyzed for identification of any relationships between pollutant levels and construction intensity.

JULY 2012						
S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

AUGUST 2012						
S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

SEPTEMBER 2012						
S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

OCTOBER 2012						
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

NOVEMBER 2012						
S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

Figure 4.6: Ferdinand site demolition timeline. Light red are low construction intensity days, red are high construction intensity days. A gray cell indicates no daily construction data was available and a black border indicates no PNC data was available. Yellow text indicates winds coming from a northwestern direction, which are the days that the EPA-STN air monitoring station would be able to measure emissions coming from the Ferdinand site.

Box plot comparison between high intensity construction days and low intensity construction days shows that there is a greater range in PNC during high intensity construction days (Figure 4.7). There is also a general shift towards higher PNC levels during the high intensity days compared to low intensity days. The box plots also reveal a peak at the beginning of the work day from about the 7:00 to 9:00 AM hours. This finding can be corroborated by observations during the B2 Demolition, where daily construction activity started immediately with the beginning of the work day. The day-level scale of the description of activities in the daily construction logs and the inconsistent notation about when different construction activities were taking place makes it unclear exactly what activities using which equipment were in progress in the mornings.

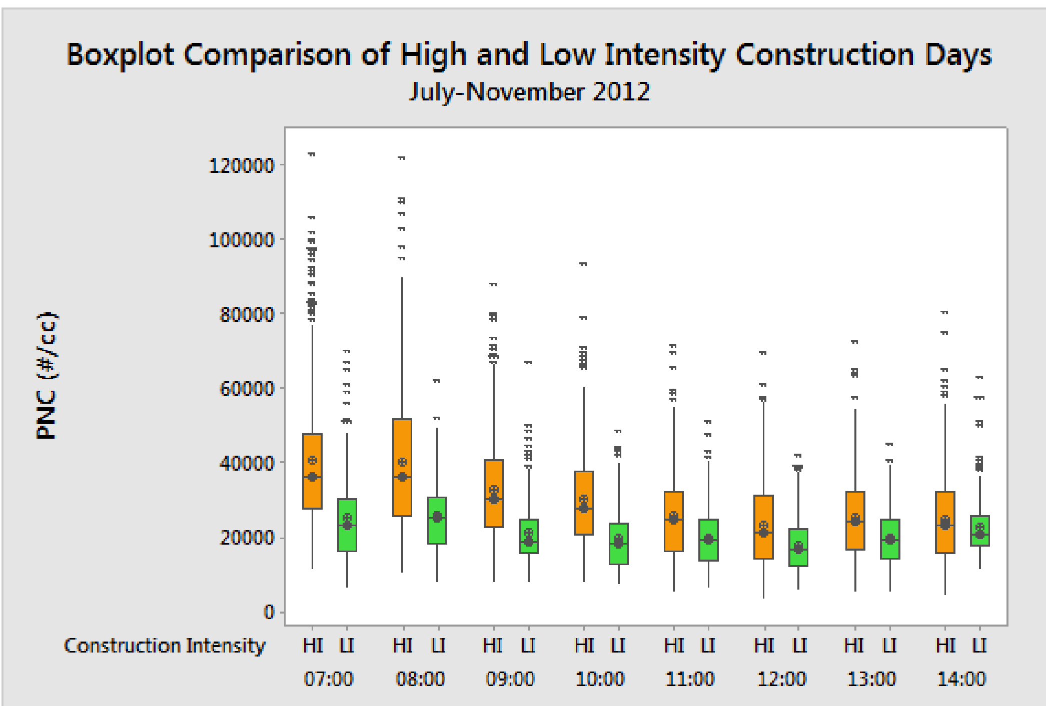

Figure 4.7: Boxplot comparison of hourly PNC on high and low intensity construction days over the entire demolition period.

The box plot comparison in Figure 4.8 shows the differences in the two groups more clearly. High intensity construction days again show a greater range in outliers and have a greater PNC mean and median than low intensity days. The difference was found to be significant ($p<0.001$) in a two-sample t-test using logged values (lnPNC) (see Table 4.1 for descriptive statistics). The t-test was used based on the lognormal distribution of the data (see Appendix C). Figure 4.9 shows box plots for each day in the demolition study period that was analyzed. Of particular note are three high intensity construction days: 8/28, 9/19 and 10/23. During these days, daily construction reports note several pieces of construction machinery in use. For example, on 8/28, there were three aerial lifts, one generator, three skid steers, a demolition robot (electric) and one front end loader in use.

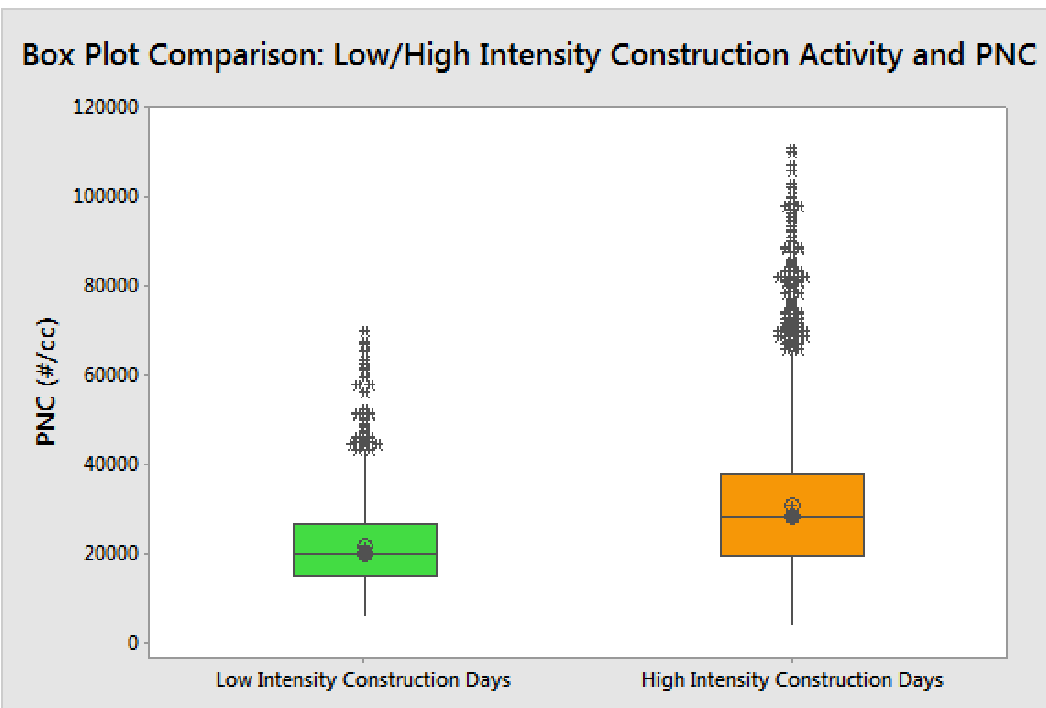

Figure 4.8: Box plot comparison of PNC during total Low Intensity and High Intensity construction days. The high intensity construction days show longer whiskers and greater range of PNC measured. Figure 4.6 indicates which days are low and high intensity. $t = -24.19$, $p<0.001$.

Table 4.1: Descriptive statistics for PNC (Particles/cm^3) on days with low and high intensity construction activity. Two sample t-test on lnPNC for each variable: t = -24.19, p<0.001.

Variable	N	Mean	St Dev	Minimum	Median	Maximum
PNC on LI Days	1920	21677	9202	5650	20200	26500
PNC on HI Days	3840	30900	15917	3640	28300	123000

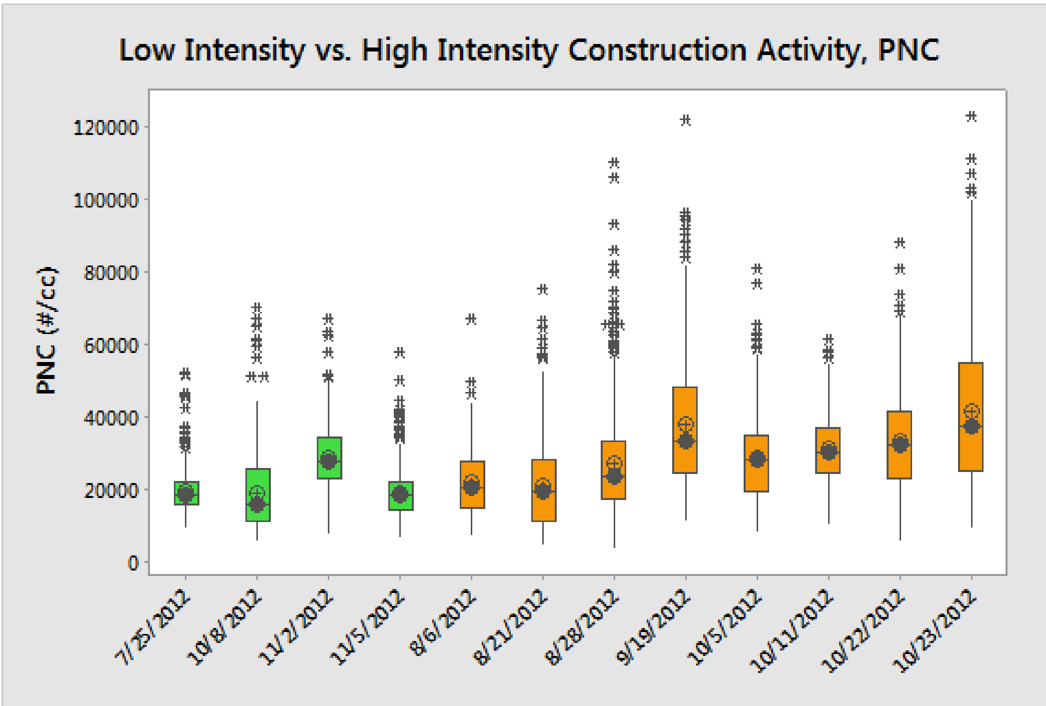

Figure 4.9: Series of daily box plots for entire demolition period, with days restricted to wind blowing from northwestern direction. The plots in green and orange are low and high intensity construction, respectively.

Comparison of time series graphs for $PM_{2.5}$ in Figures 4.10 and 4.11 are not as clear (except for a couple days with peaks above 10 micrograms/m^3). However, a t-test and the comparative box plots (Figure 4.12) reveal that the difference in $PM_{2.5}$ measurements between high and low intensity construction days is also significant (p<0.001) (Table 4.2). For days with low intensity construction activity, the range in the 1-minute average of PNC was 5,650 to 26,500 particles/cm^3, while for days with high intensity construction activity the range in PNC was 3,640 to 123,000 particles/cm^3. Median PNC levels for days with high and low intensity construction activity were 20,200 and 28,300, respectively.

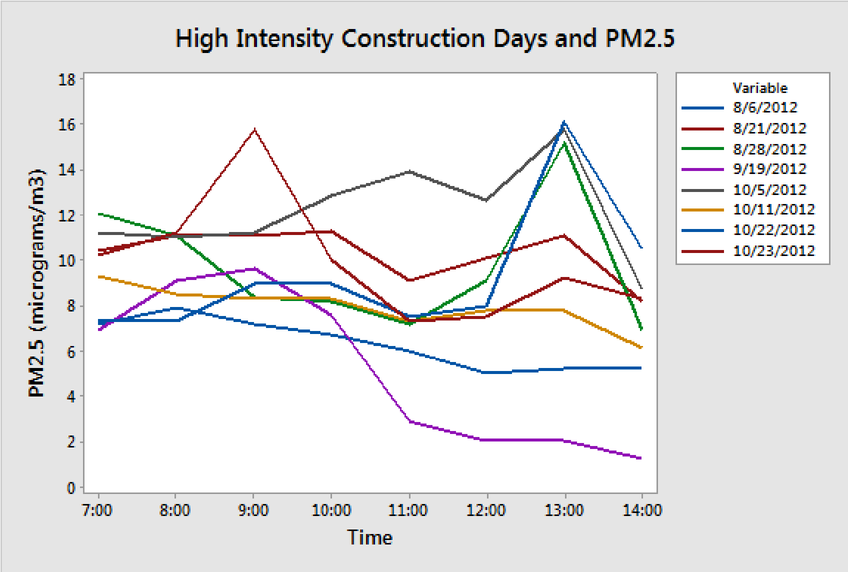

Figure 4.10: Time series plot of $PM_{2.5}$ on high intensity construction days.

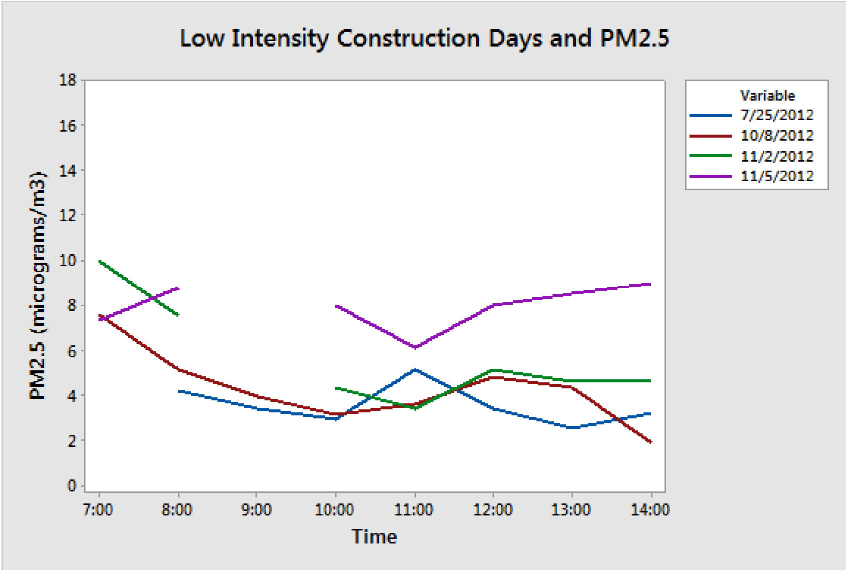

Figure 4.11: Time series plot of $PM_{2.5}$ on low intensity construction days.

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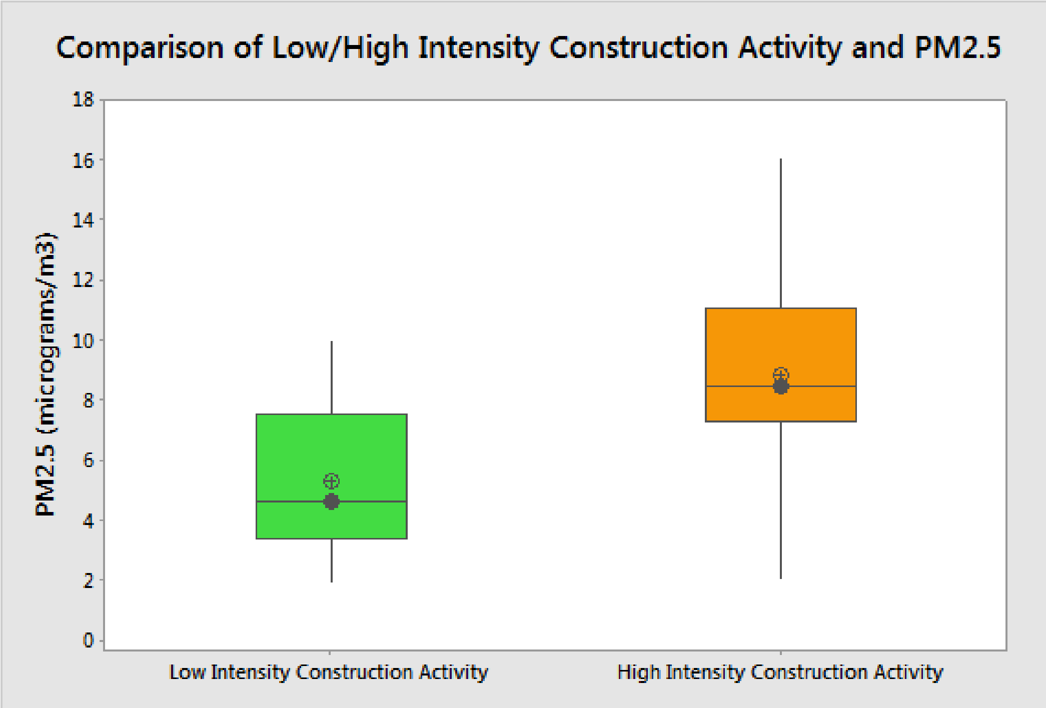

Figure 4.12: Box plot comparison of PNC during total Low Intensity and High Intensity construction days. The high intensity construction days show longer whiskers and greater range of PNC measured

Table 4.2: Descriptive statistics for $PM_{2.5}$ ($\mu g/m^3$) on days with low and high intensity construction activity. t = -6.23, p<0.001.

Variable	N	Mean	St Dev	Minimum	Median	Maximum
$PM_{2.5}$ on LI Days	32	5.317	2.254	1.900	4.600	10.000
$PM_{2.5}$ on HI Days	64	8.864	3.089	1.200	8.450	16.100

Data collection and analysis for the B2 Police Station were completed before analysis of data pertaining to the Ferdinand site was completed. As a result, there were several lessons learned about how methodology can be improved and the limits of conducting a retrospective study when focused on fine and ultrafine particles. Most crucially, this revealed the need to consider wind direction during high and low intensity construction days.

B2 Police Station

Demolition of the former B2 Police Station began on Monday, November 10, 2014 and observations and measurements were made on November 11, 2014, a public holiday. On the second day of demolition when measurements were made, the building was still entirely standing except for the exterior walls facing Dudley Street. Excavation began ahead of schedule at 6:50 AM and was continuous except for two breaks, from 9:00 to 9:30 AM and from 12:15 PM to 12:45 PM, when all equipment was powered off.

There were two diesel Caterpillar excavators on site, one primarily pulling down the concrete building (model 365C) and one recycling materials on-site (model 345C) (Figure 4.13). Recycling activities included crushing/pulverizing concrete and pulling out rebar, which was subsequently formed into a ball and deposited into a container. Two to three construction workers consistently sprayed down the area where demolition activities took place throughout the observed time period, except during the noted breaks when no demolition occurred. A pervious chain link fence separated the demolition site from the immediately adjacent sidewalk and Hubway bicycle station. The local library is located just east of the construction site.

Figure 4.13: B2 demolition on November 11, 2014. The Tufts Air Monitoring Lab (TAPL) is parked at the side of the street on the far right of the image, downwind of demolition activities occurring at the left of the image. Source: Hanaa Abdel Rohman.

Throughout the demolition period, pedestrians walked along the sidewalk, paused to observe and take pictures of the activity, and parked and took out bicycles from the Hubway station. Dudley Street provides immediate access to both the Dudley Square commercial area which has a mix of restaurants, retail stores and business headquarters and to the Dudley Square Bus Station so there was heavy pedestrian and vehicular traffic in the area.

The predominate wind directions for November 11, 2012 were identified the day prior to observation using the National Oceanic and Atmospheric Administration (NOAA) weather data. Based on this data, the Tufts Air Monitoring Lab was parked in the predicted downwind of the demolition activity (northwest of the site) in order to measure pollutants coming from the demolition site (Figure 4.14). It was important to park in the direction of predominant winds at the start of monitoring because there was little parking availability throughout the day on Dudley Street adjacent to the demolition site and we would not be able to move according to how winds shifted throughout the day.

The actual wind directions on the observation day are shown in Figures 4.15 and 4.16. The winds were coming from a southeastern direction at various brief times throughout the day, but mostly in the morning. The TAPL was correctly sited downwind of the demolition site for 22 percent of the observed demolition period. Data collection was stopped after predominant wind direction switched to a southwestern direction. Bus and truck traffic was noted throughout the observation period; the frequency ranged from one bus/truck every 30 seconds to two minutes. The TAPL was located upwind of the traffic and there were no obvious corresponding spikes in the data.

Figure 4.14: B2 Demolition site with 300m health exposure buffer. The Tufts Mobile Air Monitoring Lab was parked northwest of the demolition site because wind direction was predicted to come from a southeastern direction.

Demolition and non-demolition air quality levels can be compared from the break periods during which all equipment was turned off and then subsequently turned on again. The TAPL collected a range of air data, but this analysis focuses on fine and ultrafine particles. Box plot comparison (Figures 4.17 and 4.18) of PNC levels at the B2 demolition site and the background at EPA-STN show slight elevation in readings from the demolition activity when wind was blowing towards the TAPL. Box plots for measurements throughout the observed demolition period comparing the B2 demolition site and EPA-STN show a greater distribution in PNC levels for the demolition site than at the background location, which has a slightly lower median than at the demolition site (Figure 4.19). The associated t-test reveals that these differences are significant at $p<0.001$ (Table 4.3).

Figure 4.15: Wind direction during air monitoring of the B2 demolition. A clear signal from the construction site was observed when winds blew from the site to the TAPL from a southeastern direction.

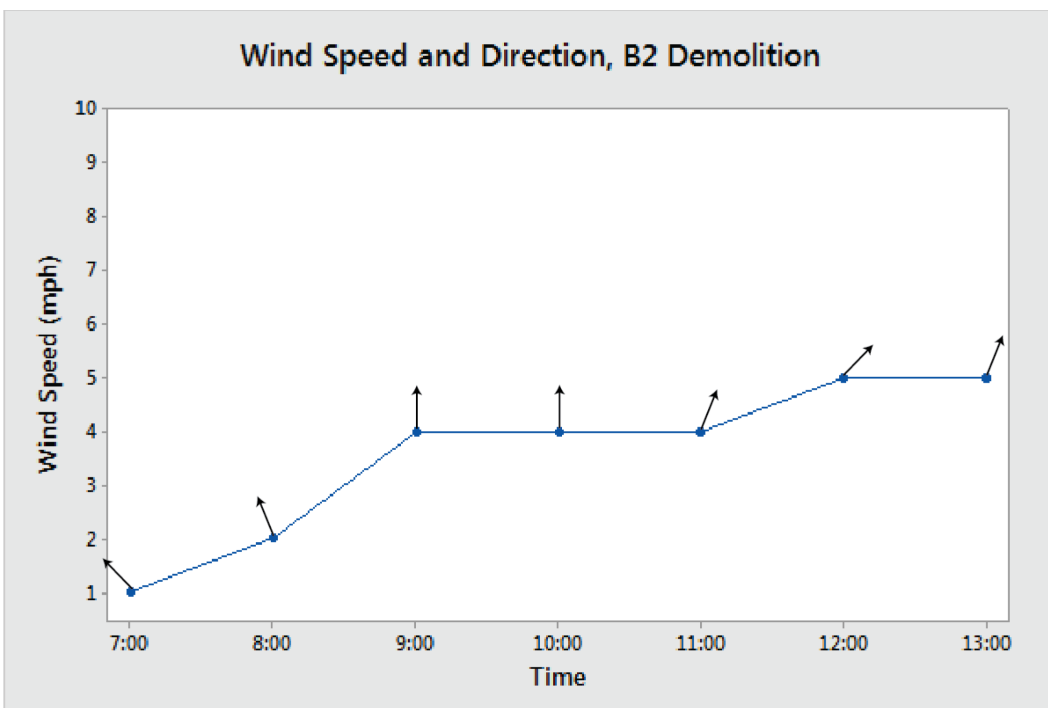

Figure 4.16: Wind speed and direction during B2 demolition. The arrows show direction of wind movement. At the beginning of the day winds were blowing towards the northwest where the TAPL was parked, but then shifted towards the northeast.

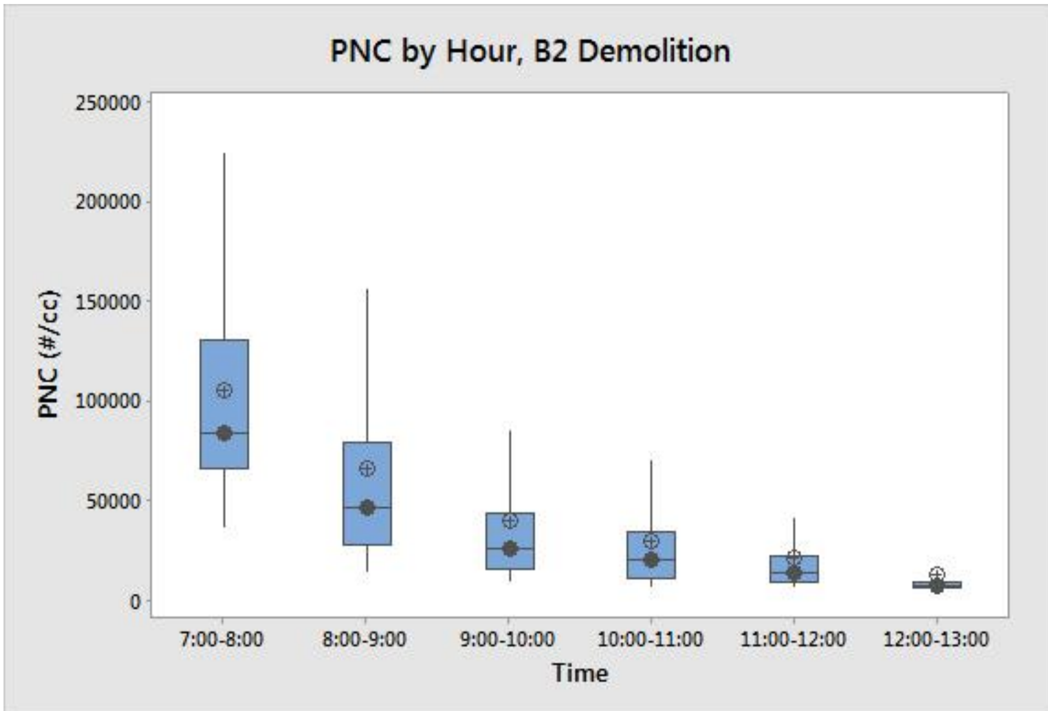

Figure 4.17: PNC levels by hour during the B2 demolition.

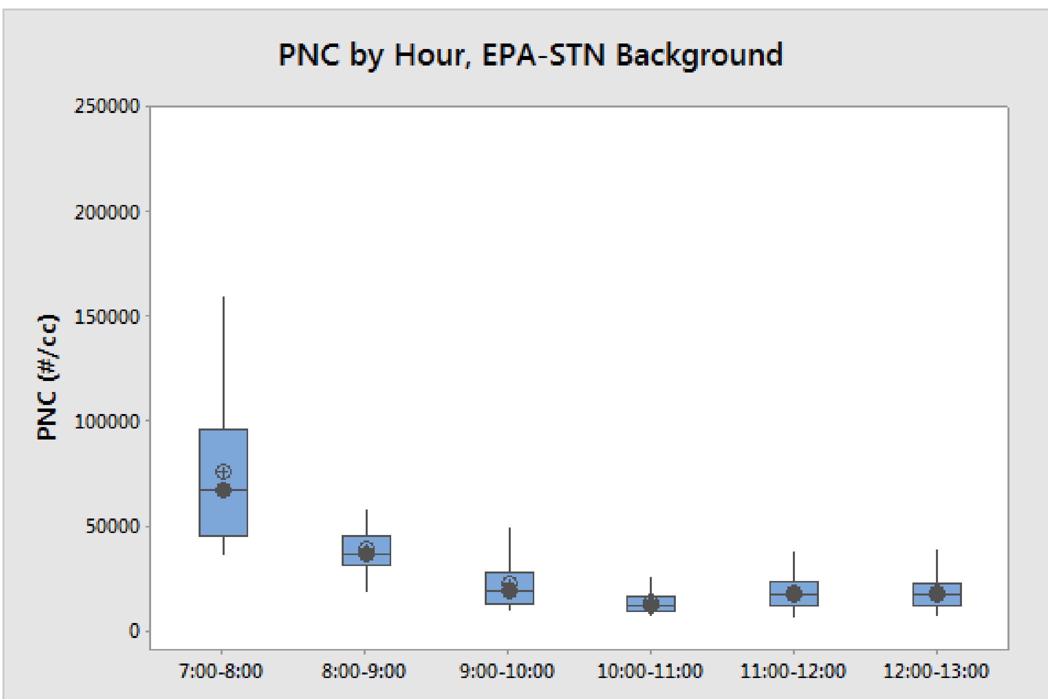

Figure 4.18: Background levels of PNC at EPA-STN at the same time as demolition at B2.

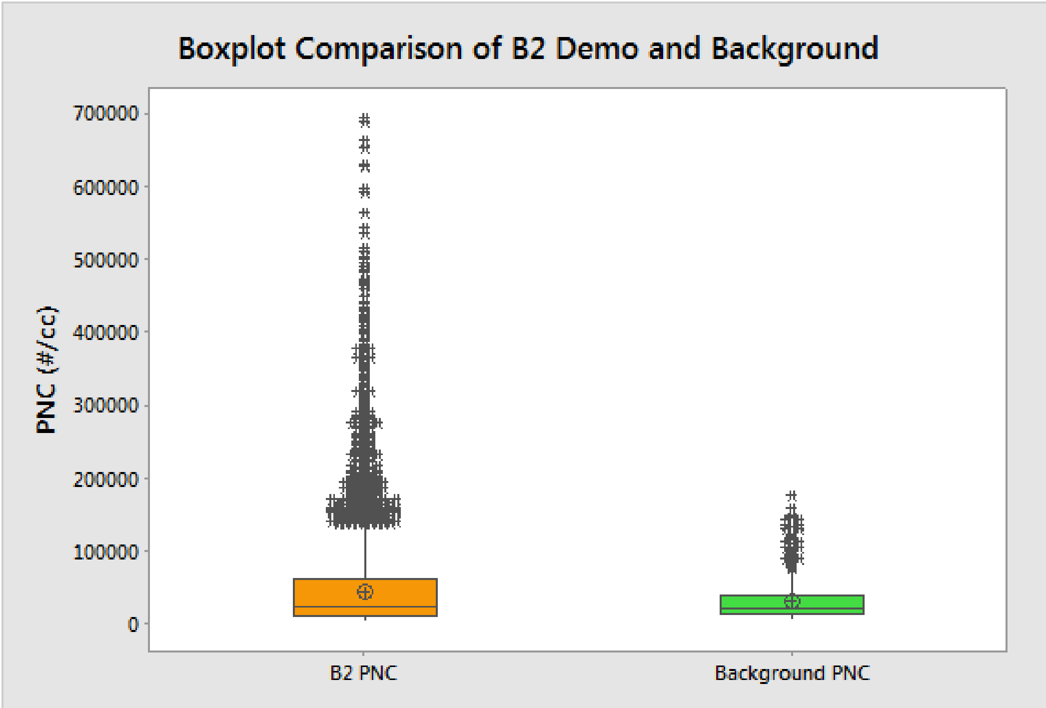

Figure 4.19: Box plot comparison of PNC between the B2 demolition and background PNC measurement at EPA-STN. $t = 12.98$, $p<0.001$.

Table 4.3: Descriptive statistics for PNC (Particles/cm^3) during B2 demolition. $t = 12.98$, $p<0.001$.

Variable	N	Mean	St Dev	Minimum	Median	Maximum
B2 PNC	22020	44698	53955	4406	24190	693300
Background PNC	840	29628	25047	5860	21400	176000

Focus on the lunch break period (Figures 4.20 and 4.21) gives finer resolution to the sudden changes in PNC that are lost when aggregated to the hourly level (although illuminated by the box plot whiskers and outliers). From these graphs, the sudden drops and peaks in PNC levels can be seen when equipment is turned off and then restarted at the end of the break. Comparison of the B2 demolition data from the background measurements taken at EPA-STN (Figure 4.21) shows that there is no abrupt change in PNC around the lunch break. The two brief peaks captured in the middle of the lunch period are likely due to passing trucks, as they are not reflected in the background PNC.

The B2 air quality study illuminates the drastic differences in PNC that occur quickly and can be masked by analysis at the hourly level. The median PNC was 24,190 particles/cm^3 but maximum of 693,300 particles/cm^3 (8:06 AM). In comparison, annual averages for UFP measured in Somerville and Chinatown range from 31,000 to 37,000 particles/cm^3 for locations nearest to Interstate 93, to 2,500 to 9,000 for locations furthest from highway (Patton 2014).

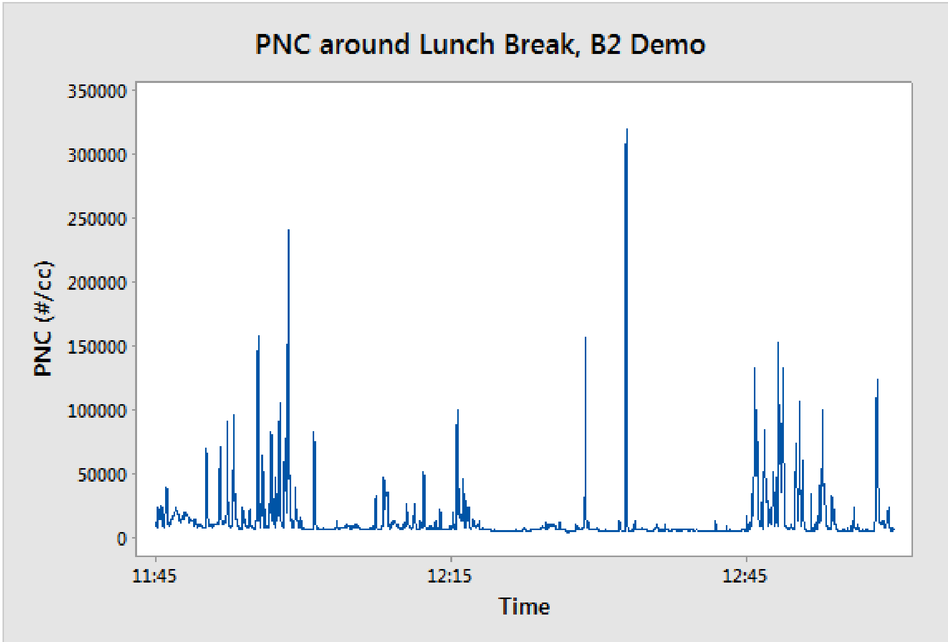

Figure 4.20: Time series graph of PNC at the demolition site before and after a lunch break (12:15 to 12:45PM). A clear drop in PNC levels to background levels can be seen precisely when equipment was turned off and picks up again when construction restarts. The two peaks occurring during the lunch period are likely from trucks passing close to the TAPL.

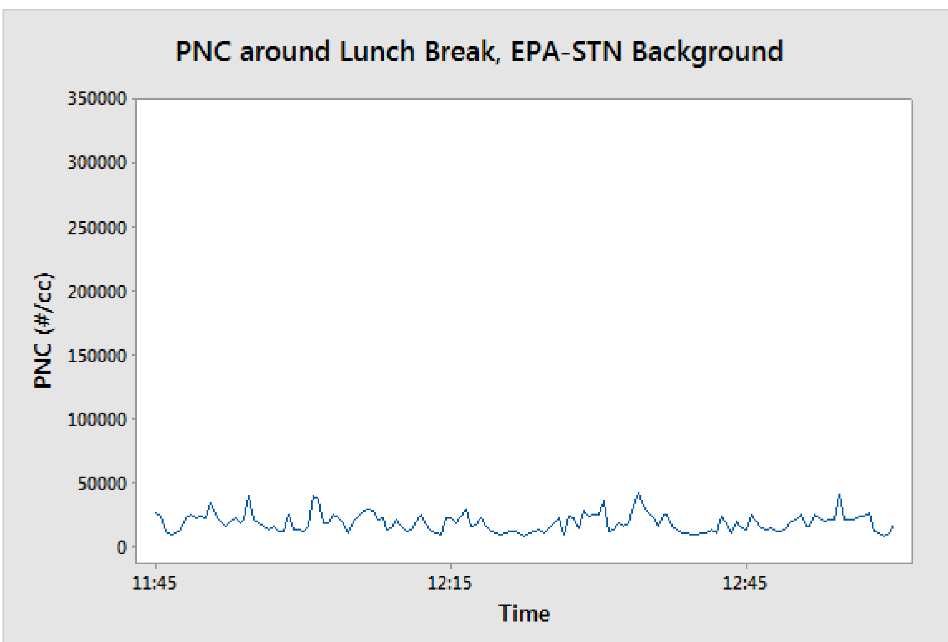

Figure 4.21: Time series graph of background PNC at EPA-STN (located about 200 meters north of the B2 demolition site) during the same 30-minute lunch break with 30-minute buffers. PNC levels are consistent throughout the study period, without the elevations from construction activity indicated in Figure 4.20.

CHAPTER 5: DISCUSSION AND CONCLUSION

POLICY AND DESIGN IMPLICATIONS

There are several policies and regulations that may work towards mitigating diesel emissions from off-road vehicles including construction equipment. The State of Massachusetts's "Sustainable Development Principles" lists ten guiding principles for development projects in the state. Among these is *advance equity,* which is defined in two ways: (1) promote equitable sharing of the benefits and burdens of development, and (2) provide technical and strategic support for inclusive community planning and decision making to ensure social, economic and environmental justice (Massachusetts Office for Commonwealth Development 2003). While these principles apply to all state agencies and their development of policies, programs, investments and regulations, Massachusetts also seeks to "advance these principles in partnership with regional and municipal governments, non-profit organizations, businesses and other stakeholders," (Massachusetts Office for Commonwealth Development 2003, 1). The scope of this principle is limited since this applies to state-funding projects, while the development projects in Dudley Square are City of Boston projects. Nevertheless, an overarching framework for incorporating equity into sustainable development sets a precedent and political tone for implementing similar municipal policies elsewhere. More specific emission reduction regulations may find support from this policy framework. Another state initiative that may be used as precedent to support more specific regulations is MassCleanDiesel: Clean Air for Kids, which was launched in 2008 and aimed to retrofit school buses serving public schools. The program retrofitted more than 2,000 diesel fueled school buses with DOCs, DPFs or flow-through-filters.

In Boston, adopting and implementing a Diesel Emissions Reduction Ordinance has been listed as one of the priority initiatives in the Energy, Environment & Open Spaces Working Group Team Report for Mayor Walsh's Transition Committee (2014). The ordinance would redesign contracting by encouraging retrofitting of diesel engines used on City projects. The ordinance is still in development, but would require a gradual adoption of DOCs and DPFs to reduce diesel emissions.

There are three general categories of technical control strategies for fine and ultrafine particles: (1) fuel-based strategies, (2) engine-based strategies, and (3) exhaust emission control strategies (Gladstein, Neandross & Associates 2013). All three methods are supported by the EPA through its National Clean Diesel Campaign. At the national level, the Diesel Emission Reduction Act adopted in the Energy Policy Act of 2005 allocates $100 million annually to the cause of reducing diesel emissions by (1) funding states to establish clean diesel grant and loan programs and (2) funding projects by regional, state, local or tribal agencies that implement EPA or California Air Resources Board (CARB) verified and certified diesel emission reduction technologies (EPA 2015).

While there are new emissions standards that will affect new equipment (2007 standard requiring DPF technology on heavy-duty engines, reducing PM emissions by about 90 percent; Tier 4 standards), the EPA emphasizes retrofitting as a crucial step to drastically reducing emissions from equipment currently in use and that may remain in use for a long period of time. In 2007, EPA released a report investigating the cost-effectiveness of reducing PM in off-road vehicles including tractors/loaders/backhoes, excavators, cranes, generators, etc. through the use of DPFs and DOCs. The cost effectiveness for both retrofit technologies ranged from $18,700 to $87,600 per ton of PM reduced (EPA 2007).

Clean construction has been highlighted as a way to apply sustainable construction practices outside of regulation and governmental incentive programs. The Northeast Diesel Collaborative's "Best Practices for Clean Diesel Construction" (2012, 2-3) outlines several steps to take towards successfully developing and implementing clean diesel specifications on development projects: (1) well written specifications in bid package, (2) organizational support across all involved entities, (3) effective communication including assurance that specifications are feasible and technology is verified, and (4) an Action Plan for Effective Implementation including a "Clean Diesel Team", an implementation timeline, leveraging opportunities and co-benefits to promote success, and identification of possible barriers to success. These strategies bring emissions control into the construction design process itself, rather than delegating responsibility to a compliant subcontractor. This process is similar to design processes undertaken with a sustainability or environmentally-conscious high performance angle, where these project objectives are woven into the design process through initial phases.

In 2012, the U.S. Green Building Council launched a pilot credit for clean construction in its Leadership in Energy and Environmental Design (LEED) program. While it is not a required component to earn certification under the program (and one of many credits to choose from), it introduces another private sector approach in the construction industry. To earn the point, certain percentages of nonroad engines used on the jobsite must comply with Tier 4 emission standards according to a schedule, culminating in 95 percent of engines. If retrofits are used to meet the requirement, they must be among those on the verified technology lists from EPA or CARB. Additionally, the credit indicates that equipment must be located away from air intakes or operable openings of adjacent buildings and an anti-idling policy should be implemented to limit equipment engine idling to no more than five minutes (or less, if regulations indicate a more stringent limit).

Economic and regulatory challenges demand a broad approach to limiting fine and ultrafine emissions. Additional research is needed to understand how to measure and determine limits for ultrafine particles as well as to more clearly understand the health effects of exposure to construction-related ultrafine particles in order for them to be adopted as a CAP under the NAAQS. In the meantime, a combination of local policy and private sector adoption of clean construction practices can take a more proactive political approach characterized by sensitivity to environmental justice challenges and concern for potential health impacts to control emissions.

LIMITATIONS AND CHALLENGES

Throughout this study, several lessons were learned about how to improve the quality of data and the methods for understanding changes in air quality during construction. I discuss some of the considerations and improvements here.

The Ferdinand air quality study was retrospective and this posed specific challenges which required several careful considerations and limitations. First, while daily construction logs provided a fairly detailed record of construction activities on a specific day, they are hand-logged and the degree of detail by day varied. A limited number of entries in the logs also appeared to be copied from previous days, so accuracy about daily activities is unknown. There was also one week during the demolition period where daily logs were missing, so it is not known whether there was construction activity during that time or not.

The study period was defined by days that the daily construction logs indicated demolition crews were on site. Each type of construction activity was listed along with the subcontractor that was responsible for the work, so it was simple to identify official start and end days for each type of activity. The purpose of focusing on demolition in this project was to obtain data for days in which heavy diesel fueled machinery were likely to be used intensely (see Appendix A) and to maintain consistency with the type of construction activity observed at the B2 Police Station demolition. However, various diesel-fueled equipment were actually present on site throughout the construction period, although with varying levels of intensity (number of pieces of equipment on site, operation time). For example, cranes were on site almost continuously, although the extent of their operation was unclear. A more robust study could consider expanding the study period to include site work, which also involves the use of diesel-fueled machinery including excavators (also typically used in demolition). At the Ferdinand, "site work" overlapped days towards the end of demolition when subcontractors were demobilizing and hauling away material. There was no active demolition by the two demolition contractors, but these days did not truly reflect "low construction intensity" days in reality because site work involved the use of cranes and several excavators. For example, November 2, 2012 shows an elevated median PNC level compared to the other low intensity construction days. While there were no demolition crews at work that day, site work involved excavation and driving piles into the ground.

Another improvement to the methodology could be to add a medium intensity level where the number and type of active equipment determines classification. This would differentiate between days where, for example, several excavators are at work and days where a single excavator was a work. A significant challenge to conducting a retrospective study was considering wind direction. In an observational study, it may be possible to measure air quality at several directions around the point source, but in this study the air monitoring station was fixed and the number of demolition days limited.

CONCLUSION

Dudley Plan, emerging from the realization of the Roxbury Strategic Master Plan, has set into motion many redevelopment projects that will further transform Dudley Square into a district shaped by its community planning process. The values and concerns expressed in the public planning process and the local history of environmental justice make it clear that the community is already aware of some of the challenges in environmental health that Dudley Square faces. Measurement and analysis of air quality data during demolition processes show that there are changes in air quality that need to be further studied for environmental health impact. This thesis has helped contribute to a more robust understanding of construction activity impacts on ambient air quality in a community redevelopment process working towards *just sustainability*.

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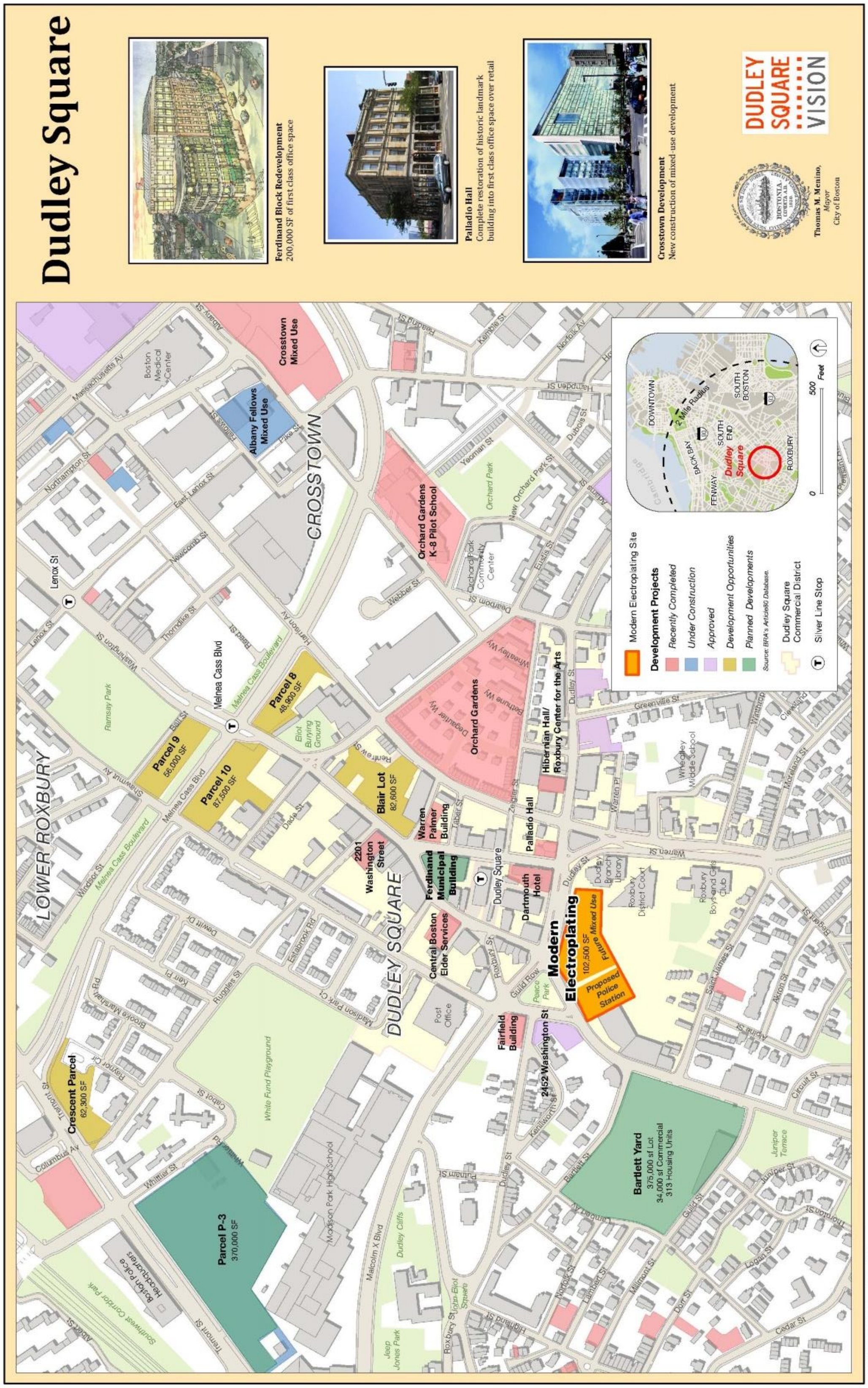
APPENDIX A: Massachusetts 2002 Construction Equipment Diesel Emissions Inventory

Diesel Emission Totals by Equipment Type and Pollutant (Tons/Year) 2002

Equipment Description	Exhaust VOC	Exhaust NOx	Exhaust CO	Exhaust PM25	Exhaust SO2	Exhaust CO2	Crankcase VOC	Diurnal VOC
CONSTRUCTION AND MINING EQUIPMENT								
Bore/Drill Rigs	19.27	211.07	81.13	16.54	25.21	13,711.21	0.39	0.00
Cement & Mortar Mixers	0.93	7.93	3.58	0.72	0.98	534.64	0.02	0.00
Concrete/Industrial Saws	1.98	11.95	10.44	1.78	2.07	1,125.77	0.04	0.00
Cranes	31.10	415.60	113.82	26.40	57.11	31,061.35	0.62	0.00
Crawler Tractor/Dozers	128.94	1,641.72	738.53	124.72	249.15	135,518.13	2.58	0.00
Crushing/Proc. Equipment	6.34	72.92	26.64	5.49	10.08	5,482.18	0.13	0.00
Dumpers/Tenders	0.75	2.33	2.63	0.47	0.35	188.54	0.02	0.00
Excavators	119.45	1,526.71	623.74	120.75	250.35	136,171.86	2.39	0.00
Graders	29.72	387.58	146.78	28.84	62.26	33,863.59	0.59	0.00
Off-Highway Tractors	17.48	198.47	112.10	16.28	26.85	14,606.36	0.35	0.00
Off-highway Trucks	102.92	1,439.65	637.13	95.55	213.93	116,359.78	2.06	0.00
Other Construction Equipment	16.29	192.54	107.28	17.00	25.69	13,973.87	0.33	0.00
Other Underground Mining Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pavers	14.55	153.90	78.10	14.33	24.66	13,412.14	0.29	0.00
Paving Equipment	2.66	24.38	14.60	2.53	3.71	2,018.77	0.05	0.00
Plate Compactors	0.90	5.27	3.15	0.64	0.66	359.36	0.02	0.00
Rollers	41.24	381.85	224.77	40.02	61.70	33,560.97	0.82	0.00
Rough Terrain Forklifts	59.31	487.86	335.61	59.76	80.02	43,527.74	1.19	0.00
Rubber Tire Loaders	148.40	1,868.45	863.06	150.93	272.31	148,114.46	2.97	0.00
Scrapers	30.27	442.18	203.16	32.40	67.16	36,531.08	0.61	0.00
Signal Boards/Light Plants	8.91	46.09	28.70	5.62	6.80	3,697.10	0.18	0.00
Skid Steer Loaders	247.37	727.95	922.08	150.92	112.66	61,294.17	4.95	0.00
Surfacing Equipment	1.79	15.93	10.72	1.73	2.23	1,213.37	0.04	0.00
Tampers/Rammers	0.05	0.34	0.20	0.04	0.10	53.77	0.00	0.00
Tractors/Loaders/Backhoes	256.21	1,135.29	1,054.35	176.09	164.69	89,591.42	5.12	0.00
Trenchers	24.57	177.71	134.98	23.35	29.25	15,909.92	0.49	0.00
Construction and Mining Equipment Totals:	**1,311.40**	**11,575.66**	**6,477.28**	**1,112.89**	**1,749.98**	**951,881.55**	**26.23**	**0.00**

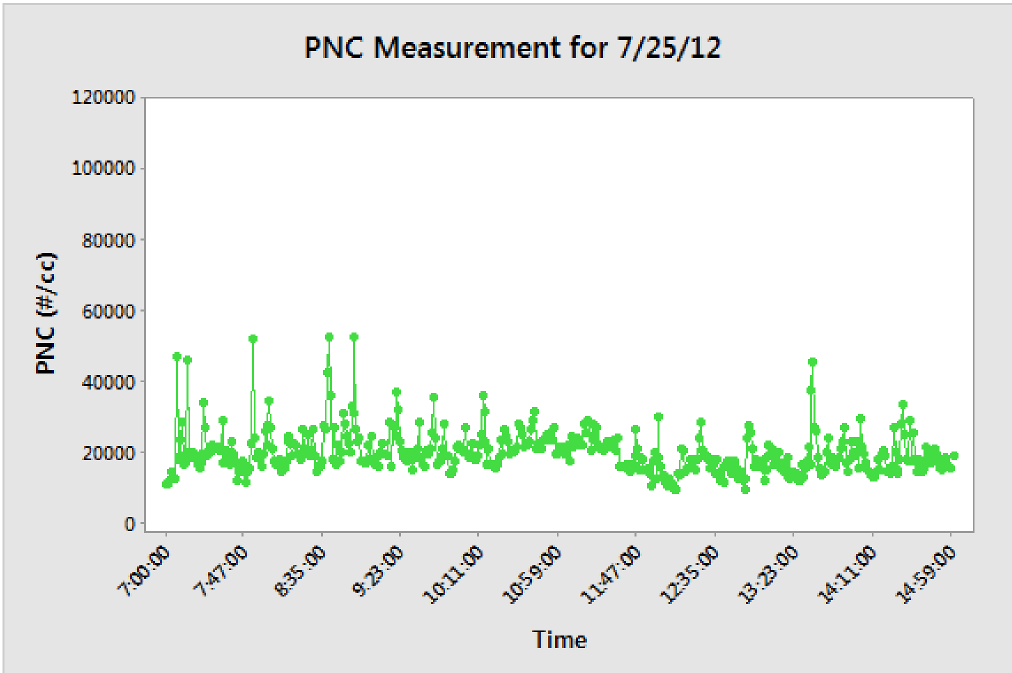
APPENDIX B: Dudley Vision Redevelopment Projects



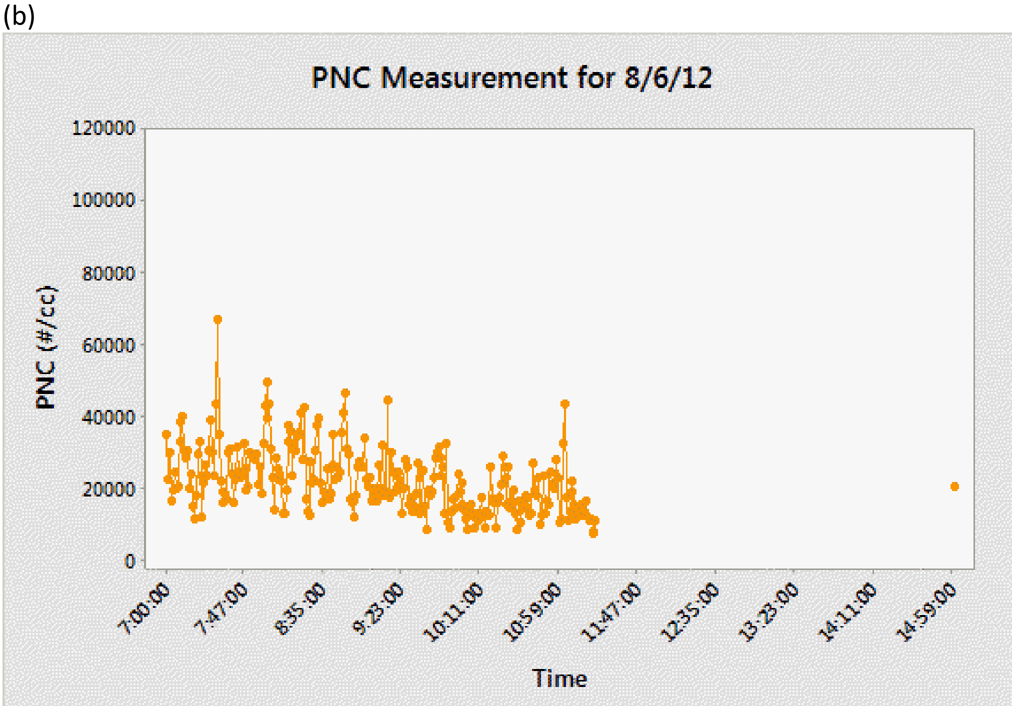
APPENDIX C: Ferdinand Site Demolition PNC Time Series and Histograms

The following time series graphs show the 1-minute average PNC measurements for each day in where the wind blew towards EPA-STN during the Ferdinand demolition. (a) Shows days with low intensity construction activity and (b) are days with high intensity construction activity.

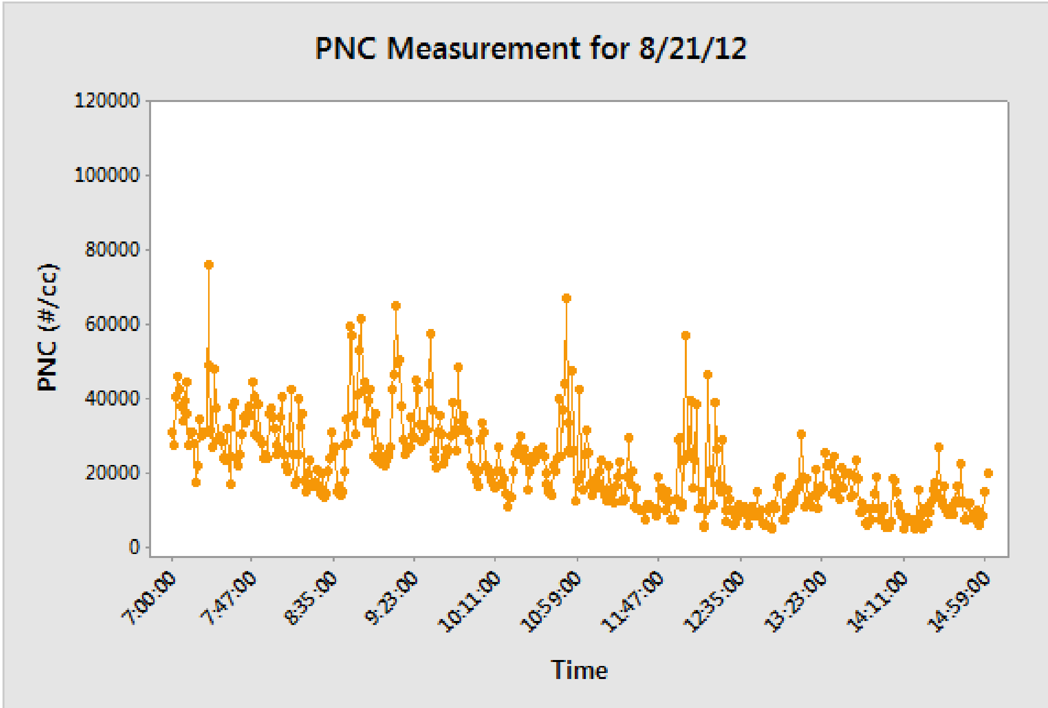
(a)



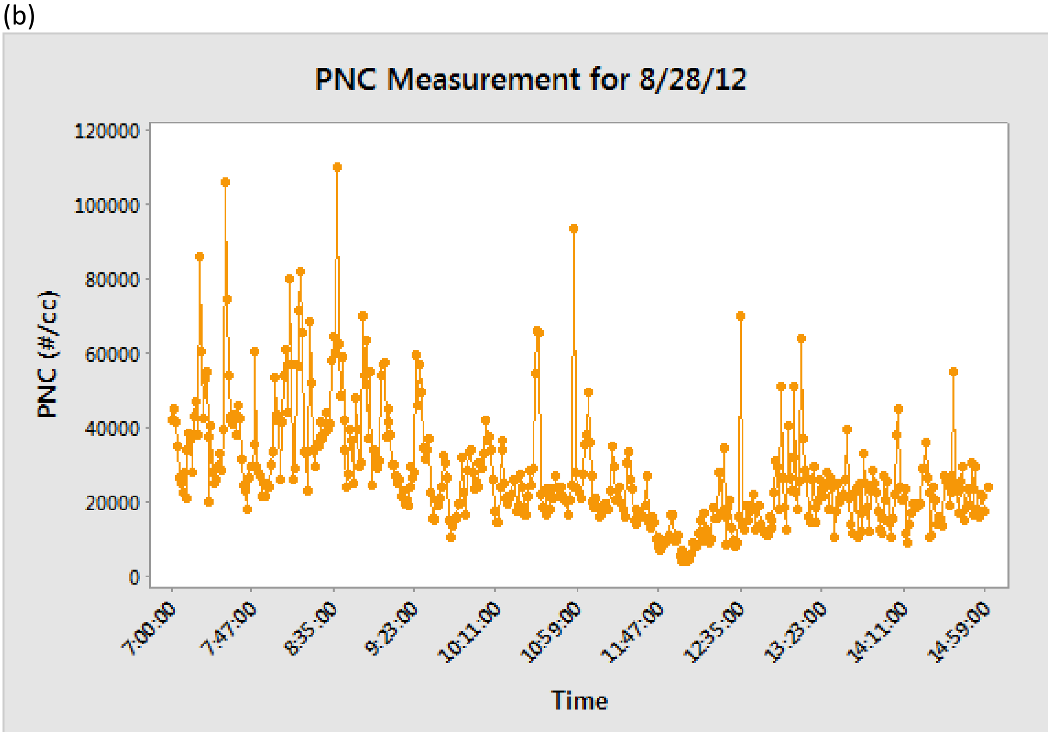
(b)



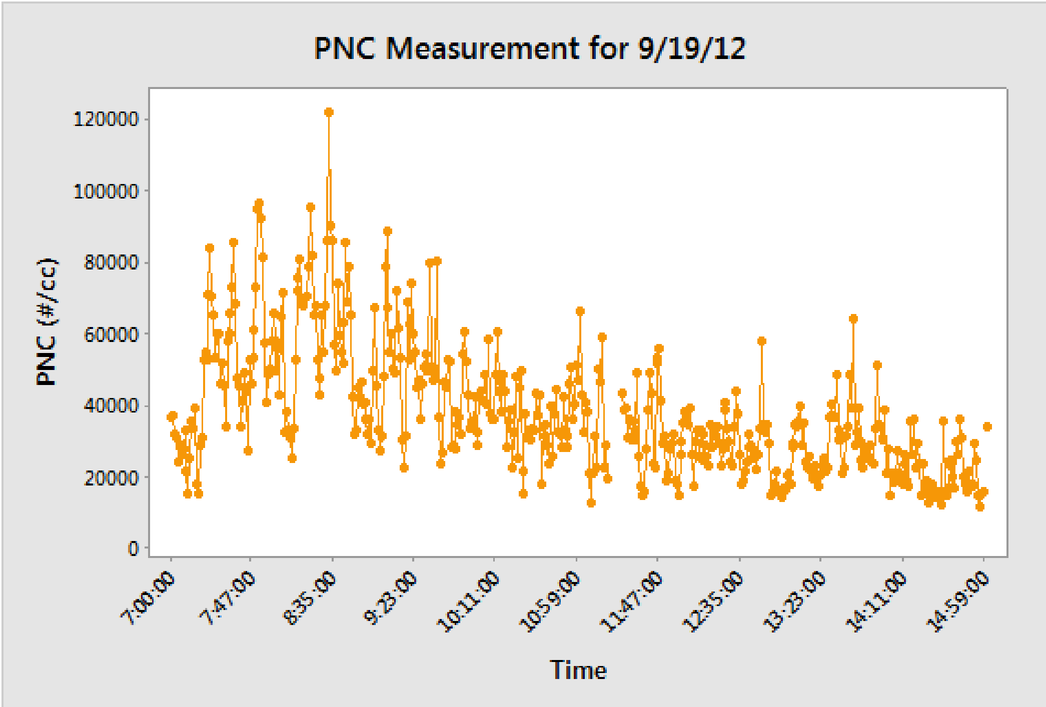
(b)


PNC Measurement for 8/21/12
PNC (#/cc)
120000
100000
80000
60000
40000
20000
0
7:00:00
7:47:00
8:35:00
9:23:00
10:11:00
10:59:00
11:47:00
12:35:00
13:23:00
14:11:00
14:59:00
Time

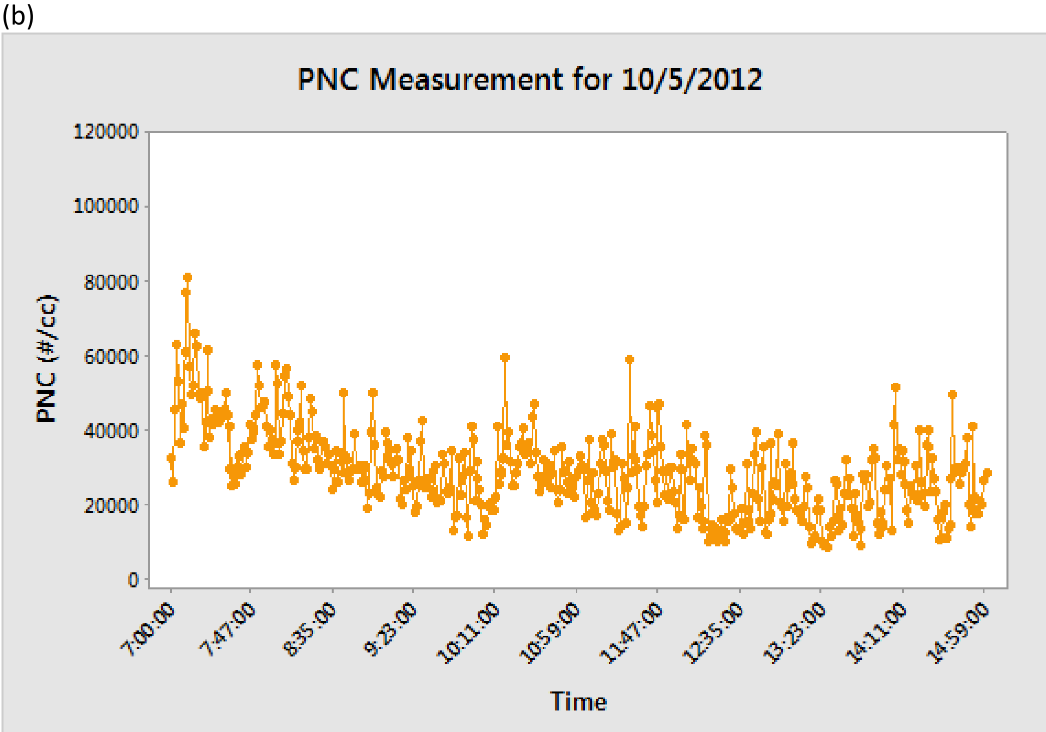
(b)


PNC Measurement for 8/28/12
PNC (#/cc)
120000
100000
80000
60000
40000
20000
0
7:00:00
7:47:00
8:35:00
9:23:00
10:11:00
10:59:00
11:47:00
12:35:00
13:23:00
14:11:00
14:59:00
Time

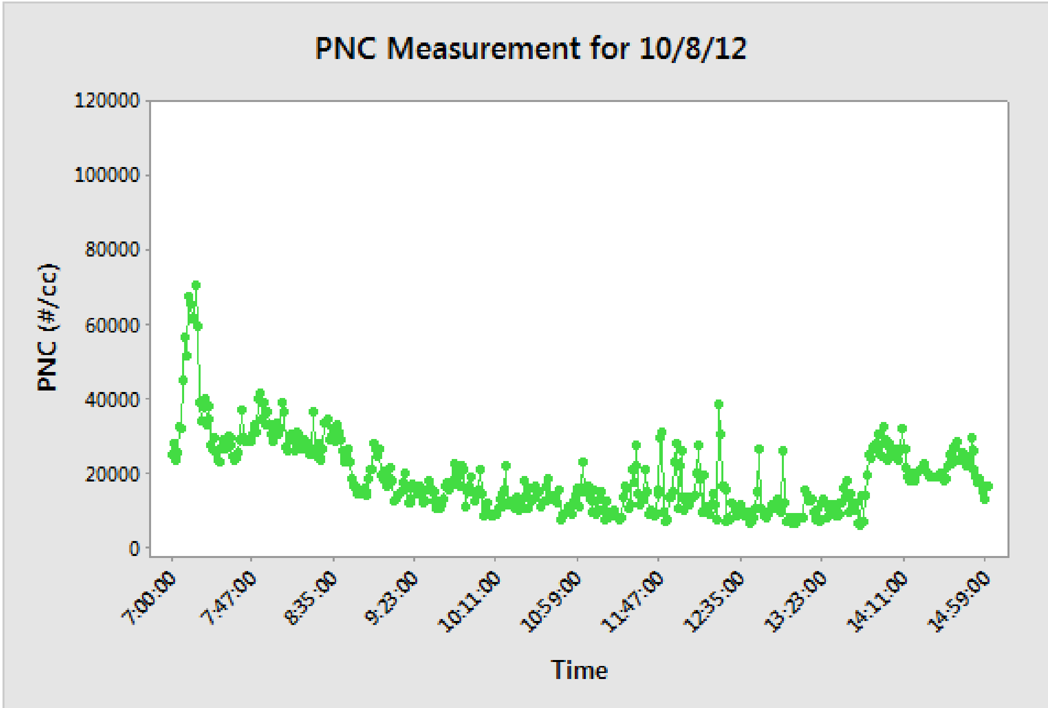
(b)


PNC Measurement for 9/19/12
PNC (#/cc)
120000
100000
80000
60000
40000
20000
0
7:00:00
7:47:00
8:35:00
9:23:00
10:11:00
10:59:00
11:47:00
12:35:00
13:23:00
14:11:00
14:59:00
Time

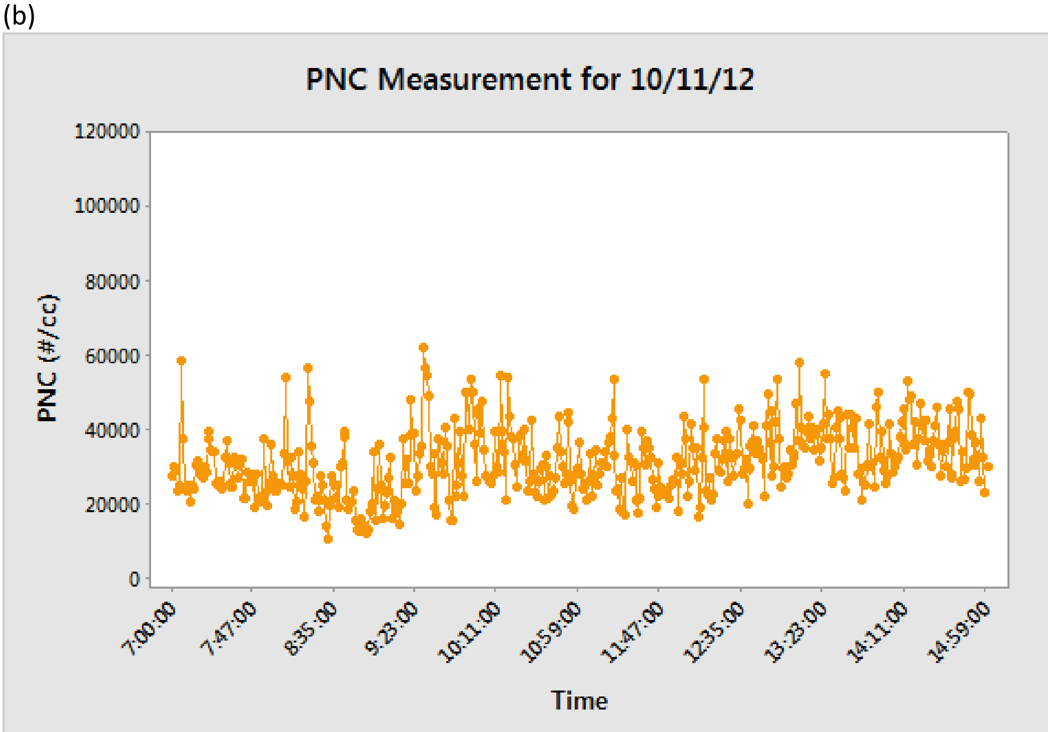
(b)


PNC Measurement for 10/5/2012
PNC (#/cc)
120000
100000
80000
60000
40000
20000
0
7:00:00
7:47:00
8:35:00
9:23:00
10:11:00
10:59:00
11:47:00
12:35:00
13:23:00
14:11:00
14:59:00
Time

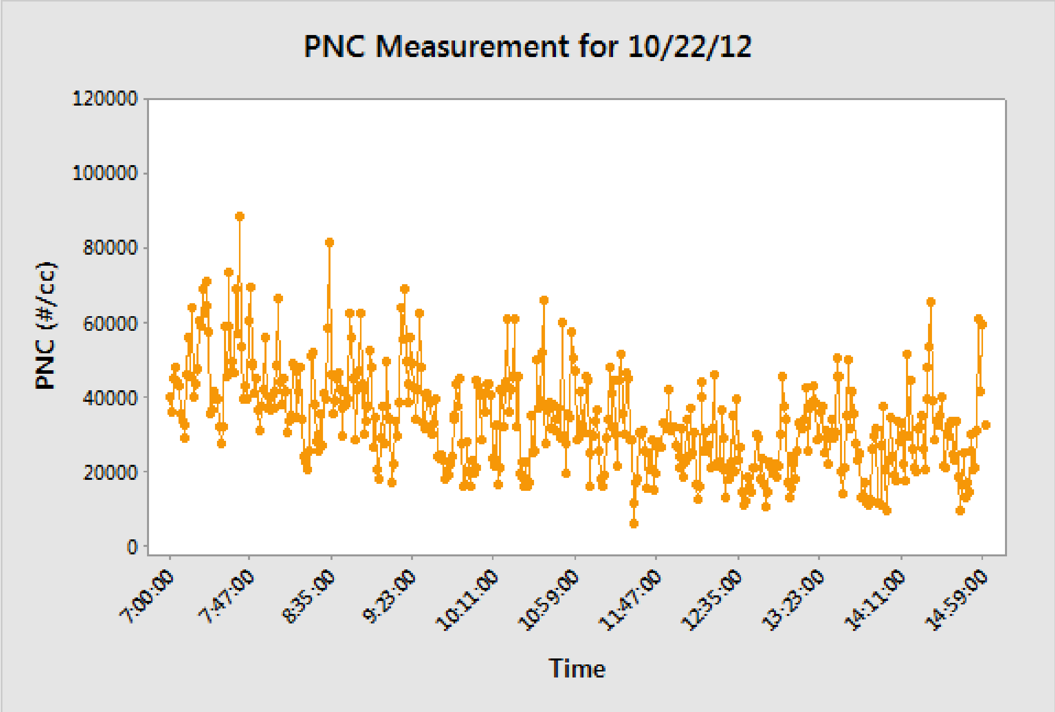
(a)


PNC Measurement for 10/8/12
PNC (#/cc)
0
20000
40000
60000
80000
100000
120000
7:00:00
7:47:00
8:35:00
9:23:00
10:11:00
10:59:00
11:47:00
12:35:00
13:23:00
14:11:00
14:59:00
Time

(b)

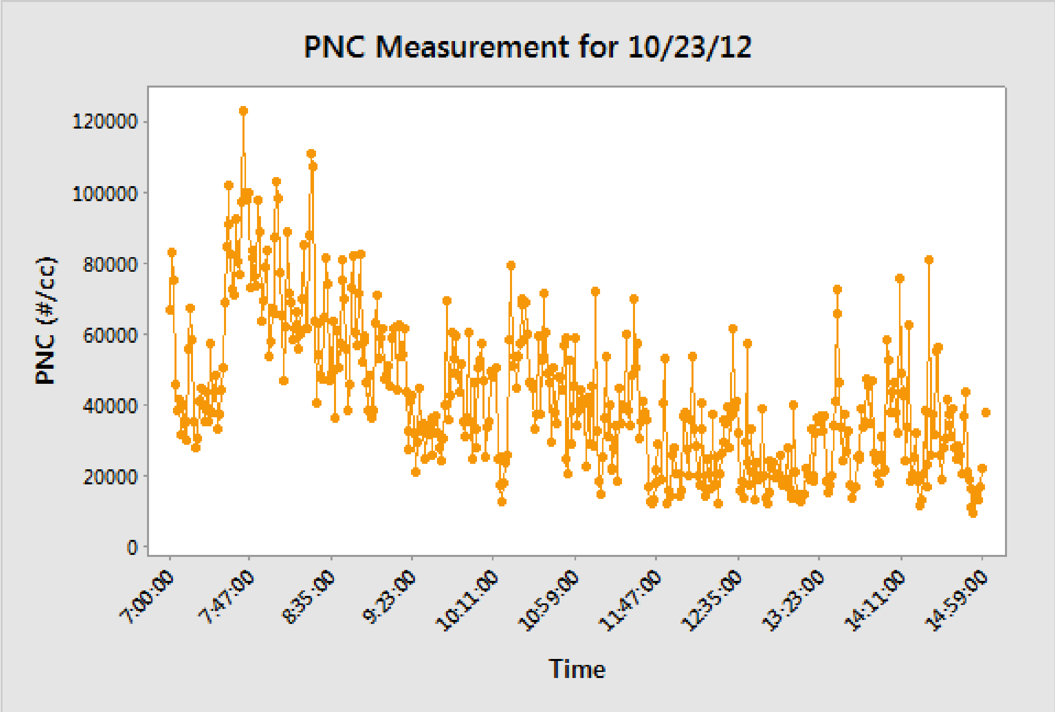

PNC Measurement for 10/11/12
PNC (#/cc)
0
20000
40000
60000
80000
100000
120000
7:00:00
7:47:00
8:35:00
9:23:00
10:11:00
10:59:00
11:47:00
12:35:00
13:23:00
14:11:00
14:59:00
Time

(b)



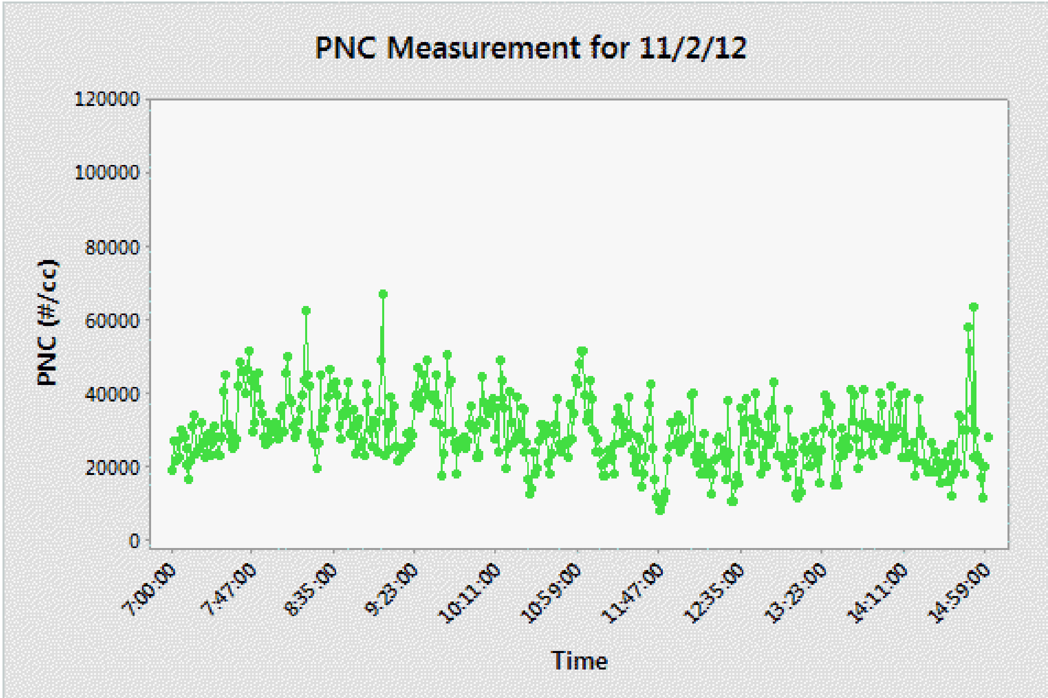
PNC Measurement for 10/22/12
PNC (#/cc)
120000
100000
80000
60000
40000
20000
0
7:00:00
7:47:00
8:35:00
9:23:00
10:11:00
10:59:00
11:47:00
12:35:00
13:23:00
14:11:00
14:59:00
Time

(b)

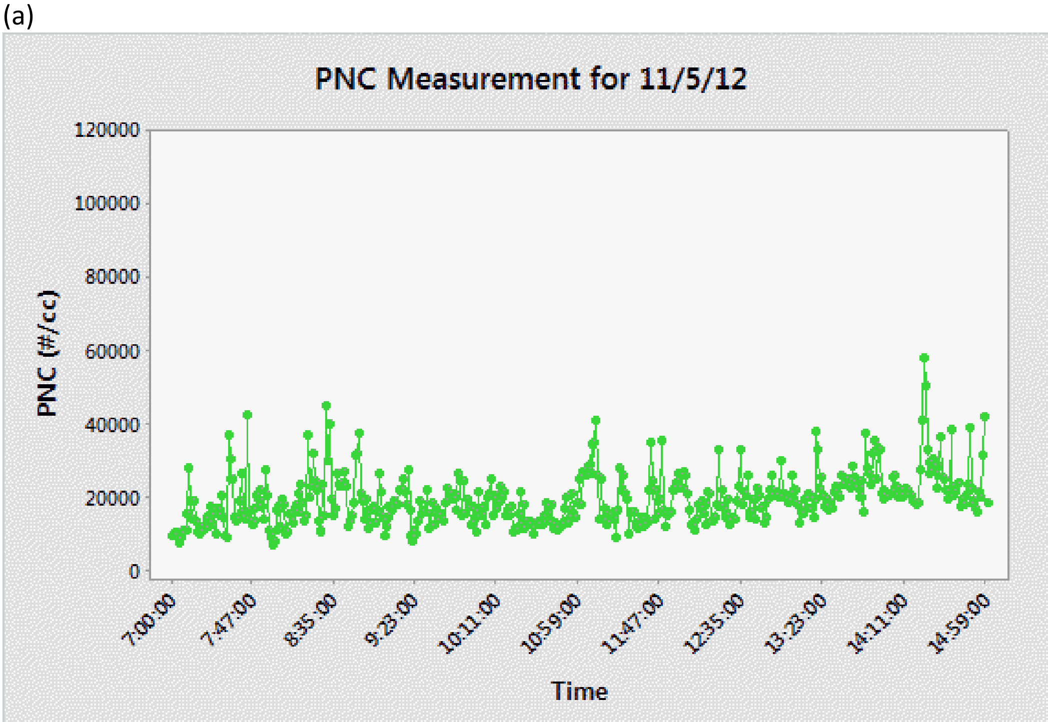


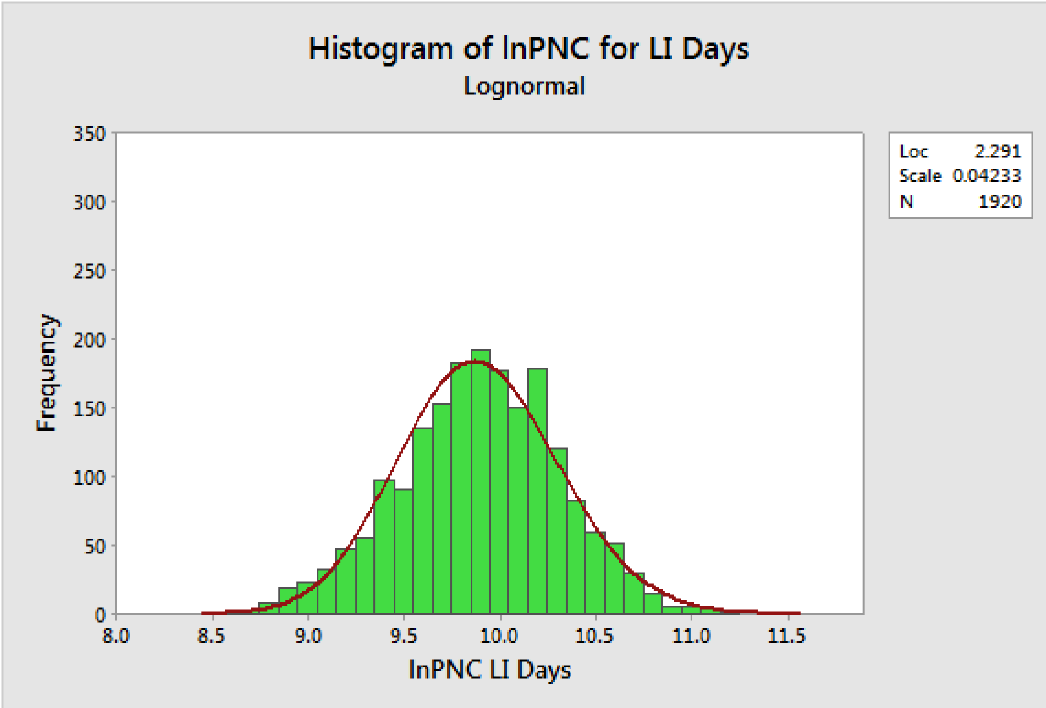
PNC Measurement for 10/23/12
PNC (#/cc)
120000
100000
80000
60000
40000
20000
0
7:00:00
7:47:00
8:35:00
9:23:00
10:11:00
10:59:00
11:47:00
12:35:00
13:23:00
14:11:00
14:59:00
Time

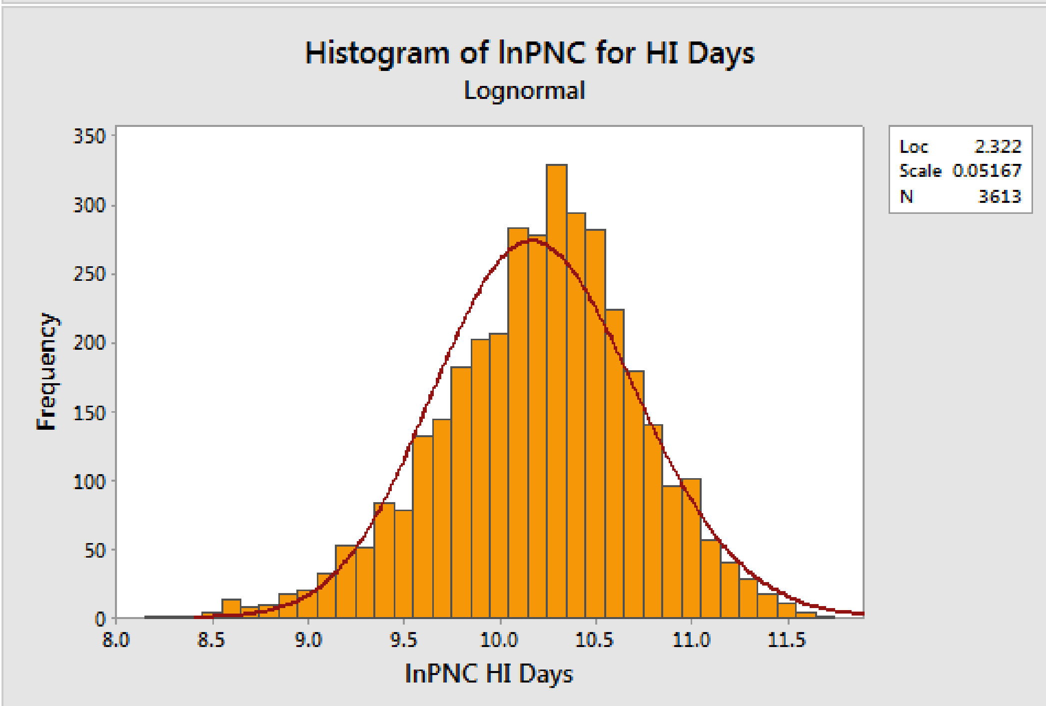
(a)

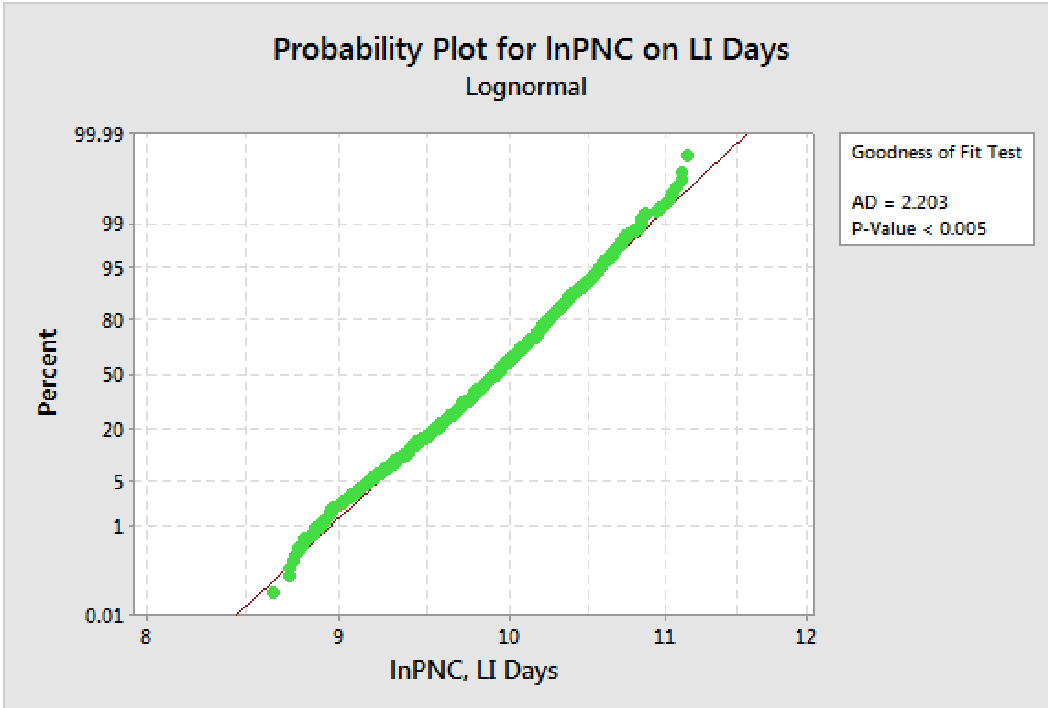

PNC Measurement for 11/2/12
PNC (#/cc)
120000
100000
80000
60000
40000
20000
0
7:00:00
7:47:00
8:35:00
9:23:00
10:11:00
10:59:00
11:47:00
12:35:00
13:23:00
14:11:00
14:59:00
Time

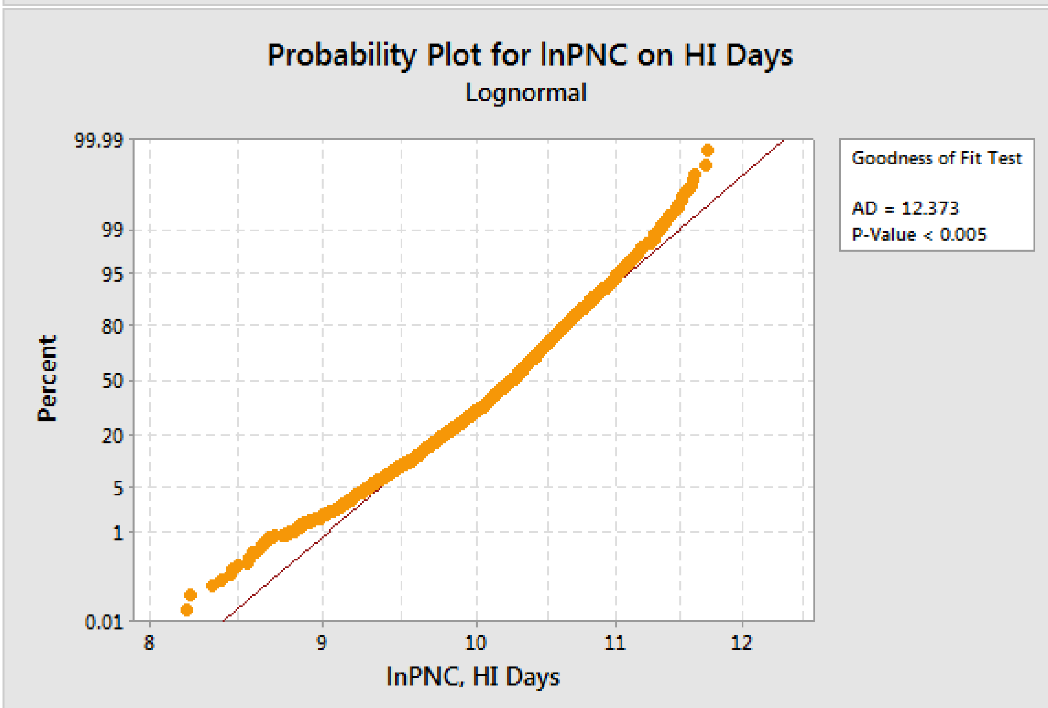
(a)


PNC Measurement for 11/5/12
PNC (#/cc)
120000
100000
80000
60000
40000
20000
0
7:00:00
7:47:00
8:35:00
9:23:00
10:11:00
10:59:00
11:47:00
12:35:00
13:23:00
14:11:00
14:59:00
Time


Histogram of lnPNC for LI Days
Lognormal
Loc 2.291
Scale 0.04233
N 1920
Frequency
lnPNC LI Days
0
50
100
150
200
250
300
350
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5


Histogram of lnPNC for HI Days
Lognormal
Loc 2.322
Scale 0.05167
N 3613
Frequency
lnPNC HI Days
0
50
100
150
200
250
300
350
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5


Probability Plot for lnPNC on LI Days
Lognormal
Goodness of Fit Test
AD = 2.203
P-Value < 0.005
Percent
99.99
99
95
80
50
20
5
1
0.01
8
9
10
11
12
lnPNC, LI Days


Probability Plot for lnPNC on HI Days
Lognormal
Goodness of Fit Test
AD = 12.373
P-Value < 0.005
Percent
99.99
99
95
80
50
20
5
1
0.01
8
9
10
11
12
lnPNC, HI Days

APPENDIX D: Sample Construction Logs from High and Low Construction Intensity Days

DAILY CONSTRUCTION REPORT

Dudley Municipal Project

General Contractor:	Shawmut	Owners Project Manager:	
Architect:	Sasaki/Mecanoo	Project Number:	
Superintendent:		On Site Owners Rep:	

Weather / Report Info

	Time	Temp dF	Condition
AM	8:00	62	clear
NOON	12:00	68	clear
PM	3:00	68	clear

Day	Wednesday
Date	
Daily Field Report #	
Contract Day #.	

Work Force

Classification	Contractor	Total Men	Total Hrs
General Contractor		3	24
Abatement		10	80
Concrete Cutting			
Helical Piles			
Restoration			
Police detail		1	8
Concrete			
Erectors		3	24
Fire watch		2	16
Tree Cutting			
Fencing Barricades			
Architectural Preservation			
Staging			
Demolition		10	80
Demolition		5	40
Concrete			
Air Quality Test		1	8
Hygienist		1	8
Masonry			

Major Construction Equipment Used

Equipment (QTY)	Company
2-Arials	
G-70 for Brokk	
Brokk	
EC 160 cl Excavator w/grapple	
Grove GMK 5225 Crane	
2-Skid Steers	
Front End Loader	
1 Skid Steer	
Crane RT 750E	
Volvo EC460C High Reach	

Visitors to Site

Name	Company/Org.

Record of Conversation/ Issue Tracking

Ongoing demo of Ferdiand @60% of steel removed. Pace appears to be slow. 9 men start abatement on the 4th floor of the Curtis building. 4 men work 8 hours, 6 men worked 12hours

Project Name

Date:	Daily Field Report #	Contract Day #

Contractor	Work Description
DEMOLTION	1 Forman, 5 men, 4 operators, ongoing demo in the Ferdinand building. 1 man in Arial lift torching a few pieces of steel beams. 1 men on fire hose dust control. Approximately 65% of the interior steel has been removed from the Ferdinand. 2 loads of steel removed. 3 loads of brick out in the morning.
DEMOLITION	1 Forman, 10 men, start abatement in the Curtis building 3rd and 4th floor on T&M. 11 men from Essex Newbury on T & M, 8hrs each.

Deliveries to Site / Warehouse

Inspection / Testing

Example High Intensity Construction Activity Day (confidential information removed).

DAILY CONSTRUCTION REPORT

Dudley Municipal Project

General Contractor:	Shawmut	Owners Project Manager:	
Architect:	Sasaki/Mecanoo	Project Number:	
Superintendent:		On Site Owners Rep:	

Weather / Report Info

	Time	Temp dF	Condition
AM	7:00	55	Overcast
NOON	12:00	55	Overcast
PM	3:00	58	Overcast

Day	Wednesday
Date	
Daily Field Report #	
Contract Day #.	

Work Force

Classification	Contractor	Total Men	Total Hrs
General Contractor		4	32
Abatement			
Concrete Cutting			
Helical Piles			
Restoration			
Police detail		1	8
Concrete			
Erectors			
Fire watch			
Tree Cutting			
Fencing Barricades			
Architectural Preservation			
Staging			
Demolition		4	32
Demolition		2	16
Concrete			
Air Quality Test			
Hygienist			
Masonry			
Site Work			
Water contamination			
Vibration Monitoring			

Major Construction Equipment Used

Equipment (QTY)	Company
Komatsu pc 78 mini	

Visitors to Site

Name	Company/Org.

Record of Conversation/ Issue Tracking

Project Name

Date: **Daily Field Report #** **Contract Day #**

Contractor	Work Description
DEMOLITION	1 Forman, 1 man, it appears that the beam removal is complete. 1 man chipping beam pockets (aprox 40 pockets) at the Ferdinand Building.
DEMOLITION	1 Forman 3 men, Demobilize.

Deliveries to Site / Warehouse

Additional steel soldier piles.

Inspection / Testing

Example Low Intensity Construction Activity Day (confidential information removed).